Immediate Airfield Rehabilitation at

René Mouawad Airport

Technical Specifications

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IMMEDIATE AIRFIELD REHABILITATION AT RENÉ MOUAWAD AIRPORT

TECHNICAL SPECIFICATIONS

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SECTION 260500 - BASIC ELECTRICAL MATERIALS AND METHODS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes the following:

1. General provisions applicable to Division 26 work and other Sections of the Specification that refer to this Section.
2. Supporting devices for electrical components.
3. Electrical identification.
4. Covers, brackets and supports.
5. Electricity-metering components.
6. Concrete equipment bases.
7. Cutting and patching for electrical construction.
8. Touchup painting.

B. Electrical Work, unless otherwise specified, includes the supply, installation, testing and commissioning of the complete electrical systems, equipment and materials shown on the Drawings and/or described in the Specification together with all associated ancillary work, support work and builder's work required to achieve full functionality as per the design intent.

C. The scope of electrical works shall include, but shall not be necessarily limited to the following:

1. Power Service and Distribution consisting of:
   a. Low voltage distribution network:
      1) Distribution panels.
      2) Final branch circuit panelboards (LPs, PPs, etc.).
      3) Feeders, sub-feeders and wires.
      4) Conduits, cable trays, wireways and supporting systems.
   b. Other electrical systems:
      1) Uninterruptible Power Supply,
      2) Earthing system.

D. Considering that the new installations will have to be integrated with the existing systems, and that the control and monitoring of the new installations will be done by the existing systems, the following is to be noted:

1. The integration will have to be seamless with full capabilities without the necessity to make any changes to the existing hardware or the need to install any additional components. Software upgrades to the existing systems to allow the integration of the new components are deemed to be included in the Contractors price.

2. It is preferable to have the new equipment and systems from the same manufacturers of the existing equipment’s / systems, in order to ensure seamless integration, interoperability, and full compatibility.

3. In the event the Contractor opts to select different manufacturers than those existing, the following conditions shall be complied with and also submitted for approval.
   a. A duly signed certificate by the proposed manufacturer and the existing manufacturer clearly stating the systems can be easily integrated with no loss or degradation in the performance or system functionality.
   b. A certificate that the proposed manufacturer / system can be integrated directly with the existing system without the need for introducing new components or custom made solutions.
   c. Written confirmation and commitment for availability of spare parts by the local dealer / vendor.
   d. A warranty of five years that the new equipment will be operated without the need for any software or hardware upgrades.

1.3 REGULATIONS AND STANDARDS

A. Regulations: Carry out electrical work in accordance with the current issue of the local codes of practice, local power authority regulations and Requirements for Electrical Installations – IET Wiring Regulations (BS 7671) as published by the Institution of Engineering and Technology and IEC Standards where not in contradiction with the local codes of practice and regulations, herein referred to collectively as 'the Regulations'.

B. Conflict: Should an instance occur in this Specification or on the Drawings in which material or construction methods called for is less than minimum requirement of the Regulations, immediately inform the Engineer in writing. Consequent to Engineer's approval, supply the materials and perform the work as though called for to minimum code standards.

C. Standards: Unless otherwise specified, equipment and materials shall be manufactured and installed in compliance with the relevant recommendations of the following or other equal and approved standards:

1. IEC: The International Electro-technical Commission.
2. ISO: The International Standardization Organization.
3. CENELEC: European Committee for Electrotechnical Standardization.
4. CCITT: The International Telephone and Telegraph Consultative Committee.
5. CCIR: The International Radio Consultative Committee.
6. CISPR: The International Special Committee on Radio Interference.
7. IET: The Institution of Engineering and Technology.
8. BS: British Standards.
9. CIE: International Commission of Illumination.
10. ITU: International Telecommunication Unit.
11. NEBS: Network Equipment Building System.

D. In case of contradiction between enforced and relevant local regulations and International Standards, the most stringent requirements shall prevail.

1.4 POWER SUPPLY

A. Power Supply: Liaise with the Local Power Authority to confirm:

1. Characteristics of supply and system earthing.
2. Location of incoming supply.
3. Space requirements and associated builder's work for the Authority's installations.
4. Make necessary arrangements at the earliest opportunity to ensure connection as and when required, and inform the Engineer in the event of any foreseen delay.

B. kWH-metering: Liaise with the Local Power Authority/Client and provide necessary instrumentation, enclosures and accessories required by them to effect a complete kWH-metering installation.

C. kWH-metering will be at low voltage unless otherwise shown on the Drawings.

D. Nominal characteristics of power supply and distribution are as follows:

1. Medium voltage: 11 kV, 3 phase, 3 wire TN-S neutral earthing.
2. Low voltage: 380 V, 3 phase, 4 wire, solidly earthed neutral.
3. Frequency: 50 Hz.

E. Distribution systems shall be supplied or derived from the voltage system previously described, as shown on the Drawings, or as otherwise specified.

F. The Contractor shall ensure that system's upstream protection device settings are re-calculated by competent agency and changed as necessary to be compatible with the final approved load conditions.

1.5 TELEPHONE PUBLIC EXCHANGE LINES

A. The Local Telephone Authority will bring telephone public exchange lines into the premises to the existing telecom service provider room in the basement and/or to be agreed with the Authority. Liaise with the Local Telephone Authority to confirm location of connection of public telephone exchange lines into the premises.

1.6 EQUIPMENT

A. Equipment Spaces and Rooms: Verify that dimensions, structure, ventilating and cooling arrangements and other provisions in equipment spaces and rooms are suitable for installation, operation and maintenance of proposed equipment. Note any discrepancies on the shop and construction drawings.

B. Equipment shall be designed for the system voltage and frequency previously described, unless otherwise specified. Special provisions shall be made for equipment sensitive to power supply frequency and voltage variations and for equipment operated at other voltages/frequencies or by direct current sources.

1.7 CLIMATIC CONDITIONS

A. Climatic Conditions at Project's Site:

1. Altitude: 33.8 m above sea level.
2. Maximum ambient temperature: 32.8 degrees C (in the shade).
3. Minimum ambient temperature: 5.6 degrees C.
4. Maximum relative humidity: 90 %.

B. Equipment shall be capable of withstanding the project environmental conditions specified here below encountered at the installed location without mechanical or electrical damage or degradation of operating capability, unless otherwise specified. For devices located in harsh environments such as interior uncontrolled or exterior environments, the Contractor shall provide the necessary housings or enclosures to ensure proper equipment operation and performance.

1. Interior, Controlled Environment: System components, installed in air-conditioned interior environments shall be rated for continuous operation in ambient conditions of 10 to 35 deg C dry bulb and 20 to 90 percent relative humidity, noncondensing.
2. Interior, Uncontrolled Environment: System components installed in non-air-conditioned interior environments shall be rated for continuous operation in ambient conditions of 5 to 45 deg C dry bulb and 10 to 95 percent relative humidity, noncondensing.
3. Exterior Environment, Under Shade: System components installed in locations exposed to weather shall be rated for continuous operation in ambient conditions of 5 to 45 deg C dry bulb and 10 to 100 percent relative humidity, condensing, when exposed to winds up to 160 km/h**.**

C. All electrical equipment including cables, relays, lighting fixtures, motors, etc. shall be designed or derated for continuous and trouble free service under the following climatic conditions:
1. Interior, Uncontrolled or Controlled Environment – as applicable where installed indoors.
2. Exterior Environment – where installed outdoors.

D. Where design and operating conditions, different from the above are required for particular equipment, they are described in the specification of the equipment concerned.

E. Equipment, apparatus, material accessories installed outdoors shall be corrosion and salinity proof. UV stabilized requirement shall be applied for outdoor installations and their surface finish and due certification shall be provided by manufacturer as necessary.

1.8 DRAWINGS

A. Equipment locations shown on the Drawings indicate approximate locations and general layout of equipment. Exact and final locations and layouts together with dimensions, weights, mounting methods and accessories, where relevant, shall be shown on Contractor's shop and construction drawings.

B. Symbols: In order to provide sufficient detail and a minimum degree of clarity on the Drawings, the symbols used for various electrical devices, particularly wall mounted devices, take up more space on the Drawings than the device does on the wall. Because of drafting limitations these locations must be considered as being indicative rather than exact physical locations of the devices. The devices shall be installed with prime regard for convenience of operation and the proper usage of the wall space rather than to coincide with the scaled locations of the symbols. In locating the outlets, follow the criteria provided on detail Drawings where provided, and coordinate with furniture. Do not scale from design Drawings.

C. Layouts and details of routing of circuits shall be shown on the Contractor's shop and construction drawings.

D. Wiring layouts shown on the Drawings for work not included in the Electrical Work are shown for convenience and reference only.

1.9 SUBMITTALS

A. Generally: Submit for approval, manufacturers' technical literature, shop and construction drawings and other information required by the Specification, before ordering equipment or materials and before executing any related work on site.

B. Product Data: Submit for approval detailed product data such as model no., all relevant ratings, country of manufacture, interface details as necessary, covers and supports.

C. Calculations: Submit for approval the manufacturer/supplier calculations for the following systems, prior to ordering/manufacturing the material:

1. Indoor and outdoor lighting distribution, with necessary supporting documents and photometric data of the lighting fixtures proposed and approved by the Contractor.
2. Circuit breakers selectivity and discrimination calculation study for a full selective and discriminated distribution scheme.
3. Voltage drop and short circuit calculations after verification of cable and breaker sizes.
4. Generators sizing calculations.
5. Power factor correction capacitors sizing based on the final approved loads.
6. Battery bank calculations to fulfill the specification requirements provided for the specific equipment.
7. Rating / derating calculations for the specified equipment.
8. Lightning risk assessment and energy coordination studies for surge protection.
9. Harmonic analysis.
10. Earthing.
11. Relay settings.
12. Design calculations associated with communications and security systems engineering, power consumption and heat dissipation, link budget, fiber count, Quality of Service (QoS), redundancy, reliability and service availability.
13. Any required calculation necessary to define component/equipment sizes for the proper operation of the electrical and ELV systems, and to confirm compliance with specified Regulations and Standards.

D. Shop and Construction Drawings:

1. Dimensioned plans and sections or elevation layouts of electrical equipment, as applicable.
2. Shop and construction drawings must demonstrate that the design requirements are understood by indicating all equipment and material proposed to be supplied and installed and by detailing fabrication and installation methods proposed to be used. Shop and construction drawings shall clearly state the name and location of the work, the names of Engineer and Contractor, submission date, cross-references to the Drawings and Specification and the specific reference number, location, service and function of each item.
3. Shop and construction drawings shall be submitted at a scale of 1:50 for general layout plans, and 1:10, or 1:20 as approved by the Engineer for sections, details, elevations, congested layouts, etc. Drawings shall include but not be limited to the following:

    a. Details of electrical installations in conjunction with all trades concerned, showing sleeves and openings for passage through floor structure.
    b. Composite construction drawings fully dimensioned, in metric, showing locations of cables, conduits, bus ducts, shafts, mechanical and electrical equipment rooms, ceiling spaces and all other critical locations
    c. Plans showing equipment layouts including all details pertaining to clearances, access, sleeves, electrical connections, location and elevation of pipes, ducts, conduits, etc.
    d. Plans, sections and elevations of electrical spaces to illustrate compliance with Standards for allocation of spaces for maintenance, movement, installation, etc.
4. Single Line Diagrams: Detailed single line diagrams and control schematics clearly indicating all equipment ratings, frame sizes, cable sizes, nomenclature/identification number shall be submitted for the Engineer’s approval. The SLD’s shall include the MV network as applicable.

E. Field Test Reports: Indicate and interpret test results for compliance with performance requirements, and arrange for certification by manufacturer / manufacturer’s authorized representative.

F. Electrical installation shall be fully rated for the power source and load characteristics as also for the fault conditions expected and protection selectively coordinated for full discrimination, considering the different manufacturers products used in the system.

G. Technical Literature: Include detailed manufacturers' specifications and original catalogues or catalogue cuts, characteristics, model number, application and operating criteria of all equipment and materials, together with other information necessary to satisfy Engineer that proposed equipment and systems are suitable and adequate.

H. List of Proposed Manufacturers: Of all equipment and materials, including all items for which choice of manufacturer is at own discretion, shall be submitted for approval.

I. Assembled Equipment: Any assembled equipment to be supplied for the project shall be assembled by the manufacturer or his authorized assembler. Submit the necessary documents to substantiate the above including the assembler staff training, quality control, etc. The Engineer reserves the right to reject any local assembler if the information submitted is not sufficient. The Engineer's rejection in that respect is final and not subject to discussion.

J. Test Certificates and Reports: Submit manufacturer's type and routine test certificates and reports for equipment and devices. Complete test results shall be submitted in clearly identified and organised booklets, indicating item of equipment, make, model, type, date of tests, type of tests, descriptions and procedures. Include in the test reports the Quality Assurance Certification, the standards to which the equipment comply, and the standards to which the equipment was tested.

K. Factory Testing: Locally manufactured/assembled equipment shall comply with the relevant standards recommendations and shall be witnessed by Engineer, where required in the relevant Specifications Section. If the manufacturer's test certificates/tests are not complying with the standards, then independent laboratory tests shall be carried out on equipment in accordance with the Specification and the Standards, and as required by Engineer. The Engineer's requirements in that respect are final and not subject to discussion.

L. Spare Parts Schedules: Submit with the Tender itemised schedules of spare parts to be provided, as required by the Specification, and state against each item the manufacturer's unit price including packaging and delivery to site.

M. Tools And Instruments Schedules: Submit with the Tender itemised schedules of tools and instruments to be provided, as required by the Specification, and state against each item the manufacturer's unit price including packaging and delivery to site.

N. Labeling Schedule: Submit for approval, prior to installation, a schedule of all equipment and devices to be labeled and the suggested details, lettering, position and fixing methods of each label indicating its application.

O. Samples: Submit samples of all equipment and materials for approval. Major items of equipment for which samples cannot be submitted shall be demonstrated in existing installations or by manufacturer's information, test certificates and reports.

P. As-Built (Record) Drawings: Prior to Substantial Completion, submit Record Drawings certified by the Engineer on installed electrical systems, in accordance with requirements of the Specification, Division 01. The As-Built (Record) Drawings, where applicable, shall include data on existing works. The As-Built Records shall be made progressively as the Work proceeds.

Q. Submit CVs of electrical Engineers, electrical personnel, and quality personnel, for Engineer’s review and approval.

1.10 QUALITY ASSURANCE

A. Comply with related Standards, specified therein.

B. Installations shall be carried out by qualified personnel.

1.11 COORDINATION

A. Coordinate chases, slots, inserts, sleeves, and openings with general construction work and arrange in building structure during progress of construction to facilitate the electrical installations that follow.

1. Set inserts and sleeves in poured-in-place concrete, masonry work, and other structural components as they are constructed.

B. Sequence, coordinate, and integrate installing electrical materials and equipment for efficient flow of the Work. Coordinate installing large equipment requiring positioning before closing in the building.

C. Coordinate electrical service connections to components furnished by utility companies.

1. Coordinate installation and connection of exterior underground and overhead utilities and services, including provision for electricity-metering components.
2. Comply with requirements of authorities having jurisdiction and of utility company providing electrical power and other services.

D. Coordinate location of access panels and doors for electrical items that are concealed by finished surfaces. Access doors and panels are specified in Division 8 Section "Access Doors and Frames." The locations of access panels shall be coordinated and proposed to ensure that all electrical equipment are accessible within “hand-reach” through the access provided.

E. Where electrical identification devices are applied to field-finished surfaces, coordinate installation of identification devices with completion of finished surface.

F. Where acoustical ceilings and similar finishes will conceal electrical identification markings and devices, coordinate installation of these items before ceiling installation.

G. Locations of all ceiling lighting fixtures, fire alarm detectors, emergency lighting, CCTV cameras, etc. shall be coordinated with false ceiling subcontractor and other mechanical services outlets, to the satisfaction of the Engineer and technical and functional requirements.

1.12 EQUIPMENT AND MATERIALS

A. Availability: Confirm availability of equipment and materials proposed for use in the work prior to submission for approval. If, after approval, equipment or materials cease to be available, submit alternative items of equal quality and type for approval.

B. Acceptance by Authority: Confirm that proposed equipment and material characteristics where required are compatible with the requirements of the Local Power Authority or other Authorities having jurisdiction and are acceptable to them. Inform Engineer of any modifications necessary to comply with the Local Power Authority's requirements.

C. Manufacturers' Standards: Equipment shall be the latest standard product of the manufacturer. Component parts shall be the product of a single manufacturer, unless otherwise approved and provided that components made by other manufacturers are of a standard design and are interchangeable.

D. Approved Manufacturers: Listing of approved manufacturers in the Specification does not necessarily constitute approval of their standard products as equal to those specified. Ascertain that listed manufacturers are able to supply equipment and material in conformity with the Specification.

E. Factory Assembly: Equipment generally shall be supplied in complete factory assembled units ready for installation on site. Dis-assembly necessary for transportation or other purposes shall be arranged to limit site work to simple re- assembly and inter-wiring of control and power cabling.

F. Storage of Materials: Equipment and materials shall be stored in an approved location, under cover, free from humidity, dust, debris and rodents. Equipment sensitive to heat and humidity shall be kept in climatically conditioned areas until installed and handed over.

G. Defective Equipment: The Employer reserves the right to operate operable defective equipment during the Defects Liability Period until it can be removed from service for repair or replacement.

H. Warranty: Where required by the Specification, provide a warranty, signed by the manufacturer (including his agreement to replace promptly, defective equipment or parts thereof, as instructed by the Engineer) covering materials and workmanship for the period stated in the Specification, starting at substantial completion. Assign the benefits of such warranty to the Employer.

I. Spare Parts: Not later than the date of substantial completion, provide spare parts required by the Specification, together with suitable means of identifying, storing and securing same.

J. Tools and Instruments: Not later than the date of substantial completion, provide sets of tools and instruments required by the Specification, together with suitable means of identifying, storing and securing same.

K. Label and identify all equipment, instruments, control and electrical devices etc. to indicate duty, service or function, to the satisfaction of Engineer. Labels shall be laminated anodized aluminum discs with black surface and white core with incised lettering in English. Alternative methods of labelling may be submitted for approval. Fix labels with non-corrodible screws to equipment, or to adjacent permanent surfaces or as approved by Engineer.

L. Systems used before substantial completion shall have all consumable elements, such as lamps etc. and defective equipment replaced by new, within 7 days prior to the date of substantial completion.

M. All panels and electrical boards shall have designs permitting easy access of internal components for maintenance and replacement without disturbing other components. All equipment shall be designed for easy and simple operation.

N. Contractor shall be responsible to define the necessary power supplies, taking into account the installed load of chosen equipment and final condition of installation, as well as any other considerations as to allow the proper operation and maintenance of equipment.

PART 2 - PRODUCTS

2.1 SUPPORTING DEVICES

A. Material: Cold-formed steel, with corrosion-resistant coating.

B. Metal Items for Use Outdoors or in Damp Locations: Hot-dip galvanized steel.

C. Slotted-Steel Channel Supports: Flange edges turned toward web, and 14-mm diameter slotted holes at a maximum of 50-mm centers in webs.

1. Channel Thickness: Selected to suit structural loading.
2. Fittings and Accessories: Products of the same manufacturer as channel supports.

D. Raceway and Cable Supports: Manufactured clevis hangers, riser clamps, straps, threaded C-clamps with retainers, ceiling trapeze hangers, wall brackets, and spring-steel clamps or click-type hangers.

E. Pipe Sleeves: Schedule 40, galvanized steel, plain ends for indoor installations from both sides and flanged for outdoor installation from any side or penetration of water tanks or similar.

F. Cable Supports for Vertical Conduit: Factory-fabricated assembly consisting of threaded body and insulating wedging plug for non-armored electrical cables in riser conduits. Plugs have number and size of conductor gripping holes as required to suit individual risers. Body constructed of malleable-iron casting with hot-dip galvanized finish.

G. Expansion Anchors: Carbon-steel wedge or sleeve type.

H. Toggle Bolts: All-steel springhead type.

2.2 ELECTRICAL IDENTIFICATION

A. Identification Devices: A single type of identification product for each application category. Use colors prescribed by these Specifications.

B. Raceway and Cable Labels: Minimum size of letters for legend and minimum length of color field for each raceway and cable size to meet IEC Standards.

1. Type: Pre-tensioned, wraparound plastic sleeves. Flexible, preprinted, color-coded, acrylic band sized to suit the diameter of the item it identifies.
2. Color: Black letters on orange background.
3. Legend: Indicates voltage.

C. Colored Adhesive Marking Tape for Raceways, Wires, and Cables: Self-adhesive vinyl tape, not less than 25 mm wide by 0.08 mm thick.

D. Underground Warning Tape: Permanent, bright-colored, continuous-printed, vinyl tape with the following features:

1. Not less than 150 mm wide by 0.102 mm thick.
2. Compounded for permanent direct-burial service.
3. Embedded continuous metallic strip or core.
4. Printed legend that indicates type of underground line.

E. Tape Markers for Wire: Vinyl or vinyl-cloth, self-adhesive, wraparound type with preprinted numbers and letters.

F. Equipment Nameplates: Non-corroding, robust metal, inscribed in English, and firmly fixed to equipment at factory. Nameplates shall indicate name and address of manufacturer, model, serial number, basic characteristics and ratings of equipment and shall include elementary diagrams etc., all in accordance with the Standards. Equipment shall also be further identified after location at site, indicating the nomenclature number as per approval. As a general practice, the identification labels shall be suitably located on adjoining surface or on separate support and not on the electrical device which could be removed and replaced.

G. Color-Coding Cable Ties: Nylon, self-locking type. Colors to suit coding scheme.

H. Engraved-Plastic Labels, Signs, and Instruction Plates: Engraving stock, melamine plastic laminate punched or drilled for mechanical fasteners 1.6-mm minimum thickness for signs up to 129 sq. cm and 3.2-mm minimum thickness for larger sizes. Engraved legend in black letters on white background.

I. Interior Warning and Caution Signs: Preprinted, aluminum, baked-enamel-finish signs, punched or drilled for mechanical fasteners, with colors, legend, and size appropriate to the application.

J. Exterior Warning and Caution Signs: Weather-resistant, non-fading, preprinted, cellulose-acetate butyrate signs with 1-mm, galvanized-steel backing, with colors, legend, and size appropriate to the application. 6-mm grommets in corners for mounting.

K. Fasteners for Nameplates and Signs: Self-tapping, stainless steel screws or No. 10/32 stainless-steel machine screws with nuts and flat and lock washers.

2.3 BRACKETS, SUPPORTS, RAILS AND TRACKS

A. Brackets, supports, rails and tracks for supporting electrical installations shall be galvanized steel, fixed with expansion bolts of approved size and material. Plastic inserts and lead anchors are not acceptable unless approved for specific light duty installations.

B. Covers shall be suitably dimensioned and matched to provide perfect level surface with flush-mounted lifting handles. Cut edges of trench covers shall be provided with neoprene trims to avoid sharp edges. Cable trench covers shall be supported with additional members at wide spaces.

C. All supports used in external locations, cable trenches and manholes shall be provided with an additional coat of U.V resistant paint, of a color to Engineer’s approval.

D. All fixing hardware used in non-air-conditioned spaces, shall be made of non-corrosive material.

2.4 CONCRETE BASES

A. Concrete Forms and Reinforcement Materials: As specified in Division 3 Section "Cast-in-Place Concrete."

B. Equipment Foundations and Bases: Reinforced concrete, as approved by Engineer after submission of design calculations. Dimensions, levels and surface finishes shall be suitable for equipment installed, as shown on the Drawings or in accordance with approved shop and construction drawings.

C. Alternatively and where concrete bases are not possible, equipment can be anchored to steel-channel sills 100 mm high (min and as necessary), arranged and sized according to manufacturer's written instructions. Attach by tack welding or bolting. Level and grout sills flush with equipment mounting surface.

2.5 EQUIPMENT FOR ELECTRICITY METERING BY EMPLOYER

A. Meter: Electronic kilowatt-hour/demand measuring to record electricity used and highest peak demand over a time period according to electric utility. Meter is designed for use on the type and rating of circuit indicated for its application.
   1. Kilowatt-Demand Display: Digital, liquid crystal type to register highest peak demand.
   2. Enclosure to have hasp for padlocking or sealing.
   3. Memory Backup: Self-contained to maintain memory throughout power outages of 72 hours, minimum.
   4. Sensors: Current-sensing type, with current or voltage output, selected for optimum range and accuracy for the ratings of the circuits indicated for this application.

      a. Type: Split core.

2.6 ANTI-CONDENSATION HEATERS AND VENTILATORS

A. Any major items of electrical equipment which are liable to suffer or be affected in the long term, from internal condensation due to atmospheric or load variations shall be equipped with heating devices suitable for electrical operation at 220 A.C 50 Hz, single phase of sufficient capacity to raise the internal ambient temperature by 5 deg. C.

B. A humidistat shall be included in the heater circuit. The protected electrical apparatus shall be designed such that the maximum permitted rise in temperature is not exceeded if the heaters are energized while the apparatus is in operation. Where fitted, a suitable terminal box and control switch, with indicating lamp shall be provided and mounted in a convenient accessible position.

C. All such equipment, whether fitted with a heating device or not, shall be provided with suitable drainage and shall be free from pockets in which moisture can collect.

2.7 ELECTRICAL CONTROL LOCATIONS

A. Equipment may be electrically controlled from a number of different control points as specified in the appropriate sections of the Specification. The control positions shall be designated as follows:
   1. Local Control: Located within or adjacent to the item of plant to facilitate maintenance, inspection and emergency operation.
   2. Remote Control: Located at a substation control room where specified items of Plant are monitored and controlled by direct wire connection.
   3. Supervisory Control: Located at a System Control Centre where principal items of plant at a number of substations are remotely controlled via a telecontrol system.

2.8 TOUCHUP PAINT

A. For Equipment: Equipment manufacturer's paint selected to match installed equipment finish.

B. Galvanized Surfaces: Zinc-rich paint recommended by item manufacturer.

PART 3 - EXECUTION

3.1 ELECTRICAL EQUIPMENT INSTALLATION

A. Installations Generally:

   1. Carry out Electrical Work in accordance with the Drawings, Specification and Regulations, ensuring compliance with design and performance requirements, to provide safe and protected systems with equipment readily accessible for operation, maintenance and repair.
   2. Installations shall be complete, ready for operation and fully integrated and coordinated with all other work.
   3. Provide accessories necessary to complete the installations, of the types specified or recommended for the purpose by the manufacturer of the equipment or accessories.

B. Headroom Maintenance: If mounting heights or other location criteria are not indicated, arrange and install components and equipment to provide the maximum possible headroom.

C. Materials and Components: Install level, plumb, and parallel and perpendicular to other building systems and components, unless otherwise indicated.

D. Equipment: Install to facilitate service, maintenance, and repair or replacement of components. Connect for ease of disconnecting, with minimum interference with other installations.

E. Right of Way: Give to raceways and piping systems installed at a required slope. Generally, all cabling, power conductor routing shall be located above any piping, unless specifically approved otherwise.

3.2 ELECTRICAL SUPPORTING DEVICE APPLICATION

A. Damp Locations and Outdoors: Hot-dip galvanized materials or nonmetallic, U-channel system components.

B. Dry Locations: Steel materials.

C. Support Clamps for PVC Raceways: Click-type clamp system.

D. Selection of Supports: Comply with manufacturer's written instructions.

E. Strength of Supports: Adequate to carry present and future loads, times a safety factor of at least three or 90-kg concentrated load, whichever is more stringent.

3.3 SUPPORT INSTALLATION

A. Install support devices to securely and permanently fasten and support electrical components.

B. Install individual and multiple raceway hangers and riser clamps to support raceways. Provide U-bolts, clamps, attachments and other hardware necessary for hanger assemblies and for securing hanger rods and conduits.

C. Support parallel runs of horizontal raceways together on trapeze- or bracket-type hangers.

D. Size supports for multiple raceway installations so capacity can be increased by a 25 percent minimum in the future.

E. Support individual horizontal raceways with separate, malleable-iron pipe hangers or clamps.

F. Install 6-mm- diameter or larger threaded steel hanger rods, unless otherwise indicated.

G. Arrange supports in vertical runs so the weight of raceways and enclosed conductors is carried entirely by raceway supports, with no weight load on raceway terminals.

H. Simultaneously install vertical conductor supports with conductors.

I. Separately support cast boxes that are threaded to raceways and used for fixture support. Support sheet-metal boxes directly from the building structure or by bar hangers. If bar hangers are used, attach bar to raceways on opposite sides of the box and support the raceway with an approved fastener not more than 600 mm from the box.

J. Install metal channel racks for mounting cabinets, panelboards, disconnect switches, control enclosures, pull and junction boxes, transformers, and other devices unless components are mounted directly to structural elements of adequate strength.

K. Install sleeves for cable and raceway penetrations of concrete slabs and walls unless core-drilled holes are used. Install sleeves for cable and raceway penetrations of masonry and fire-rated gypsum walls and of all other fire-rated floor and wall assemblies. Install sleeves during erection of concrete and masonry walls.

L. Securely fasten electrical items and their supports to the building structure, unless otherwise indicated. Perform fastening according to the following unless other fastening methods are indicated:

1. Wood: Fasten with wood screws or screw-type nails.
2. Masonry: Toggle bolts on hollow masonry units and expansion bolts on solid masonry units.
3. New Concrete: Concrete inserts with machine screws and bolts.
4. Existing Concrete: Expansion bolts.
5. Instead of expansion bolts, threaded studs driven by a powder charge and provided with lock washers may be used in existing concrete.
6. Steel: Welded threaded studs or spring-tension clamps on steel.
7. Welding to steel structure may be used only for threaded studs, not for conduits, pipe straps, or other items.
8. Light Steel: Sheet-metal screws.
9. Fasteners: Select so the load applied to each fastener does not exceed 25 percent of its proof-test load.

3.4 IDENTIFICATION MATERIALS AND DEVICES

A. Comply with BS 822 and IEC 60034-8.

B. Install at locations for most convenient viewing without interference with operation and maintenance of equipment.

C. Coordinate names, abbreviations, colors, and other designations used for electrical identification with corresponding designations indicated in the Contract Documents or required by codes and standards. Use consistent designations throughout Project.

D. Identify raceways and cables with color banding as follows:

1. Bands: Pre-tensioned, snap-around, colored plastic sleeves. Make each color band 50-mm wide, completely encircling conduit, and place adjacent bands of two-color markings in contact, side by side.
2. Band Locations: At changes in direction, at penetrations of walls and floors, at 15-m maximum intervals in straight runs, and at 8-m maximum intervals in congested areas.
3. Colors: As follows:

    a. Fire Alarm System: Red.
    b. Security System: Blue and yellow.
    c. Telecommunication System: Green and yellow.

E. Tag and label circuits designated to be extended in the future. Identify source and circuit numbers in each cabinet, pull and junction box, and outlet box. Color-coding may be used for voltage and phase identification.

F. Install continuous underground plastic markers during trench backfilling, for exterior underground power, control, signal, and communication lines located directly above power and communication lines. Locate 150 to 200 mm below finished grade. If width of multiple lines installed in a common trench or concrete envelope does not exceed 400 mm, overall, use a single line marker.

G. Install warning, caution, and instruction signs where needed to ensure safe operation and maintenance of electrical systems and of items to which they connect. Install engraved plastic-laminated instruction signs with approved legend where instructions are needed for system or equipment operation. Install metal-backed butyrate signs for outdoor items.

H. Install engraved-laminated emergency-operating signs with white letters on red background with minimum 9-mm- high lettering for emergency instructions on power transfer, load shedding, and other emergency operations.

I. Labels: Labels shall be provided inside the boxes or cubicles to describe the functions of the various items of equipment. Where the cubicle is divided into compartments each door shall have an external label to identify the compartment.

3.5 FIRE STOPPING

A. Apply fire stopping to cable and raceway penetrations of fire-rated floor and wall assemblies to achieve fire-resistance rating of the assembly. Fire stopping materials and installation requirements are specified in Division 07 Section "Firestopping."

3.6 CABLE SEGREGATION AND FIRE RISK

A. All cables shall be routed and connections designed to reduce fire risk, outage and damage to other plant and buildings.

B. Cables shall be segregated to reduce damage if fire occurs and avoid faulty operation of equipment due to induced voltages as follows:
   1. Control and protection cables shall be separated from power cables to avoid damage in the event of a power cable fault.
   2. Telephone, communication, analogue and digital system cables shall not be at any point less than 300 mm away from power cables, unless otherwise required by relevant Standards and Regulations.
   3. All cable holes through walls and floors shall be sealed with approved silicone foam fire seals or other approved materials after the cables have been installed and the cost thereof is deemed to be included in the Contract.

C. Each cable shall be run in one continuous length, straight through joints will not be permitted unless specifically authorized by the Engineer in writing.

D. Wherever cables/wires are routed with a likelihood of these being exposed to high temperature, they shall be provided with additional “heat resistant” sleeves to Engineer’s approval.

3.7 CONCRETE BASES

A. Construct concrete bases of dimensions indicated or otherwise required, but not less than 100 mm larger, in both directions, than supported unit. Follow supported equipment manufacturer's anchorage recommendations and setting templates for anchor-bolt and tie locations, unless otherwise indicated. For concrete and reinforcement characteristics, refer to Division 03 Section "Cast-in-Place Concrete."

3.8 SUPPORT FRAMES FOR SWITCHGEAR

A. Support frames for switchgear located over cable trenches, where shown on the Drawings or required by equipment design, shall be installed prior to pouring concrete.

3.9 HOLES AND ANCHORS

A. Drilling for anchor bolts shall be carried out using appropriate electric drills and in approved positions.

B. Holes and chases in in situ concrete shall be cast in. Do not cut hardened concrete or drill holes larger than 10-mm diameter without prior approval.

C. Holes and Chases in Pre-cast Concrete: do not cut or drill pre-cast concrete without prior approval.

D. Holes in Structural Steelwork: Do not cut or drill structural steelwork without prior approval.

E. Holes and chases in masonry must not exceed:

1. Size of holes: 300-mm square.
2. Depth of vertical chases: 1/3 wall thickness or, in cavity walls, 1/3 leaf thickness.
3. Depth of horizontal chases: 1/6 wall or leaf thickness.

F. Cutting Masonry:

1. Ensure mortar is fully set before commencing.
2. Cut carefully and neatly, avoiding spalling, cracking or other damage to surrounding structure.
3. Keep holes to smallest practicable size and do not exceed specified dimensions.
4. Cut chases in straight lines and horizontally and vertically only; do not set back to back; offset by a distance not less than wall thickness.

G. Preformed Holes in Masonry: Submit proposals for bridging over holes for ducts etc. which exceed 450-mm width.

3.10 DEMOLITION

A. Demolition shall comply with Division 02 Sections "Selective Demolition".

3.11 RENOVATION

A. Dismantled equipment and materials shall be properly stored to the benefit of the Employer, in the Employer's designated stores. In case the Employer is willing to use these items of equipment and materials in the new layout, test each component in the presence of the Engineer, to identify which items of equipment and materials can be re-installed.

B. Work and Renovation Rules: The site is an existing passenger terminal building and the following rules shall be adhered to:

1. All work shall be complementary to the base building design and installations. Where an exact method of installation has not been indicated, follow the methods used on the base building. Generally, the standard of work shall be equal or better than that of the base building. Additions and/or changes to existing systems shall be made using equipment identical to that already used in the base building, unless specifically indicated otherwise.
2. Visit the site to thoroughly examine and familiarize with the existing systems and installations and every other condition which may affect the work. No claims for variations will be allowed for work or materials necessary for proper execution and completion of the Works or for the Tender's failure, error or negligence in this regard.
3. All places are considered critical. Coordinate all work to produce the minimum disturbance possible and respond promptly to all requests by the Engineer or the Employer, or the Employer's designated representatives, to curtail, suspend or reschedule noisy and dirty activities from time to time. No extension of time will be granted for activities that are suspended intermittently for short durations or for activities that are re-scheduled to more suitable time-slots, whether during or outside normal working hours.
4. Areas outside the site and the buildings can only serve as passage to transport material to and from the site. They shall not serve for any reason as a storage place for supplied material or carted debris. All supplied materials shall be transported directly from the truck

to the site and all debris shall be put in bags and transported directly from the site to the truck. Do not allow the pile-up of these materials and debris at the above mentioned areas.

5. Work associated with existing installation shall be carried out as follows:

   a. All modifications and additions to the existing electrical distribution system as well as communication, security and miscellaneous systems shall be carried out in such a way that the interruptions to normal operations are kept to an absolute minimum. All such work shall be scheduled to the satisfaction of the Engineer and the Employer, whose consideration will be of the foremost importance.
   b. Where existing electrical equipment shall be re-used, (refer to paragraph 3.11A above), the electrical subcontractor shall be responsible for disconnecting this equipment, removing and reinstalling in the new locations and reconnecting as detailed on drawings.
   c. All existing electrical installations, in areas to be renovated, will be removed if these have been replaced by new installations or where these have not been specifically indicated for re-use.
   d. Render safe the installations at locations from which existing equipment has been removed, by withdrawing the existing wiring and removing conduits unless these conduits can be re-used for new installations. Where conduits are cast in concrete or are inaccessible, they will be sealed and left in place.
   e. All existing materials that are removed, which are not scheduled for re-use shall be placed in the Employer's stores as directed. Should the Employer not wish to store the materials, remove them from the site.
   f. Restore any circuits that may be disrupted by the removal of existing equipment, or as a result of renovations.
   g. Not all existing equipment and devices may be shown on the drawings. The Tenderer shall obtain clarification from the Consultant on unidentified equipment prior to submittal of the Tender. Restore power to all equipment or devices in the area of renovation, prior to Substantial Completion.
   h. Update directories in all panelboards where circuits have been modified or new circuits added.
   i. All existing fire alarm, power and communication cables supplying areas outside of area being renovated, but passing through the renovated area, must be maintained functional throughout entire construction period. No interruptions will be allowed. Coordinate with the Employer or the Employer's designated representative and identify services that must be maintained.
   j. Any damage to any fixed or movable item caused during the execution of the Work shall be repaired at own cost.
   k. All electrical works shall be carried out in coordination with the Employer or the Employer's designated representative.

3.12 CUTTING AND PATCHING

A. Cut, channel, chase, and drill floors, walls, partitions, ceilings, and other surfaces required to permit electrical installations. Before start of work, re-confirm from existing “As-builts” the locations of existing services in the area and obtain approval for work notification. Perform cutting by skilled mechanics of trades involved.

B. Repair and refinish disturbed finish materials and other surfaces to match adjacent undisturbed surfaces. Install new fireproofing where existing fire stopping has been disturbed. Repair and refinish materials and other surfaces by skilled mechanics of trades involved.

3.13 DELIVERY, STORAGE, AND HANDLING

A. Install equipment only in dust-free environment and maintain the condition with protective covering as necessary. If air-conditioning is required, ensure it is available by installation time. In general, ensure that locations are complete and ready to receive equipment.

B. Ensure that rooms where equipment are installed are provided with lockable doors.

3.14 FIELD QUALITY CONTROL

A. Inspect installed components for damage and faulty work, including the following:

1. Supporting devices for electrical components.
2. Electrical identification.
3. Electricity-metering components.
4. Concrete bases.
5. Cutting and patching for electrical construction.
6. Touchup painting.

B. Test Employer's electricity-metering installation for proper operation, accuracy, and usability of output data.

1. Connect a load of known kW rating, 1.5 kW minimum, to a circuit supplied by the metered feeder.
2. Turn off circuits supplied by the metered feeder and secure them in the "off" condition.
3. Run the test load continuously for eight hours, minimum, or longer to obtain a measurable meter indication. Use a test load placement and setting that ensure continuous, safe operation.
4. Check and record meter reading at end of test period and compare with actual electricity used based on test load rating, duration of test, and sample measurements of supply voltage at the test load connection. Record test results.
5. Repair or replace malfunctioning metering equipment or correct test setup; then retest. Repeat for each meter in installation until proper operation of entire system is verified.

C. Ensure that all warning signs and signages as dictated by the regulations are in place and the room doors locked, once equipment is energized.

D. Field tests shall, in addition to those specified by regulation, specifically include the following:

1. Insulation resistance tests for all parts of the electrical system, irrespective of voltage class and shall include individual measurement between the various live conductors as also between the individual live conductors and ground.
2. Earthing resistance at each equipment.
3. Loop impedance of each circuit.
4. Earth leakage protection device test.

3.15 REFINISHING AND TOUCHUP PAINTING

A. Refinish and touch up paint. Paint materials and application requirements are specified in Division 9 Section "Painting."

1. Clean damaged and disturbed areas and apply primer, intermediate, and finish coats to suit the degree of damage at each location.
2. Follow paint manufacturer's written instructions for surface preparation and for timing and application of successive coats.
3. Repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer.
4. Repair damage to PVC or paint finishes with matching touchup coating recommended by manufacturer.

3.16 CLEANING AND PROTECTION

A. On completion of installation, including outlets, fittings, and devices, inspect exposed finish. Remove burrs, dirt, paint spots, and construction debris.

B. Protect equipment and installations and maintain conditions to ensure that coatings, finishes, and cabinets are without damage or deterioration at time of Substantial Completion.

END OF SECTION 260500

SECTION 260519 - LOW VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes low voltage (LV) feeder cables, branch circuit wiring, control and signal cables, termination, jointing and splicing.

B. Related Sections include the following:
   1. Division 26 Section "Basic Electrical Materials and Methods".
   2. Division 26 Section "Cable Trays for Electrical Systems" with its related sections.

1.3 SUBMITTALS

A. Technical Data: Submit data for approval including, but not limited to, the following:

   1. Constructional details, standards to which cables comply, current carrying capacities, de-rating factors for grouping and temperature.
   2. Manufacturer's catalogue cuts.
   3. Dimensional and electrical characteristics.
   4. Manufacturer's drawings showing the outline of the lugs and sleeve connectors together with all pertinent dimensions. Any variation in these dimensions due to manufacturing tolerances shall be indicated.

B. Samples of each cable and wire and, if requested by Engineer, other accessories.

C. Shop and Construction Drawings: Submit drawings for approval including, but not limited to, the following:

   1. Exact routing layouts, sections and profiles of trays, feeder, sub-feeder cables and branch circuits, with indication of any equipment to show and verify coordination between various trades.
   2. Details of supports and fixings for buses, trays and cables.
   3. Details of connections to transformers, switchboards, panelboards etc.
   4. Details of terminations, splices and tapings where permitted, glands and bushings at enclosures.
   5. Number and size of conductors in conduit for all branch circuits in accordance with final conduit routing.

D. Certificate of Origin: For each lot of cable supplied, provide a certificate of origin issued by manufacturer stating origin, date of manufacture, composition, standards to which it complies and test certificates. All test certificates shall comply with the test requirements of the relevant standard to which the cable is manufactured.

E. Tests and Certificates: Submit complete certified manufacturer's type test records for cables and accessories in accordance with the Standards.

F. Point-wise compliance statement to the specifications, duly signed by the manufacturer / manufacturer's authorized representative and the contractor.

G. Cable Jointing Qualifications: Submit details of the proposed cable jointers qualifications prior to work commencing on site.

H. Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

1.4 QUALITY ASSURANCE

A. Installer Qualifications: Engage an experienced and certified cable splicer to install, splice and terminate low-voltage cables.

B. Standards: Wires and cables shall comply with IEC or other equally approved standards and shall bear the mark of identification of the Standards to which they are manufactured. Wires and cables not having this identification will be rejected.

C. Current carrying capacities of conductors have been determined in accordance with the Regulations for specified type of insulation and expected conditions of installation. No change will be accepted in specified type of insulation unless warranted by special conditions and approved by Engineer. Check various loads and current carrying capacities and report any discrepancies or insufficiency of sizes indicated to Engineer.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Deliver wires and cables properly packaged in factory packed or fabricated containers, wound on factory reels.

B. Store wires and cables in dry areas, and protect from weather, fumes, water, debris, etc.

C. Handle wire and cable carefully to avoid abrasing, puncturing and tearing wire and cable insulation and sheathing. Ensure that dielectric resistance integrity of wires/cables is maintained.

1.6 COORDINATION

A. Coordinate layout and installation of cables with other installations.

B. Revise locations and elevations from those indicated, as required to suit field conditions and as approved by Engineer.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Approved Manufacturers: Subject to compliance with requirements, provide products by one of the following or approved equal:

1. Low Voltage Cables:

a.	B.I.C.C.	(U.K.)
b.	Nexans	(France)
c.	Prysmian	(Italy / U.K.)

d.	Lapp Kabel	(Germany)
e.	General Cables	(U.S.A.)
f.	Belden	(U.S.A.)
g.	The Okonite Co.	(U.S.A.)
h.	Draka	(Holland)
i.	Bahra Cables	(K.S.A.)
j.	Ducab	(U.A.E.)
k.	Liban Cables	(Lebanon)
l.	Modern Cables	(Lebanon)

2. Low Voltage Variable Frequency Drive Cables:

a.	Lapp Kabel	(Germany)
b.	Nexans	(France)
c.	Prysmian	(Italy / U.K.)
d.	Leoni	(Switzerland)
e.	Belden	(U.S.A.)
f.	General Cables	(U.S.A.)

3. Low Current Fire Resistant Cables:

a.	Prysmian	(Italy / U.K.)
b.	Nexans	(France)
c.	Bahra Cables	(K.S.A.)
d.	Ducab	(U.A.E.)
e.	Draka	(U.K.)

4. Cable Connectors:

a.	Raychem	(U.S.A.)
b.	3M	(U.S.A.)
c.	B.I.C.C.	(U.K.)
d.	Nexans	(France)
e.	Prysmian	(Italy / U.K.)
f.	Klauke	(Germany / U.K.)

5. Cable Glands:

a.	CMP	(U.K.)
b.	Hawke	(U.K.)
c.	Stahl	(Germany)
d.	Thomas & Betts	(U.S.A.)
e.	Prysmian	(Italy / U.K.)

2.2 GENERALLY

A. Conductors: Unless otherwise specified or shown on the Drawings, cables and other feeders shall have copper conductors. Cable conductors shall be stranded for sections 4 mm2 and above, based on IEC 60228 Class 2. Signal and control cables shall have solid conductors unless otherwise specified. Flexible cords shall have finely stranded conductors. Conductors of single-core cables 25-mm2 and above shall be compacted. Multi-core cables 35-mm2 and above shall be sectorial shape.

B. Conductor sizes shall be metric. Conductors with cross-sectional area smaller than specified will not be accepted.

C. Low voltage cables, cable terminations and building wiring insulation shall be color coded or otherwise identified as required by the Regulations and as follows:

1. Neutral shall be black.
2. Protective earth shall be green/yellow striped.
3. Phase colors shall be red, yellow, blue or use color coding in accordance with local regulations and standards.

D. Maintain color coding throughout installation. Phase-conductors for which outer jacket is not color-coded shall have engraved alphanumeric mark (L1, L2, L3) or color coded heat-shrinkable sleeves.

E. Buried Cables: Cables buried directly in the ground shall be armored type, unless otherwise indicated in particular Sections of the Specification or on the Drawings.

F. Water tight cables shall be used for buried cables in high water content soil where indicated on the drawings shall be provided with water blocking swellable tape above insulation as longitudinal water barrier, PE laminated aluminum foil longitudinally applied with suitable overlap as radial water barrier and an external outer sheath made of extruded black medium density polyethylene compound. As an alternative, subject to Engineer's approval, tree retardant cross linked polyethylene (XLPE/TR) to ASTM D6097 insulated cables with an external outer sheath made of extruded black medium density polyethylene compound can be used.

G. Outdoor cables exposed to sunlight shall be provided with ultraviolet resistant PVC sheath having 2.5% black carbon content.

2.3 LV WIRES AND CABLES

A. Single Core PVC Insulated Non-Sheathed Cables (Building Wires): Unless otherwise specified, single conductor cables for wiring in conduit shall have annealed copper conductors, compacted, generally with concentric strands and insulated with flame retardant insulation to IEC 60332-1, moisture and heat resistant PVC/E to IEC 60227-1 and 3, suitable for wet locations and for conductor temperature of 70 deg. C. Wires and cables shall be 450/750 V grade.

B. Multi-Core PVC Insulated Cables (0.6/1 kV): To have annealed, copper conductors, compacted, insulated with PVC/A to IEC 60502-1, moisture and heat resistant, suitable for wet locations and conductor temperatures of 70 deg. C, laid up, bedded with suitable filler and sheathed with flame retardant PVC/ST2. Armored cables shall have single layer of galvanized steel wire armor with flame retardant PVC/ST2 over-sheath. Cables shall comply with IEC 60332-3, and IEC 60811.

C. Single Core XLPE Insulated Feeder Cables (0.6/1 kV): Single-core circular stranded, annealed copper conductors, compacted, insulated with moisture and heat resistant cross-linked polyethylene (XLPE), suitable for wet locations and conductor temperatures of 90 deg. C. and flame retardant PVC/ST2 over-sheath. Armored cables shall have taped bedding, single wire aluminum armor and flame retardant PVC/ST2 over-sheath. Cables shall comply with IEC 60502-1, IEC 60332-3, and IEC 60811.

D. Multi-Core XLPE Insulated Feeder Cables (0.6/1 kV): Multicore annealed copper conductors, compacted, XLPE insulated, for conductor temperature of 90 deg. C, laid up and bedded with suitable non-hygroscopic material compatible with the insulation and flame retardant PVC/ST2 over-sheathed, color black. Armored cables shall have single layer of galvanized steel wire applied helically over extruded flame retardant PVC/ST2 bedding (which may be an integral part of filling) and over-sheathed with flame retardant PVC/ST2, color black. Cables shall comply with IEC 60502-1, IEC 60332-3, and IEC 60811.

E. Multi-Core Dual Shielded XLPE Insulated Feeder Cables (minimum 0.6/1 kV) for Variable Frequency Drives (VFD): To have stranded copper conductors, class 5 to IEC 60228, compacted, adequately thick XLPE insulated, for conductor temperature of 90 deg. C. An overall tinned copper braided screen in conjunction with an aluminium/polymer tape shield shall be provided to achieve transfer impedance not exceeding 100 mOhm/m in the frequency range up to 100 MHz calculated in accordance with IEC 61196-1 or ANSI/NEMA WC 61. Cable shall have a flame

retardant PVC/ST2 or LS0H over-sheath, LS0H over-sheath shall comply with IEC 61034 for low smoke emission, IEC 60754-1 for halogen acid gas content and IEC 60754-2 for degree of acidity of evolved gas, color black. Each feeder shall be provided with 3 nos. symmetrically arranged grounding conductors except for feeders less than 16 mm2 which shall be four core having the fourth core acting as a ground conductor. Cables shall be used with variable frequency drive applications. Cable length shall not exceed 40 m unless proper common mode, (dv/dt), or sinus filters are specified in the VFD, or as otherwise recommended by the manufacturer and approved by the Engineer. Cables shall comply with IEC 60092 or IEEE 1580, IEC 60502-1, IEC 60332-3, and IEC 60811.

F. VFD Cables Feeding Life Safety Equipment (Such as smoke / pressurization fans … etc.): Class 2 to IEC 60228, fire resistant type to IEC 60331-21 with LS0H over sheath to IEC 61034 for low smoke emission, IEC 60754-1 for halogen acid gas content and IEC 60754-2 for degree of acidity of evolved gas.

G. Low Smoke Zero Halogen (LS0H) Cables: 600/1000 V grade, copper conductor, compacted, insulated with extruded material to IEC 61034 for low smoke emission, IEC 60754-1 for halogen acid gas content and IEC 60754-2 for degree of acidity of evolved gas. Cores and cross sectional area shall be as needed. Phases shall be color coded in conformity with the Standards, and overall cable sheath shall be extruded black LS0H material. Cables shall comply with IEC 60332-3.

H. Flexible cable for connection to appliances, window fans, pendants etc. shall be 300/500 V grade to IEC 60227-5, class 5 to IEC 60228, three or four core, with tinned finely stranded copper wires, heat resistant with PVC/E insulation and PVC/ST10 sheath. As an alternative, EPR insulation, twisted and sheathed with Chlorosulphonated Polyethylene (CSP) compound and with strengthening cord may be used.

I. Fire resistant LS0H Cable (similar to Prysmian - Type FP 100 , or approved equal): Single core stranded plain annealed copper conductors to IEC 60228, fire resistant insulation category CWZ to BS 6387 for sizes up to 6 mm2, PH120 classified to BS EN 50200, and 120 minutes rating when tested in accordance with BS 8434-2 when tested in 20 mm rigid steel conduit and Low Smoke Zero Halogen (LS0H) composite sheath to IEC 61034 and IEC 60754 or BS EN 50267-2-1. Cable shall comply with IEC 60332-1 & 3 (category C) for flame retardant properties. Cable shall comply with BS EN 50363 and rated 450/750 V, capable of accepting voltage surges up to 5 kV, operating conductor temperature of 90 deg. C.Cable shall be LPCB and BASEC certified, audited and marked by embossing on cable sheath . Cable shall be used as branch circuits installed in steel conduits for use in central battery system, smoke curtains and other similar loads where shown on the drawings.

J. Fire resistant LS0H Cable (similar to Prysmian - Type FP 300, or approved equal) : Multi core solid or stranded plain annealed copper conductors to IEC 60228 (in sizes up to 16 mm2), dual layer insulation with fire resistant tape primary insulation layer and XLPE secondary insulation layer, category CWZ to BS 6387, complying with BS EN 50363, LS0H composite sheath with tinned earth continuity conductor/drain wire to IEC 61034 and IEC 60754 or BS EN 50267-2-1. Cable shall comply with IEC 60331 for fire resistant characteristics at an enhanced temperature of 950 deg. C. and shall comply with IEC 60332-1-2 for flame retardant properties. Cable shall be rated 600/1000 V, capable of accepting voltage surges up to 5 kV, operating conductor temperature of 90 deg. C. Cable shall be LPCB and BASEC certified, audited and marked by embossing on cable sheath. Cable shall be installed in steel conduits for use in main incoming cable in central battery system and other life safety equipment where shown on the drawings.

K. Fire resistant LS0H Cable (similar to Prysmian - Type FP 200 Gold, or approved equal) : Multi core solid or stranded plain annealed copper conductors to IEC 60228 (in sizes up to 4 mm2), fire resistant insulation, galvanized steel wire armored, category CWZ to BS 6387, PH60 classified to BS EN 50200, and 30 minutes rating when tested with additional water spray in accordance BS EN 50200 Annex E and complying with BS EN 50363, laminated aluminum screen and LS0H composite sheath with tinned earth continuity conductor/drain wire to IEC 61034 and IEC 60754 or BS EN 50267-2-1. Cable shall comply with IEC 60332-1 & 3 (category C) for flame retardant properties. Cable shall be rated 300/500 V, capable of accepting voltage surges up to 5 kV,

operating conductor temperature of 70 deg. C. Cable shall be LPCB and BASEC certified, audited and marked by embossing on cable sheath. Cable shall be used for fire alarm, voice evacuation installations, branch circuits in central battery system and other loads requiring category 1 circuits in accordance with BS 8519 including buildings with evacuation time not exceeding 30 minutes unless otherwise specified under fire alarm section and where shown on the drawings.

L. Fire resistant LS0H Cable 600/1000 V, (similar to Prysmian - Type FP-400, or approved equal): Multi core plain copper stranded circular or shaped conductor (sizes up to 400mm^2) complying with IEC 60228 with fire resistant insulation category CWZ to BS 6387, category F2 to BS 7846, PH60 classified to BS EN 50200 and 30 minutes rating when tested with additional water spray in accordance with BS EN 50200 Annex E and complying with BS EN 50363 operating conductor temperature 90ºC, single galvanized steel wire armour and extruded low smoke zero halogen (LS0H) over sheath wire to IEC 61034 and IEC 60754 or BS EN 50267-2-1. Cable shall comply with IEC 60332-1 & 3 (category C) for flame retardant properties. Cable shall be LPCB and BASEC certified, audited and marked by embossing on cable sheath. Cable shall be used for feeders of the fire pumps, smoke and pressurizing fans, fire fighting elevators and other firefighting and life safety loads requiring category 1 circuits in accordance with BS 8519 including buildings with evacuation time not exceeding 30 minutes and where shown on the drawings.

M. Fire resistant LS0H Cable (similar to Prysmian - Type FP 100, or approved equal): Single core stranded plain annealed copper conductors to IEC 60228, fire resistant insulation to IEC 60331 and Low Smoke Zero Halogen (LS0H) composite sheath to IEC 61034 and IEC 60754 or BS EN 50267-2-1. Cable shall comply with IEC 60332-1 & 3 (category C) for flame retardant properties. Cable shall comply with BS EN 50363 and rated 450/750 V for sizes up to 10 mm2 and 600/100 V for sizes greater than 10mm2, capable of accepting voltage surges up to 5 kV, operating conductor temperature of 90 deg. C. Cable shall be LPCB and BASEC certified, audited and marked by embossing on cable sheath. Cable shall have green/yellow striped color and shall be used as earth conductor for fire resistant feeders.

2.4 CONTROL AND SIGNAL CABLES

A. Multi-Core PVC Insulated Control Cables: 0.6/1 kV rating, solid 1.5 mm2, 2.5 mm2 or stranded 4 mm2 plain circular copper conductors, with heat resistive PVC/A to IEC 60502-1, rated for 70 deg. C, of 7, 12, 19, 24, 30 or 37 cores. Cores shall be laid up together and filled with non-hygroscopic material, and covered with copper wire or tape screen and over sheathed with flame retardant PVC/ST1, to form compact and circular cable for use in switchgear, control gear and generally for control of power and lighting systems. Armored cable shall have extruded PVC bedding which may be an integral part of the filling, galvanized steel wire armoring, and over-sheath of flame retardant PVC/ST1 to IEC 60502-1 and IEC 60332-1, color black. Core identification shall be white printed numbers 1, 2, 3 etc. over black insulation.

B. PE insulated control and signal cables, for use on data systems, shall be generally 300 V rating, polyethylene insulated, color-coded, tinned copper conductors (0.6-mm diameter), twisted together into pairs. Multi-pair core assembly shall be covered with binder tape, spirally wound 0.075-mm bare copper shielding tape and provided with drain wire and overall PVC sheath.

C. Control and signal cables, enclosed in conduit and raceways with power cables, shall be insulated for same voltage grade.

D. Multi core PVC insulated cables (300/500 V) annealed copper conductors, solid conductors, up to 4 mm^2 unless otherwise indicated, insulated with moisture and heat resistant PVC/C to IEC 60227 and with over sheath of flame redundant PVC type ST1 to IEC 60227 and IEC 60332-1.

2.5 TERMINATION AND SPLICE CONNECTORS (LV POWER)

A. Connector terminations and splices shall be of class A to IEC 61238-1.

B. Connectors shall be compression, barrel crimped type.

C. Connectors for copper conductors shall be made of electrolytic copper.

D. Connectors for aluminum conductors shall be made of aluminum alloy of purity not less than 99.5%.

E. All termination and splice connectors specified above shall be tin plated with minimum thickness of 5 microns for copper material and 7 microns for aluminum material. Aluminum connectors shall incorporate neutral grease to avoid aluminum oxidation

F. Termination connectors for aluminum-copper termination shall consist of barrel made of aluminum alloy of purity not less than 99.5% and palm made of forged copper connected using a friction stir welding.

G. Splice connectors for aluminum-copper termination shall consist of two barrels, one is made of electrolytic copper and the other is made of aluminum alloy of purity not less than 99.5% connected using a friction stir welding.

H. Splice connectors shall have a central stop to divide the connector into two equal parts to facilitate the correct cable positioning.

I. Connectors shall be as recommended by manufacturer, to render joints equal to cable in characteristics, in terms of insulation, stress distribution and water-tightness. Materials and methods of jointing shall be approved before confirmation of order.

J. Connectors shall be suitable for cable size used.

K. Connector - Type A-1: Heat shrinkable or cold shrinkable for making T-taps and splices on conductors used in external lighting fittings connections.

L. Connector - Type A-2: Pressure indent type, for terminating or making T-taps and splices on conductors 10 mm2 and smaller. Connector shall be non-ferrous copper alloy applied to conductor by mechanical crimping pressure, with vinyl insulating sleeves or phenolic insulating covers.

M. Connector - Type A-3: Bolted pressure split type for terminating or making T-taps and splices on conductors 16 mm2 and larger. Connector shall be cast non-ferrous copper alloy applied to conductor by clamping with minimum of two screws and provided with phenolic insulating cover.

N. Connector - Type B-1: Pre-insulated, spring type, for branch circuit and fixture wiring. Connector shall be steel encased spring with shell, insulated with vinyl cap and skirt.

O. All components of lugs and connectors shall be clearly marked with the manufacturer’s name, die number, cable / conductor size, number of crimps and position.

2.6 CABLE GLANDS

A. Cable glands shall comply with BS 6121-1, BS 6121-5 and BS EN 50262.

B. Cable glands used with unarmored cables shall be made of brass, type A2 to BS 6121-5, with mechanical retention class B to BS EN 50262, impact resistance category 8 to BS EN 50262 and an environmental seal to the cable outer sheath. Glands shall be deluge protected, with IP66 degree of protection to IEC 60529.

C. Cable glands used with single steel wire armored cables shall be made of brass, type CW to BS 6121-5, with mechanical retention class B to BS EN 50262, impact resistance category 8 to BS EN 50262, electrical continuity via armor wire termination category B to BS EN 50262, earth tag to

BS EN 50262 and an environmental seal to the cable outer sheath. Glands shall have IP66 degree of protection to IEC 60529.

D. Cable glands used with steel tape or wire braid armor shall have similar characteristics as specified in paragraph 2.6C except gland type which shall be CX instead of CW to BS 6121-5.

E. Cable glands used with single steel wire armored cables where sprinkler / water mist firefighting systems are used shall be made of brass, type E1W to BS 6121-5, with mechanical retention class B to BS EN 50262, impact resistance category 8 to BS EN 50262, electrical continuity via armor wire termination category B to BS EN 50262, earth tag to BS EN 50262 and an environmental seal to the cable inner and outer sheaths. Glands shall be deluge protected, with IP66 degree of protection to IEC 60529.

F. Cable glands used with steel tape or wire braid armor shall have similar characteristics as specified in paragraph 2.6E except gland type which shall be E1X instead of E1W to BS 6121-5.

G. Cable glands for use in explosive hazardous areas shall be flame proof with protection Ex d to IEC 60079-1 and have same applicable characteristics according to cable type as above.

H. Stainless steel grade 316 cable glands shall be used in installations in chemical and extremely corrosive areas and where stainless steel enclosures are used. Glands shall have same applicable characteristics according to cable type as above.

I. Aluminum cable glands shall be used for cables with aluminum wire armor. Glands shall have same applicable characteristics according to cable type as above.

J. Cable glands used with LS0H or fire resistant cables shall be of the applicable type as stated above and provided with low smoke fume shroud.

K. Cable glands shall be suitable for cable size used.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine raceways and building finishes receiving wires and cables for compliance with requirements for installation tolerances and other conditions affecting performance of wires and cables. Do not proceed with installation until unsatisfactory conditions have been corrected.

B. Before pulling wires in conduit check that inside of conduit (and raceway in general) is free of burrs and is dry and clean.

3.2 INSTALLATION

A. General: Building wires and cables shall be installed in conduit, trunking or ducts indoors and in conduit outdoors, unless otherwise shown the Drawings.

B. Circuits: Unless otherwise shown on the Drawings, final branch circuit wiring shall be run inside trunking or conduits, D.C. wiring shall be run in separate conduits from A.C. wiring, and emergency lighting and power circuits shall be run in separate conduits from normal circuits.

C. Branch circuit work originating from light and power panelboards shall be arranged as shown on the Drawings. Loads on various phases of panelboards shall be balanced. Ensure that the lighting load and other loads are balanced with a difference of not more than 10% between the phases.

D. Control cables may be fixed to racks, installed directly on cable trays or pulled in conduit and trunking indoors, and in underground ducts or in conduit outdoors.

E. Bunching of wires in raceways shall be in accordance with raceway filling factors permitted by the Regulations.

F. Lubricants shall be used for pulling wire or cable if character of pull would otherwise damage conductors, insulation or jacket. Lubricants shall be approved by the Engineer.

G. Pull conductors into raceways simultaneously where more than one is being installed in the same raceway.

H. Support: Cables and wires pulled inside very high conduit risers shall be supported at upper end of risers and at intermediate points by split rubber grommets to relieve any stresses on conductors, where required.

I. Wiring at Outlets: Leave a slack of at least 200mm at each outlet.

J. Extra Length: At every branch circuit outlet and pull-box, every cable passing through shall be left slack to allow inspection and for connections to be made. Cables terminating in outlet boxes shall be left with at least 250-mm extra length for terminations.

K. Joints or taps in wires and cables, if permitted, shall be permanently accessible or made only in boxes or cabinet gutters.

L. Insulating covers shall be applied to prevent exposure of bare cable connections.

M. Switch legs for local wall switches shall have distinctive color, selected as complementary to cable color coding used in the project.

N. Terminations: Conductors of wires and cables up to 6 mm2 for copper conductors and up to 10 mm2 for aluminum conductors shall be tightly twisted and where possible doubled back before being clamped with set screws. Where two or more wires are looped into same terminal these conductors shall be tightly twisted together before inserting into terminals. As an alternative, fork / ring, compression / twisting type connectors may be used for cable termination. In no case bare conductor shall be allowed to project beyond any insulated shrouding or mounting of a line terminal. Cables sizes 10 mm2 and larger for copper conductors and 16 mm2 and larger for aluminum conductors shall terminate in compression lug connectors.

O. Tagging: Tag main and feeder cables in pull-boxes, wireways and wiring gutters of panelboards or distribution cabinets. Tags shall identify cable or circuit number and conductor size in accordance with the Schedules.

P. Tagging: Where two or more circuits are run to or through a control device, outlet box or ceiling junction box, each circuit shall be tagged as a guide in making connections.

3.3 FEEDER AND SUB-FEEDER INSTALLATION (0.6/1 KV)

A. Cables generally shall be run through duct-banks, shafts or special recesses, clamped to steel racks or cable trays. Cables run through ventilation shafts shall be LS0H type or installed in steel conduits.

B. Fixing: Single cables above suspended ceilings or in concealed spaces shall be fixed directly to walls or ceilings but must be accessible. Where two or more cables are run in parallel, they shall be fixed on galvanized steel perforated trays or on other approved special cable supporting and protecting arrangement.

C. Clamps: Where cables are fixed to steel trays or supporting structures, approved galvanized cast steel clamps (or nonmagnetic clamps for single core cables) shall be used at distances not exceeding 20 diameters.

D. Joints or splices will not be accepted on main and sub-feeders. Cables shall be supplied in lengths sufficient for straight-through un-jointed termination to termination pull.

E. Directly buried cables crossing under roads, pipe banks or other services, shall be laid in heavy duty PVC duct banks. In no case are cables to be directly buried in concrete, in masonry or in floor finishing.

F. Buried cables liable to mechanical damage shall be drawn through PVC conduit or asbestos cement pipe. If steel conduit is used, all three-phase conductors, neutral and protective earth circuits shall be in the same conduit.

G. Exposure to Heat: Route wires and cables to prevent exposure to excessive heat or to corrosive agents. If such condition is unavoidable, cables shall be type designed for particular condition.

H. Insulating covers shall be applied to prevent exposure of bare cable connections. Insulating cover shall be purpose made and shall provide minimum insulation level equal to that of conductor insulation.

I. Glands for various single-core and multi-core cables shall be purpose made and suitable for rigid mounting to equipment enclosure.

J. Seal around cables penetrating fire-rated elements using approved fire-stopping material according to Division 07 Section "Penetration Firestopping".

K. Identify wires and cables according to Division 26 Section "Basic Electrical Materials and Methods."

3.4 CABLE CONNECTIONS, JOINTING AND TERMINATIONS

A. Through joints will not be allowed in feeder cables where adequate manufacturer's lengths are available. Where a joint is necessary, it has to be made inside boxes.

B. Recommendations: Through joints and terminations shall be carried out strictly in accordance with cable manufacturer's recommendations, and made with correct specified materials, boxes, tapes, compounds or mixtures, stress cones, glands and bonds as applicable.

C. Jointing: Joints shall be filled with epoxy resin after taping unless contrary to cable manufacturer's recommendations. Sample site constructed cable terminations and through-joints shall be submitted prior to commencing work on site. Samples shall be constructed in the presence of the Engineer and shall be available for test and inspection in accordance with manufacturer's recommendations.

D. Cutting tools for jointing and terminating cables shall be purpose made, to prevent damage to insulation in general.

E. Cleaning of lacquer on conductors shall be by use of 'Scotch Brite' sponge and white spirit or equal approved.

F. Tighten electrical connectors and terminals including screws and bolts, in accordance with manufacturers published torque-tightening values. Where manufacturer’s torquing requirements are not indicated, tighten connectors and terminals to comply with international standards.

3.5 FIELD QUALITY CONTROL

A. Cable tests shall be carried out in accordance with the requirements of the Regulations and Standards.

B. Test Equipment: Provide megger testers of various ranges as applicable. Use 500 V megger on installations with nominal voltage up to 500 V, and 1000 V megger on installations with nominal voltage over 500 V up to 1000 V.

C. Insulation resistance for LV power and lighting installations shall be carried out in accordance with BS 7671 (“The IEE wiring Regulations”).

D. Insulation resistance for control and signal cables shall be minimum 10000 Megohm-km for PE insulated cables and 100 Megohm-km for PVC insulated cables, all measured core-core and core-earth, in accordance with the Regulations.

E. Prior to energization of circuitry, check installed wires and cables with megohm meter to determine insulation resistance levels to ensure requirements are fulfilled.

F. Prior to energization, test wires and cables for electrical continuity and for short-circuits.

G. Subsequent to wire and cable hook-ups, energize circuitry and demonstrate functioning in accordance with requirements. Where necessary, correct malfunctioning units, and then retest to demonstrate compliance.

END OF SECTION 260519

SECTION 260526 - GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 1 Specification Sections, apply to this Section.

B. The following Sections contain special requirements that relate to this Section:

1. Division 26 Section "Underground Ducts and Raceways for Electrical Systems" for ground earth pits.
2. Division 26 Section "Basic Electrical Materials and Methods".
3. Division 26 Section "LV Power Conductors and Cables".

1.2 SUMMARY

A. This Section includes complete installations to earth every source of energy and to provide protective earthing and equipotential bonding, based on the TN-S system arrangement, including:

1. Transformer neutral earthing.
2. Main earthing terminals or bars.
3. Exposed conductive parts of electrical equipment.
4. Extraneous conductive parts.
5. Generator neutral earthing.

Earthing requirements specified in this Section may be supplemented by special requirements of systems described in other Sections.

1.3 DEFINITIONS

A. The following terms used on the Drawings and in the Specification are equivalent and may be used interchangeably: "earth" and "ground"; "earthing" and "grounding".

B. Earth: Conductive mass of the Earth whose electric potential at any point is conventionally taken as zero.

C. Earth Electrode: Conductor or group of conductors in initial contact with, and providing electrical connection to, Earth.

D. Exposed Conductive Part: Any part which can be readily touched and which is not a live part, but which may become live under fault conditions.

E. Extraneous Conductive Part: Any conductive part not forming part of the electrical installation such as structural metalwork of a building, metallic gas pipes, water pipes, heating tubes etc. and non-electrical apparatus electrically connected to them i.e. radiators, cooking ranges, metal sinks etc. and non-insulating floors and walls.

F. Protective Conductor: Conductor used for some measure of protection against electric shock and intended for connecting together any of the following parts:

1. Exposed conductive parts.

2. Extraneous conductive parts.
3. Earth electrode(s).
4. Main earthing terminal or bar(s).
5. Earthed point of the source(s).
6. Samples of conductors connectors, or any other accessories as requested by the engineers.

G. Electrically Independent Earth Electrodes: Earth electrodes located at such distance from one another that maximum current likely to flow through one of them does not significantly affect the potential of the other(s).

H. Main Earthing Terminal or Bar: The terminal or bar provided for the connection of protective conductors, including equipotential bonding and functional earthing conductors if any to the means of earthing.

I. Equipotential Bonding: Electrical connection to put exposed and extraneous conductive parts at a substantially equal potential.

J. Earthing Conductor: Protective conductor connecting main earthing terminal or bar of an installation to earth electrode or to other means of earthing.

1.4 SUBMITTALS

A. Product Data: Prior to ordering materials, submit data for approval including, but not limited to, manufacturer's catalogues for each type of product indicated including the following:

1. Ground rods.
2. Connecting clamps.
3. Earthing conductors, protective conductors, and bonding conductors.
4. Connectors and other accessories.
5. Exothermic welding kits and tools.

B. Qualification Data: For firms and persons specified in "Quality Assurance" Article to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names and addresses of architects/engineers and owners, and other information specified or required by Engineer.

C. Field Test Reports: Submit written test reports to include the following:

1. Test procedures used and test conditions.
2. Test results that comply with requirements.
3. Results of failed tests and corrective action taken to achieve test results that comply with requirements.

D. Shop and Construction Drawings: Submit drawings for approval including, but not limited to, the following:

1. Exact location of earth pits, rods and details of installation and connections.
2. Exact routing of buried earthing conductors with indication of cross-section, depth of laying and covering.
3. Cross sectional area of all earthing, protective and bonding conductors.
4. Layout and details of earthing provisions at substations, generator rooms, switchgear, distribution panelboards etc., indicating fittings used, insulation, plates and marking, passage and routing of earthing conductors, conduit, sleeves, grooves, niches etc., giving sizes and dimensions of component parts.

E. Records: Submit the following:

1. Scaled drawings, as-installed, showing actual layout and specification of all components of earthing system.
2. Nature of soil and any special earth arrangements etc.
3. Date and particulars of soil conditioning method and agents if used.

F. Samples: Submit samples of conductors, as requested by Engineer.

1.5 QUALITY ASSURANCE

A. Installer Qualifications: Engage an experienced installer who has specialized in installing earthing systems similar in material, design and extent to those indicated for this Project and whose work has resulted in installations with a record of successful in-service performance.

B. Standards: Carry out work in accordance with the following:

1. IEC 60364-1, IEC 60364-51, IEC 60364-5-55 and IEC 60364-4-41: Electrical Installations in Buildings.
2. Latest edition of the IEE Wiring Regulations, BS 7671.
3. BS 7430: Code of Practice for Earthing.
4. TIA J-STD-607-A: Commercial Building Grounding and Bonding Requirements for Telecommunications.

C. Comply with IEC 62305 when interconnecting with lightning protection system.

PART 2 - PRODUCTS AND SYSTEMS

2.1 MANUFACTURERS:

A. Approved Manufacturers: Subject to compliance with requirements, provide products by one of the following or approved equal:

1. BICC (U.K.)
2. Copperweld (U.S.A.)
3. Furse (U.K.)
4. Wallis (U.K.)

2.2 GENERAL REQUIREMENTS

A. Component parts of earthing system are to include the following:

1. Earth electrode (rods, tapes etc.)
2. Main earthing terminals or bars.
3. Earthing conductors.
4. Protective conductors.
5. Equipotential bonding conductors.
6. Electrically independent earth electrodes for special systems.
7. Accessories and termination fittings, bonding, welding kits and other materials.

B. Provide a common earth termination network for all services, consisting of bonding earthing networks of all individual services. The resistance to earth should, in this case be the lowest value needed for any of the individual services. Combined resistance to ground of the whole network is not to exceed 1 Ohms.

C. Ground Electrode: Provide one or a combination of the following arrangements as necessary and/or shown on the drawings:

D. Earth electrode is to consist of one or more earth rods, interconnected by buried earthing tape or cable; distance between two rods is not to be less than twice the length of one rod driven depth.

E. Main earthing bar is to be provided at point of service entrance or medium voltage, transformer, generator, low voltage, low current, and mechanical distribution rooms; as described in the Specification or shown on the Drawings. Connect all earthing conductors, protective conductors and bonding conductors to the main earthing bar. Provide two insulated main earthing conductors, one at each end of the bar, connected via testing joints to the earth electrode at two separate earth pits. Conductor is to be sized to carry maximum earth fault current of system at point of application with final conductor temperature not exceeding 160 deg. C for at 1 second for medium voltage systems and 0.4 seconds for low voltage systems. Main earthing conductors are to be minimum 120 mm2 or as shown on drawings.

F. Testing joints (test links) are to be provided, in an accessible position, on each main earthing conductor, between earthing terminal or bar and earth electrode.

G. Protective conductors are to be separate for each circuit. Where protective conductor is common to several circuits, cross-sectional area of protective conductor is to be the largest of the conductor sizes.

1. Selection of sizes is to be in accordance with Table 54.7 of IEE Wiring Regulations (BS 7671).

H. Protective conductors are not to be formed by conduit, trunking, ducting or the like. Where armored cable is specified and armor is steel, it may be used as a protective conductor, if approved and if not otherwise shown on the Drawings.

I. Continuity of Protective Conductors: Series connection of protective conductor from one piece of equipment to another is not permitted. Extraneous and exposed conductive parts of equipment are not to be used as protective conductors, but are to be connected by bolted clamp type connectors and/or brazing to continuous protective conductors which are to be insulated by molded materials.

J. Ensure by calculation that Earth Fault Loop Impedance values for final circuits are to satisfy the requirements of BS 7671 regulations.

K. Supplementary Equipotential Bonding: Connect all extraneous conductive parts of the building such as metallic water pipes, drain pipes, other service pipes and ducting, metallic conduit and raceways, cable trays and cable armor to nearest earthing terminals by equipotential bonding conductors. Cross-section of protective bonding conductor shall not be less than half of the protective conductor connected to respective earthing terminal with a minimum of 4-mm2.

L. Main Equipotential Bonding: Main incoming and outgoing water pipes and any other metallic service pipes are to be connected by main equipotential bonding conductors to main earth terminal or bar. Bonding connections are to be as short as practicable between point of entry/exit of services and main earthing bar. Where meters are installed, bonding is to be made on the premise side of the meter. Cross-sections of conductors are not to be less than half that of the earthing conductor connected thereto, and minimum 6 mm2.

M. Identification: Connection of every earthing conductor to earthing electrode and every bonding conductor to extraneous conducting parts is to be labeled in accordance with the Regulations, as follows:

1. SAFETY ELECTRICAL CONNECTION - DO NOT REMOVE.

N. Identification: Protective and earthing conductors are to be identified by combination of green-and-yellow colors of insulation or by painting bar conductors with these colors, as approved.

O. Identification: Source earthing conductor (or neutral earthing conductor) is to be identified along its entire length by continuous black insulation labeled 'neutral earthing'.

2.3 GROUNDING CONDUCTORS

A. Buried Earth Conductors: Bare annealed copper strip conductors 30 x 4 mm, or annealed stranded copper conductors 120 mm2 cross-section, unless otherwise indicated on drawings.

B. Earthing Conductors: Insulated or bare copper conductor as described in 2.2 (F).

C. Protective Conductors: Single core stranded annealed copper, PVC insulated cables, having rated insulation grade compatible with circuit protected, or to be a conductor forming part of a multi-core cable, color coded.

D. Protective Bonding Conductors: Bare copper strip conductor, annealed stranded copper cable or flexible strap (flexible braid) of cross-sectional area as described in Article "General Requirements" hereof.

E. Power Systems (transformer, medium voltage switchgear, generator, and main distribution board) Main Earthing Bar: Consisting of hard drawn copper bar, 50 x 6 mm, unless otherwise indicated on drawings. Earth bar is to be labeled 'Main Earth Bar' and is to be drilled, for connection of conductors, at a spacing not less than 75 mm, and is to be supplied with copper alloy bolts, nuts and washers and wall mounting insulators.

F. Telecommunication Systems Main Earthing Bar: similar to above but with minimum dimensions 100 x 6 mm for the main grounding busbar of the main telecommunication room, and 50 x6 mm for equipment rooms grounding busbars.

2.4 CONNECTOR PRODUCTS AND EARTHING ACCESSORIES

A. Copper or copper alloy, purpose made, of approved design, compatible with points of connection, and of adequate cross-section and current carrying capacity.

B. Bolted Connectors and Clamps: Bolted-pressure-type connectors and clamps, or compression type. Bolts, nuts and washers are to be high quality phosphor bronze or copper silicon alloys.

C. Welded Connectors: Exothermic-welded type, in kit form, and selected per manufacturer's written instructions.

2.5 GROUNDING ELECTRODES

A. Ground Rod: 16-mm diameter high strength, low carbon steel core of high tensile strength (600 N/mm2), with 99.99% pure electrolytic copper molecularly bonded into steel core, 0.25 mm minimum thickness. Driving head is to be high strength steel. Couplings are to be long length silicon bronze, internally threaded. Threads are to be rolled onto rod to ensure uniform layers of copper and strength. Earth rod is to be complete with couplings, head and bolted connector of sufficient size, and number of bolted clamps to connect all cables terminated thereto.

1. Minimum Length of Rod: 2.4 m, extendible as necessary to obtain required earth resistance.

B. Earth Pit: Precast, square or circular section concrete handhole (minimum 450 mm internal diameter), with concrete cover, and extending to about 150 mm below top of earth rod. Earth pit is to be provided for each earth rod where connected to an earthing conductor. Cover is to have inset brass plate with inscription 'Earth Pit - Do Not Remove'.

PART 3 - EXECUTION

3.1 TRANSFORMER SUBSTATION EARTHING

A. Medium Voltage (MV) switchgear is to have a separate main earthing bar connected to MV switchgear room earth bar by two insulated earthing conductors not less than 120mm2 for LSC2A type switchgear, and 120mm2 for LSC2B, unless otherwise shown on drawings.

B. LV switchgear (main distribution board) is to have separate main earthing bar connected to LV room earth bar by two insulated earthing conductors not less than 120 mm2, unless otherwise shown on drawings.

C. Transformer room is to have a separate MV main earthing bar, to which the transformer earthing terminal is to be connected by insulated copper earthing conductor not less than 120mm2, unless otherwise shown on drawings.

D. Transformer neutral (star point) is to be connected by insulated earthing conductor (color black) to transformer room MV main earthing bar. Neutral earthing conductor is to be sized for maximum earth fault current for 1 second with final conductor temperature not exceeding 160 deg. C or sized not less than 120 mm^2 for transformer ratings below 500 kVA and 300 mm^2 for higher ratings unless otherwise indicated on drawings. Where a neutral is directly connected to earth electrode, an insulated disconnecting device is to be provided at the transformer.

E. Lightning arresters are to be directly connected to earth electrode, following the shortest path. Each lightning arrester is to be connected at a dedicated earth rod, unless otherwise shown on drawings.

3.2 EARTHING OF MAIN DISTRIBUTION BOARDS, PANELBOARDS, LIGHTING INSTALLATIONS AND WIRING ACCESSORIES

A. For earthing of main distribution boards, refer to item 3.1 (B).

B. Distribution, lighting and power panelboards are to be connected by protective conductors run together with incoming feeder cable, connecting earth terminals in panelboards with respective main distribution board earthing bar.

C. Socket outlets are to be earthed by protective conductor looped around with the branch circuit and connected to earth terminal within socket outlet box and to which socket outlet terminal is to be connected.

D. Final Ring Sub-Circuits: Protective conductor of every final ring sub-circuit is to be in the form of a ring having both ends connected to earth terminal at origin of circuit in panelboard.

E. Lighting fixtures and other exposed conductive parts of electrical installations, such as switches, heaters, air conditioning units etc. are to be connected by protective earth conductors to earthing terminals of respective panelboards.

3.3 GENERATOR PLANT EARTHING

A. Generator room is to have a separate main earthing bar, to which the generator neutral (star point) is to be connected by insulated earthing conductor through the neutral earthing link or device. Neutral earthing conductor is to be suitably sized to carry maximum earth fault current for time it takes the system protection to operate with final conductor temperature not exceeding 160 deg. C, but not less than 120 mm2 for generator ratings below 500 kVA and 300 mm2 for higher ratings, unless otherwise shown on the drawings.

B. Generator earthing terminal is to be connected to the generator room main earthing bar by insulated copper conductor of cross section not less than 120 mm2, unless otherwise shown on the drawings.

C. Switchgear (ATS) and Control Gear: Earthing terminals or bars of switchgear and control gear are to be connected by separate protective conductors to respective normal and emergency main distribution board earth bars.

D. Extraneous conductive parts including steel frames, battery racks, day-tank, pumps and piping are to be connected by bare copper earthing conductors to main earth bar in compliance with bonding regulations.

3.4 SIGNAL AND COMMUNICATION SYSTEMS

A. Signal and communication systems room is to have separate earthing bar conveniently located, and connected by two insulated earthing conductors, one at each end of the bar, through testing joints to the earth electrode at two separate earth pits, or to the main LV earth bar. Earthing conductors are to be minimum 70 mm2 or as shown on drawings.

B. For telephone, alarm, voice and data, and other communication systems, provide 16mm2 minimum insulated grounding conductor in raceway from grounding electrode system to each service location, terminal cabinet, wiring closet, and central equipment location, unless otherwise indicated on drawings or recommended by system provider.

3.5 INSTALLATION

A. Continuity: Ensure that complete earthing system is electrically continuous and mechanically secure.

B. Earth Rods: While siting earth rods, ensure that resistance areas associated with individual rods do not overlap. Earth rods are to be located at a distance greater than 1 m horizontally from foundations of buildings. Where rock is encountered, a hole of sufficient size is to be drilled before lowering the rod. Conductive filler such as Marconite or Bentonite or equal filler that will not corrode, is to be provided around the rod.

C. Buried earthing conductors are to be laid at a depth not less than 0.5 m from ground surface.

D. Earthing conductors are to follow shortest path between earth rods and main earthing terminals or bars, and are to run in PVC conduit (duct) fastened to building structure by approved supports and extending 0.2 m above level, and are to be protected against mechanical damage and corrosion.

E. Protective Conductors: Separate protective conductors, which are not part of a cable, are to be fixed on same support or drawn into same conduit as circuit conductors.

F. Protective Bonding: Remove any non-conductive paint, enamel or similar coating at threads, contact points and surfaces and ensure that bonding is made by fittings designed to make secure bonds.

3.6 CONNECTIONS

A. Protection against Corrosion: Protect bolted connections against corrosion either by filling with Vaseline or coating with a special anti-corrosion compound and proper capping.

B. Connections: Earth connections are to be readily accessible. If inaccessible earth connection is permitted, approved exothermic welding or brazing technique is to be employed.

C. Connections: Where earth connections between dissimilar metals must be made, use bimetallic fittings and protect by coating with moisture resisting bituminous paint or compound, or by wrapping with protective tape to exclude moisture.

D. Exothermic-Welded Connections: Comply with manufacturer's written instructions. Welds that are puffed up or that show convex surfaces indicating improper cleaning are not acceptable.

E. Tighten screws and bolts for grounding and bonding connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in applicable Standards.

3.7 FIELD QUALITY CONTROL

A. Combined resistance of earth electrodes is to be measured during dry season and checked against specified resistance.

B. Excessive Ground Resistance: If resistance to ground exceeds specified values, notify Engineer promptly and include recommendations to reduce ground resistance.

C. Electrical continuity of all earthing and protective conductors including main and supplementary equipotential bonding conductors is to be checked.

D. Earth fault loop impedance of all circuits is to be measured and checked against calculated impedance figures.

E. Operation of residual current protective devices is to be checked.

3.8 GRADING AND PLANTING

A. Restore surface features, including vegetation, at areas disturbed by Work of this Section. Reestablish original grades, unless otherwise indicated. If sod has been removed, replace it as soon as possible after backfilling is completed. Restore areas disturbed by trenching, storing of dirt, cable laying, and other activities to their original condition. Include application of topsoil, fertilizer, lime, seed, sod, sprig, and mulch. Comply with Division 2 Section "Landscaping." Maintain restored surfaces. Restore disturbed paving as indicated.

END OF SECTION 260526

SECTION 260536 - CABLE TRAYS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes cable trays, cable ladders and related installations and accessories necessary to support and protect cables, feeders, sub-feeders, branch circuit wiring and wiring of low current systems, communications and signal cables. Supporting accessories shall include but not limited to necessary carriage bolts with nut below head, roofing bolts with nut, channel withstanding threaded rod, wall bracket, uni-strut, fish plate, washers, etc.

B. Related Sections include the following:
   1. Division 26 Section "Basic Electrical Materials and Methods" for cable tray / ladder supports not specified in this Section.

1.3 SUBMITTALS

A. Technical Data: Submit data for approval including, but not limited to, the following:

   1. Manufacturers' catalogues with specifications of cable trays / ladders and related accessories.
   2. Samples of each type of tray / ladder and accessory.

B. Shop and Construction Drawings: Submit drawings for approval including, but not limited to, the following:

   1. Detail fabrication and installation of cable tray / ladder, including plans, elevations, and sections of components and attachments to other construction elements. Designate components and accessories, including clamps, brackets, hanger rods, splice-plate connectors, expansion-joint assemblies, straight lengths, fittings and earthing connections.

C. Point-wise compliance statement to the specifications, duly signed by the manufacturer/ manufacturer’s authorized representative and the contractor.

D. Approved Third Party Test Certificates: Submit to verify compliance with the IEC 61537 or NEMA VE-1, as applicable.

E. Coordination Drawings: Include floor plans and sections drawn to scale. Include scaled cable tray / ladder layout and relationships between components and adjacent structural and mechanical elements.

F. Seismic Qualification Certificates: For cable trays, accessories, and components, from manufacturer.

   1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

G. Design Calculations: Submit design calculations to verify the following:
1. Loading capacities for supports.
2. Perforation base area for cable trays according to the specified Class.
3. Free base area for cable ladders according to the specified Class.

H. Factory Test: Submit Factory tests including safe working load, deflection tests and measurement of steel and galvanization thicknesses.

I. Maintenance Data: For cable trays to be included in the maintenance manuals specified in Division 01.

J. As-Built (Record) Drawings: At Project close-out, submit Record Drawings of installed cable trays in accordance with requirements of the Specification, Division 01.

1.4 QUALITY ASSURANCE

A. Source Limitations: Obtain cable trays and components through one source from a single manufacturer.

B. Comply with the following standards:

1. IEC 61537.
2. ISO 1461.
3. ISO 12944-2.

As an alternative, cable trays in compliance with NEMA VE1 are acceptable.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Materials shall not be stored in damp and open environment and shall be stored in covered places only.

1.6 PROJECT CONDITIONS

A. Existing Utilities: Do not interrupt utilities serving facilities occupied by the Employer or others unless permitted under the following conditions and then only after arranging to provide temporary utility services according to requirements indicated.

1. Notify Engineer not less than 1 week in advance of proposed utility interruptions.
2. Do not proceed with utility interruptions without Engineer's written permission.

1.7 COORDINATION

A. Coordinate layout and installation of cable tray / ladder with other installations to ensure clear access to the cable trays to facilitate maintenance, checking and further pulling of cables.

1. Revise locations and elevations from those indicated as required to suit field conditions and as approved by the Engineer.

1.8 FACTORY VISIT

A. Approved supplier's manufacturing facilities of locally assembled products under this Contract are subject to factory visit by the Engineer. Factory visit shall include checking of quality assurance and factory's capabilities along with witnessing of factory production tests including but not limited to: safe working load, deflection tests, measurement of steel and galvanization thicknesses, review calculations of perforation base area for cable trays and free base area for cable ladders according to the specified Class. Visit program shall be submitted for approval prior to the scheduled visit. Allow for visit expenses including business class transportation and hotel accommodation as necessary for two persons from the Engineer's/ Employer's side.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Approved Manufacturers: Subject to compliance with requirements, provide products by one of the following or approved equal:

1.	B-Line Systems, Inc.	(U.S.A.)
2.	Thomas & Betts	(U.S.A.)
3.	Swifts	(U.K.)
4.	Wibe	(Sweden)

B. Locally manufactured cable trays / ladders are acceptable subject to compliance with design requirements.

2.2 CABLE TRAYS AND LADDERS

A. Cable trays and ladders shall comply with IEC 61537.

B. Cable trays shall meet Class C requirements for perforation free area as per IEC 61537 as a minimum.

C. Cable ladders shall meet Class Y requirements for free base area as per IEC 61537 as a minimum.

D. Components: To include cable trays or ladders, bends, elbows, tees, couplings and plates, rubber grommets, hangers, bracket supports and other system accessories required for safety and protection of the cable installations. All fittings and accessories shall be purpose made from the manufacturer. Field fabricated fittings and accessories are not acceptable.

E. Trays: Provide to carry the maximum load of cables with a factor of safety 300% or 90 kg concentrated load whichever is more stringent.

F. Trays: Heavy gauge perforated sheet steel, heavy duty, hot-dip galvanized after manufacture, minimum 1.5 mm thickness for cable trays up to 300 mm width and 2 mm thickness for cable trays exceeding 300 mm width, with sides not less than 60 mm depth for cable trays up to 300 mm width, 85 mm depth for cable trays exceeding 300 mm width and up to 600 mm width and 110 mm depth for cable trays exceeding 600 mm width with outwards return flanges, unless otherwise recommended by manufacturer and approved by the Engineer. Fittings shall be made of the same material as tray. Covers, where shown on the Drawings, shall be minimum 1.0 mm thick for cable trays up to 600 mm width and 1.5 mm thick for cable trays exceeding 600 mm width and shall be made of sheet steel hot-dip galvanized after manufacture, snap-on or bolt type, forming a rigid assembly with the tray.

G. Trays Perforation: Cable trays perforation size and direction shall be properly designed to suit cable ties or cleats to be used for cable fixation. Contractor shall submit method of cable fixation for Engineer's approval prior to installation.

H. Ladders: Hot-dip galvanized after manufacture, fabricated from 2 mm mild carbon steel. Ladder side channels shall be minimum 125 x 22 mm, strengthened by reinforcing inserts for torsional rigidity. Rungs shall be slotted to take cable cleats or ties and conduit clamps. Rungs shall be minimum 50 x 25 mm channels, spaced at 300 mm centers.

I. Fully controlled, stringent pretreatment process including, alkaline de-greasing, rinsing, pickling, fluxing and drying shall be carried out before hot dip galvanizing.

J. Galvanizing shall be in accordance with ISO 1461, applied after fabrication with local coat thickness of 45 µm (local coating mass of 325 g/m2) and mean coat thickness of 55 µm (mean coating mass of 395 g/m2). Cable trays manufactured to NEMA VE1 shall have galvanization in accordance with NEMA VE 1 requirements.

K. Cable trays / ladders installed in corrosive atmosphere shall be provided with powder coating over hot dip galvanization of high chemical resistant polyster / epoxy to meet the requireemnts of the below classification. High bonding between the galvanizing and the paint finish shall be certified by the manufacturer with a guaranteed life of 20 years.

1. For installations in outdoor industrial areas and coastal areas with moderate salinity and indoor in swimming pools, chemical plants, coastal ship and boatyards; use galvanization and powder coating in compliance with corrosion risk category C4 to ISO 12944-2.
2. For installations in outdoor industrial areas with high humidity and aggressive atmosphere and in indoor areas with almost permanent condensation and with high pollution; use galvanization and powder coating in compliance with corrosion risk category C5-I to ISO 12944-2.

L. Bolts and Screws: Cadmium plated or electrolytically galvanized.

M. Sizes: Trays and ladders shall be standard metric sizes, 150, 300, 450, 600 and 900 mm wide, and at least 3 m length of section. Size of tray or ladder shall be determined by number and sizes of cables in accordance with the Regulations and / or as shown on the Drawings. Tray or ladder shall have strength and rigidity to provide support for cables contained within. Deflection between supports shall comply with IEC 61537 requirements.

N. Earthing connector for trays or ladders shall be provided on each coupling between adjacent sections.

O. Seismic Performance: Cable trays and supports shall withstand the effects of earthquake motions determined according to UBC97 for seismic zone exceeding 2B.

1. The term "withstand" means "cable trays will remain in place without separation of any parts when subjected to the seismic forces specified."

P. Products shall be provided with stamped markings by manufacturers.

Q. Cable trays and ladders shall be provided with galvanized ventilated sunshade covers when installed in outdoor locations. Sun shade and fixings shall be from the same manufacturer of cable tray/ladder.

R. Finish of the cable trays/ladders used outdoors shall be certified to be UV stabilized.

2.3 WIRE-BASKET CABLE TRAYS

A. Description:
   1. Configuration:
      a. Wires are formed into a standard (50-by-100-mm) wire mesh pattern with intersecting wires welded together. Mesh sections must have at least one bottom longitudinal wire along entire length of section.
      b. Utilize the appropriate under floor or overhead basket-type cable tray components and fittings when applicable.
   2. Materials: High-strength-steel longitudinal wires with no bends.
   3. Safety Provisions:
      a. Wire ends along wire-basket sides (flanges) rounded during manufacturing to maintain integrity of cables and installer safety.
      b. The cable tray system shall include all continuous grounding hardware components.
      c. Consider exposure rating of cable tray components for all installation environments including air handling (plenum) spaces, extreme, harsh, indoor or outdoor areas.
   4. Sizes:
      a. Straight sections shall be furnished in standard 3000-mm lengths.
      b. Select cable tray width and depth parameters to maintain a final fill capacity of no greater than **25% as per TIA 569 recommendations**.
      a. Available dimensions:
         1) Wire-Basket Depth: 50-mm usable loading depth by 100 mm, 150 mm, 200 mm, 300 mm, 450 mm, 600 mm wide.
         2) Wire-Basket Depth: 100-mm usable loading depth by200 mm, 300 mm, 450 mm, 600 mm wide. wide.
   5. Connector Assemblies: Bolt welded to plate shaped to fit around adjoining tray wires and mating plate. Mechanically joins adjacent tray wires to splice sections together or to create horizontal fittings.
   6. Connector Assembly Capacity: Splices located within support span shall not diminish rated loading capacity of cable tray.
   7. Hardware and Fasteners: A full complement of fittings for the cable tray shall be available including, but not limited to 45 and 90 degree flat elbows, vertical inside and outside elbows, tee fittings, couplings for joining sections of the tray, hangers, end blanks, and all other components necessary to make the system workable. The fittings and accessories shall be of compatible material and color.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install cable tray / ladder level and supporting system according to manufacturer's written instructions, Coordination Drawings, original design, and referenced standards.

B. Spare capacity shall be 25 % for vertical installations and 15% for horizontal installations.

C. Each run shall be completed before installation of cables. Submit calculations taking into consideration the maximum cables load on cable trays with a factor of safety 300%.

D. Remove burrs and sharp edges from cable trays / ladders. Fix trays / ladders using approved suspension rods or uni-struts or angle brackets at spacing not exceeding 1.5 m and as per the approved supports calculations.

E. Cables Fixation: Secure cables to tray / ladder with purpose made straps, cleats or saddles as specified in Division 26 Section "Low Voltage Electrical Power Conductors and Cables" and Division 26 Section "Medium Voltage Cables". Cable cleats and ties shall be correctly sized and tightened to secure the cable without indenting the insulation sheath.

F. Cables Arrangement: Arrange cables in one layer only, with minimum spacing of one diameter of the larger of the two adjacent cables or of a trefoil formation of single core cable circuit, unless otherwise shown on the Drawings.

G. Cables Bending Radius: Cables installation on trays / ladders shall ensure that the minimum cable bending radius as recommended by the manufacturer is not violated.

H. Fasten cable tray / ladder supports securely to building structure and install seismic restraints as specified in Division 26 Section "Basic Electrical Materials and Methods," unless otherwise indicated.

1. Design supports, including fastenings to the structure, to carry the total load of cables and trays multiplied by a safety factor of 3. Submit calculations for approval. Comply with seismic-restraint details according to Division 26 Section "Vibration and Seismic Controls for Electrical Systems.

I. Cables Installation on Trays / Ladders: Use necessary rollers and pulleys at proper spacing for installation of large and long run cables. Pulleys / rollers shall be fixed to structural elements and not cable trays / ladders. Necessary pulling tools such as basket grips or pulling eyes shall be used with a proper force and speed to ensure not exceeding the manufacturer's recommended maximum cable pulling tension.

J. Make connections to equipment with flanged fittings fastened to cable tray / ladder and to equipment. Support cable tray / ladder independently of fittings. Do not carry weight of cable tray / ladder on equipment enclosure.

K. Install expansion connectors where cable tray / ladder crosses a building expansion joint and in cable tray / ladder runs that exceed 39 m, unless otherwise calculated by the manufacturer and approved by the Engineer considering a maximum movement of 25 mm.

L. Make cable tray / ladder connections, changes in direction and elevation using standard fittings. Fittings shall be properly curved / designed to satisfy the minimum bending radius requirements and avoid sharp edges / corners.

M. Locate cable tray / ladder above piping, unless accessibility to cable tray / ladder is required or unless otherwise indicated.

N. Seal penetrations through fire zones or smoke barriers as specified in Division 07 Section "Penetration Firestopping."

O. If cable trays / ladders are sized for future cables, furnish necessary provisions for penetrations with capped sleeves for future cables through fire-rated partitions, or use "repairable" fire stopping-penetration sealing material.

P. Workspace: Install cable trays / ladders with sufficient space to permit access for installing cables. Minimum clearance of 250 mm shall be maintained between top of tray / ladder and ceiling, beams and other services and between tray / ladders in multi-tier formation.

Q. Barriers: Where tray / ladders carry conductors of different systems, such as power, communications and data processing, or different insulation levels, such as 600V, 5000V, and 20,000 V use separate cable tray / ladders. In case of absolute necessity, install insulating barriers to separate the systems after obtaining the Engineer's approval. Barriers and spacing between system's cables shall be in accordance with relevant codes, standards and manufacturers' recommendations.

R. Install covers after installation of cable is completed.

S. Labeling of trays shall be provided at every change in direction and at every 12 meters on straight runs. Size of letters and color of labels, marking and references shall be as per the relevant standard regulations.

T. Cable trays/ladders shall not be installed in lengths below water/sewage pipes.

U. Electrical continuity strips / links shall be provided by the manufacturer of the tray/ladder.

3.2 CONNECTIONS

A. Ground cable trays / ladders according to manufacturer's instructions.

1. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values.

3.3 WARNING SIGNS

A. After installation of cable trays / ladders is completed, install warning signs in visible locations on or near cable trays / ladders.

3.4 FIELD QUALITY CONTROL

A. Perform the following tests and inspections in coordination with the contractor as proper and applicable:

1. Visually inspect cable insulation for damage. Correct sharp corners, protrusions in cable trays, vibrations, and thermal expansion and contraction conditions, which may cause or have caused damage.
2. Verify that the number, size, and voltage of cables in cable trays meet specification and the approved Shop Drawings requirements. Verify that communications or data-processing circuits are separated from power circuits by barriers or are installed in separate cable trays.
3. Verify that there are no intruding items such as pipes, hangers, or other equipment in the cable tray.
4. Remove dust deposits, industrial process materials, trash of any description, and any blockage of tray ventilation.
5. Visually inspect each cable tray joint and each ground connection for mechanical continuity. Check bolted connections between sections for corrosion. Clean and re-torque in suspect areas.
6. Verify that no corroded units are present.
7. Check for improperly sized or installed bonding jumpers.
8. Check for missing, incorrect, or damaged bolts, bolt heads, or nuts. When found, replace with specified hardware.
9. Perform visual and mechanical checks for adequacy of cable tray grounding; verify that all takeoff raceways are bonded to cable trays. Test entire cable tray system for continuity. Maximum allowable resistance is 1 ohm.

B. Grounding: Do not use metal trays / ladders as earth continuity conductor. Connect trays / ladders by flexible tinned copper straps to nearest bare earthing conductor and at maximum 30-m spacing.

C. Anchorage: Test pullout resistance for toggle bolts and powder-driven threaded studs for each type and size of anchorage material.

1. Furnish equipment, including jacks, jigs, fixtures, and calibrated indicating scales, required for reliable testing.

2. Obtain Engineer's approval before transmitting loads to the structure. Test to 90 percent of rated proof load for fastener.

D. Replace malfunctioning units and retest until satisfactory results are achieved.

E. Prepare test and inspection method for Engineer’s approval. Submit test reports after completion on site.

3.5 CLEANING

A. On completion of cable tray / ladder installation, including fittings, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes, including chips, scratches, and abrasions.

3.6 PROTECTION

A. Provide final protection and maintain conditions, in a manner acceptable to manufacturer and Installer that ensure cable tray / ladder is without damage or deterioration at the time of Substantial Completion.

1. Repair damage to galvanized finishes with zinc-rich paint recommended by cable tray / ladder manufacturer.
2. Repair damage to PVC or paint finishes with matching touchup coating recommended by cable tray / ladder manufacturer.

END OF SECTION 260536

SECTION 260543 - UNDERGROUND DUCTS AND RACEWAYS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes underground conduits and ducts, duct banks, pull boxes and handholes, manholes, and other underground utility structures.

B. Related Requirements include the following as applicable:

1. Division 31 Section "Earth Moving" for excavation, backfill, and related items for ducts, manholes, and handholes.
2. Division 03 Section "Concrete Forming and Accessories" for formwork, waterstops, and joints accessories and details requirements.
3. Division 03 Section "Concrete Reinforcing" for reinforcement requirements.
4. Division 03 Section "Cast-in-Place Concrete" for concrete requirements.
5. Division 03 Section "Precast Structural Concrete" for precast elements requirements.
6. Division 07 Section "Self-Adhering Sheet Waterproofing" for waterproofing of manholes and handholes.
7. Division 07 Section "APP-Modified Bituminous Sheet Waterproofing" for waterproofing of manholes and handholes.
8. Division 07 Section "SBS-Modified Bituminous Sheet Waterproofing" for waterproofing of manholes and handholes.
9. Division 07 Section "Bituminous Damp-proofing" for dampproofing of manholes and handholes.
10. Division 26 Section "Basic Electrical Materials and Methods".
11. Division 26 Section "Grounding and Bonding for Electrical Systems" for ground rods at manholes.

1.3 SYSTEM DESCRIPTION

A. Underground Ducts for Electrical Utility Service: UPVC encased in concrete, unless otherwise shown on Drawings.

B. Underground Ducts for Electrical Feeders: **UPVC encased in concrete**, unless otherwise shown on Drawings.

C. Underground Ducts for Electrical Branch Circuits: [**Direct-buried UPVC conduit**] [**UPVC encased in concrete**], unless otherwise shown on Drawings.

D. Underground Ducts for Telephone Utility Service: UPVC utility duct encased in concrete or in sand surround, unless otherwise shown on Drawings, and as per the Telephone service provider requirements.

E. Underground Ducts for Communication Circuits: UPVC underground conduit encased in concrete.

F. Manholes: Underground, precast concrete utility structures.

G. Manholes: Cast-in-place concrete.

1.4 SUBMITTALS

A. Product Data: For each type of products include the following:

1. Duct-bank materials, including separators and miscellaneous components.
2. Ducts, conduits and their accessories, including elbows, end bells, bends, fittings, and sealing compound.
3. Accessories and covers for manholes, handholes, boxes.
4. Warning tapes and concrete tiles.

B. Sustainable Design Submittals: All related Sustainable Product Data as detailed in Division 01 Sustainability sections, as applicable, for Low-Emitting Materials for solvents and adhesives.

C. Shop Drawings:

1. Cast-in-place Underground Utility Structures: Show details for manholes and handholes including:

a. Plans, elevations, sections, details, reinforcement details and schedules, formwork details and waterstoping, plans, calculation notes, attachments to other work, and accessories.
b. Duct entry provisions, including locations and duct sizes.
c. Frame and cover design and manhole frame support rings.
d. Ladder details.
e. Grounding details.
f. Dimensioned locations of cable rack inserts, pulling-in and lifting irons, and sumps.

2. Precast Underground Utility Structures: Show details and design calculations for precast manholes and handholes, including reinforcing steel. Include Shop Drawings prepared by registered professional structural engineer, as indicated by seal on Shop Drawings. Details shall include:

a. Plans, elevations, sections, calculation notes, details, connection details and joints treatment, attachments to other work, and accessories.
b. Duct entry provisions, including locations and duct sizes.
c. Reinforcement details and schedules.
d. Frame and cover design and manhole frame support rings.
e. Ladder details.
f. Grounding details.
g. Dimensioned locations of cable rack inserts, pulling-in and lifting irons, and sumps.

3. Prefabricated Handholes and Boxes: Details shall include:

a. Dimensioned plans, sections and installation details.
b. Duct entry provisions, including locations and duct sizes.
c. Include cover design.

D. Coordination Drawings: Show duct profiles and coordination with other utilities and underground structures. Include plans and sections drawn to scale.

E. Field Test Reports: Indicate and interpret test results for compliance with performance requirements.

F. Record (As-Built) Drawings: At project Closeout, submit record drawings of installed electrical ducts, handholes, manholes, etc… in accordance with requirements of the Specification, Division 01 and showing dimensioned locations of underground ducts and structures.

G. Duct Schedule: Provide a duct schedule of each manhole indicating duct sizes, number of ducts utilized, size of cables installed and number of free ducts.

1.5 QUALITY ASSURANCE

A. Products, materials and equipment shall demonstrate compliance with requirements specified in Section 016000 "Product Requirements".

B. Comply with specified Standards.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver ducts to Project site with ends capped. Store nonmetallic ducts with supports to prevent bending, warping, and deforming.

B. Store precast concrete units at Project site as recommended by manufacturer to prevent physical damage. Arrange so identification markings are visible.

C. Lift and support precast concrete units only at designated lifting or supporting points.

1.7 PROJECT CONDITIONS

A. Existing Utilities: Do not interrupt utilities serving facilities occupied by Employer or others unless permitted under the following conditions and then only after arranging to provide temporary utility services according to requirements indicated.

1. Notify Engineer not less than 2 days in advance of proposed utility interruptions.
2. Do not proceed with utility interruptions without Engineer's written permission.

1.8 COORDINATION

A. Coordinate layout and installation of ducts, manholes, and handholes with final arrangement of other utilities as determined in the field.

B. Coordinate elevations of duct and duct-bank entrances into manholes and handholes with final profiles of conduits as determined by coordination with other utilities and underground obstructions. Revise locations and elevations from those indicated as required to suit field conditions and to ensure duct runs drain to manholes and handholes, and as approved by Engineer.

PART 2 - PRODUCTS

2.1 STANDARD COMMERCIAL PRODUCTS

A. Refer to Division 01 Section 016000, "Product Requirements".

2.2 UNPLASTICIZED POLYVINYL CHLORIDE (UPVC) DUCTS

A. UPVC Ducts for Outdoor Installations: Non-sparking type, suitable for direct burial in ground, [**Class B to BS 3506 or Class 3 to DIN 8062**][**Class C to BS 3506 or Class 4 to DIN 8062**], supplied in standard 6 m lengths, with one end of each length tapered.

1. Nominal Size: As shown on Drawings.

2. Average Wall Thickness: [**4 mm for 4 inches ducts; 5.2 mm for 6 inches ducts and 6.1 mm for 8 inches ducts**][**5.2 mm for 4 inches ducts; 7.5 mm for 6 inches ducts and 8.8 mm for 8 inches ducts**].
3. Minimum Wall Thickness: [**3.4 mm for 4 inches ducts; 4.5 mm for 6 inches ducts and 5.3 mm for 8 inches ducts**][**4.5 mm for 4 inches ducts; 6.6 mm for 6 inches ducts and 7.8 mm for 8 inches ducts**].
4.

B. Duct Supports: Rigid UPVC spacers selected to provide minimum duct spacings and concrete cover depths indicated, while supporting ducts during casting.

C. Duct Sealing Compound: Non-hardening, safe for human skin contact, not deleterious to cable insulation, and workable at temperatures as low as 1 deg C. Capable of withstanding temperature of 149 deg C without slump and of adhering to clean surfaces of plastic ducts, metallic conduits, conduit coatings, concrete, masonry, lead, cable sheaths, cable jackets, insulation materials, and common metals. Sealants shall be water tight.

D. Where innerduct is utilized, coordinate conduits and innerducts to ensure compatibility. Refer to Division 26 Section "Raceways and Boxes for Electrical Systems".

2.3 COVERS FOR MANHOLES AND HANDHOLES

A. Frames and Covers: BS EN 124-1, BS EN 124-2, and BS EN 124-3, checkered cast iron or cast steel, water tight, recessed type, classified as [**Group 4**] [**Group 5**] [**Group 6**] to BS EN 124-1.

B. Covers: Cast-in legend "M.V." for Medium Voltage, "L.V." for Low Voltage, "E.L.V." for Extra Low Voltage, as appropriate.

C. Manhole opening cover must be near a side wall.

D. Cover shall be lockable, smart type with auxiliary contact. Alarm shall be sent to [**SCADA**] [**BMS**] in case of unauthorized intervention or intrusion.

2.4 GENERAL REQUIREMENTS FOR HANDHOLES AND MANHOLES

A. All electrical manholes shall be provided with stub-out at the blank wall of the manhole. The number of stub-outs shall not be less than 25 percent of the total number of ducts entering the manhole, with not less than 2 units as a minimum.

B. Provide suitable arrangement in the manhole for supporting cables along the walls of the manhole. Cables shall not be left on the floor of the manholes.

C. Access for maintenance shall be provided by means of GRP/metallic ladder with steps to be fixed at each 300 mm on the manhole/handhole (of 1.5 m depth and above).

D. Grounding shall comply with Division 26 Section "Grounding and Bonding for Electrical Systems".

E. Each manhole and handhole shall be provided with proper water drainage at its bottom.

F. Each manhole and handhole shall be provided with drainage pit of suitable dimensions (minimum 300 x 300 mm) to allow for manual suction of water through portable submersible pump.

2.5 CAST IN PLACE UNDERGROUND UTILITIES

A. Concrete: Comply with Division 03 Section "Cast-in-Place Concrete" for concrete and Division 03 Section "Concrete Reinforcing" for reinforcement, and Division 03 Section “Concrete Forming and Accessories” for formwork and waterstops.

B. Concrete Envelope: Duct banks crossing water, gas and sewage mains, under roadways and where required or shown on the Drawings, shall be 28 MPa, 28-day, compressive-strength on cylinder reinforced concrete using [**ordinary Portland cement**] [**Moderate Sulfate Resisting Cement**] [**a combination of ordinary Portland cement, GGBS, and Fly Ash, as specified in Section 033000 “Cast-in-Place Concrete”**]. Reinforcement shall consist of 12-mm diameter longitudinal bars at approximately 300-mm centers along bottom and sides of duct bank with 10-mm diameter U-shaped transversal bars at 400-mm centers. Extend concrete envelope at least 300 mm beyond each side of crossing, etc.

C. Cable Manholes and Handholes: 28 MPa, 28-day, compressive strength on cylinder reinforced concrete using [**ordinary Portland cement**] [**Moderate Sulfate Resisting Cement**] [**a combination of ordinary Portland cement, GGBS, and Fly Ash, as specified in Section 033000 “Cast-in-Place Concrete”**], with approved waterproof membrane on external surfaces, and with cable supports and accessories where necessary, pull-eyes, and drain pit and drain pipe. Dimensions and reinforcement are to be as shown on the Drawings or in accordance with approved standard details shown on shop and construction drawings.

2.6 UNDERGROUND, PRECAST CONCRETE UTILITY STRUCTURES

A. Precast Units: Interlocking, mating sections, complete with accessory items, hardware, and features as indicated. Include concrete knockout panels for conduit entrance and sleeve for ground rod.

B. Design structure according to details on Drawings.

C. Structural Design Loading: **Heavy traffic** to ASTM C857.

D. Covers: Recess on cover accepts finish material in landscaped and paved areas.

E. Joint Sealant: Continuous extrusion of asphaltic-butyl material with adhesion, cohesion, flexibility, and durability properties necessary to withstand maximum hydrostatic pressures at the installation location with the ground water level at grade.

2.7 PREFABRICATED HANDHOLES AND BOXES

A. Cast-Metal Handholes / Boxes: Cast aluminum, sized as indicated, with outside flanges and recessed, gasketed cover for flush mounting. Nonskid finish on cover.

B. Fiberglass Handholes / Boxes: Molded fiberglass, sized as indicated, with 150-mm square cable entrance at each side and weatherproof cover with nonskid finish.

C. Cover Legend: "L.V." for Low Voltage, "E.L.V." for Extra Low Voltage, as appropriate.

2.8 CONSTRUCTION MATERIALS

A. Waterproofing: Comply with Division 07 Section "Self-Adhering Sheet Waterproofing."

B. Waterproofing: Comply with Division 07 Section "APP Modified Bituminous Sheet Waterproofing."

C. Waterproofing: Comply with Division 07 Section "SBS Modified Bituminous Sheet Waterproofing."

D. Dampproofing: Comply with Division 07 Section "Bituminous Dampproofing."

2.9 CABLE PROTECTION COVERS/TAPES

A. The cable protection covers/tapes shall be suitable for direct burying in ground.

B. Materials: The protection covers/tapes shall consist of a base material either high density polyethylene (HDPE) or high impact grade polyvinyl chloride (PVC) to which has been added only those materials to give the required good finish, strength, durability, color and capacity. Protection covers/tapes shall be detectable type to IEC standard.

C. Dimensions

DESCRIPTION	CABLE PROTECTION COVERS		CABLE PROTECTION TAPES	
Length	1m to 1.5m each cover (effective length excluding overlapping for interlocking)		50 to 100m each Tape Roll	
Thickness	2.0 mm (minimum)		2.0 mm (minimum)	
Width	150 mm	200 mm	150 mm	200 mm

D. Colors shall be as per relevant IEC Standards.

E. Cable protection tapes shall be of the detectable type.

F. The cable protection covers/protection tapes shall have the following caption printed on top in [**English**][**Arabic & English**], in characters not less than 15 mm size and shall be specially protected against deterioration.

1. On all cable protection covers/tapes

"DANGER"

And as follows:

a. For HV or MV: "ELECTRIC HV/MV POWER CABLE 20 CM BELOW"
b. For LV: "ELECTRIC 400V POWER CABLE 20 CM BELOW"
c. For Telephone: "TELEPHONE".
d. For Data & Communication: "DATA / COMMUNICATION".
e. For Airfield Ground Lighting “Airfield Ground LIGHTING”

2. In the case of covers, above caption shall appear on each cover whereas in the case of tapes, gap between successive captions shall not be more than 30 cm.

G. Inter-locking (applicable only to Protection Covers)

1. Suitable inter-locking shall be provided on each cable protection cover along its width. The inter-locking arrangement shall be subject to the Employer's/Engineer's approval and shall be such as to ensure easy installation and shall have same tensile strength as the cover.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions to receive ducts and utility structures for compliance with requirements for installation tolerances and other conditions affecting performance of underground ducts and utility structures. Do not proceed with installation until unsatisfactory conditions have been corrected.

3.2 EARTHWORK

A. Excavation and Backfill: Comply with Division 31 Section "Earth Moving" but do not use heavy-duty, hydraulic-operated, compaction equipment unless approved by the Engineer.

B. Trenches: Width is to be as small as practicable with sides vertical. Remove mud, rock projections, boulders and hard spots from trench bottom and trim level. Inform the Engineer in advance to give him reasonable opportunity to inspect trench for each section of the work.

C. Restore surface features at areas disturbed by excavation and reestablish original grades, unless otherwise indicated. Replace removed sod immediately after backfilling is completed.

D. Restore all areas disturbed by trenching, storing of dirt, cable laying, and other work. Restore vegetation and include necessary topsoiling, fertilizing, liming, seeding, sodding, sprigging, and mulching. Perform according to Division 32 related Sections.

E. Restore Disturbed Pavement. Refer to Division 32 related Sections.

3.3 DIRECTLY BURIED UPVC CABLE DUCTS

A. Lay and join ducts to required line and level on sand bed, cover with sand and backfill trench to ground level with excavated soil, free from stones and other debris, well compacted in layers not exceeding 300 mm thick.

B. Lay approved concrete tiles to fully cover cable duct, extending minimum 50 mm beyond sides of duct and placed 300 mm below ground level.

C. Provide warning tape or galvanized steel mesh, detectable type, along duct runs at a depth 200 mm below ground level.

3.4 UNDERGROUND CABLE DUCT ASSEMBLIES

A. Install duct as indicated, according to manufacturer's written instructions.

B. Form duct assembly to required line and level, using duct supports spaced to prevent sagging of ducts and breaking of couplings and watertight seals, and secured with cords (not tie wires) where necessary.

C. Slope: Pitch ducts a minimum of 1:300 (preferably 1% slope) to drain toward manholes and handholes and away from buildings and equipment. Slope ducts from a high point in runs between 2 manholes to drain in both directions.

D. Join ducts using waterproof cement, to manufacturer's recommendations, to give waterproof and sand-proof joint with at least 80 mm overlap.

E. Provide 3 mm galvanized steel wire inside empty ducts, for future pulling of cables, extending 1 m beyond duct banks at both ends and securely fixed to wooden bungs sealing the duct.

F. Concrete-Encased Ducts: Support on plastic separators coordinated with duct size and required duct spacing, and install according to the following:

1. Separator Installation: Space separators close enough to prevent sagging and deforming of ducts, and secure separators to the earth and to ducts to prevent floating during concreting. Do not use tie wires or reinforcing steel that may form conductive or magnetic loops around ducts or duct groups.
2. Provide duct separators in basic sizes that can be joined together to support any number of ducts. Duct spacers shall be made of UPVC or an approved alternative. Duct spacers shall provide a uniform separation of the ducts within the formation in the trench (both vertically and horizontally).
3. Concreting: Spade concrete carefully during pours to prevent voids under and between conduits and at exterior surface of envelope. Do not use power-driven agitating equipment unless specifically designed for duct-bank application. Pour each run of envelope between manholes or other terminations in one continuous operation. When more than 1 pour is necessary, terminate each pour in a vertical plane and install 19-mm reinforcing rod dowels extending 450 mm into the concrete on both sides of joint near the corners of the envelope.
4. Reinforcement: Reinforce duct banks where they cross disturbed-earth and where indicated.
5. Forms: Use the walls of the trench to form the side walls of the duct bank where the soil is self-supporting and concrete envelope can be poured without soil inclusions; otherwise, use forms.
6. Minimum Clearances between Ducts: 75 mm between ducts and exterior envelope wall, 50 mm between ducts for like services, and 100 mm between power and signal ducts, unless otherwise shown on Drawings.

G. Sealing: Provide temporary closure at terminations of ducts that have cables pulled. Seal spare ducts at terminations. Use sealing compound and plugs.

3.5 INSTALLATION OF CABLES AND ACCESSORIES

A. Depth of Laying: The depth of laying cables shall be as shown on Drawings and as per the final approved utility disposition layouts.

3.6 ENDS OF DUCTS

A. Ducts ending in cable manholes or handholes are to be neatly cut and reamed and set behind chamfered precast concrete duct end blocks or terminated with appropriate bell-mouth bushing set in concrete wall. Ducts not ending in cable manholes or handholes are to be properly capped.

B. Sealing Ends Of Ducts: Completely seal conduits and ducts, active or spare, at entry into buildings or manholes, with approved plastic molds or wooden bungs to prevent entry of water, rodents, gas and vapor.

3.7 SLEEVES OR DUCTS IN EQUIPMENT FOUNDATIONS

A. Provide sleeves or ducts in equipment foundations, whether or not shown on Drawings, in accordance with approved shop drawings or as instructed by the Engineer. Obtain approval of sleeve or duct installation prior to pouring concrete.

3.8 UNDERGROUND UTILITY STRUCTURE INSTALLATION

A. Drainage: Install drains in bottom of units to ensure proper drainage while avoiding any water penetration from outside.

B. Waterproofing: Apply waterproofing to exterior surfaces of units after concrete has cured at least 3 days unless otherwise recommended by waterproofing membrane manufacturer. Apply according to Division 07 Section [**"Self-Adhering Sheet Waterproofing."**] [**"APP Modified Bituminous Sheet Waterproofing."**] [**"SBS Modified Bituminous Sheet Waterproofing."**] After ducts have been connected and grouted, and before backfilling, waterproof joints and connections and touch up abrasions and scars. Waterproof exterior of manhole and handhole chimneys after brick mortar has cured at least 3 days.

C. Dampproofing: Apply dampproofing to exterior surfaces of units after concrete has cured at least 3 days unless otherwise indicated by dampproofing manufaturer. Apply according to Division 07 Section "Bituminous Dampproofing.". After ducts have been connected and grouted, and before backfilling, dampproof joints and connections and touch up abrasions and scars. Dampproof exterior of manhole and handhole chimneys after brick mortar has cured at least 3 days.

D. Cast-in-Place, Underground Structure Installation: Comply with applicable requirements of Division 03 Section "Cast-in-Place Concrete."

1. Finish interior surfaces with a smooth troweled finish.

E. Precast Concrete, Underground Structure Installation: Install as indicated, according to manufacturer's written instructions.

1. Install units level and plumb and with orientation and depth coordinated with connecting ducts to minimize bends and deflections required for proper entrances.
2. Support units on a level bed of crushed stone or gravel, graded from the 25-mm sieve to the 4.75-mm sieve and compacted to the same density as adjacent undisturbed earth.

F. Drawpits, Bases and Foundations:

1. All excavation and backfill works shall conform to the requirements of relevant sections.
2. The excavation shall be well cleaned and a waterproof membrane lining placed in the bottom and on the sides before the concrete is poured.
3. Walls and roof slabs of drawpits shall be properly formed.
4. Steel reinforcement shall be provided and placed as shown on the Drawings, UPVC ducts shall be installed as detailed.
5. Manholes and handholes shall be provided with approved [**waterproofing membrane**] [**damp proofing**] on all external surfaces, and with cable supports (stainless steel), pull eyes, drain pit and drain pipe (as required).
6. Where duct openings provided in the drawpit wall are unused, they shall be fitted with a 300 mm length of capped stub duct.
7. Foundations for feeder pillars shall be in accordance with the manufacturer's detailed drawings.
8. Foundations for lighting columns and high mast shall be in accordance with the dimensions, details and technical requirements as shown on the Drawings. The Contractor shall be responsible to confirm the value of the soil bearing capacity and submit foundations calculations for Engineer's approval. In case of any deviation in the value, Contractor shall refer to the Engineer.

G. Trenching for Duct or Cable Laying:

1. Trenches shall be excavated to the depth shown on the Drawings in any material including soil, sand or rock, in level of sloping ground in the locations shown. The trenches shall be wide enough to accommodate the ducts or cables at the spacing indicated or as shown on Drawings. Excavation to link the trenches with every location into ducts at road crossings and into enclosures shall be included.
2. A bed of sand of 100 mm to 200 mm thickness shall be laid in the bottom of the trench prior to the ducts being laid.
3. After laying of the ducts, a surrounding and covering layer of sand or concrete encased 200 mm deep shall be placed over the ducts, followed by the interlocking cable tiles (for surround

only), then the backfill incorporating the marker PVC tape which shall be to ASTM standards incorporating a steel wire (to enable magnetic identification) and the whole then compacted. These operations shall be carefully coordinated with the duct layer who shall supervise the duct covering operations to ensure there shall be no damage to the ducts.

3.9 FIELD QUALITY CONTROL

A. Inspection of Duct Systems: Inspect directly buried ducts and underground duct assemblies in the presence of the Engineer, before backfilling or concreting. Steel mandrel or other approved device, diameter equal to 90% of inside diameter of duct and 500 mm long, is to be pulled through entire run of duct and is to pass through without getting stuck. Ducts, which do not allow mandrel to be pulled through, are to be repaired or replaced to the satisfaction of the Engineer.

B. Testing: Demonstrate capability and compliance with requirements on completion of installation of underground ducts and utility structures.

C. Correct installations where possible and retest to demonstrate compliance. Remove and replace defective products and retest.

3.10 CLEANING

A. Clean ducts with stiff bristle brush pulled through each duct prior to pulling in cables. Pull brush through full length of ducts. Use round-bristle brush with a diameter 12 mm larger than the ID of duct.

B. Clean internal surfaces of manholes, including sump. Remove foreign material.

END OF SECTION 260543

SECTION 262413 - SWITCHBOARDS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes Main Distribution Board(s) work for low voltage (LV) distribution, ancillary mounting frames, fittings, cable termination accessories and supports.

B. Connection to BMS system, including interface elements such as relays, transducers, etc. .

C. Related Sections include the following:

1. Division 26 Section "Basic Electrical Materials and Methods".
2. Division 26 Section "Grounding and Bonding".
3. Division 26 Section "Low Voltage Electrical Power Conductors and Cables".

1.3 DEFINITIONS

A. MDB: Main distribution board.

B. CT: Current Transformer.

C. VT: Voltage Transformer.

D. EMI: Electromagnetic interference.

E. RMS: Root mean square.

F. The following terms used on the Drawings and in the Specification are synonymous and may be used interchangeably: "Switchboard" and "Main Distribution Board".

1.4 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Switchboards shall withstand the effects of earthquake motions determined according to UBC97.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

1.5 SUBMITTALS

A. Product Data: Submit for approval detailed description of main distribution boards including all components supported by manufacturer’s catalogues, indicating compliance with the Standards specified under "Quality Assurance" Article, equipment characteristics, details of construction,

operating data, dimensions and weights etc. Give details of miscellaneous items including incoming and outgoing feeder terminal arrangement, connections at busbars, isolating, earthing, interlocks, control devices, indicating and metering instruments etc. Boards shall be factory assembled and tested and shipped as complete package (s).

B. Shop and Construction Drawings: Submit drawings for approval including, but not limited to, the following:

1. Plans and elevations with indication of built-on equipment, exact dimensions, and weights.
2. Arrangement of boards inside rooms allocated, indicating spaces and clearances.
3. Arrangement of equipment inside board.
4. One-line diagram of power system showing current ratings of switchgear and busbars and types and locations of protective gear (relays, instruments, CTs, VTs etc.)
5. Schematics and wiring diagrams of control circuits. Differentiate between manufacturer-installed and field-installed wiring.
6. Foundation details and grouting holes installation details.
7. Arrangement of incoming and outgoing feeders, terminal fittings, instruments, busbar connections etc.
8. Metering provisions.

C. Point-wise compliance statement to the specifications, duly signed by the manufacturer / manufacturer's authorized representative and the contractor.

D. Technical Literature: Submit the following for approval prior to placing orders for equipment manufacture:

1. Schedule of circuit breakers application, indicating type, range, features and characteristics, short- circuit ratings, time-current curves etc.
2. Method of setting of protective devices for overload, short-circuit and earth-fault currents as coordinated with upstream and downstream systems based on specific coordination curves of protective devices used and specific calculated prospective short-circuit currents at various points.
3. Test methods on site and references, including testing equipment for microprocessor controlled trip units.

E. Qualification Data: For firms and persons specified in "Quality Assurance" Article. Provide evidence of applicable registration or certification.

F. Tests and Certificates: Submit complete certified manufacturer's type and routine test records, in accordance with the Standards specified in "Quality assurance" Article.

G. Field Test Reports: Submit written test reports and include the following:

1. Test procedures used.
2. Test results that comply with requirements.
3. Results of failed tests and corrective action taken to achieve test results that comply with requirements.

H. Manufacturer's field service report.

I. Seismic Qualification Certificates: Submit certification that switchboards, overcurrent protective devices, accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration and Seismic Controls for Electrical Systems." Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

J. Maintenance Data: For main distribution boards and components to include in maintenance manuals specified in Division 01. In addition to requirements specified in Division 01 include the following:

1. Routine maintenance requirements for main distribution boards and all installed components.
2. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.
3. Time-current curves, including selectable ranges for each type of overcurrent protective device.

K. Coordination Study: Submit coordination study along with setting of protective devices for overload, short-circuit and earth-fault currents as coordinated with upstream and downstream systems based on specific coordination curves of protective devices used and specific calculated prospective short-circuit currents at various points.

1.6 QUALITY ASSURANCE

A. Installer Qualifications: Engage an experienced installer with minimum five years of successful installation experience on projects utilizing main distribution boards units similar to those required for this project.

B. Manufacturer Qualification: A firm regularly engaged in the manufacture of main distribution boards, of types, sizes, and capacities required, and whose products have been in satisfactory use in similar service for not less than five years.

C. Codes and Standards: Comply with the latest issue of:

1. IEC 61439-1 & IEC 61439-2: Low Voltage Switchgear and Control Gear Assemblies.
2. IEC 60947-1: Low Voltage Switchgear and Control Gear: Part 1: General Rules.
3. IEC 60947-2: Low Voltage Switchgear and Control Gear: Part 2: Circuit Breakers.
4. Relevant IEC Standard for other components, where not otherwise specified.

D. Compliance with Local Requirements: Comply with applicable local regulations/code requirements of authorities having jurisdiction. These will have precedence over other codes/standards nominated for the project, unless otherwise approved in writing.

E. Product Selection for Restricted Space as per existing conditions: Drawings indicate maximum dimensions for main distribution boards, including clearances between main distribution boards, and adjacent surfaces and other items. Comply with indicated maximum dimensions.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver in sections of lengths that can be moved past obstructions in delivery path. Deliver MDBs and components properly packaged and mounted on pallets, or skids to facilitate handling of heavy items. Utilize factory-fabricated type containers or wrappings for MDBs and components to protect equipment from damage. Inspect equipment to ensure that no damage has occurred during shipment.

B. Store indoors in clean dry space with uniform temperature to prevent condensation. Protect from exposure to dirt, fumes, water, corrosive substances, and physical damage.

C. Handle MDBs carefully to prevent physical damage to equipment and components. Remove packaging, including the opening of crates and containers, avoiding the use of excessive

hammering and jarring which would damage the electrical equipment contained therein. Do not install damaged equipment; remove from site and replace damaged equipment with new.

1.8 WARRANTY

A. Manufacturer's Warranty: Submit a written warranty signed by the manufacturer agreeing to repair, restore or replace any defective equipment specified in this section during the specified warranty period

1. Warranty Period: 1 year from date of Substantial Completion.

1.9 PROJECT CONDITIONS

A. Installation Pathway: Remove and replace doors to provide pathway for moving main distribution boards into place.

B. Existing Utilities: Do not interrupt utilities serving facilities occupied by Employer or others unless permitted under the following conditions and then only after arranging to provide temporary utility services according to requirements indicated:

1. Notify Engineer not less than seven days in advance of proposed utility interruptions. Identify extent and duration of utility interruptions.
2. Indicate method of providing temporary utilities.

C. Environmental Limitations: Rate equipment for continuous operation under the following, unless otherwise indicated:

1. Ambient Temperature: Not exceeding 40 deg C.

1.10 COORDINATION

A. Coordinate layout and installation of main distribution boards and components with other construction and electrical work, including conduit, piping, equipment, adjacent surfaces, raceways, electrical boxes and fittings, and cabling/wiring work. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3 Section "Cast-in-Place Concrete."

1.11 EXTRA MATERIALS

A. Spare Parts: Provide manufacturer's recommended spare parts for emergency replacement and/or one year's maintenance including, but not limited to, the following:

1. One set of fixed and moving contacts for every type of replaceable (consumable) contact set.
2. One operating motor and/or coil for each type of electrically operated circuit breaker.
3. Two sets of each type of indicating lights, fuses, LEDs, control switches, and similar devices subject to failure or breakage at any time.

B. Tools and Instruments: Provide tools and instruments required for normal routine inspection and maintenance and testing of circuit breakers and protective devices as appropriate for type of switchgear supplied.

1.12 FACTORY ACCEPTANCE TEST

A. Factory acceptance tests of equipment under this Contract are subject to be witnessed by the Engineer for locally assembled equipment. Witness test shall include complete routine and function testing on all units to be witnessed. Test procedure and program shall be submitted for approval prior to test conduction. Allow for test expenses including business class transportation and hotel accommodation as necessary for two persons from the Engineer's/ Employer's side.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Approved Manufacturers: Subject to compliance with requirements, provide products by one of the following or approved equal:

1.	ABB	(Germany/Italy)
2.	Cutler – Hammer / Eaton Corp.	(U.S.A.)
3.	Schneider Electric	(France)
4.	Siemens	(Germany)
5.	Schneider Electric / Square D	(U.S.A)

B. Locally assembled products by one of the above approved manufacturers are acceptable subject to compliance with design requirements and adequacy of reference list and quality control of the local factory.

2.2 GENERAL REQUIREMENTS

A. Generally: Main distribution boards shall be dead-front type, metal enclosed, multi-cubicle, floor mounted, free standing, with 1000V rated insulation voltage, 600 V rated operational voltage, and with 12 kV impulse withstand voltage, with fixed or draw-out switchgear, manually or manually and electrically operated, with matching vertical sections to form a continuous integral and rigid structure. Outgoing sections shall be of equal width.

B. Generally: Coordinate with existing Building Management System (BMS) and provide all necessary interfaces, relays, transducers, etc, necessary for the functions specified in the BMS schedules and/or shown on the Drawings.

C. General Construction: Rigidly framed and bolted, with Electro-galvanized sheet steel enclosures, phosphatized, primed with rust inhibiting primer and finished with thermal polymerized polyester epoxy powder coating, gray colour (RAL 7035 ANSI 61) or standard manufacturer's colour subject to Engineer's approval. Switchgear shall be vermin, dust and rodent proof, IP 31 protection to IEC 60529 for indoor installations and IP 54 protection for installations in wet areas and IP55 degree of protection for outdoor installations, with adequate lifting means and base-frames and capable of being moved into position and directly bolted to floor without additional sills. For ratings up to 3200A, enclosures shall have mechanical impact resistance of IK10 to IEC 62262 for enclosures protection degree IP 54 and higher, and IK08 to IEC 62262 for enclosures protection degree lower than IP 54. Test certificates for mechanical impact shall be submitted for approval; otherwise enclosure thickness shall not be less than 1.5mm. For rating larger than 3200A, enclosures shall have minimum thickness of 2mm.

D. Ventilation: Compartments shall be ventilated, by approved methods complying with the Standards.

E. Main Distribution Boards shall have a short circuit withstand current of the rating needed for 1 sec.

F. Seismic Requirements: Fabricate and test switchboards to withstand seismic forces defined in Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

G. Fastenings between structural members shall be bolted.

H. Extension of structure and busbars shall be possible at either end of switchboard for form 3 and form 4 type switchboards.

I. Arrangement shall permit incoming and outgoing busbars and cables to enter enclosure as needed and connect at respective terminals without inconvenience to installation or maintenance.

J. Removing Circuit Breakers: Suitable arrangements and equipment shall be provided for extracting, lifting and unloading switchgear from enclosures as appropriate for type of switchgear.

K. Spare and space positions are defined as follows:

1. Spare position: Fully equipped enclosure with switchgear
2. Space position: Fully equipped enclosure ready to receive switchgear.

L. Busbars: Site rated to same rating of main circuit breaker frame size as a minimum unless otherwise shown on drawings, and braced for a symmetrical rms short-circuit duty as specified. Busbars shall be copper, of sufficient size to limit temperature rise to allowable equipment temperature ratings, and not exceeding IEC 61439-1&-2 limits. Connections and buswork shall be bolted with compatible hardware material as per manufacturer’s recommendations and shall be accessible for inspection and maintenance. Contact surfaces shall be properly tin or Electro-silver plated as necessary.

M. Connections from busbar to switching element shall be rated to carry full continuous current rating of switching element frame as a minimum, unless otherwise shown on drawings.

N. Main horizontal busbars and vertical distribution busbars shall be insulated unless bare busbars are recommended by the manufacturer and used in the type test.

O. Full size neutral shall be continuous through all sections. Neutral bus shall be insulated and separate from earth bus and connected to it with removable links, at every bus section. Links shall be of the same cross-section of the earth bus.

P. Earth bus shall extend full length of board, firmly fixed to each section in accordance with the Regulations and Standards, complete with two main earthing lugs (one at each end), and required number of feeder protective earth connectors.

Q. Earth bus shall be half size of phase buses, unless otherwise indicated on drawings.

R. Switchboard Type: Switchboard(s) shall be of the following type(s):

1. Form 3b.
2. Incoming: Withdrawable type – Air Circuit Breaker (ACB).
3. Outgoing: Fixed type Moulded Case Circuit Breaker (MCCB) for ratings up to 1250A and Fixed type ACB for ratings greater than 1250A.

S. Withdrawable metal enclosed circuit breaker section shall consist of compartmented unit(s), stationary part with rear busbar and cable connection compartments and front draw-out circuit breaker assembly. Partitions between sections shall be bolted steel plate and partitions between compartments shall be tough solid insulating removable bolted barriers. Each unit shall have hinged lockable front door with grip-handle and door mounted instrumentation.

T. Drawout circuit breaker assembly shall have disconnecting contacts, wheels and interlocks to prevent connecting or disconnecting circuit breaker unless in the open position, and to prevent

closing circuit breaker while racking into any of the three positions (connect, test, disconnect). Racking mechanism and rail assembly shall be approved worm and lever mechanism. It shall be possible to close the unit door with breaker in any of the three positions and when removed. External position indicator shall be provided. Fixed disconnecting primary contacts shall be accessible and replaceable from front and shall be silver plated copper. Moving primary disconnect contacts shall consist of self-aligning, silver plated, spring pressure, finger-cluster, copper contact fitted on line and load studs of circuit breaker.

U. Fixed main circuit breaker section shall individually accommodate main circuit breaker, main cable entry with terminal fitting assembly and metering compartment. Where placed against a wall, accessibility shall be possible from front and sides or only from front of section.

V. Pull Sections: An additional cable pull section shall be provided, depending on actual configuration shown on the Drawing, and subject to Engineer's approval.

W. Where busway is used as an incoming or outgoing feeder of the switchboard, the switchboard manufacturer shall provide all necessary accessories as recommended by the busway manufacturer such as adaptor box for the switchboard to be able to accept the busway flange. The contractor is responsible for coordination between the two manufacturers.

X. Where single core cables are used, top / bottom cable entry plates shall be made of bakelite or Aluminum with adequate thickness and rigidity to support cables.

Y. Form 1 and form 2 switchboards shall be front accessible, unless otherwise indicated on the Drawings; front, rear or front and rear aligned as recommended by the manufacturer and approved by the Engineer, fixed group mounted MCCB distribution sections, with all devices removable from the front and mounted on a panelboard type base. Construction shall allow all connections and maintenance to be made without rear access. Cables shall be accommodated in extra wide vertical gutters. Sides, top and rear shall be covered with removable screw-on plates having formed edges all around. Front plates shall be sectionalized and removable, covered by trims, and secured by self-tapping screws.

Z. Form 3 and form 4 switchboards shall be front and rear accessible unless otherwise indicated on the Drawings; front, rear or front and rear aligned as recommended by the manufacturer and approved by the Engineer, individually mounted fixed MCCB or ACB distribution sections, with compartmentalized construction, consisting of front modular circuit breaker compartments, busbar system compartments and rear cable termination compartments unless otherwise recommended by the manufacturer and approved by the Engineer, with insulating barriers between front compartments and busbar compartments and between rear compartments and busbar compartment (removable for maintenance). MCCBs shall be closely coupled to busbars (to minimize chances of bus-side faults), and to rear cable terminals, through compatibly frame-sized insulated connectors. MCCB modules shall be covered on the front, by recessed frame-type bolted covers, 1.5 mm minimum thickness, to protect circuit breaker handles. Top, sides and rear shall be covered with removable screw-on plates having formed edges all around.

AA. All main distribution boards shall be equipped with combined Class I + II surge protective devices as specified under Division 26 Section "Surge Protection for Low-Voltage Electrical Power Circuits". SPDs along with their fused-disconnect switch shall be integrated within or adjacent to the MDB's enclosure.

2.3 AIR-BREAK METAL ENCLOSED CIRCUIT BREAKER (ACBs)

A. Type: Enclosed in steel structure, air ventilated, air break, for normal operation at maximum temperature within enclosure at point of application, tested to approved standards, manually operated for normal functions, and automatically tripped under over-current conditions. Trip power shall be derived from main power circuit, with sufficient tripping energy to reliably trip circuit breaker. Fixed mounted circuit breaker shall be rear connected.

B. Construction: Manually or manually and electrically operated, as needed, with two-step, spring charged, stored energy mechanism, quick-make, quick-break type, electrically and mechanically trip-free, to prevent maintaining circuit breaker closed against over-current condition whether under manual or automatic operation. Electrically operated circuit breakers shall have integrally mounted, spring charging motor mechanism automatically recharged upon closing. Both manually or manually and electrically operated circuit breakers shall have mechanical built-in charging lever and shall include open and close direct acting push buttons. Stored energy provision shall allow open/close/open sequence of operation without use of external energy. Circuit breaker shall have arc-quenching device on each pole and replaceable arcing contacts.

C. Control Power: For electrically charged circuit breaker and/or for shunt trip device, where required, control power shall be 110V or 120V AC as recommended by the manufacturer obtained from in-built MDB control power transformer connected and fused on line-side of circuit breaker. Where shunt trip and/or under voltage release are required, a sufficient capacitor trip device to cover any temporary loss or excessive drop of supply voltage shall be provided.

D. Rating: 3-pole, unless otherwise shown on the drawings. With continuous current rating (frame size) as needed, ranging between 1600 A and 5000 A (1600, 2000, 2500, 3000, 4000 and 5000 A), fully rated (100%) for service under worst site conditions. Breakers shall be rated for a symmetrical rms service short-circuit breaking capacity as needed, to IEC 60947-2 sequence II (rated service short-circuit breaking capacity) at specified voltage and frequency, meeting IEC 60947-2, sequence I, II, III and IV tests (for circuit breakers of utilization category B), tested in an enclosure substantially the same as the enclosure in which they shall be installed.

E. Trip Unit: Totally enclosed, programmable, solid state device, interchangeable for compatible frame sizes, pluggable into front of circuit breaker, tamper-proof and with transparent, sealable cover. Trip unit shall measure sinusoidal and non–sinusoidal current wave forms (fundamental to thirteenth harmonic) by continuously sampling each phase through out every cycle. Trip unit shall be direct acting trip device, current transformer operated, with flux transfer shunt trip that requires no external power. It shall have adjustable current setting (0.5 - 1.0 times trip unit rating) with adjustable long-time delay up to 24 seconds, short-time pick-up and short-time delay, earth-fault pick-up and time delay instantaneous over current pickup. Current setting range shall be by means of replaceable trip-units within the maximum frame size rating. Once removed, circuit breaker shall remain in the trip-free position. Earth-fault trip shall be adjustable, range 10% to 60% of normal current rating of the circuit breaker and a maximum of 1200A, with adjustable time delay between 0.1 and 0.5 seconds. Short time delay shall be adjustable in steps, 2 - 9 times current setting, with adjustable time delay having maximum delay of up to 0.4 seconds. Instantaneous trip shall be adjustable in steps at least 2 – 13 times the trip unit rating. Over-ride protection shall allow full sensitivity up to interrupting capacity of circuit breaker. Slight difference in setting ranges according to manufacturers standard products may be accepted subject to engineer’s approval.

F. Position Indicators: Positive with trip indication target. Target indicator shall be mechanical and shall give indication even when control power has been lost.

G. Trip unit shall have inputs from conventional potential transformers for every phase. Current sensors transformers for every phase. Current sensors shall be encased in epoxy filled plastic housing to protect against damage and moisture and shall be integrally mounted in breakers.

H. Neutral current transformer: Provide on the neutral conductor of each main, tie or outgoing circuit having earth fault protection, located after the link connecting neutral and earth busbars from load side. Rating and characteristics of the neutral current transformer shall be suitable for proper operation of the earth fault protection system.

I. Circuit breaker accessories shall include the following:

1. Padlocking or keylocking provisions for all positions (disconnected, test, connected, closing blocking, open)
2. Overload, short-circuit, and ground fault trip LEDS

3. Trip indicator and reset button
4. Operations counter.
5. On/off pilot lights.
6. Shunt-trip coil and closing solenoid for remote control.
7. Bell alarm for remote overcurrent trip indication.

J. Auxiliary Contacts: Include N.O. and N.C. contacts on switchgear as required for remote monitoring and control, plus 2 N.O. and 2 N.C. spare contacts.

K. Electrical Interlock: If electrical interlock is required between power air circuit breakers, the mechanical closing button of the circuit breaker shall be disabled in the connect position and an additional electrical push button shall be provided for the closing of the circuit breaker through the breaker's shunt close coil. The electrical interlock shall be provided on both shunt trip and close coils of the circuit breaker in order to perform simultaneous tripping and inhibit closing functions on the interlocked breaker.

2.4 MOLDED CASE CIRCUIT BREAKERS (MCCBs)

A. Type: Tested to approved standards, , totally enclosed, molded case, constructed from high quality, high temperature resistant, tropicalized, molded insulating materials, for normal operation at maximum temperature within enclosures at point of application, and provided with front operated single toggle type handle mechanism for manual operation of main contacts in addition to automatic operation under over-current conditions. Multi-pole breakers shall have common integral trip bar for simultaneous operation of all poles. Ampere rating shall be clearly visible. All terminals shall be box lug or clamp type with set screws, suitable for copper or aluminum conductors.

B. MCCBs shall be 160 A minimum frame size, unless otherwise shown on the drawings.

C. MCCBs generally shall be thermal-magnetic type for ratings below 250 A frame size, unless otherwise shown on the Drawings. MCCBs 250 A and larger shall be electronic solid-state trip type. All circuit breakers shall be 3-pole unless otherwise shown on drawings.

D. Thermal magnetic circuit breaker trip units: shall have bi-metallic inverse time delay over-current element for small overloads and instantaneous magnetic over-current trip element for operation under short-circuit conditions on each pole. Circuit breakers rated 150/160 A shall have adjustable instantaneous trips.

E. Electronic trip circuit breakers shall have solid state trip units with long time delay setting range at least between 0.5 and 1.0 times maximum trip rating with adjustable time delay up to 24 seconds, short time delay range 3 to 10 times maximum trip rating with maximum clearing time of 0.2 seconds, and instantaneous protection adjustable from 5 to 10 times continuous rating. Solid state trip units shall be insensitive to changes in ambient temperature between -20 and +55 deg. C. Earth fault protection shall be provided or built into trip unit where specified or shown on drawings, and shall be adjustable between 0.2 and 0.6 normal phase current pick-up with maximum time delay of 0.2 seconds, and shall be suitable for connection to external current sensor. Push-to-trip button shall be provided on cover for testing the trip unit. Short time over current protection is only required for circuit breakers 630A and above.

F. Deration: Thermal and electronic over-current trips shall be ambient temperature derated at specified ambient temperature. In case of adjustable thermal settings, range of adjustment shall not exceed maximum trip rating needed. MCCB shall not be derated if the space where the switch boards are installed is air-conditioned.

G. Switching Mechanism: Quick-make, quick-break type, with positive trip-free operation so that contacts cannot be held closed against excess currents under manual or automatic operation. Contacts shall be non-welding silver alloy with approved arc-quenching devices of metallic grid construction.

H. Trip current rating (amps) indicates nominal maximum rating at which overload element is set to operate.

I. MCCBs: MCCBs frames rated 800 A and above shall have utilization category B (with an intended short time withstand capability), and shall have rated service short circuit breaking capacities (sequence II) with suitably selected frame sizes and trip ranges to meet the electrical requirements at the distribution panelboard location and schedules, with declared ratings as percentage (100%, 75% or 50%) of the ultimate ratings as quoted by the circuit breaker manufacturer marked on the circuit breaker rating plate. MCCBs frames up to 630 A shall have utilization category A with rated ultimate short circuit breaking capacity (sequence III) to meet the electrical requirements at the switchboards locations.

J. Tripped Position: When tripped automatically by over current condition, operating mechanism of circuit breaker shall assume an intermediate position clearly indicated by the handle between on and off positions.

K. Interchangeable Trips: Thermal magnetic circuit breakers of 150/160 A frame size shall have interchangeable trip units.

L. Sealing: Non-interchangeable trip circuit breakers shall have sealed covers. Circuit breakers with interchangeable trips shall have trip unit covers sealed to prevent tampering.

M. Accessories: Circuit breaker design shall allow addition of open / close electrical motor operator, control and interlocking functions, under-voltage release, shunt-trip coils, alarm and auxiliary switches, padlocking devices, key-lock devices, and the like.

2.5 METERING INSTRUMENTS

A. Generally: Instruments shall be housed in enameled, square, metal cases for flush installation. Scales and markings shall be protected and sealed. Accuracy of instruments shall be within 2% unless otherwise specified.

B. Voltmeters: Moving iron type, with center zero adjuster, range 1.25 times nominal system voltage, 90 degree angle, size 76 x 76 mm.

C. Voltmeter Selector Switch: 7-position rotary type.

D. Ammeters: Moving iron type, with center zero adjuster, range 2 times nominal circuit amperage, 90 degree angle, size 76 x 76 mm.

E. Provide ammeters and pilot lights for each phase.

F. Provide p.f. meter moving iron type with center zero adjuster, size 76 x76mm.

G. Current Transformer (CT): Indoor dry type, rated secondary current 5 A. Rated primary current, core size and accuracy shall be determined in accordance with nominal current of plant protected, short-circuit level and burden.

H. Voltage Transformer (VT): Provide where required, complete with primary and secondary fuses and disconnecting device.

2.6 DIGITAL METERING UNITS

A. Metering unit shall be provided on the incoming and outgoing feeders having the following functions for each phase:

1. Voltage.
2. Current.
3. Frequency.
4. Energy.
5. Total power.
6. Peak power demand.

B. The metering unit shall be provided by adequate interface link with the BMS system.

2.7 DIGITAL VOLTAGE RELAY

A. This unit shall be provided on the incoming and coupler section to perform the following functions, for connection to the automatic transfer system and monitoring by BMS system:

1. Over-voltage (adjustable from 90 to 120%, with time delay adjustable from 0.5-5 Sec).
2. Under-voltage (adjustable from 75 to 95%, with time delay adjustable from 0.5-5 Sec).
3. Phase Voltage unbalance (detect voltage unbalances over 10%).
4. Phase reversal.

2.8 WIRING

A. Arrangement: Wiring shall be modularly and neatly arranged on master terminal boards with suitable numbering strips and appropriate cartridge type fuses where required.

B. Connections shall be made at front of terminal board and with no live metal exposed.

C. Metal cases of instruments, control switches, relays etc. shall be connected, by bare copper conductors not less than 2.5 mm2 section, to nearest earthing bar.

D. Control Wiring: Copper, PVC insulated, 85 deg. C, 600 V grade, and PVC sheathed for multi-core cables. Finely stranded copper conductor, silicon rubber insulated cables shall be used in proximity to higher temperature components and as flexible cable.

E. Ferrules: Wires shall be fitted with numbered ferrules of approved type at each termination.

2.9 MISCELLANEOUS

A. Anti-condensation heaters with disconnect switch and pilot lamp shall be provided in switchboard, controlled by thermostat and/or hygrostat.

B. Schematic and wiring diagram shall be provided suitably located within each cubicle.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine elements and surfaces to receive main distribution boards for compliance with installation tolerances and other conditions affecting performance. Notify Engineer in writing of conditions detrimental to proper completion of the work.

1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install main distribution boards as indicated, in accordance with manufacturer's written instructions, and with recognized industry practices; complying with applicable requirements of applicable standards or codes approved.

B. Equipment Bases: Ensure that concrete bases and foundations provided for installation of equipment are constructed in accordance with approved shop and construction drawings and equipment manufacturers' drawings and that holes for fixing bolts and provisions for passage of cables etc. are provided as required.

C. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from main distribution board units and components.

D. Cable Trenches: Ensure that trench construction and covers provided for installation of power and control cables are in accordance with approved shop and construction drawings.

E. Built-in Items: Ensure that equipment supports, fixings and the like, and sleeves for passage of feeders and cables which shall be built into concrete foundations, bases, cable trenches or building structure are provided as and when required and that they are properly installed.

F. Equipment: Install on concrete bases etc., and assemble completely plumb and level, before grouting in holding-down bolts.

G. Comply with mounting and anchoring requirements specified in Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

H. Supports and Terminations: Install all incoming and outgoing cable supports, cable ends and termination fittings required for power and control cables.

I. Relays: Set in accordance with manufacturer's instructions and in accordance with an approved scheme.

J. Make Good damage painted surfaces, clean and apply rust-inhibiting prime coat and two finishing coats of approved enamel upon delivery of equipment to site, or as required by Engineer.

K. Operating Instructions: Frame and mount the printed basic operating instructions for main distribution boards, including control and key interlocking sequences and emergency procedures. Fabricate frame of finished wood or metal and cover instructions with clear acrylic plastic. Mount on front of main distribution boards.

3.3 IDENTIFICATION

A. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Division 26 Section "Basic Electrical Materials and Methods."

B. Main Distribution Board Nameplates: Label each main distribution board compartment with engraved metal or laminated-plastic nameplate mounted with corrosion-resistant screws.

3.4 CONNECTIONS

A. Install equipment-grounding connections for main distribution boards with ground continuity to main electrical ground bus.

B. Tighten electrical connectors and terminals, including screws and bolts, according to manufacturer's published torque-tightening values and / or recommendations. If manufacturer's torque values are not indicated, use those specified in applicable Standards.

3.5 FIELD QUALITY CONTROL

A. Equipment: Inspect equipment upon delivery to Site and report any damage to Engineer.

B. Switchgear: Inspect and check switchgear for completeness, component ratings, types, sizes, and wiring connections. Check phasing of busbars, contacts and clearances.

C. Prior to energization of circuitry, check all accessible connections to manufacturer's torque tightening specification.

D. Tests: After installation and before hand-over, carry out all visual and mechanical inspection and electrical tests required by the governing codes and any other tests the Engineer may require to check compliance of installation with the Specification, including, but not limited to, the following. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

1. Insulation resistance tests for each main distribution board bus, component, connecting supply, feeder, and control circuit.
2. Continuity tests of each circuit.
3. Operational tests.

E. Main and Control Circuits: Using 1000 V megger (2000 Megohm range), check insulation resistance between phases, between phases and earth/enclosure and between neutral and earth.

F. Primary Injection Tests: Provide portable test equipment to test time-delay characteristics of circuit breakers by simulating an overload or fault condition. Measure and record all test results and ambient conditions and compare with manufacturer's data.

G. Instantaneous Trip Elements: Test by high current primary injection, using high-current primary injection test-sets and reports all readings.

H. Routine Tests on Site: Carry out on every main distribution board in accordance with the Standard specified (IEC 61439-1 and IEC 61439-2) for FBAs assembled from standardized components outside the works of the manufacturer. Routine tests are also to be carried out on every FBA, delivered to site, if requested by Engineer.

3.6 ADJUSTING

A. Set field-adjustable switches and circuit breaker trip ranges.

3.7 CLEANING

A. On completion of installation, inspect interior and exterior of main distribution boards. Remove paint splatters and other spots. Vacuum dirt and debris; do not use compressed air to assist in cleaning. Repair exposed surfaces to match original finish.

3.8 DEMONSTRATION

A. Train Employer's maintenance personnel to adjust, operate, and maintain the system installation. Refer to Division 01 Sections.

END OF SECTION 262413

SECTION 262416 - PANELBOARDS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Panelboards for distribution and subdistribution of electric power and for protection of circuits, including fixing and supporting materials and materials for termination of feeders, sub-circuits and branch circuits for the following types:

1. Lighting and appliance branch-circuit panelboards.
2. Distribution panelboards.

B. Connection to BMS system, including interface elements such as relays, transducers, etc. as shown on the Drawings.

C. Related Sections include the following:

1. Division 26 Section "Basic Electrical Materials and Methods".

1.3 DEFINITIONS

A. MCB: Miniature circuit breaker.

B. MCCB: Molded case circuit breaker.

C. LP, EPP: Final branch circuit panelboards for lighting and power respectively, with miniature circuit breaker (MCB) protection on branch circuits, as shown on the Drawings. When fed from local generator, their references become respectively ELP and ESSPP. When fed from UPS, the power panel becomes EPPU.

D. DP: Distribution panelboards for power distribution with MCCB protection on main incoming and outgoing feeder circuit breakers Type 1 or Type 2. When fed from local generator, it is referenced as ESSDP. When fed from UPS, it is referenced as EDPU.

E. RMS: Root mean square.

1.4 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Panelboards shall withstand the effects of earthquake motions determined according to UBC97.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

1.5 SUBMITTALS

A. Equipment Data: Submit data for approval including, but not limited to, the following:

1. Manufacturers' catalogues indicating specific equipment selected.
2. Types of panelboards and circuit breaker characteristics including duties and deration at specified ambient conditions and corresponding temperatures within the enclosures, MCB shall not be derated if the space where the panels are installed is air-conditioned.
3. Dimensions of panels and specific contents of each panelboard.
4. Integrated equipment tabulations for coordinated short- circuit series combinations of circuit breakers.

B. Tests and Certificates: Submit complete certified manufacturer's type test and routine test records in accordance with the Standards.

C. Point-wise compliance statement to the specifications, duly signed by the manufacturer / manufacturer’s authorized representative and the contractor.

D. Shop and Construction Drawings: Submit drawings for approval including, but not limited to, the following:

1. Exact composition of each panelboard, indicating busbar rating, frame and trip ratings of circuit breakers.
2. Typical installation details of panelboards, indicating main feeder and branch circuit conduit connections, terminal provisions, tags, labels, mounting methods and materials used.

E. Coordination Study: Submit coordination study along with setting of protective devices for overload, short-circuit and earth-fault currents as coordinated with upstream and downstream systems based on specific coordination curves of protective devices used and specific calculated prospective short-circuit currents at various points.

F. Details of Electrical Closets: Submit details to verify clearances, spaces and ventilation of the installation of proposed equipment, prior to starting construction.

G. Field Test Reports: Submit written test reports and include the following:

1. Test procedures used.
2. Test results that comply with requirements.
3. Results of failed tests and corrective action taken to achieve test results that comply with requirements.

H. Seismic Qualification Certificates: Submit certification that panelboards, overcurrent protective devices, accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration and Seismic Controls for Electrical Systems." Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

I. Panelboard Schedules: For installation in panelboards submit final versions after load balancing.

J. Maintenance Data: For panelboards and components to include in maintenance manuals specified in Division 01 and to the satisfaction of the Employer’s requirements. In addition to requirements specified in Division 01 include the following:

1. Manufacturer's written instructions for testing and adjusting over-current protective devices.
2. Time-current curves, including selectable ranges for each type of over-current protective device.

1.6 QUALITY ASSURANCE

A. Comply with

1. IEC 61439-1 & IEC61439-2 "Low Voltage Switchgear and Control Gear Assemblies".
2. IEC 61439-3 "Low Voltage Switchgear and Control Gear Assemblies - Distribution boards intended to be operated by ordinary persons (DBO)".
3. IEC 60947-1 "Low Voltage switchgear and control Gear- General Rules".
4. IEC 60947-2 "Low Voltage switchgear and control gear - circuit breakers".
5. IEC 60947-3 "Low Voltage switchgear and control gear - Switches, disconnectors, switch-disconnectors and fuse-combination units circuit breakers".
6. IEC 60947-4-1 "Low Voltage switchgear and control gear - Contactors and motor-starters — Electromechanical contactors and motor-starters".
7. IEC 60898-1 "Miniature circuit breakers".
8. IEC 61009 "Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)".
9. Other components where not specified shall comply with the relevant IEC standards.

1.7 WARRANTY

A. Manufacturer’s Warranty: Submit a written warranty signed by the manufacturer agreeing to repair, restore or replace any defective equipment specified in this section during the specified warranty period

1. Warranty Period: 1 year from date of Substantial Completion.

1.8 COORDINATION

A. Coordinate layout and installation of panelboards and components with other construction that penetrates walls or is supported by them, including electrical and other types of equipment, raceways, piping, and encumbrances to workspace clearance requirements.

1.9 SCHEDULES

A. Schedules indicate the designation and required type of panelboard using the following criteria:

1. Type of construction (MCB or MCCB), referring to type of branch circuit breakers.
2. Voltage, number of phases and wires.
3. Branch circuit breaker trip rating and wire size.
4. Main circuit breaker trip rating and frame size (maximum continuous rating) for MCCB and MCB.
5. Short-circuit interrupting capacity (IC) in kA.
6. Special arrangement or provisions.

1.10 FACTORY ACCEPTANCE TEST

A. Factory acceptance tests of equipment under this Contract are subject to be witnessed by the Engineer for locally assembled equipment. Witness test shall include complete routine and

function testing on all units to be witnessed. Test procedure and program shall be submitted for approval prior to test conduction. Allow for test expenses including business class transportation and hotel accommodation as necessary for two persons from the Engineer's/ Employer's side.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Approved Manufacturers: Subject to compliance with requirements, provide products by one of the following or approved equal:

1.	Cutler-Hammer/Eaton Corp.	(U.S.A.)
2.	Schneider Electric	(France)
3.	Siemens - ITE	(Germany or USA)
4.	Schneider Electric / Square D Co.	(USA)
5.	ABB	(Germany/Italy)

B. Locally assembled products by one of the above approved manufacturers are acceptable subject to compliance with design requirements and adequacy of reference list and quality control of the local factory.

2.2 GENERAL REQUIREMENTS

A. Rated insulation voltage shall be in accordance with the respective standards.

B. Panelboards shall be totally enclosed, dead front type, protection code IP 31 for indoor installations, IP54 for installations in wet areas and IP 55 for outdoor installations, in accordance with IEC 60529, and shall be factory designed and assembled.

C. Earthing bar shall be half size the phase busbars.

D. Neutral bar shall be sized as the phase bus bars.

E. Protection shall be fully rated throughout the systems.

F. Circuit breakers shall be non-fused type.

G. Circuit Breaker Arrangement: Panelboards shall have one main incoming circuit breaker or switch and the required number of branch circuit breakers, arranged as shown on the schedules, including spare circuit breakers and spaces for future expansion. Three-phase panelboards shall be designed for sequence phase connection of branch circuit devices.

H. Branch Circuit Numbering: On 3-phase panelboard schedules, circuits 1 and 2 shall be connected to red (R) phase, 3 and 4 to yellow (Y) phase, 5 and 6 to blue (B) phase etc., to conform with branch circuit numbering.

I. Fabricate and test panelboards to withstand seismic forces defined in Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

2.3 PANELBOARD ENCLOSURES

A. Type: General purpose type, suitable for relevant ambient conditions, flush or surface mounted as shown on the drawings, comprising box, trim, or trim and door to approved manufacturer's standards and sizes.

B. Construction: Box, trim and doors where required, shall be Electro-galvanized sheet steel of gauges not less than specified and in accordance with the standards. Welded joints shall be galvanized after manufacture. Gutter spaces shall conform to the standards, adequate for the utilized cables/wires subject to the Engineers' approval and in no case less than 100 mm on all sides. Enclosure shall have pre-designed angles or threaded end studs to support and adjust mounting of interior panelboard assembly.

C. Trims shall cover and overlap front shield, covering all terminals and bus compartments, to form a dead front panel. Trims shall be fixed to cabinet/box by quarter-turn clamps engaging flange of box (use of screws engaging holes in flange of box is not acceptable). Screws where used shall be oval-head, countersunk and flush. Trims for flush mounted panelboards shall overlap box and front shields by at least 20 mm. Trims for surface mounted panelboards shall be exactly sized to form flush fit to box.

D. Doors shall have concealed hinges integral with trim, and flush combination cylinder lock and catch. Doors over 1000 mm high shall have vault-type handle and multiple point latch mechanism. Locks shall be keyed alike.

E. Finish: Inner and outer surfaces of cabinet/boxes, trims, doors etc. Shall be cleaned, phosphatized, chrome passivated and treated with final thermosetting epoxy powder modified by polyester resins providing high resistance to mechanical injury, heat, acid and alkali solvents, grease, aging and corrosion and of standard gray color to the approval of Engineer.

F. Directories under glassine, or an approved alternative durable arrangement, shall be provided on inside face of doors, or in metal label holders when trim without doors are specified. Directories shall be typed to identify panelboards and clearly indicate circuit number and description of load.

G. Outdoor enclosures shall be heavy duty sheet steel cabinets, suitable for mechanical impact resistance of IK10 to IEC 62262, fully weatherproofed (IP 54), without knockouts, but with removable sealed/gasketed bottom gland plates and gasketed doors.

H. Where single core cables are used, top / bottom cable entry plates shall be made of bakelite or Aluminum with adequate thickness and rigidity to support cables.

2.4 BUSBARS

A. Type: One piece, 98% pure electrolytic copper, tin-plated, based on total maximum operating temperature of 90 deg C at any point of the bus, at full continuous rating. Bolted or clamped contact surfaces shall be properly tin or silver plated as necessary, and shall have maximum current density not exceeding requirements of the approved standards. Aluminum shall not be used for busbars or panelboard parts.

B. Design: Busbars shall be rigidly designed so that branch circuit devices can be removed without disturbing adjacent units or changed without additional machining, drilling or tapping. Busing shall be full size without reduction. Busing and blank plates shall allow installation of future circuit devices, where indicated on the drawings.

C. Main horizontal busbars and vertical distribution busbars shall be insulated unless bare busbars are recommended by the manufacturer and used in the type test.

D. Rating: Busbar rating shall be at least equal to main-circuit breaker frame size. Where no main circuit breaker is required, busbars shall have main lugs or disconnect switch, with nominal rating equal to 1.25 times the up stream circuit breaker trip rating, and as shown on the drawings.

E. Short-circuit Duty: Busbars shall carry at least 125% of the maximum short-circuit level at point of application for one second, without showing any signs of degradation.

F. Terminals and connections shall be anti-turn, solder-less screw-pressure type. Screws and bolts used for making copper/copper connections shall be hard copper alloy with lock washers (riveted bus connections are not acceptable).

G. Neutral bar shall be solid and fully insulated from cabinet or box. One solder-less box type set-screw connector shall be provided for neutral wire of each branch circuit and one bolted clamp-type connector or anti-turn lug with set-screw for main incoming neutral wire. Neutral shall be fully sized and rated as for phase busbars.

H. Earthing bar shall be copper, brazed to panelboard cabinet, with bolted pressure connector for main conductor and one set-screw-type tunnel terminal for each outgoing conductor, to provide secure and reliable contact with all metal parts and enclosure.

2.5 MOLDED CASE CIRCUIT BREAKERS (MCCBs)

A. Type: Tested to approved standards, , totally enclosed, molded case, constructed from high quality, high temperature resistant, tropicalized, molded insulating materials, for normal operation at maximum temperature within enclosures at point of application, and provided with front operated single toggle type handle mechanism for manual operation of main contacts in addition to automatic operation under over-current conditions. Multi-pole breakers shall have common integral trip bar for simultaneous operation of all poles. Ampere rating shall be clearly visible. All terminals shall be box lug or clamp type with set screws, suitable for copper or aluminum conductors.

B. MCCBs shall be 160 A minimum frame size, unless otherwise shown on the drawings.

C. Circuit Breaker Trip Units: Unless otherwise specified or shown on the drawings, moulded case circuit breakers of final branch circuit panel boards (LPs), power panel boards (PPs) and subdistribution panel boards (SDPs) shall be thermal magnetic type, while moulded case ciruit breakers of distribution panel boards (DPs) shall be thermal magnetic for frame sizes up to 160 amperes and electronic type for higher frame sizes.

D. Thermal magnetic circuit breaker trip units: shall have bi-metallic inverse time delay over-current element for small overloads and instantaneous magnetic over-current trip element for operation under short-circuit conditions on each pole. Circuit breakers rated 150/160 A shall have adjustable instantaneous trips.

E. Deration: Thermal and Electronic over-current trips shall be ambient temperature derated at specified ambient conditions and corresponding temperature within the enclosures. MCCB shall not be derated if the space where the panels are installed is air-conditioned.

F. Electronic trips units, applicable to circuit breakers 250 A frame size and larger, shall be solid state with long time delay settings between 0.5 and 1.0 times maximum trip rating, short time delay range of 3 to 10 times maximum trip rating with a maximum clearing time of 0.2 seconds, and instantaneous protection adjustable from 5 to 10 times continuous rating. Solid state trip units shall be insensitive to changes in ambient temperature between -20 and +55 deg C. Earth fault protection shall be built into trip unit where specified, and shall be suitable for connection to external current sensor. Push-to-trip button shall be provided on cover for testing the trip unit. Short time over current protection is only required for circuit breakers 630A and above.

G. Switching Mechanism: Quick-make, quick-break type, with positive trip-free operation so that contacts cannot be held closed against excess currents under manual or automatic operation. Contacts shall be non-welding silver alloy with approved arc-quenching devices of metallic grid construction.

H. Trip current rating (amps) indicates nominal maximum rating at which overload element is set to operate.

I. MCCBs for LPs, PPs, SDPs, DPs Type 2 and feeder pillars: Comply with IEC 60947-2 test sequences I, II, utilization category A, and shall have rated ultimate short circuit breaking capacities (sequence III) to meet the electrical requirements at the panelboard location, with preferred ratings in accordance with following tables.

J. MCCBs for DP Type 1: MCCBs frames rated 800 A and above shall have utilization category B (with an intended short time withstand capability), and shall have rated service short circuit breaking capacities (sequence II) with suitably selected frame sizes and trip ranges to meet the electrical requirements at the distribution panelboard location , with declared ratings as percentage (100%, 75% or 50%) of the ultimate ratings as quoted by the circuit breaker manufacturer marked on the circuit breaker rating plate. MCCBs frames up to 630 A shall have utilization category A with rated ultimate short circuit breaking capacity (sequence III) to meet the electrical requirements at the panel boards locations with preferred ratings in accordance with the below tables.

K. Frame size is defined as maximum continuous current rating of circuit breaker which corresponds with its maximum trip range listed below and which shall be related to minimum acceptable short-circuit interrupting ratings, based on fully rated interrupting duties: normal duty (N), high break (H), or current limiting (L), as specified.

L. Frame sizes are generally to be selected with minimum interrupting capacities at specified voltages and rated frequency, in accordance with the following table:

Trip range frame size(amperes)	Minimum Symm. rms rated breaking capacity (ultimate in kA)			Rating volts(A.C.)
	N	H	L	
Thermal-magnetic				
15-100 (1,2,3p)	14	-	-	277/480
15-150 (1,2,3,4p)	25	65	100	277/480
Electronic				
100-250 (2,3,4p)	30	50	70	480
160-400(2,3,4p)	35	65	100	480
400-800 (3p)	35	65	100	480
800-1200 (3p)	50	65	100	480
Thermal-magnetic				
15-100 or 160 (1,2p)	18	-	-	220/240
15-100 or 160 (2,3,4p)	18	-	-	380/415
15-160 (2,3,4p)	35	60	100	380/415
Electronic				
100-250 (2,3,4p)	35	60	150	380/415
160-400 (3,4p)	35	60	150	380/415
250-630 (3,4p)	40	60	150	380/415
320-800 (3,4p)	50	60	150	380/415
500-1250 (3,4p)	50	70	150	380/415

M. Tripped Position: When tripped automatically by over-current condition, operating mechanism of circuit breaker shall assume an intermediate position clearly indicated by the handle between on and off positions.

N. Interchangeable Trips: Thermal-magnetic trip circuit breakers of 150/160 A frame size shall have interchangeable trip units.

O. Sealing: Circuit breakers with non-interchangeable trip units shall be sealed. Circuit breakers with interchangeable trip units shall have trip unit covers sealed to prevent tampering.

P. Accessories: Circuit breakers shall be designed to accommodate standard attachments including shunt-trip, under-voltage release, combined auxiliary and alarm switches, and open / close electrical motor operator to any circuit breaker of rating (frame size) 100 A and over. Padlocking devices shall be provided, where shown on the Drawings.

Q. Residual current operated circuit-breakers with integral overcurrent protection (RCBOs) type A to IEC 61009 are provided as add-on or built-in earth leakage accessories, where required .Protection against earth fault current, in addition to over-current and short-circuit protection, shall be in accordance with the Regulations. Trip current sensitivity on breakers for branch circuits shall be 30mA for circuits feeding general purpose socket outlets as socket/outlets dedicated for power supply of appliances as required. Circuit breakers shall include current transformer with tripping coil assembly, test button and trip free mechanism to ensure circuit breaker cannot be held closed against earth faults.

R. Current Limiting Circuit Breakers: Molded case type without fusible elements. When operating within current limiting range, the I^2t of let-through current shall be less than 1/2 cycle wave of symmetrical protective short-circuit current as compatible with breaker construction.

S. Current limiting circuit breakers shall have, on each pole, adjustable inverse time-delay over-current characteristics for overload protection and instantaneous trip for short-circuit protection. Operation of main contacts shall be based on Electro-magnetic repulsion forces between contacts created by fault current. Ratings are specified at rated voltage for an rms value of prospective short-circuit current.

2.6 MOLDED CASE SWITCHES (MCSs)

A. Molded Case Switch: Similar to circuit breakers but without overload/short circuit protection. Short time rating of switches shall not be less than twelve times the maximum rated operational current for 1 second. Switches shall comply with IEC 60947-3. Switches shall have utilization category AC-22B to IEC 60947-3.

2.7 MINIATURE CIRCUIT BREAKERS (MCBs)

A. Type: Thermal magnetic non-adjustable type, 6-125 A rating, tested in accordance with IEC 60898-1 for breakers with short circuit rating up to 15 kA and in accordance with IEC 60947-2 for breakers with short circuit rating above 15 kA and up to 25 kA as needed s.

B. Construction: MCBs shall be tropicalized for operation at ambient temperatures up to 70 degree C within panelboard enclosure and humidity up to 95%, and shall be constructed from high quality, high temperature, molded insulating materials. Guaranteed duties and characteristics shall be submitted for temperatures at and above 40 deg C.

C. MCBs and combination devices shall be modular, of unified profile and suitable for mounting either to a standard din rail, or a plug-in system.

D. Operation: Under overload conditions, thermal tripping shall provide close protection of insulated conductors. Under short-circuit conditions, magnetic trip shall operate at 5 - 10 times normal rated current (Curve C). Magnetic operation shall be in the current limiting region and opening time shall not exceed 5 milliseconds.

E. Ratings: Preferred rated currents shall be 6, 10, 15, 20, 25, 30, 40, 50, 60, 80, 100 and 125 A, calibrated at 40deg.c, available as 1, 2, 3 and 4-pole circuit breakers. De-rating above 40 deg C shall not exceed 1% per deg C and loading shall not exceed 70% of circuit breaker rating.

F. Residual current devices for earth leakage protective circuit breakers shall be add-on devices, or built-in and integral with the standard circuit breaker. Non-adjustable sensitivities of 30 mA, 100 mA and 300 mA shall be available for all ratings of 2-pole and 4-pole circuit breakers.

G. Auxiliaries where shown on the drawings, shall include alarm switch, auxiliary switch, shunt trip, under voltage trip and similar units which shall be modular additions to the circuit breakers.

2.8 DISTRIBUTION PANELBOARDS (DP)

A. DP Type 1: Form 2b to IEC 61439-1&-2, and have a minimum rated insulation voltage of 750V and with 8 kV impulse withstand voltage, free standing , with doors (unless otherwise shown on the Drawings), suitable for ratings of main breaker and busbars ranging from 630 A to 1250 A, 3-phase, 4-wire (or 3-wire where specifically indicated), suitably and orderly arranged for any selected combination of branch MCCBs ranging from 150/160 A to 1250 A frame size and short-circuit interrupting ratings as needed. Circuit breakers smaller than 250 A frame size, where indicated, may be grouped on an integral sub-assembly mounted to main chassis.

B. DP Type 2: Form 2a to IEC 61439-1&-2, and have a minimum rated insulation voltage of 690V and with 8 kV impulse withstand voltage. Panelboard shall be recessed or surface mounted type, as shown on the Drawings, complete with trim and door, adjustable trim fixation for flush panels, and with ratings of main circuit breaker and busbars up to 400 A, 3-phase, 4-wire, with 2 or 3-pole branch circuit breakers, 100 A or 150/160 A or 250 A frame size.

C. Circuit breakers for DP’s shall be fitted with a plug-in base type of modular construction complete with its accessories; non draw-out type.

D. Construction: Sheet steel, for cabinet/box; suitable for mechanical impact resistance of IK10 to IEC 62262 for enclosures protection degree IP54 and higher and IK08 to IEC 62262 for enclosures protection degree lower than IP54. Test certificates for mechanical impact shall be submitted for approval; otherwise enclosure thickness shall not be less than 1.5mm. Fronts shall be single or twin covers to shield circuit breakers, terminals and live ends.

E. All distribution panelboards shall be equipped with Class II surge protective devices as specified under Division 26 Section "Surge Protection for Low-Voltage Electrical Power Circuits". SPDs along with their fused-disconnect switch shall be integrated within or adjacent to the DP’s enclosure.

F. Interior of panelboard shall be pan assembly consisting of galvanized sheet steel chassis , folded, flanged and reinforced, with busbars vertically arranged and mounted on molded insulators.

G. Molded insulators shall have minimum temperature rating of 130 deg C and insulation grade of 3.5 kV for one minute.

H. Circuit breakers shall be mounted in twin arrangement (except for larger circuit breakers) and bolted rigidly to copper cross and center bus connectors.

I. Metering Instruments: Instruments shall be housed in enameled, square, metal cases for flush installation. Scales and markings shall be protected and sealed. Accuracy of instruments shall be within 2% unless otherwise specified.

1. Voltmeters: Moving iron type, with center zero adjuster, range 1.25 times nominal system voltage, 90 degree angle, size 76 x 76 mm.
2. Voltmeter Selector Switch: 7-position rotary type.
3. Ammeters: Moving iron type, with center zero adjuster, range 2 times nominal circuit amperage, 90 degree angle, size 76 x 76 mm.
4. Ammeter Selector Switch: 4-position rotary type.
5. Provide ammeters and pilot lights for each phase.

6. Current Transformer (CT): Indoor dry type, rated secondary current 5 A. Rated primary current, core size and accuracy shall be determined in accordance with nominal current of plant protected, short-circuit level and burden.
7. Voltage Transformer (VT): Provide where required, complete with primary and secondary fuses and disconnecting device.

2.9 FINAL BRANCH CIRCUIT, POWER AND SUB-DISTRIBUTION PANELBOARDS - GENERALLY

A. Arrangement: Comprise set of homogeneous branch circuit breakers with unified profile and base, and one main circuit breaker or switch as shown on drawings. Single and multi-pole circuit breakers or other devices shall occupy modular spaces. Accommodation of contactors and split-bus arrangement or other devices shall not change regularity of standard box width.

B. Indoor Enclosure: Sheet steel, minimum 0.8 mm thick for box/cabinet and minimum 1.5 mm thick for front shield, trim and door. Fixings for flush trim shall be adjustable to allow for mis-alignment between box and wall surface. Wiring spaces (gutters) shall be at least 100 mm wide. Larger gutters shall be provided where tap-off insulated split connectors are required. Knockouts shall be provided in top or bottom of enclosures and shall provide a neat and uniform conduit/cable terminal arrangement.

C. Contactors: 2 or 3-pole, Electro-magnetic type, class AC 5a for discharge lamps, class AC 5b for tungsten halogen lamps and class AC 3 for motors to IEC 60947-4, and rated not less than overload setting of protective device upstream. Contacts shall be double break, silver cadmium plated, having self-cleaning wiping action. Control shall be provided by phase-neutral (maximum 230 V) split-coil, for on/off activation by local and/or by remote direct-wired, on/off push buttons. Contactor shall be mechanically latched. Control circuit shall be fused. Auxiliaries shall include local pilot light, parallel remote indicating circuit, 2 N.O. and 2 N.C. auxiliary contacts.

D. All final branch circuits feeding sensitive electronic equipment such as: electronic equipment and telecom racks shall be equipped with class III surge protective devices as specified under Division 26 Section "Surge Protection for Low-Voltage Electrical Power Circuits". SPDs along with their fused-disconnect switch shall be integrated within the panelboard’s enclosure.

2.10 FINAL BRANCH PANELBOARDS - TYPE MCB

A. Type: Rated insulation voltage rating of 500V as a minimum.

B. Internal Assembly: Comprise removable back plate or back pan of rigid construction, attached to enclosure by four captive screws through keyhole fixings, and provided with DIN rails in horizontal arrangement for SPN panels and in vertical arrangement for TPN panels. Assembly shall be complete with neutral terminal block, earthing bar and one piece insulated bolt-on/comb-type phase busbar. Busbars shall be single-phase or 3-phase with spade connectors for fixing by tightening a single screw on circuit breaker. Insulation shall be high thermal rating, capable of carrying maximum short-circuit current for one second without overheating beyond acceptable limits required by the Standards. Panelboards shall comply with IEC 61439-3.

C. Internal Assembly: Comprise removable back plate or back pan of rigid construction, attached to enclosure by four captive screws through keyhole fixings, and provided with busbars in horizontal arrangement for SPN panels and in vertical arrangement for TPN panels. Assembly shall be complete with neutral terminal block, earthing bar and one-piece insulated phase busbar. Busbars shall be single-phase or 3-phase with spade connectors for fixing by tightening a single screw on circuit breaker. Insulation shall be high thermal rating, capable of carrying maximum short-circuit current for one second without overheating beyond acceptable limits required by the Standards.

D. SPN type panelboards shall be suitable for 240 V maximum service voltage, single-phase and neutral, with MCBs on branch circuits and main incoming.

E. SPN type main circuit breaker shall be double-pole MCB, with or without earth leakage device (RCBO), as shown on the Schedules.

F. Single-pole and double-pole MCBs for 240 V service, shall have trip ratings between 6 A and 125 A, with ICs as required in the Schedules.

G. TPN type panelboards shall be suitable for up to 415 V A.C. maximum service voltage, 3-phase and neutral, with MCBs on branch circuits and 3 or 4-pole MCCB or MCS main incoming, as shown in the Schedules or on the Drawings.

H. Triple-pole branch circuit breakers shall have trip ratings between 6 A and 125 A, with IC as required in the Schedules.

I. TPN type panelboard main circuit breakers shall be MCCB or MCS, 100A or 160A frame size as needed, with trip range from 32 A to 160A, normal (N) or high-break (H) duty with/without RCBO as needed.

2.11 FINAL BRANCH CIRCUIT PANELBOARDS; SPLIT-BUS MCB TYPES

A. Assembly shall be as specified for MCB type of branch circuit panelboard, but with split-bus arrangement, part of which is controlled by in-built submain contactor for group control of a number of branch circuits. Panelboard shall have main circuit breaker for protection and isolation.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Fixing Generally:

1. Align, level and securely fasten panelboards to structure.
2. Fix surface mounted outdoor panelboards at least 25mm from wall ensuring supporting members do not prevent flow of air.
3. Do not use connecting conduits to support panelboards.
4. Close unused openings in panelboard cabinets.

B. Panelboard Interiors: Do not install in cabinets until all conduit connections to cabinet have been completed.

C. Wiring Inside Panelboards: Neatly arranged, accessible and strapped to prevent tension on circuit breaker terminals. Tap-off connections shall be split and bolted type, fully insulated.

D. Trim: Fix plumb and square prior to painting. Fix trim for flush mounted cabinets flush with wall surface finish.

E. Comply with mounting and anchoring requirements specified in Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

F. Mounting Heights: Top of trim 1880 mm above finished floor, unless otherwise indicated.

G. Mounting: Plumb and rigid without distortion of box. Mount recessed panelboards with fronts uniformly flush with wall finish.

H. Circuit Directory: Create a directory to indicate installed circuit loads after balancing panelboard loads. Obtain approval before installing. Use a computer or typewriter to create directory; handwritten directories are not acceptable.

I. Protection: Treat concealed surfaces of recessed cabinets with heavy field application of waterproof compound prior to installation.

J. Install filler plates in unused spaces.

K. Provision for Future Circuits at Flush Panelboards: if asked by the engineer, stub four empty conduits from panelboard into accessible ceiling space or space designated to be ceiling space in the future. Stub four empty conduits into raised floor space or below slab not on grade.

3.2 IDENTIFICATION

A. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Division 26 Section "Basic Electrical Materials and Methods".

B. Panelboard Nameplates: Label each panelboard with engraved metal or laminated-plastic nameplate mounted with corrosion-resistant screws.

3.3 CONNECTIONS

A. Install equipment-grounding connections for panelboards with ground continuity to main electrical ground bus.

B. Tighten electrical connectors and terminals, including screws and bolts, according to manufacturer’s published torque-tightening values and / or recommendations. If manufacturer’s torque values are not indicated, use those specified in applicable Standards.

3.4 FIELD QUALITY CONTROL

A. Generally: Carry out all tests, required by the governing codes and by the Engineer, on panelboards after installation, to verify compliance with the specifications and standards. Inspect conditions within panelboards and verify insulation conditions by use of a megger.

B. Circuit Breakers: Tests shall include operation of every circuit breaker manually. Check automatic operation of selected circuit breakers, as required by Engineer, by applying necessary short-circuit, overload and earth leakage current for tripping circuit breaker as applicable and compare with manufacturer's data/characteristic curves. Measure and report ambient temperature inside enclosure.

C. Insulation Check Tests: Carry out insulation tests on all busbars, between phases and between phases and earth/cabinet, and between neutral and earth. Record all readings, using 500 V megger for equipment on 240 V systems, and 1000 V megger for equipment on systems up to 600 V, for 1-minute, with circuit breakers in open position.

D. Routine tests on site shall be carried out, in accordance with the Standards, on all panelboards assembled from standardized components of the manufacturer outside the works of the manufacturer.

E. Prepare for acceptance tests as follows:

1. Test insulation resistance for each panelboard bus, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

F. Testing: After installing panelboards and after electrical circuitry has been energized, demonstrate product capability and compliance with requirements.

3.5 ADJUSTING

A. Set field-adjustable switches and circuit breaker trip ranges.

3.6 CLEANING

A. On completion of installation, inspect interior and exterior of panelboards. Remove paint splatters and other spots. Vacuum dirt and debris; do not use compressed air to assist in cleaning. Repair exposed surfaces to match original finish.

3.7 DEMONSTRATION

A. Train Employer's maintenance personnel to adjust, operate, and maintain the system installation. Refer to Division 01 Sections.

END OF SECTION 262416

SECTION 263353 - STATIC UNINTERRUPTIBLE POWER SUPPLY

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes, on-line, static-type, continuous duty, solid state, double conversion uninterruptible power supply (UPS) system installation and static transfer switch, comprising the following:

1. Complete rectifier/charger-battery-inverter system with 100% rated for continuous automatic static switch and maintenance manual by-pass switch.
2. Input harmonic filter.
3. Output isolation transformer.
4. Power conditioner.
5. Interplant power and control cabling.
6. Connection of normal AC power from assigned terminals/switch/circuit breaker,
7. Earthing system.

B. Related Sections include the following:

1. Division 26 Section "Basic Electrical Materials and Methods".
2. Division 26 Section "Grounding and Bonding".
3. Division 26 Section "Low Voltage Electrical Power Conductors and Cables".

C. For integration with existing systems, as well as for selection of manufacturers, refer to requirements listed in Article 1.2.D of Section "260500 - Basic Electrical Materials and Methods".

1.3 DEFINITIONS

A. EMI: Electromagnetic interference.

B. LCD: Liquid-crystal display.

C. LED: Light-emitting diode.

D. UPS: Uninterruptible power supply.

1.4 PERFORMANCE REQUIREMENTS

A. Seismic Performance: UPS shall withstand the effects of earthquake motions determined according to UBC97.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.

1.5 SUBMITTALS

A. Equipment Data: Submit full technical data of equipment for approval including, but not limited to, the following:

1. Manufacturers' catalogues, detailed description, compliance with the Standards, dimensions and weights, system operation, operating characteristics, methods of operation, protective and control provisions, heat losses, ambient conditions and limitations on electronic components, inverter cut-off voltage, battery calculation to IEEE 485, etc. beyond which such components may suffer partial or permanent damage.

B. Shop and Construction Drawings: Submit drawings for approval including, but not limited to, the following:

1. Plans and front and side elevations, with indication of built-on control and indicating devices and instruments, exact dimensions and weights, cabling etc.
2. One-line diagram with ratings of each piece of equipment, cabling, grounding etc.
3. Control and elementary diagrams, wiring diagrams and the like.
4. Installation and mounting details.
5. Batteries arrangement and mounting details.

C. Point-wise compliance statement to the specifications, duly signed by the manufacturer / manufacturer's authorized representative and the contractor.

D. Manufacturer Certificates: Signed by manufacturers certifying that they comply with requirements.

E. Qualification Data: For firms and persons specified in "Quality Assurance" Article.

F. Seismic Qualification Certificates: For UPS equipment, from manufacturer.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

G. Test Certificates: Submit type test and routine test certificates. System shall undergo a functional and load test program approved by the Engineer, and shall undergo a minimum 8 hours 'burn-in' test, under site simulated conditions, prior to shipment.

H. Field Test Reports: Indicate test results compared with specified performance requirements, and provide justification and resolution of differences if values do not agree.

I. Maintenance Data: For UPS units to include in maintenance manuals specified in Division 01. Include the following and to the satisfaction of Employer's requirements:

1. Lists of spare parts and replacement components recommended being stored at Project site for ready access.
2. Detailed operating instructions covering operation under both normal and abnormal conditions.

1.6 QUALITY ASSURANCE

A. Manufacturer's Certification: The manufacturer shall be specialized in manufacturing of on line, double conversion three phase UPS modules specified in this document with a minimum of twenty

years documented worldwide experience and shall have a nationwide first party service organization. The manufacturer shall be ISO 9001 certified and shall design to internationally accepted standard.

B. Factory Testing: Prior to shipment the manufacturer shall complete a documented test procedure to test all functions of the UPS modules and batteries (via a discharge test), when supplied by the UPS manufacturer and guarantee compliance with the specification. The manufacturer shall provide a copy of the test report upon request. Tests shall comply to IEC 62040-3 and include but not necessarily limited to the following:

1. Light load test.
2. AC input failure test.
3. AC input return test.
4. Transfer test.
5. Full load test.
6. UPS efficiency test.
7. Unbalanced load test.
8. Balanced load test.
9. Short-circuit test.
10. Harmonic components test.

C. Materials and Assemblies: All materials and parts comprising the UPS shall be new, of current manufacture, and have not been in prior service, except as required during factory testing. All active electronic devices shall be solid state and not exceed the manufacturers recommended specified tolerances for temperature or current to ensure maximum reliability. All semiconductor devices shall be sealed. All relays shall be provided with dust covers. The manufacturer shall conduct inspection on incoming parts, modular assemblies, and final products.

D. Installer Qualifications: Experienced installer who is an authorized representative of UPS manufacturer for both installation and maintenance of units required for this Project.

E. Local Representative: Provide evidence that proposed equipment manufacturer has a locally established and authorized organization which can be called upon for professional advice and maintenance as may be required, and which can immediately supply spare parts to support day to day and emergency maintenance requirements. Failure to satisfy Engineer may disqualify a manufacturer.

F. Standards: Installation shall comply with the following standards:

1. IEC 62040-1,2&3 “Uninterruptible Power Systems”.
2. IEC 61000-3-4 “Electromagnetic compatibility (EMC) - Part 3-4: Limits - Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A”.
3. IEC 61000-4 “Electromagnetic compatibility (EMC) – Testing and Measurement Techniques”.
4. IEEE 485 “IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications”.
5. IEC 62310 “Static Transfer Systems”.
6. IEC 61000-3-2 “Electromagnetic compatibility (EMC) - Part 3-4: Limits - Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A”.
7. IEC 61000-3-3 “Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection”.
8. IEC 61000-6-2 “Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments”.
9. IEC 61000-6-3 “Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments”.

G. Materials and components shall be manufacturer's latest design, and Standards used shall be approved prior to manufacture.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver equipment in fully enclosed vehicles after specified environmental conditions have been permanently established in spaces where equipment shall be placed.

B. Prior to shipping all products shall be inspected at the factory for damage.

C. Store equipment in spaces with environments controlled within manufacturers' ambient temperature and humidity tolerances for non-operating equipment.

D. Equipment containing batteries shall not be stored for a period exceeding 3 months without powering up the equipment for a period of 8 hours to recharge the batteries. . Relevant Certificate for the batteries production date shall be submitted to the engineer.

1.8 PROJECT CONDITIONS

A. Temperature limits within which equipment shall be designed to operate are zero to +40 deg. C at 100% rated output. Equipment shall be capable of operating under up to 55 deg. C ambient conditions with derating factor of 1.25% per deg. C over 40 deg. C.

1.9 WARRANTY

A. Manufacturer’s Warranty: Submit a written warranty signed by the manufacturer agreeing to repair, restore or replace any defective equipment specified in this section during the specified warranty period

1. Warranty Period: 1 year from date of substantial completion.

B. Battery: The battery manufacturer’s warranty shall be passed through to the final customer and shall have a minimum period of one year.

1.10 EXTRA MATERIALS

A. Spare Parts: Provide and deliver to client stores manufacturer's recommended spare parts for one year operation of UPS system. Spare parts shall include as a minimum complete set of fuses for all types and ratings along with cooling fans.

B. Provide list of manufacturer's spare parts for five years operation together with current prices.

C. Tools and Instruments: Provide tools and instruments required for normal routine inspection, testing, operation and general maintenance, as recommended by the manufacturer.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Approved Manufacturers: Subject to compliance with requirements, provide products by one of the following or approved equal:
1. Eaton (U.S.A.)

2. APC/Schneider Electric (France)

2.2 SYSTEM DESCRIPTION

A. System: UPS system shall be online, continuous duty, double conversion, class VFI-SS-111 to IEC 62040-3.

B. System shall be of the programmable type, microprocessor based with CPU and memory capabilities for storage of alarms, faults, status change, etc. The UPS shall permit setting parameters for the environment and type of usage to be specified by the Engineer. UPS shall be of the self-diagnostic type, equipped with a self-test function to verify correct system operation. The self-test shall identify the parts of the UPS requiring repair in case of a fault. The system shall be provided with multi-password levels to limit access to software and data.

C. General: System shall be interposed between normal AC power supply and critical load, to secure a minimum period of continuity of no-break battery back-up for 15 minutes in case of failure of normal AC supply and maintain output voltage, frequency and phase deviation within specified tolerances.

D. System shall be 100% fully rated, external-2N redundant (through 2nr UPS units) for number and capacity; with two sets of battery strings operating in parallel for each unit for ratings up to 80 kVA and two to four sets of battery strings in parallel for each unit for ratings above 80 kVA unless otherwise recommended by the manufacturer and approved by the Engineer. UPS shall be maintained (continuously supplying load through the inverter), with automatic no-break transfer to or retransfer from alternate source (bypass) in case of failure or overload on rectifier- battery-inverter system.

E. Normal AC power supply will be available from one protected source fed from either normal AC network or from AC Characteristics of output of generator set (when provided) and UPS system shall be coordinated for best results. Study and advise on special requirements of generator characteristic output and stability.

F. Separate filters shall be provided for each rectifier/charger unit separately to limit the THD to less than 7% this applies for all load currents from 25 to 100% of full load.

G. System overall efficiency shall not be less than 93 % at full load and 91 % at half load.

H. Noise level of complete assembly shall not exceed 65 dB(A) at 1.0 m distance anywhere within UPS room.

2.3 SYSTEM OPERATION

A. Under normal conditions inverter(s) shall be synchronized and phase locked to normal AC supply. Upon loss of normal AC supply, battery shall continue supply of no-break power to inverters, which then free-run on self- generated UPS frequency reference. Upon restoration of normal AC supply, inverters shall re-synchronize to AC line, gradually (at slew rate), if frequency and voltage deviation of normal AC supply is within preset limits specified.

B. Automatic Transfer To Bypass: Static transfer switch shall automatically transfer critical (100%) load from inverter to by-pass source (which is normal AC supply) if:

1. Inverter output voltage characteristics fall outside specified limits.
2. Critical load exceeds overload rating of UPS.
3. Over-temperature is sensed.
4. Manual (push button) command is given.
5. Transfer to by-pass mode shall be inhibited, and an alarm initiated if voltage, frequency and/or phase shift of by- pass power is outside acceptable tolerances.

C. Re-Transfer To Inverter: Re-transfer of critical load from auto by-pass source to inverter (UPS mode) is only to be possible under the following conditions:

1. Inverter output voltage characteristics return to within specified tolerances.
2. Original load current reduces to within rated full load capacity of UPS.
3. Re-transfer selector switch is in automatic position.

D. Lock-out feature shall inhibit re-transfer if by-pass source conditions are outside preset tolerances or if UPS output and by-pass are not synchronized and phase locked or if UPS output is not restored to normal conditions.

E. Normal Power Restored: When normal power is restored following an outage, rectifier/charger shall initially draw no power except for transformer in-rush current and shall gradually continue providing power to the inverter and recharging the battery. After approximately 15 seconds (walk-in time), input power requirements shall rise to power level to drive critical load and recharge battery.

F. Automatic Restart: When normal power is restored to normal conditions following an outage and after a complete battery discharge, the UPS shall automatically restart and resume supplying power to the connected load via the inverter.

G. Provide maintenance disconnecting switch fully rated to carry the full load input current of the UPS.

2.4 SYSTEM CHARACTERISTICS

A. Rectifier/Charger Input:

1. Nominal Input Voltage: 380V, 3 phase, 4 wire, 50Hz.
2. Voltage input variation: +10%, -15% from nominal.
3. Frequency: +/-5% from nominal.
4. Transformer Exciting Current In Rush: Less than 600 % nominal current.
5. Power Factor: minimum 0.9 lagging at full load and nominal input voltage.
6. Total Feedback Current Harmonics: Maximum **7** % for UPS ratings above 20kVA and 8% for UPS ratings 20kVA and below.
7. Current Limiting: 115% max. of that required to operate inverters and charge battery at full rated load, adjustment possible between 100% and 125%.
8. Walk-in Current in Rush: 25% to 100% FLC in 15 seconds.

B. Rectifier/Charger Output:

1. Float and Equalize Operation: Adjustable, automatic, compatible with battery.
2. Regulation: +/-1% max. from 0-100% load.
3. Ripple: +/-2% rms. (0 to 100% resistive load).

C. Static Inverters:

1. Nominal net system power output rating in kVA: with load power factor 0.8 lag.
2. Nominal output voltage: 380 V, 3 phase, 4 wire, 50 Hz, adjustable +/-5% of nominal.
3. Output voltage regulation:
   a. Balanced load: +/-2% (0 - 100% load)
   b. Unbalanced load (3-phase output only): +/-10% (at each 10% of load)
4. Phase Displacement: 120 deg. (+/-3 deg.) at 100% load unbalance.
5. Output Voltage Waveform: 5% max. total harmonic, 3% max. single harmonic.

6. Frequency Stability: Normally synchronized to input line frequency over +/-2 adjustable ranges; free running at +/-0.5. Full battery voltage variation, load and p.f. range; slew rate shall not exceed 0.1 Hz/sec.
7. Dynamic Output Voltage Tolerance Sudden Full Load Removal: +/-10% max. recovering application or to within 1% in less than 100 milliseconds.
8. Over-load Rating: 125% for 10 minutes, 150% for 60 seconds, 1000% for 5 cycles, 105% continuous.
9. Load crest factor without derating (Ipk/Irms): 3:1

D. Automatic Static Bypass Transfer Switch:

1. Transfer Time: 150 microsecond (overlapping) maximum.
2. Total Sensing and Transfer/Retransfer Time: 2 milliseconds, maximum.
3. Retransfer Mode: automatic/inhibit (selectable).
4. Retransfer Delay: 2 - 32 secs. in auto mode (selectable).
5. Transfer Point: +/-10% of nominal output voltage (adjustable).
6. Retransfer Point: +/-5% of nominal output voltage (adjustable).
7. Transfer Inhibit Point: +/-20% of nominal output voltage (adjustable).
8. Bypass circuit shall be provided with backfeed protection to IEC 62040-1 through internal backfeed contactor to prevent feedback to the mains from the inverter in case of mains failure and a fault in bypass circuit.

2.5 COMPONENTS AND ACCESSORIES

A. Materials and Parts: Electronic devices shall be solid state, hermetically sealed. Indicator lights shall be twin LED type, those denoting blown fuse conditions shall be seen by operator without removing panels or opening cabinet doors. Power connections and remote alarm and control wiring shall be accessible at terminal boards. Power semi- conductors shall be fused. Metal surfaces including copper and aluminium heat sinks and busbars shall be treated with permanent protective coating. Electro-mechanical power devices and relays shall be vacuum impregnated, insulated for maximum operating voltage conditions, and enclosed in dust-tight enclosures. Cables shall be fire resistant high temperature grade.

B. UPS shall be provided with a socket connection for a serial interface to be linked to a portable PC, to a modem or to the BMS system for communication with the UPS. It shall enable interrogation of the UPS about status, faults, data stored, reprogramming, etc.

C. Housing: Equipment shall be housed in a free-standing, well ventilated, totally enclosed modular assembly with front accessible lockable doors, giving easy access for maintenance, inspection and adjustments, and with provisions for handling and lifting during and after installation. Enclosures shall be suitable for industrial, tropical environments, protection IP 21 to IEC 60529, of galvanized sheet steel construction treated against corrosion and with light grey RAL7032 baked paint or epoxy finish to approved standard.

D. Where single core cables are used, top / bottom cable entry plates shall be made of bakelite or Aluminum with adequate thickness and rigidity to support cables.

E. Sub-assemblies and components shall be mounted on pull- out and/or swing-out trays, of the plug-in type where possible. Where it is not possible to mount components in pull-out or swing-out trays, they shall be easily accessible inside the enclosure. Assemblies shall be replaceable without requiring any adjustments or settings in the UPS.

F. Ventilation: For units rated over 3 kVA, an integral, forced-air, cooling system shall be provided in each UPS module to remove dissipated heat efficiently, and ensure components operate within environmental ratings. Air shall enter bottom of cabinet through replaceable filters, and exhaust through the top. At least two fans shall be provided for ventilating each enclosure. No degradation of performance shall occur in the event of a single fan failure. Temperature sensors,

mounted on semi-conductor heat sinks, shall initiate alarm if maximum working temperature is exceeded.

G. Rectifier/charger unit shall be as follows:

1. Active front end (AFE) Insulated Gate Bipolar Transistor (IGBT) or 6-pulse silicon controlled rectifier (SCR) type for UPS ratings up to 40 kVA.
2. IGBT type UPS ratings 40 kVA and up to 200 kVA.
3. IGBT or 12 pulse SCR type with filter for UPS ratings above 200 kVA.

The unit shall have mainline circuit breaker and a rectifier input transformer for 12 pulse UPS, and shall be automatic with soft start-up (walk-in) feature, using IGBT with vector control design or silicon controlled rectifiers (SCR) with control logic circuitry to control firing angles to SCR to suit power output requirements and protect against primary power surges, lightning transients, under-voltage and over-voltage conditions. Output shall be passed through LC filters to DC bus.

H. Rectifier/charger unit shall be microprocessor based and capable of supplying full load power to inverter, and to charge the battery from a discharge condition to 90% charge within ten to twelve hours, and maintain full charge at floating voltage until next operation. The rectifier/battery charger shall employ input AC current limiting as well as battery charge current limiting for battery protection. Charger current shall be voltage regulated and current limited. The control of the optimum charging method shall be completely controlled by the charger's microprocessor.

I. Inverter shall employ IGBT technology in three leg, vector control or high frequency switching and real time control technique, and complete with output transformer and filters. Inverter start-up shall be automatic, to reach full voltage within milliseconds and deliver power to the load within 2 seconds. Inverter shall start at any load including short-circuit. Inverter shall be provided with an inverter output transformer. For UPS ratings 200kVA and below transformer-less technique may be used, subject to Engineer's approval.

J. Inverter oscillator shall operate and maintain output frequency of inverter within specified tolerances, and be capable of synchronization and phase-locking to normal power supply frequency. When inverter is phase-locked to normal power supply, and latter fails, oscillator shall automatically revert to free running state (quartz oscillator) and maintain specified limits.

K. Modular UPS system where shown on the Drawings shall consist of multiple units with equal capacities, each not exceeding 50 kVA, connected in parallel architecture and share one common frame or more according to the required number of modules, each frame shall have common input and output busses and separate battery system consisting of two parallel strings as a minimum. Modular UPS system shall be online, double conversion, IGBT rectifier, IGBT inverter with transformerless technique. The modular UPS system shall have the following features as a minimum:
1. Each module shall be provided with fully rated static and maintenance bypass.
2. The modular system shall be expandable by adding modules without shutting down the system (hot pluggable).
3. Modules shall be replaceable without shutting down the system during the replacement process (hot swappable).
4. The modular system shall not have a single point of failure. Fault on any of the modules shall not affect the whole system.
5. Sufficient space for the number modules for future expansion shall be provided as shown on the Drawings.
6. Redundancy, if required on the Drawings, shall be achieved by adding a number of modules with total power capacity shown on the Drawings.
7. Battery capacity shall be expandable by adding independent battery strings to cater for the increase in the system power. Adding battery strings shall be done without shutting down the system.

L. Automatic static bybass transfer switch shall be continuously rated at full load (100% FL), hybrid type (make-before-break), solid state transfer device with logic thyristor assembly isolatable or

completely removable for maintenance. When signal to close switch is initiated, thyristors shall instantaneously conduct power to prevent deviations and breaks in load voltage outside specified tolerances.

M. Maintenance By-Pass Switching: Manual (make-before- break) by-pass switch shall allow load to be transferred to by-pass source without interruption of output, and provide isolation of UPS and static switch during maintenance. Test position shall permit testing of static switch while load is being fed from bypass power circuit. Transfer inhibited warning circuit shall be provided to give an alarm indication in case by-pass supply is beyond acceptable tolerances.

N. Rectifier input and bypass isolating transformers shall be provided for all UPS ratings 80 kVA and above.

O. UPS inverter output, IGBT rectifier input and bypass input transformers shall be two-winding type, while 12 pulse rectifier input transformers shall be three winding type. Bypass input transformers' vector group shall be Delta / ZigZag (Dz0) to provide zero phase shift between primary and secondary windings to allow for parallel external bypass to the whole UPS system.

P. Transformers shall be galvanically isolated dry-type, Class H insulated, with metallic electrostatic shielding, and high efficiency (98% or higher) type. Transformers shall be installed either within the UPS enclosure or in a separate enclosure as applicable and approved by engineer.

Q. Protection: UPS modules shall have built-in or inherent electronic current-limiting protection against permanent self damage effective down to short-circuits. Fast acting, current limiting devices shall protect against failure of any solid state component. Internal failure in any UPS module shall cause immediate isolation from input and output by operation of static interrupters or causing shut down of faulty module. Protection shall be provided against, but is not limited to, the following:

1. Input over and under voltage and power line surges
2. Output over voltage and voltage surges
3. Sudden abnormal changes in output load conditions
4. Short-circuits at output terminals
5. Inverter and rectifier overcurrent
6. Auxiliary Control Circuit Overcurrent.

R. UPS Bypass and Output Neutral: Designed to continuously carry twice the full load phase current.

S. Input Passive Filter Disconnection: UPS control system shall not disconnect the input passive filters unless the UPS is operating at light loads (less than 25%).

T. Battery: High rate discharge, heavy duty, industrial, high impact resistant, clear plastic encased, sealed lead- acid (gas recombination) type cells with automatically re-closing explosion proof safety vents. Electrolyte specific gravity shall not exceed 1.25 when fully charged at 25 deg. C. Ampere-hour rating shall be sufficient for emergency period specified with all inverters operating at full rated output, to a discharge limit of not less than 1.75 V per cell. Cells shall be normally maintained at 2.25 V per cell. Guaranteed life shall not be less than 10 years, with a capacity drop down to not less than 80% under normal expected service.

U. Battery Cabinet: shall be factory assembled from UPS manufacturer, of welded construction and formed from heavy gauge steel with added supports to retain cabinet squareness and integrity during harsh shipping and handling conditions, Adjustable battery rails or trays shall be provided to allow for multiple battery configurations and facilitate battery upgrades in the future, Heavy duty polyester strapping material shall be used to tie down batteries, Cabling shall be routed down the sides of the cabinet, away from the front of the batteries allowing full access for easy maintenance, series wiring shall be routed efficiently and neatly with tier to tier jumpers located at front batteries allowing for safe and easy maintenance, Cabinets shall be top coated with a hybrid epoxy-polyester powder coat and oven cured for a chip and corrosion resistant long lasting finish, All circuit breakers used on the cabinets shall be rated to 600 VDC. Each battery string shall be

provided with its own circuit breaker for the individual string fault protection and disconnecting means. Battery cabinet enclosure degree of protection shall be IP 20.

V. Battery checking system shall be provided for each UPS to check the battery continuity and improve life time through regular automatic test and measurements for battery status, voltage and current. System shall provide a predictive and automatic diagnostics of battery health, optimize the recharge time and provide an advance warning about the end of battery life upon detection of a weak / defective battery.

W. The battery cells age, at the time of delivery into site, shall be less than three months.

X. Battery calculations according to IEEE 485 shall be carried out by UPS supplier and submitted for approval, based on the following:

1. Nominal active power factor of not less than 0.8 Lag.
2. Temperature factor for operation at 25 Deg C.
3. Aging factor of 1.25.
4. Design margin factor of 1.15.
5. Recharge time up to 90% of its capacity within 10 to 12 hours.

Y. Mimic Panel: UPS assembly shall include a mimic diagram with digital and LED displays, indicating instruments and control devices, in true relative positions.

Z. Local panel instruments shall include at least the following (digital readings):

1. Inverter input voltage: measuring DC bus voltage.
2. Battery current: measuring charge / discharge currents.
3. AC voltage: measuring inverter output voltage, normal supply voltage or system output.
4. UPS output measurements: for current, voltage and frequency.
5. Remaining battery backup time.
6. Input voltages.
7. Input current.
8. Total power.
9. Total harmonic distortion on input feedback current (THDi).
10. Total harmonic distortion on input voltage (THDv).

AA. Local Panel Indicators shall include at least the following:

1. System on battery supply.
2. Inverter phase locked to verify synchronization between inverter output and normal AC supply input.
3. Static switch on normal AC supply (bypass mode).
4. Static switch inhibited.
5. Over-temperature, indicating excessive temperature in heat sinks for transformers, rectifier/charger and inverter (alarm to automatically transfer load to by-pass circuit).
6. Inverter output overload, indicating inverter output beyond specified rating failure of any stage, DC bus earth fault, inverter output earth fault.

BB. Local built-in controls shall include at least the following:

1. Inverter on/off.
2. Battery input circuit breaker.
3. Auto/manual reset-test switch.
4. Manual reset switch.
5. Hybrid switch transfer test push-button.
6. Re-transfer auto/inhibit selector switch to allow automatic re-transfer of load to inverter after timed interval of normal operation and inhibit re-transfer of load to inverter until hybrid switch is in auto-mode.

7. Battery automatic/equalize recharge timer, 0 - 30 hours adjustable, with automatic/boost/equalize switch (accessible to maintenance personnel only and to be used only with manufacturer's recommendation for type of battery specified).
8. Voltage and frequency adjustment controls with locking devices (accessible to maintenance personnel only).
9. Indicator test/reset switch.
10. Control power supply isolator (accessible to maintenance personnel only).
11. Alarm test-accept-reset.

CC. Local built-in alarms causing horn to sound, with tripping command if required, shall include at least the following:

1. Fan failure: Alarm only.
2. Over Temperature: Alarm with automatic transfer of load to by-pass after a safe preset period.
3. DC Volts out of Limits: Alarm with indication.
4. Fuse Failure: Alarm.
5. Battery on Load/Disconnected: Alarm only.
6. Overloads: Alarm only with a trip command if pro- longed, for each rectifier/inverter unit.
7. Normal AC Supply Failure: Alarm only.
8. Hybrid Switch Operation to by-pass Mode: Alarm only.
9. Low and High Output Voltage: Alarm only.

DD. Connection to existing BMS system for full monitoring, including proper interface digital software link for remote monitoring from BMS for the following points, as a minimum:

a. By-pass source available.
b. Inverter AC output available.
c. Inverter synchronized and phase locked.
d. Critical load connected to inverter.
e. Critical load connected to by-pass source.
f. Hybrid transfer switch inhibited.
g. High/low DC voltage.
h. Over-temperature.
i. Inverter output overload.
j. Fan failure.
k. Over temperature.
l. Battery on load.
m. Battery disconnected.
n. Remaining battery backup time.
o. Overload.
p. Normal AC power supply failure.
q. Input voltages.
r. Output voltage.
s. Input current.
t. Output current.
u. Total power.
v. Total harmonic distortion on input feedback current (THDi).
w. Total harmonic distortion on input voltage (THDv).

EE. Input active harmonic filter shall be provided to limit input current harmonic distortion to less than 7% THD at all load currents from 0 to 100% of full load and improve power factor to not less than 0.9. The input filter shall be mounted inside the UPS cabinet or in a separate enclosure.

FF. Seismic-Restraint Design: UPS, battery racks, cabinets assemblies, subassemblies, and components (and fastenings and supports, mounting, and anchorage devices for them) shall be designed and fabricated to withstand static and seismic forces.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Equipment Bases: Ensure that concrete bases and foundations provided for installation of equipment are constructed in accordance with approved shop and construction drawings and equipment manufacturers' drawings and that holes for fixing bolts and provisions for passage of cables etc. are provided as required.

B. Built-In Items: Ensure that equipment supports, fixings and the like, and sleeves for passage of feeders and cables which shall be built into concrete foundations, bases or building structure are provided as and when required and that they are properly installed.

C. Tools: Use only tools recommended by equipment manufacturers for installations, particularly in making connections and adjustments.

D. Supervision: Carry out equipment installation under the direct supervision of a qualified technician, licensed by and trained at the factory. Final adjustments and putting into satisfactory operation shall be made by a specialist delegated by the factory.

3.2 GROUNDING

A. Provide direct interference free grounding circuit in accordance with Division 26 Section "Grounding and Bonding" of the Specification.

3.3 IDENTIFICATION

A. Identify components and wiring according to Division 26 Section "Basic Electrical Materials and Methods."

3.4 BATTERY EQUALIZATION

A. Equalize charging of battery cells according to manufacturer's written instructions. Record individual-cell voltages.

3.5 FIELD QUALITY CONTROL

A. Electrical Tests and Inspections: Perform tests and inspections according to manufacturer's written instructions and as listed below to demonstrate condition and performance of each component of the UPS:

1. Inspect interiors of enclosures, including the following:
    a. Integrity of mechanical and electrical connections.
    b. Component type and labeling verification.
    c. Ratings of installed components.
2. Test manual and automatic operational features and system protective and alarm functions.
3. Test communication of status and alarms to remote monitoring equipment.

B. Power Supply Output Disturbance: Provide microprocessor based instrument, and monitor and record power supply output disturbance of voltage and frequency. Instrument details shall be submitted for approval.

C. Test Periods shall be prolonged (over 24 hours) and as requested by Engineer, to verify and obtain realistic voltage and frequency profile under any loading and switching conditions within the criteria specified.

D. Data logging shall include high and low average voltage, sags and surges, spikes and spike bursts, drop-outs, high and low frequencies etc. with print-out and storage on cassette tape for subsequent re-entry into instrument's memory for display or print-out.

E. Seismic-restraint tests and inspections shall include the following:

1. Inspect type, size, quantity, arrangement, and proper installation of mounting or anchorage devices.
2. Test mounting and anchorage devices according to requirements in Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

F. Tests shall include loads at various power factors from low-load to overload condition, and measurements of temperature, heat losses, output voltage, wave shape, and harmonic content and frequency stability.

G. Retest: Correct deficiencies and retest until specified requirements are met.

H. Record of Tests and Inspections: Maintain and submit documentation of tests and inspections, including references to manufacturers' written instructions and other test and inspection criteria. Include results of tests, inspections, and retests.

3.6 DEMONSTRATION

A. Train Employer's maintenance personnel to adjust, operate, and maintain the system installation.

END OF SECTION 263353

SECTION 263600 - TRANSFER SWITCHES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes transfer switches rated 600 V and less, including the following:

1. Automatic transfer switch.
2. Bypass/isolation switch.

B. Related Sections include the following:
1. Division 26 Section "Basic Electrical Materials and Methods".
2. Division 26 Section "Switchboards" for circuit breakers.

1.3 SUBMITTALS

A. Technical Data: Include ratings and dimensioned plans, sections, and elevations showing minimum clearances, conductor entry provisions, gutter space, installed features and devices, and material lists for each switch specified.

B. Wiring Diagrams: Detail wiring for transfer switches and differentiate between manufacturer-installed and field-installed wiring. Show both power and control wiring.

C. Point-wise compliance statement to the specifications, duly signed by the manufacturer / manufacturer’s authorized representative and the contractor.

D. Product Certificates: Signed by manufacturer certifying that products furnished comply with requirements and that switches have been tested for load ratings and short-circuit closing and withstand ratings applicable to units for Project.

E. Manufacturer Seismic Qualification Certification: Submit certification that transfer switches accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration and Seismic Controls for Electrical Systems." Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

F. Field Test Reports: Indicate and interpret test and inspection results for compliance with performance requirements.

G. Maintenance Data: For each type of product to include in maintenance manuals specified in Division 01 and to the satisfaction of the Employer's requirements. Include all features and operating sequences, both automatic and manual. List all factory settings of relays and provide relay setting and calibration instructions, including software, where applicable.

1.4 QUALITY ASSURANCE

A. Local Representative: Provide evidence that proposed equipment manufacturer has a locally established and authorized organization which can be called upon for professional advice and maintenance as may be required, and which can immediately supply spare parts to support day to day and emergency maintenance requirements. Failure to satisfy the Engineer may disqualify a manufacturer.

B. Source Limitations: Obtain automatic transfer switch, bypass/isolation switch and related control panels through one source from a single manufacturer.

C. Comply with IEC 60947-6.

D. Comply with UL 1008, NFPA 70 and NFPA 110.

E. Comply with NFPA 99.

1.5 WARRANTY

A. Manufacturer's Warranty: Submit a written warranty signed by the manufacturer agreeing to repair, restore or replace any defective equipment specified in this section during the specified warranty period

1. Warranty Period: 1 year from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Approved Manufacturers: Subject to compliance with requirements, provide products by one of the following or approved equal:

1.	Asco/Emerson Electric	(U.S.A.)
2.	Caterpillar, Inc.; Engine Division.	(U.S.A.)
3.	Cummins Corp.	(U.S.A.)
4.	Schneider Electric / Square D	(U.S.A.)
5.	Kohler Co.	(U.S.A.)
6.	Russelectric, Inc.	(U.S.A.)
7.	GE/Zenith Controls, Inc.	(U.S.A.)
8.	Cutler-Hammer/Eaton Corp.	(U.S.A.)
9.	GE/Zenith Controls, Inc.	(U.S.A.)

B. Locally assembled transfer switches meeting the Specification are not acceptable.

2.2 MAINS FAILURE AUTOMATIC TRANSFER SWITCH (ATS)

A. Type: Conforming to IEC 60947-6 and to applicable standards, capable of frequently switching mixed motors and resistive loads with utilization category AC33A to IEC 60947-6-1 or equivalent.

Wall or floor mounted, galvanized sheet steel cubicle of equal construction to control cubicle, comprising switching and controls necessary for automatic transfer of power supply from normal source to stand-by source, voltage sensing control relay and time delay relays to signal generator start and stop, auxiliary switches and indicating lights etc. as necessary for the required operation of the system.

B. ATS shall be class PC with double throw single switch and having rated short time withstand and short circuit making current to IEC 60947-6-1, based on short circuit level of the network at equipment location.

C. ATS shall be class CB with two single throw circuit breakers and having rated short time withstand and short circuit making and breaking current to IEC 60947-6-1, based on short circuit level of the network at equipment location.

D. Operation: When voltage and/or frequency of any phase drops below an adjustable setting (80-100%) of normal supply, for an adjustable period of 1 - 300 seconds, power failure relay shall actuate engine starting control. After an adjustable period of 0 - 10 seconds from sensing stabilized rated voltage and frequency of generator at the ATS, (Voltage pick-up adjustable from 85% to 100% nominal), frequency pick-up adjustable from 90% to 100% nominal, the ATS shall transfer to the emergency position. Upon restoration of normal mains supply to above the preset limits, adjustable between 90% and 100% of rated voltage and/or frequency, for an adjustable preset period of 2 - 30 minutes, the ATS shall transfer the load to normal position.

E. Engine Shutdown: Initiate after retransfer of the load to normal source. (Refer to generator set controls upon shut-down).

F. Mechanical and Electrical Interlocks: shall be provided in C.B. type ATS to prevent circuit breakers from being closed simultaneously at any time. Transfer mechanism shall be powered from the source to which the load is being transferred.

G. Selector Switches shall be provided as follows:

1. Operating selector switch shall include the following positions:
    a. Normal: Generator set is set for automatic operation and the generator set starts if a power outage occurs, as described above.
    b. Test: Stimulates a power outage, starts and runs the generating set as Normal position.
    c. Stop: Shuts down the generating set and prevents it from starting. This is used when servicing the generator.

2. Another selector switch shall be provided for two positions, "With load" and "Without load" for testing or exercising:
    a. "With Load": the generating set shall carry the load during testing or exercising periods.
    b. "Without Load": generating set shall start but not assume the load.

H. Pilot Lights shall indicate all ATS positions and sources available.

I. Instruments shall include voltmeter and ammeter with selector switches.

J. Automatic Retransfer: automatic retransfer selector switch marked “AUTO”, “MANUAL” shall be provided. On manual position, automatic retransfer is disabled, while it is enabled in the auto position.

K. Circuit Breakers shall be electrically and manually operated non-automatic type, conforming to IEC 60947-2 utilization category B, sequence II (service rating), with two N.O and two N.C spare contacts each.

L. Degree of Protection: ATS shall have an IP31 degree of protection to IEC 60529 for indoor installations, IP54 degree of protection for installations in wet areas and for ATS serving life safety and firefighting equipment and IP55 degree of protection for outdoor installations.

M. Wiring: Moisture and heat resistant, silicon rubber insulated, stranded copper conductors, modularly and neatly arranged on master terminal blocks, with suitable numbering strips and appropriate cartridge type fuses where required. Flexible wiring shall be used on all hinged/draw-out components.

N. Connections shall be made at front insulating terminal blocks with no live metal exposed. Power cables shall terminate on fixed insulated copper connectors suitably sized to receive specified cables. Cable glands and gland plates shall be provided.

O. Metal Cases of instruments, control switches, relays etc. shall be connected by flexible protective conductors, of not less than 2.5 mm2 section, to nearest earthing bar or terminal.

P. Earthing: Earthing bar shall be provided for connection of protective earthing conductors, using set-screw or bolted anti-turn pressure terminations.

Q. Ferrules: Wire ends shall be fitted with numbered ferrules of approved type at each termination.

R. All automatic transfer switches fed main distribution board / distribution panel shall be equipped at the utility incomer with class II surge protective devices . SPDs along with their fused-disconnect switch shall be integrated within the ATS’s enclosure.

2.3 ATS WITH MANUAL BYPASS SWITCHES

A. Provide Manual Bypass Switches to combine manual and automatic transfer operation with a drawout isolation system. Bypass switch shall consist of non-automatic Kirk-key interlocked switches or circuit breakers, fully rated, manually operated and rated for same loads as automatic transfer switch.

B. Bypass switch shall provide bypass to either normal or emergency source by use of a selector switch and a permanently mounted external lever, mechanically interlocked to prevent paralleling of sources.

C. An engine start switch shall be provided to allow generator set to be started when bypass is on emergency sources.

D. Bypass switch shall be of the make-before-break type. A dead source lockout shall prevent any possibility of bypassing the load to an unenergized source.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Floor-Mounted Switch: Level and anchor unit to floor.

B. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Division 26 Section "Vibration and Seismic Controls for Electrical Systems."

C. Identify components according to Division 26 Section "Basic Electrical Materials and Methods."

3.2 WIRING TO REMOTE COMPONENTS

A. Match type and number of cables and conductors to control and communications requirements of transfer switches as recommended by the manufacturer. Increase raceway sizes at no additional cost to Employer if necessary to accommodate required wiring.

3.3 CONNECTIONS

A. Ground equipment as indicated and as required by the Standards.

3.4 FIELD QUALITY CONTROL

A. Testing: Perform the following field quality-control testing in addition to tests recommended by the manufacturer:

1. Before energizing equipment, after transfer-switch products have been installed:
    a. Measure insulation resistance phase-to phase and phase-to-ground with insulation-resistance tester. Include control circuits. Use test voltages and procedure recommended by manufacturer. Meet manufacturer's specified minimum resistance.
    b. Check for electrical continuity of circuits and for short circuits.
    c. Inspect For:
        1) Physical damage.
        2) Proper installation and connection
        3) Integrity of barriers, covers, and safety features.
    d. Verify that manual transfer warnings are properly placed.
    e. Perform manual transfer operation.

2. After energizing circuits, demonstrate interlocking sequence and operational function for each switch at least three times.
    a. Simulate power failures of normal source to automatic transfer switches and of emergency source with normal source available.
    b. Verify time-delay settings.
    c. Verify pickup and dropout voltages by data readout or inspection of control settings.
    d. Test bypass/isolation unit functional modes and related automatic transfer-switch operations.
    e. Verify proper sequence and correct timing of automatic engine starting, transfer time delay, retransfer time delay on restoration of normal power, and engine cool-down and shutdown sequence.

B. Coordinate tests with tests of generator plant and run them concurrently.

C. Report results of tests and inspections in writing. Record adjustable relay settings and measured insulation and contact resistances and time delays. Attach a label or tag to each tested component indicating satisfactory completion of tests.

3.5 CLEANING

A. After completing equipment installation, inspect unit components. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish.

B. Clean equipment internally, on completion of installation, according to manufacturer's written instructions.

3.6 DEMONSTRATION

A. Train Employer's maintenance personnel to adjust, operate, and maintain the system installation. Refer to Division 01 Sections.

END OF SECTION 263600

SECTION 311000 - SITE CLEARING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Clearing and grubbing.
2. Stripping and stockpiling topsoil.
3. Removing above- and below-grade site improvements.
4. Disconnecting, capping or sealing, and removing site utilities or abandoning site utilities in place.
5. Temporary erosion and sedimentation control measures.

B. Related Sections:

1. Section 015000 "Temporary Facilities and Controls" for temporary utility services, construction and support facilities, security and protection facilities

1.3 DEFINITIONS

A. Subsoil: All soil beneath the topsoil layer of the soil profile, and typified by the lack of organic matter and soil organisms.

B. Surface Soil: Soil that is present at the top layer of the existing soil profile at the Project site. In undisturbed areas, the surface soil is typically topsoil; but in disturbed areas such as urban environments, the surface soil can be subsoil.

C. Topsoil: Top layer of the soil profile consisting of existing native surface topsoil or existing in-place surface soil and is the zone where plant roots grow.

D. Vegetation: Trees, shrubs, groundcovers, grass, and other plants.

E. Utilities: Underground pipes, conduits, ducts and cables, including manholes, chambers, tanks and other underground appurtenances: above ground utility structures, poles lines, services and the likes

1.4 MATERIAL OWNERSHIP

A. Except for stripped topsoil and other materials indicated or directed to be stockpiled or otherwise remain the Employer’s property, cleared materials shall be removed from Project site.

1.5 SUBMITTALS

A. Existing Conditions: Documentation of existing trees and plantings, adjoining construction, and site improvements that establishes preconstruction conditions that might be misconstrued as damage caused by site clearing.

1. Use sufficiently detailed photographs or videotape.
2. Include plans and notations to indicate specific wounds and damage conditions of each tree or other plants designated to remain.

B. Record Drawings: Identifying and accurately showing locations of capped utilities and other subsurface structural, electrical, and mechanical conditions.

1.6 QUALITY ASSURANCE

A. Preinstallation Conference: Conduct conference at Project site prior to commencing site-clearing operations.

1.7 PROJECT CONDITIONS

A. Traffic: Minimize interference with adjoining roads, streets, walks, and other adjacent occupied or used facilities during site-clearing operations.

1. Do not close or obstruct streets, walks, or other adjacent occupied or used facilities without permission from the Engineer and authorities having jurisdiction.
2. Provide alternate routes around closed or obstructed traffic ways if required by the Engineer or authorities having jurisdiction.

B. Improvements on Adjoining Property: Authority for performing site clearing indicated on property adjoining the Employer's property will be obtained by the Employer before award of Contract

C. Protection of Existing Improvements: Provide protections necessary to prevent damage to existing improvements indicated or directed to remain in place. Restore damaged improvements to their original condition, to the satisfaction of the Engineer.

D. Do not proceed with work on adjoining property until directed by the Engineer.

E. A No objection certificate (N.O.C) shall be obtained from the concerned authorities prior to the start of any clearing and grubbing works.

F. Salvable Improvements: Carefully remove items indicated to be salvaged and store on the Employer premises where indicated.

G. Utility Locator Service: Notify utility locator service for area where Project is located before site clearing.

H. Do not commence site clearing operations until temporary erosion- and sedimentation-control measures are in place.

I. The following practices are prohibited within protection zones:

1. Storage of construction materials, debris, or excavated material.
2. Parking vehicles or equipment.
3. Foot traffic.
4. Erection of sheds or structures.
5. Impoundment of water.

6. Excavation or other digging unless otherwise indicated.
7. Attachment of signs to or wrapping materials around trees or plants unless otherwise indicated.

J. Do not direct vehicle or equipment exhaust towards protection zones.

K. Prohibit heat sources, flames, ignition sources, and smoking within or near protection zones.

L. Soil Stripping, Handling, and Stockpiling: Perform only when the topsoil is dry or slightly moist.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Satisfactory Soil Material: Requirements for satisfactory soil material are specified in Section 312000 "Earth Moving."

1. Obtain approved borrow soil material off-site when satisfactory soil material is not available on-site.

B. Antirust Coating: Fast-curing, lead- and chromate-free, self-curing, universal modified-alkyd primer complying with MPI #79, Alkyd Anticorrosive Metal Primer] [or] [SSPC-Paint 20 or SSPC-Paint 29 zinc-rich coating.

1. Use coating with a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

PART 3 - EXECUTION

3.1 PREPARATION

A. Protect and maintain benchmarks and survey control points from disturbance during construction.

B. Protect existing structures, utilities, sidewalks, pavements and other facilities on or adjacent to the site, including existing site improvements and features to remain from damage during construction.

1. Promptly repair and restore damaged improvements to their original condition, as acceptable to the Engineer.

3.2 TEMPORARY EROSION AND SEDIMENTATION CONTROL

A. Provide temporary erosion and sedimentation control measures to prevent soil erosion and discharge of soil-bearing water runoff or airborne dust to adjacent properties and walkways, according to erosion- and sedimentation-control Drawings and requirements of authorities having jurisdiction.

B. Verify that flows of water redirected from construction areas or generated by construction activity do not enter or cross protection zones.

C. Inspect, maintain, and repair temporary erosion- and sedimentation-control measures during construction until permanent vegetation has been established.

D. Remove temporary erosion and sedimentation controls and restore and stabilize areas disturbed during removal.

3.3 EXISTING UTILITIES

A. Retain one of first two paragraphs below. Retain first if Owner arranges for this work; retain second if Contractor performs this work.

B. Locate, identify, disconnect, and seal or cap existing utilities indicated to be removed or abandoned in place.

1. Arrange with utility companies to shut off indicated utilities.

C. Locate, identify, and disconnect utilities indicated to be abandoned in place.

D. Interrupting Existing Utilities: Do not interrupt or interfere with utilities serving facilities on the site or on adjoining properties unless permitted by the Engineer under the following conditions and then only after arranging to provide temporary utility services according to requirements indicated:

1. Notify the Engineer not less than two days in advance of proposed utility interruptions.
2. Do not proceed with utility interruptions without the Engineer's written permission.

E. Excavate for and remove underground utilities indicated to be removed.

F. Temporarily or permanently re-route or re-locate existing utilities as necessary to facilitate new construction

G. Removal of underground utilities is included in earthwork sections and with applicable fire suppression, plumbing, HVAC, electrical, communications, electronic safety and security and utilities sections and Section 024116 "Structure Demolition" and Section 024119 "Selective Structure Demolition."

3.4 CLEARING AND GRUBBING

A. Remove obstructions, trees, shrubs, and other vegetation to permit installation of new construction. Removal includes digging out and disposal of stumps and roots.

B. Fill depressions caused by clearing and grubbing operations with satisfactory soil material unless further excavation or earthwork is indicated.

1. Place fill material in horizontal layers not exceeding a loose depth of 200 mm, and compact each layer to a density equal to adjacent original ground.

3.5 TOPSOIL STRIPPING

A. Remove sod and grass before stripping topsoil.

B. Strip topsoil to depth of (150 mm) in a manner to prevent intermingling with underlying subsoil or other waste materials.

1. Remove subsoil and nonsoil materials from topsoil, including clay lumps, gravel, and other objects more than 50 mm in diameter; trash, debris, weeds, roots, and other waste materials.

C. Under existing pavements; scarify and recompact top 200 mm of existing subgrade to 100 % of maximum dry unit weight according to ASTM D1557, and underneath the top 200 mm at 95 % MDD.

D. Over the full graded strip, and beneath new shoulders and blast pads, remove and replace the top 300 mm with subgrade layer material placed in one layer and compacted to not less than 95% of maximum dry density (MDD) in accordance with ASTM D1557. The replacement material shall be conforming with the following requirements:

1. Liquid Limit: 25% Maximum.
2. Maximum Plasticity Index: 6 %.
3. Passing from sieve No. 200 (0.075 mm): 18% Maximum.
4. 4-day soaked CBR: Not less than 15 %; AASHTO T 193 when compacted at 95% of AASHTO T-180 (Method D).

E. Stockpile topsoil away from edge of excavations without intermixing with subsoil. Grade and shape stockpiles to drain surface water. Cover to prevent windblown dust and erosion by water.

1. Limit height of topsoil stockpiles to 1800 mm.
2. Do not stockpile topsoil within protection zones.
3. Dispose of surplus topsoil. Surplus topsoil is that which exceeds quantity indicated to be stockpiled or reused.
4. Stockpile surplus topsoil to allow for respreading deeper topsoil.

3.6 SITE IMPROVEMENTS

A. Remove existing above- and below-grade improvements as indicated and necessary to facilitate new construction.

B. Remove slabs, paving, curbs, gutters, and aggregate base as indicated.

1. Unless existing full-depth joints coincide with line of demolition, neatly saw-cut along line of existing pavement to remain before removing adjacent existing pavement. Saw-cut faces vertically.
2. Paint cut ends of steel reinforcement in concrete to remain with two coats of antirust coating, following coating manufacturer's written instructions. Keep paint off surfaces that will remain exposed.

3.7 DISPOSAL OF SURPLUS AND WASTE MATERIALS

A. Remove surplus soil material, unsuitable topsoil, obstructions, demolished materials, and waste materials including trash and debris, and legally dispose of them off the Employer’s property.

B. Separate recyclable materials produced during site clearing from other unrecyclable materials. Store or stockpile without intermixing with other materials and transport them to recycling facilities. Do not interfere with other Project work.

END OF SECTION 311000

SECTION 320129 - RIGID PAVING REPAIR

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Project Requirements, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Removing defective concrete pavement, preparing surfaces and joints to receive repairs, furnishing materials, placing, and finishing new pavement and its joints, as directed on Site.

B. Types of concrete repairs include the following:

1. Full-Depth Repair
2. Partial-Depth Repair
3. Diamond Grinding
4. Joint and Crack Resealing

C. Related Requirements:

1. Section 031000 - Concrete Forming and Accessories,
2. Section 032000 - Concrete Reinforcing,
3. Section 033000 - Cast-in-Place Concrete, for general building applications of concrete.
4. Section 321313 - Concrete Paving.
5. Section 321373 - Concrete Paving Joint Sealants.

1.3 DEFINITIONS

A. Full-Depth Repair: this type of repair involves full-depth replacement of part or all of a concrete slab. When the entire slab is replaced, it is called “slab replacement”. It is used to repair a variety of distresses, most of which occur near joints or cracks. Such distresses include joint deterioration, corner breaks and durability cracking. When a full-depth patch is performed adjacent to a joint or crack, the load transfer across the joint or the crack should be restored. Deterioration of a reflected joint or crack in an existing asphalt concrete overlay (if any) is also a candidate for full-depth patching of the underlying concrete pavement.

B. Partial-Depth Repair: this type of repair involves removing shallow localized areas of deterioration or spalled concrete pavement and replacing it with a suitable patch material such as cement concrete or epoxy concrete. This technique is used to repair concrete pavement distresses that are confined to the top few inches of the slab, such as joint and corner spalling, surface scaling and or badly patched spots of old distress.

C. Diamond Grinding: is the process of removing a thin layer of the existing concrete surface by grinding it with a series of closely spaced rotating diamond saw blades. This method is used to re-profile jointed concrete pavements that have developed a rough ride because of faulting or slab warping. It is also used to restore transverse drainage and to provide a textured pavement surface.

D. Joint and Crack Resealing: resealing damaged joint sealant shall be the last procedure in the concrete pavement restoration sequence, which often includes full- and partial-depth repair and diamond grinding. Moreover, crack sealing is the process of cleaning and sealing or resealing cracks in concrete pavement.

1.4 PREINSTALLATION MEETINGS

A. Preinstallation Conference: Conduct conference at Project site to comply with the Project Requirements and procedures related to concrete paving including, but not limited to, the following:

1. Review proposed sources of paving materials, including capabilities and location of plant that will manufacture concrete mix.
2. Review condition of substrate and preparatory work performed by other trades.
3. Review requirements for protecting paving work, including restriction of traffic during installation period and for remainder of construction period.
4. Review and finalize construction schedule for paving and related repair work. Verify availability of materials, paving Installer's personnel, and equipment required to execute the Work without delays.
5. Review inspection and testing requirements, governing regulations, and proposed installation procedures.
6. Review forecasted weather conditions and procedures for coping with unfavorable conditions.

1.5 ACTION SUBMITTALS

A. Shop Drawings: Indicate pavement markings, lane separations, and defined parking spaces. Indicate dedicated handicapped spaces with international graphics symbol

B. Material Test Reports: Indicate and interpret test results for compliance of materials with requirements indicated.

C. Procedures: Submit schedule of intended removal, remixing, and rolling procedures.

D. Product Data: For each product specified. Include technical data and tested physical and performance properties.

1.6 INFORMATIONAL SUBMITTALS

A. Qualification Data: For firms and persons specified in the "Quality Assurance" Article to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names, and addresses of engineers and employers, and other information specified or required by Engineer.

B. Material Certificates: Certificates signed by manufacturers certifying that each material complies with requirements.

1.7 QUALITY ASSURANCE

A. Material and Equipment shall demonstrate compliance with the project requirements.

B. Installer Qualifications: Engage an experienced installer who has completed Rigid Pavement repair works similar in material, design, and extent to that indicated for this Project and with a record of successful in-service performance.

C. Manufacturer Qualifications: Engage a firm experienced in manufacturing Rigid Pavement similar to that indicated for this Project and with a record of successful in-service performance.

D. Testing Agency Qualifications: Demonstrate to Engineer's satisfaction, based on Engineer's evaluation of criteria, that the independent testing agency has the experience and capability to satisfactorily conduct the testing indicated in accordance with Standards, without delaying the Works.

E. Regulatory Requirements: Conform to applicable standards of authorities having jurisdiction for Rigid Pavement works.

PART 2 - PRODUCTS

2.1 CONCRETE MATERIALS FOR FULL- OR PARTIAL-DEPTH REPAIR)

A. Aggregates, Portland cement, and water shall be in accordance of Clause 2.3 of Section 321313 “Concrete Paving” of the Specifications.

B. Admixtures:

1. The use of any material added to the concrete mix shall be approved by the Engineer. The Contractor shall submit certificates indicating that the material to be furnished meets all of the requirements indicated under Clause 2.4 of Section 321313.

C. Pre-molded Joint Filler:

1. Pre-moulded joint filler for expansion joints shall conform to the requirements of Clause 2.6 of Section 321313.
2. The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint, unless otherwise specified by the Engineer. When the use of more than one piece is authorized for a joint, the abutting ends shall be fastened securely and held accurately to shape by stapling or other positive fastening means satisfactory to the Engineer.

D. Joint Sealer: The joint sealer for the joints in the concrete pavement shall meet the requirements of Clause 2.6 of Section 321313 of the Specifications.

E. Dowel and Tie Bars:

1. Tie bars shall be deformed steel bars and conform to the requirements of ASTM A615/ A615M, Grade 60, deformed.
2. Dowel bars shall be high tensile plain steel bars conforming to BS 4449, ASTM A615/ A165M, ASTM A955/ A955M, and shall be free from burring or other deformation restricting slippage in the concrete. Before delivery to the construction site, a minimum of two-thirds of the length of each dowel bar shall be painted with one coat of zinc-chromate. If plastic or epoxy-coated steel dowels are used, no zinc-chromate coating is required, except when specified for a particular situation on the contract plans. Coated dowels shall conform to the requirements given in AASHTO M254.
3. The sleeves for dowel bars used in expansion joints shall be Metal, of an approved design to cover 50mm to 75mm of the dowel, with a closed end and with a suitable stop to hold the end of the bar at least 25mm from the closed end of the sleeve. Sleeves shall be of such design that they will not collapse during construction.

F. Cover material for curing:

1. Curing materials shall conform to Clause 2.5 of Section 321313.

G. Epoxy Mortar: approved epoxy mortar material shall be used for repairing scaled concrete slabs, patching small potholes and/or minor partial-depth repairs.

2.2 MIX DESIGN

A. Proportioning requirements for concrete shall be designed according to Clause 2.9 of Section 321313.

B. The minimum cementitious material content shall be 380kg per cubic meter. The ratio of water to cementitious material, including free surface moisture on the aggregates but not including moisture absorbed by the aggregates shall not be more than 0.40 by weight.

C. The mix determined shall be workable concrete having a slump for side-form concrete between 25 mm and 50 mm as determined by ASTM C143/ C143M.

D. Admixtures:

1. Air Entraining: Air-entraining admixture shall be added in such a manner that will insure uniform distribution of the agent throughout the batch. The air-entraining admixture shall be according to the relevant requirements under Section 321313.
2. Chemical: Water-reducing and set-controlling admixtures shall be added to the mix in the manner recommended by the manufacturer and in the amount necessary to comply with the specification requirements. Tests shall be conducted on trial mixes, during the mix design, in accordance with ASTM C494/ C494M.

2.3 EQUIPMENT

A. All plant and equipment shall be approved by the Engineer before starting any work on Site and shall meet the requirements listed under Clause 2.10 of Section 321313.

PART 3 - EXECUTION

3.1 PREPARATION OF PAVEMENT

A. Cracks in concrete pavement which, in the opinion of the Engineer do not require reconstruction shall be prepared by wire brushing and blowing out with compressed air. For the case of a newly laid airfield concrete pavement, testing and assessing any cracks shall be done in accordance with item P-501-4.19 of the FAA-AC 5370-10H in order to adopt the appropriate treatment measure.

B. Defective concrete pavement that require reconstruction based on testing and assessment of concrete pavement conditions shall be cut back to good material using appropriate cutting tools. The cut edges shall be square or rectangular. The depth of cut shall be determined by the Engineer and may include, in addition to the concrete surface, base and sub-base layers and subgrade layers (in the case of failed pavement, excavation shall include a minimum of 300 mm depth of subgrade material). All excavated materials shall be removed and disposed of off-site. When the bottom of the excavation consists of earth or granular material it shall be thoroughly compacted using mechanical compactors to the satisfaction of the Engineer. Hollowed concrete surfaces shall be thoroughly cleaned and wire brushed prior to receiving repair materials.

3.2 CONCRETE PAVEMENT REPAIR TECHNIQUES

A. Full-Depth Patching

1. The full-depth patching technique consists of the following steps:

    a. Square off the area to be patched, including all underlying deterioration. Deterioration near joints may be larger at the bottom of the slab by as much as a few feet. To prevent rocking of the patch, it is recommended that the minimum dimension be >120cm. The minimum dimension is also a function of whether load transfer devices are used. The design of the patch sides should be such that:

        1) Use deformed tie bars for sides away from joints.
        2) Use dowel bars or restore existing load transfer at transverse joints.

    b. Saw the panel boundaries, except when one of the boundaries is a joint. Partial- or full-depth sawing may be used. Partial-depth sawing leaves some aggregate interlock but allows potential spalling at the bottom of the patch during breakup and removal of the concrete. Breakup of the concrete should start from the center of the patch using gravity or pneumatic air hammers. To avoid damage to the adjacent concrete, ball breakers should not be used. All exposed slab joints shall be dowelled (installed by Drilling and Epoxying at least 8cm from the location of the existing dowels which were cut off) prior to concrete casting. Partial Slabs removal and replacement is not permitted for new concrete slabs at airside pavement as per the stipulations of FAA-AC 5370-10H Clause 4.19 Item P-501. Only full slabs removal is permitted.
    c. Remove all broken concrete and prepare the foundation. Excessive moisture should be removed or dried. Granular subbases are difficult to compact; therefore, partial, or full replacement of the granular subbase with concrete is recommended.
    d. Straighten or realign existing deformed tie bars and dowels. Install new tie bars or dowels as required by drilling holes in the face of the existing slab.
    e. Place the concrete and ensure the edges receive good vibration. If the patch cannot be closed to traffic for several days, use an early strength concrete mix that contains higher cement content and additives.
    f. In case the existing stabilized base (CTB or Asphalt) layer underlying the damaged concrete pavement is found to be also damaged; the affected portion of this base shall be removed and replaced with flowable lean concrete that will be cast to become flush to the top levels of the existing stabilized base.
    g. Slabs that are located near underlying Fuel Lines shall be removed thru pulling and with extra care so as not to disturb or damage the fuel line.

B. Partial-Depth Repair:

1. The partial-depth repair technique consists of the following steps:

    a. Square off the area to be patched and mark off approximately 8cm beyond the distressed area. Use a concrete saw to make a vertical cut a minimum of 5cm deep around the marked area. Ensure cuts (both at corners and along the edges) intersect to obtain a rectangular or square patch with vertical sides.
    b. After cutting, break out the area with pneumatic drills or jackhammers down to sound concrete. After the unsound concrete is removed, blow out the holes with compressed air to remove residual material and dust. Then thoroughly pressurize the area.
    c. Use a stiff broom or brush to apply a bonding grout approximately 1.5mm thick over the entire area to be patched immediately before the concrete patch material is placed (epoxy grout for epoxies). If the material does not use a bonding grout, use a large brush to dampen the surface (no standing water) with water before placing material. Bonding grout mixture is 1-part Portland cement, 1-part fine sand, and no more than 20 liters of water per sack of cement.
    d. Insert a thin strip of wood, joint fiberboard, or oil-coated metal, for the new joint. Scoring the fibreboard about 20mm from top will make routing or removing the board easier. Another alternative is to completely cut and grease the material, removing it when patch material is set.
    e. Mix, place, and finish the concrete. All concrete type materials should be extended with aggregate to match the existing concrete as close as possible. Do not drop the

concrete from heights greater than 30cm. Ensure that you have estimated for enough aggregate/patching material, plus extra, before mixing begins.

1) When finishing has been completed, broom finish to match adjacent areas.
2) After concrete has attained its initial set, remove filler board, if used.

f. Cure the patch a minimum of 3 days (unless using epoxy, polymer, etc.) using some type of pigmented curing compound.
g. Route out and clean the joint, finally filling the joint with the appropriate filler material.
h. Partial Slabs removal and replacement is not permitted for new concrete slabs at airside pavement as per the stipulations of FAA-AC 5370-10H Clause 4.19 Item P-501. Only full slabs removal is permitted.

C. Diamond Grinding:

1. Diamond grinding shall consist of removing a thin layer of the existing concrete surface by grinding it with a series of closely spaced rotating diamond saw blades to obtain the two concrete edges of a joint as close as possible at the same elevation.
2. Other repair procedures that may be needed before diamond grinding include:

a. Full- and partial-depth repair.
b. Load transfer restoration.
c. Joint and crack sealing is performed after diamond grinding.
d. Grinding shall be carried out prior to joints grooving.

D. Joint and Crack Resealing:

1. Joint Resealing:

a. Removing old sealant: This can be done by one of the following methods:

1) Manual Removal: Typically, compression seals can be easily removed by hand. This simple method provides a quick result whenever feasible and does not leave much material on the reservoir sidewalls.
2) Sawing with diamond blades: It is the most common and efficient removal method as it also shapes the reservoir for the new material. However, it may not be effective on sticky sealing materials such as PVC coal tar. Sticky materials can clog diamond blades.
3) Plowing: can be very effective for removing most of the old sealant. A small plow pulled through the reservoir dislodges the material. The Contractor should however avoid the V-shaped plows because they tend to scour the reservoir corners and can easily spall the surrounding concrete. Very little damage occurs with a rectangular plow.
4) Cutting: requires a worker to run a knife blade along the faces of the joint. Afterward, the sealant easily pulls free by hand.

b. Shaping the Reservoir: Saws can be used to widen the sealant reservoir after the sealant is removed. Saws with dry or wet diamond blades are acceptable. Sawing should remove any remaining old sealant and provide the proper dimensions for the new sealant. In certain instances, this step may not be required. Shaping is unnecessary if the sealant was removed by hand and the existing reservoir provides adequate dimensions. Sawing out the old sealant typically provides an adequate reservoir and should not require this step either. Some minor spalling (i.e. largest dimension $\leq$ 2cm) along the joint face will not inhibit performance of most sealants. However, larger spalls shall be patched before the application of the sealing material.
c. Cleaning the reservoir: The following procedures shall be used for cleaning the reservoir:

1) Immediately after sawing, wash away the slurry from the sawing operation. Perform this operation in one direction to minimize contamination of surrounding areas.

2) After the joint has dried sufficiently, sandblast the joint to remove any remaining residue. Do not sandblast straight into the joint. Hold the sandblast nozzle close to the surface at an angle to clean the top inch of the joint face. One pass along each reservoir face is considered sufficient.

3) To ensure that the sealant enters a clean reservoir, air blast the joint and pavement surface to remove sand, dirt, and dust before pumping the sealant. Make sure the air compressor does not introduce oil into the lines because this will contaminate the joint faces. The compressor should deliver air at a minimum of 3.5 m3 per minute and develop at least 90 psi nozzle pressure.

4) Do not use chemical solvents to wash the joint reservoir. Solvents can carry contaminants that will inhibit bonding of the new sealant.

d. Installing Backer Rods: Install backer rods after cleaning the joint but before installing the liquid sealant. The backer road should be compatible with the liquid sealant and have a diameter about 25% greater than the reservoir width. Backer roads can be placed easily with a double-wheeled, steel roller or any smooth, blunt tool that will force it into the joint uniformly to the desired depth. Good practice is to roll the insertion wheel over the backer rod twice.

e. Installing the Sealant: Before installing the sealant, wipe the reservoir sidewalls with your finger to check for dirt and dust. If you find any traces of contamination, re-clean the joint. Installation requirements are slightly different for each sealant type. There the Contractor should install the approved sealant in strict compliance with the Manufacturer's recommendations.

2. Crack Sealing:

a. The crack filling technique consists of the following steps:

1) Remove old sealant (as described earlier) if previously filled.

a) Route the crack using a vertical spindle router (do not use a rotary impact router as it spalls the concrete).

b) This step may be done by hand by breaking off the end of a hoe and using the curved metal rod at the left.

2) Different filling procedures are required based on crack width and amount of spalling for different classifications of cracks. The following procedures are recommended:

a) Hairline to 3mm, no spalling: do not widen or seal. With minor spalling: blow out and seal.

b) 3 mm to 10mm, no spalling: if edges are rough, blow out or route before sealing. With minor spalling: route and seal.

c) 10mm to 20mm, no spalling: route and consider using a backer rod if too deep. With major spalling: repair the spall as a joint, while maintaining the crack through the spall.

d) Greater than 20mm, no spalling: route and consider using a backer rod if too deep. With major spalling: rebuild crack as if it were a joint.

e) Cracks approximately 40mm may be temporarily patched using bituminous concrete if they are not "working" cracks. For a permanent repair, rebuild as a joint.

3) After routing, sandblast the crack, then air blow and vacuum. As a minimum, air blow debris away from the crack and sweep it up.

4) Install a backer rod if required. Apply the proper sealant from bottom to top of crack.

3.3 SURFACE TOLERANCES

A. Levels shall be checked by straight edge in relation to the adjacent existing pavement.

B. The tolerances on elevations of the final repaired surface shall comply with the relevant requirements under Clause 3.20 of Section 321313.

3.4 TESTING STANDARDS AND CODES

AASHTO M254	Standard Specification for Corrosion-Resistant Coated Dowel Bars
ASTM A615/ A615M	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A955/ A955M	Standard Specification for Deformed and Plain Stainless Steel Bars for Concrete Reinforcement
ASTM C143/ C143M	Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C494/ C494M	Standard Specification for Chemical Admixtures for Concrete
BS 4449	Steel for the reinforcement of concrete - Weldable reinforcing steel - Bar, coil and decoiled product – Specification

END OF SECTION 320129

SECTION 321116.16 - AGGREGATE SUBBASE COURSE

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Aggregate for subbase course composed of crushed aggregates constructed on the prepared underlying course in accordance with the Specification and shall conform to the lines, grades, dimensions, and typical cross-section shown on the Drawings.

B. Related Requirements:

1. Section 312000 - Earth Moving - For subgrade preparation and grading.
2. Section 321123 - Aggregate Base Course.
3. Section 321216 - Asphalt Paving.
4. Section 321400 - Unit Paving.
5. Section 016000 "Product Requirements".

1.3 DEFINITIONS

A. Aggregate Subbase Course: Subbase course composed of mineral aggregate uniformly blended and mixed with water. Usually placed between the base and subgrade layer.

B. Subgrade: Compacted soil layer immediately below the base or subbase course.

C. Subgrade Layer: 300 mm depth of soil material immediately below base or subbase course.

D. Test Section: 2000 m² of compacted aggregate subbase course, constructed for the purpose of verification of Contractor’s means, methods, and equipment, and subject to approval by the Engineer, prior to commencement of the Works.

E. Lot of Compacted Material: 500 m² of compacted subbase course on each layer.

F. Utilities include on-site underground pipes, conduits, ducts, and cables, as well as underground services within buildings.

1.4 PREINSTALLATION MEETINGS

A. Pre-installation Conference: Conduct conference at the Project site to comply with requirements in Division 1 Section 013100 “Project Management and Coordination”.

1.5 ACTION SUBMITTALS

A. Product Data: For each type of manufactured or processed material and product indicated.

B. Samples: For the following:

1. 100-kg samples, sealed in airtight containers, of each proposed aggregate material.

C. Design Mixes: For subbase course mix, include alternate mix designs when characteristics of materials, project conditions, weather, test results, or other circumstances warrant adjustments.

1. Provide CBR test results and moisture-density curves

D. Field Records for the Following:

1. Test Section.
2. Verification of compliance of subgrade, in accordance with specified requirements, prior to placement of sub-base course.
3. Laboratory reports; laboratory density test results for each lot.
4. Field reports; in-place density test results for each lot.

E. Photographs or videotape, sufficiently detailed, of existing conditions of adjoining construction and site improvements that might be misconstrued as damage caused by earthwork operations.

F. Daily Progress Reports: Include location of all construction joints.

G. Minutes of Preinstallation Meeting

1.6 INFORMATIONAL SUBMITTALS

A. Qualifications Data: For firms and persons specified in “Quality Assurance” Article to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names, and addresses of Engineers and Employers, and any other information required by the Engineer.

B. Material Test Reports: From a qualified testing agency indicating and interpreting test results for compliance of the following with requirements indicated, based on comprehensive testing of current materials:

1. Classification according to ASTM D2487 of each on-site or quarry material proposed for aggregate subbase course layer.
2. Laboratory compaction curve according to ASTM D1557 or AASHTO T 180 (Method D) for each on-site or quarry material proposed for aggregate subbase course layer.

C. Material Certificates: Certificates signed by the manufacturers certifying that each material complies with requirements.

1.7 QUALITY ASSURANCE

A. "All products, materials, and equipment shall demonstrate compliance with requirements specified in Section 016000 "Product Requirements".

B. Codes and Standards: Comply with the local authority advisory circulars and standards, except where different requirements are specified or shown on the Drawings.

C. Installer Qualifications: Engage an experienced Installer who has completed aggregate subbase course similar in material, design, and extent to that indicated for this Project and with a record of successful in-service performance.

D. Manufacturer Qualifications: Engage a firm experienced in manufacturing similar to that indicated for this Project and with a record of successful in-service performance.

E. Testing Agency Qualifications: Demonstrate to the Engineer's satisfaction, based on the Engineer's evaluation of criteria, that the independent testing agency has the experience and capability to satisfactorily conduct the testing indicated in access with standards without delaying the Work.

F. Regulatory Requirements: Conform to applicable standards of authorities having jurisdiction for asphalt paving work.

G. Materials and installed work may require testing and re-testing at any time during progress of work. Tests, including re-testing of rejected materials or installed work, shall be done at Contractor’s own expense.

1.8 FIELD/PROJECT CONDITIONS

A. Provide a minimum 48-hour notice to the Engineer, and receive written notice to proceed, before interrupting any service, facility or utility operated or occupied by the Employer or others.

B. Protect subbase course from rain, wind, and sun, indentation, contamination, and physical damage.

C. Finished portions of the subbase course that are used by equipment in the construction of an adjoining section shall be protected to prevent marring or damaging the completed work.

D. Project Site Information: A sub-surface site investigation and test report has been prepared for Project and has been made available for information only. The report is not part of the Contract. The Contractor is entirely responsible for his own assessment, interpretation, use, and conclusions drawn from the information, data, tests, analyses, and opinions contained in any Site Investigation report discussed or related to the project conditions.

1. Make additional test borings and conduct other exploratory operations as necessary, at Contractor’s own cost and expense.

E. Traffic: Minimize interference with adjoining airfield**,** roads, streets, walks, and other adjacent occupied or used facilities during earthwork operations.

1. Do not close or obstruct airfield**,** streets, walks, or other adjacent occupied or used facilities without permission from Employers and authorities having jurisdiction.
2. Provide alternate routes around closed or obstructed traffic ways if required by authorities having jurisdiction.

F. Notify utilities companies and authorities having jurisdiction for area where Project is located before commencing earthwork operations.

G. Existing Utilities: Do not interrupt utilities serving facilities on or adjacent to Project site unless permitted in writing by the Engineer and then only after arranging to provide temporary utility services according to requirements.

1. Notify the Engineer not less than two days in advance of proposed utility interruptions.
2. Do not proceed with utility interruptions without the Engineer's written permission.

H. Demolish and completely remove from site existing underground utilities indicated to be removed. Coordinate with utility companies to shut off services if lines are active.

PART 2 - PRODUCTS

2.1 AGGREGATE

A. Aggregate: Shall be either natural gravel, crushed stone, or crushed gravel. The fine aggregate shall consist of screenings obtained from crushed stone, gravel, or sand. Aggregate may be washed, if directed, to remove excessive quantities of clay, silty clay, or salts.

B. Crushed Stone: Shall consist of hard, durable particles or fragments of stone, free from dirt, organic material or other objectionable matter, and shall contain not more than 8 % of flat, elongated, soft, or disintegrated pieces (when tested according to ASTM D4791 or U.S. Army, Corps of Engineers CRD-C 119-91 at 5:1 ratio).

C. Crushed Gravel: Shall consist of hard durable stones, rocks, and boulders crushed to specified sizes and shall be free from excess flat, elongated, soft or disintegrated pieces, dirt, or other objectionable matter.

D. The method used in production of crushed gravel shall be such that the finished product shall be as uniform as practicable. The crushing of the gravel shall result in a product, which shall have at least 90 % by weight of particles with at least one fractured face when tested according to ASTM D5821. All stones, rocks, and boulders of inferior quality occurring in the pit shall be wasted.

E. Any material passing 4.75 mm (No. 4) sieve and produced in the crushing process shall be incorporated in the subbase material up to the gradation limits required for the subbase course aggregate.

F. The crushed aggregate shall meet the requirements of one of the gradations shown in Table 1 when tested in accordance with AASHTO T 11 and T 27.

Table 1: requirements for gradation of aggregate

Sieve Designation (Square openings)	**Percent by weight passing [to be verified with specific country's general specifications]**
50 mm (2 in)	100
25 mm (1 in)	75 - 95
9.5 mm (3/8 in)	40 - 75
4.75 mm (No.4)	30 - 60
2.00 mm (No. 10)	20 - 45
0.425 mm (No.40)	15 - 30
0.075 mm (No.200)	5 - 20

G. The amount of the fraction of material passing the No. 200 mesh sieve shall not exceed one half the fraction passing the No. 40 mesh sieve.

H. The percentage of wear shall not exceed 30 % after 500 revolutions, when tested in accordance with AASHTO T 96 (Los Angeles Abrasion Test).

I. The crushed aggregate subbase course material shall have a 4-day soaked CBR of not less than 30% when compacted at 100% of modified proctor, AASHTO T 180 (Method D) and tested in accordance with AASHTO T 193.

J. When tested for soundness in accordance with AASHTO T 104, the material shall not show signs of disintegration and the loss by weight shall not exceed 12 % in the case of the sodium sulphate test and 18 % in the case of the magnesium sulphate test.

K. The portion of aggregate, including any blended material, passing the 0.425 mm (No. 40) mesh sieve shall have a liquid limit (LL) of not more than 25 and plasticity index (PI) of not more than 6 when tested in accordance with AASHTO T 89 and T 90.

L. If additional fine material is required to correct the aggregate gradation, or for adjusting the LL or PI of the fraction passing the 0.425 mm (No. 40) sieve, it shall be uniformly blended and mixed with the aggregate material plant at the crushing plant or by an approved plant. Reworking of the material in situ to obtain the specified gradation will not be permitted. Additional fine material for these purposes shall be obtained from the crushing of stone, gravel, or natural material.

M. The sand equivalent shall be 35% minimum when tested according to ASTM D2419.

N. The crushed aggregate subbase course material shall have chloride content of less than 1.0% and sulphate content of less than 0.5% when tested in accordance with BS EN 1744-1.

O. The linear shrinkage of the crushed aggregate material shall not exceed 3% when tested according to BS 1377-2 standard.

P. The aggregate shall not contain more than 1% of clay lumps and friable particles when tested according to ASTM C142/ C142M.

2.2 EQUIPMENT

A. Equipment used to handle, place, spread, moisten, compact, and finish the subbase course shall be on the site in first-class working condition, and approved by the Engineer before construction is permitted to start.

PART 3 - EXECUTION

3.1 OPERATION AT SOURCES OF SUPPLY

A. All work involved in clearing and grubbing of quarries and pits, including the handling of unsuitable material, shall be performed at Contractor’s own expense. The subbase material shall be obtained from approved sources. The material shall be handled in a manner that shall secure a uniform and satisfactory product.

3.2 SURFACE PREPARATION

A. The aggregate subbase course shall be placed directly on completed subgrade, preparation and the subgrade surface shall be as specified in Section 312000.

3.3 MIXING AND SPREADING

A. The subbase course material may be premixed with water, in a pugmill mixing plant or on site. The amount of water added, as determined, shall be such that the material will be uniform and within the specified moisture content range at the time of compaction.

B. The Engineer may allow other methods of mixing provided such methods(s) do not reduce the standard of work. Demonstrate, in the presence of the Engineer, the ability to attain the requirement given in the Specification.

C. Premixed material shall be placed on the subgrade in a uniform layer not less than 75 mm nor more than 150 mm of compacted thickness, unless the Contractor can prove by successful trial sections

that a maximum of 200 mm compacted thickness can achieve the specified degree of compaction in sub-clause 3.4.C.

D. The subbase course material shall be placed to the required width using a self-propelled spreader or motor grader and shall be delivered such that it is ready for compaction without further shaping.

E. The material shall not be handled in such a way as to cause segregation. If the spreader causes segregation in the material or leaves ridges or other objectionable marks on the surface which cannot be readily eliminated or prevented by adjustment of the spreader operation, the use of such spreader shall forthwith be discontinued and it shall be replaced by a spreader capable of spreading the material in a proper manner.

F. Segregated material shall be removed and replaced with well graded material. "Skin" patching will not be permitted. Only minor surface manipulation and watering to achieve the required surface tolerances will be permitted during the compaction process.

G. Hauling or placement of material will not be permitted when, in the judgement of the Engineer, the weather or surface conditions are such that hauling operations will cause cutting or rutting of subgrade or cause contamination of the subbase course material.

3.4 COMPACTION

A. Compaction: Plan the sequence of operations so that the least amount of water will be lost by evaporation from uncompleted surfaces. If placing of succeeding layer of material is delayed to the extent that additional water is required to prevent raveling or excessive drying, the application of such water shall be carried out in an approved manner and at Contractor’s own expense.

B. Subbase course: material shall be compacted by means of approved compaction equipment, progressing gradually from the outside towards the center, with each succeeding pass uniformly overlapping the previous pass.

C. Rolling: Continue until the entire thickness of each subbase layer is thoroughly and uniformly compacted to 100 %, as per AASHTO T 180 (Method D), maximum density.

1. Final rolling of the completed course shall be by means of an approved self-propelled roller.
2. Rolling shall be accompanied by sufficient blading, to ensure a smooth surface, free from ruts or ridges and having the proper shape.
3. When additional water is required, it shall be applied in an approved manner.

D. Areas Inaccessible to Normal Compaction: Compact by use of portable mechanical tampers until the required standard of compaction is achieved, or to the satisfaction of the Engineer.

E. Each layer shall be completely compacted and approved prior to delivery of materials for the following layer.

F. Prior to placing a following layer, the surface shall be made sufficiently moist as directed, to ensure proper bond between the layers.

G. Edges and Edge Slopes of the Subbase Course: Bladed or otherwise dressed to conform to the lines and dimensions shown on the Drawings and to present straight, neat lines and slopes as free of loose material as practicable.

H. Material which has dried out prior to final compaction, or which has dried and decompacted subsequent to final compaction, shall be watered and recompacted using approved equipment and procedures. If unable to return the material to its original or specified condition with respect to compaction, thickness and surface tolerances, for the final layer only, scarify the material and reconstruct the subbase course on a re-approved sub-grade surface or to the satisfaction of the Engineer.

3.5 TOLERANCES AND MAINTENANCE OF COMPLETED SUBBASE

A. Compacted and Completed Subbase Course: Conform to the lines, grades and cross sections as shown on the Drawings.

B. Elevations of the Finished Subbase Course: Checked in the presence of the Engineer at intervals of 20m on straight lines and of 10m on curves, and at intermediate points as directed.

C. Tolerances (for final only): Elevations of finished surface shall not exceed + 10mm or - 15mm.

D. Finished Surface: When tested with a 4.0 m long straightedge, placed parallel to, or at right angles to the centerline, the maximum deviation of the surface from the testing edge between any 2 contact points shall not exceed 12 mm.

E. Specified Tolerances: Areas which exceed shall be corrected by removing the defective sections of subbase course and reconstructing them or, by scarifying and adding new material and recompacting and finishing to the specified standard.

F. Completion and Acceptance of the Subbase Course: Maintained at Contractor's own expense as follows:

1. The surface shall be broomed, rolled, and otherwise maintained, keeping it free from raveling and other defects until such time as the following course is placed.
2. Water shall be applied at such times and in such quantities as directed.

3.6 FIELD QUALITY CONTROL

A. General

1. Testing Laboratory

a. Employ an independent testing agency to perform tests and to submit test reports
b. Be responsible for taking, identifying, and delivering to the test laboratory all test samples called for in this specification. The testing laboratory shall be responsible for the testing. Collect all test results and deliver them to the Engineer in the format and details as specified.

B. Subbase Course Material: Test in accordance with Table 2 below after mixing with water at the mixing plant or in-situ compaction and if satisfactory shall be approved for use. This approval shall not be deemed to constitute acceptance of the subbase course for full payment purposes.

C. Compaction: Test in accordance with ASTM D1556/ D1556M (Sand Cone Method) or ASTM D2167 (Rubber balloon Method) or ASTM D6938 (Nuclear Method). The Nuclear Method has to be first calibrated in comparison with Sand Cone Method for at least three sample tests. If there is a significant delay between the construction of any layer and the following layer, the Engineer may require the compaction of the lower layer to be re-verified to ensure that it has not loosened due to traffic, passage of construction equipment, adverse weather conditions or otherwise.

3.7 REQUIRED TESTS AND MINIMUM REPETITION FOR SUBBASE COURSE MATERIAL:

Table 2: Minimum repetition for subbase course material

(A) Source of Materials		**(B) Control on Site (The Road)**	
Required Tests (A)	**Repetition Required for all Test in (A)**	**Required Tests (B)**	**Repetition Required for all Tests in (B)**
1. Gradation of material	As requested by the Engineer	1. Proctor	As requested by the Engineer
2. Plasticity Index and liquid limit	1 sample in every 1000 m3	2. Gradation	As requested by the Engineer
3. Abrasion	1 sample in every 1000 m3	3. Plasticity Index and liquid limit	1 sample in every 1000 m3
4. CBR	1 sample in every 1000 m3	4. CBR	1 sample in every 1000 m3
5. Sand equivalent	1 sample in every 500 m3	5. Abrasion	1 sample in every 1000 m3
6. Percentage of fractured Grains/Base course	As requested by the Engineer	6. Sand Equivalent	1 sample in every 500 m3
7. Chloride content (combined aggregate)	1 sample in every 1000 m3	7. Clay lumps & friable Particles	1 sample in every 1000 m3
8. Sulphate content (combined aggregate)	1 sample in every 1000 m3	8. Field Density	1 sample in every 500 m3
9. Flakiness and Elongation (combined aggregate)	1 sample in every 1000 m3	9. Thickness	As requested by the Engineer
10. Linear shrinkage	1 sample in every 1000 m3	-	-

3.8 PROTECTION

A. Do not perform work when the Engineer determines that weather or other conditions are such that construction operations will damage the finished work.

B. Do not haul over aggregate subbase without approval. Repair damages resulting from occasional routing of equipment over the work.

C. Following the completion of the aggregate subbase course, all maintenance work necessary to keep the subbase course in a condition satisfactory for further work shall be performed.

END OF SECTION 321116.16

SECTION 321123 - AGGREGATE BASE COURSE

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Aggregate for base course composed of crushed aggregates constructed on the prepared underlying course in accordance with the Specification and shall conform to the lines, grades, dimensions, and typical cross-section shown on the Drawings.

B. Related Requirements

1. Section 312000 - Earth Moving - For subgrade preparation and grading.
2. Section 321116.16 - Aggregate Subbase Course.
3. Section 321216 - Asphalt Paving.
4. Section 321400 - Unit Paving.
5. Section 016000 "Product Requirements".

1.3 DEFINITIONS

A. Aggregate Base Course: Base course composed of mineral aggregate uniformly blended and mixed with water. Usually placed between the subbase or subgrade layer and the asphalt concrete or Portland cement concrete layer or under the bedding course in case of interlocking concrete blocks pavement

B. Subgrade: Compacted soil layer immediately below the base course or subbase course.

C. Subgrade Layer: 300 mm depth of soil material immediately below subbase or base **c**ourse.

D. Test Section: 2000 m² of compacted aggregate base course, constructed for the purpose of verification of Contractor’s means, methods, and equipment, and subject to approval by the Engineer, prior to commencement of the Works.

E. Lot of Compacted Material: 500 m² of compacted base course on each layer.

F. Utilities include on-site underground pipes, conduits, ducts, and cables, as well as underground services within buildings.

1.4 PREINSTALLATION MEETINGS

A. Pre-installation Conference: Conduct conference at the Project site to comply with requirements in Division 1 Section 013100 “Project Management and Coordination”.

1.5 ACTION SUBMITTALS

A. Product Data: For each type of manufactured or processed material and product indicated.

B. Samples: For the following:

1. 100-kg samples, sealed in airtight containers, of each proposed aggregate material.

C. Design Mixes: For base course mix, include alternate gradation when characteristics of materials, project conditions, weather, test results, or other circumstances warrant adjustments.

1. Provide CBR test results and moisture-density curves

D. Field Records for the Following:

1. Test Section.
2. Verification of compliance of subgrade, in accordance with specified requirements, prior to placement of subsequent subbase or base course.
3. Laboratory reports; laboratory density test results for each lot.
4. Field reports; in-place density test results for each lot.

E. Photographs or videotape, sufficiently detailed, of existing conditions of adjoining construction and site improvements that might be misconstrued as damage caused by earthwork operations.

F. Daily Progress Reports: Include location of all construction joints.

G. Minutes of Preinstallation Meeting

1.6 INFORMATIONAL SUBMITTALS

A. Qualifications Data: For firms and persons specified in “Quality Assurance” Article to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names, and addresses of Engineers and Employers, and any other information required by the Engineer.

B. Material Test Reports: From a qualified testing agency indicating and interpreting test results for compliance of the following with requirements indicated, based on comprehensive testing of current materials:

1. Classification according to ASTM D2487 of each on-site or quarry material proposed for aggregate base course layer.
2. Laboratory compaction curve according to ASTM D1557 or AASHTO T 180 (Method D) for each on-site or quarry material proposed for aggregate base course layer.

C. Material Certificates: Certificates signed by the manufacturers certifying that each material complies with requirements.

1.7 QUALITY ASSURANCE

A. "All products, material, and equipment shall demonstrate compliance with requirements specified in Section 016000 "Product Requirements".

B. Codes and Standards: Comply with the local authority advisory circulars and standards, except where different requirements are specified or shown on the Drawings.

C. Installer Qualifications: Engage an experienced Installer who has completed aggregate base course similar in material, design, and extent to that indicated for this Project and with a record of successful in-service performance.

D. Manufacturer Qualifications: Engage a firm experienced in manufacturing similar to that indicated for this Project and with a record of successful in-service performance.

E. Testing Agency Qualifications: Demonstrate to the Engineer's satisfaction, based on the Engineer's evaluation of criteria, that the independent testing agency has the experience and capability to satisfactorily conduct the testing indicated in access with standards without delaying the Work.

F. Regulatory Requirements: Conform to applicable standards of authorities having jurisdiction for asphalt paving work.

G. Materials and installed work may require testing and re-testing at any time during progress of work. Tests, including re-testing of rejected materials or installed work, shall be done at Contractor’s own expense.

1.8 FIELD/PROJECT CONDITIONS

A. Provide a minimum 48-hour notice to the Engineer, and receive written notice to proceed, before interrupting any service, facility or utility operated or occupied by the Employer or others.

B. Protect base course from rain, wind and sun, indentation, contamination and physical damage.

C. Finished portions of the base course that are used by equipment in the construction of an adjoining section shall be protected to prevent marring or damaging the completed work.

D. Project Site Information: A sub-surface site investigation and test report has been prepared for Project and has been made available for information only. The report is not part of the Contract. The Contractor is entirely responsible for his own assessment, interpretation, use, and conclusions drawn from the information, data, tests, analyses, and opinions contained in any Site Investigation report discussed or related to the project conditions.

1. Make additional test borings and conduct other exploratory operations as necessary, at Contractor’s own cost and expense.

E. Traffic: Minimize interference with adjoining airfield**,** roads, streets, walks, and other adjacent occupied or used facilities during earthwork operations.

1. Do not close or obstruct airfield**,** streets, walks, or other adjacent occupied or used facilities without permission from Employers and authorities having jurisdiction.
2. Provide alternate routes around closed or obstructed traffic ways if required by authorities having jurisdiction.

F. Notify utilities companies and authorities having jurisdiction for area where Project is located before commencing earthwork operations.

G. Existing Utilities: Do not interrupt utilities serving facilities on or adjacent to Project site unless permitted in writing by the Engineer and then only after arranging to provide temporary utility services according to requirements.

1. Notify the Engineer not less than two days in advance of proposed utility interruptions.
2. Do not proceed with utility interruptions without the Engineer's written permission.

H. Demolish and completely remove from site existing underground utilities indicated to be removed. Coordinate with utility companies to shut off services if lines are active.

PART 2 - PRODUCTS

2.1 AGGREGATE

A. Aggregate: Shall be either natural gravel, crushed stone, or crushed gravel. The fine aggregate shall consist of screenings obtained from crushed stone, gravel, or sand. Aggregate may be washed, if directed, to remove excessive quantities of clay, silty clay, or salts.

B. Crushed Stone: Shall consist of hard, durable particles or fragments of stone, free from dirt, organic material or other objectionable matter, and shall contain not more than 8 % of flat, elongated, soft, or disintegrated pieces (when tested according to U.S. Army, Corps of Engineers CRD-C 119-91 at 5:1 ratio).

C. Crushed Gravel: Shall consist of hard durable stones, rocks, and boulders crushed to specified sizes and shall be free from excess flat, elongated, soft or disintegrated pieces, dirt, or other objectionable matter.

D. The method used in production of crushed gravel shall be such that the finished product shall be as uniform as practicable. The crushing of the gravel shall result in a product, which shall have at least 90 % by weight of particles with at least one fractured face when tested according to ASTM D5821. All stones, rocks, and boulders of inferior quality occurring in the pit shall be wasted.

E. Any material passing 4.75 mm (No. 4) sieve and produced in the crushing process shall be incorporated in the base material up to the gradation limits required for the base course aggregate.

F. The crushed aggregate shall meet the requirements of one of the gradation shown in Table 1 when tested in accordance with AASHTO T 11 and T 27.

Table 1: Requirements for gradation of aggregate

Sieve Designation (Square openings)	**Percent by weight passing [to be verified with specific country's general specifications]**
50 mm (2 in)	100
37 mm (1 ½ in)	95 - 100
25 mm (1 in)	70 - 95
19 mm (¾ in)	55 - 85
9.5 mm (3/8 in)	40 - 70
4.75 mm (No.4)	30 - 60
0.60 mm (No.30)	12 - 30
0.425 mm (No.40)	-
0.075 mm (No.200)	5 - 10

G. The amount of the fraction of material passing the No. 200 mesh sieve shall not exceed one half the fraction passing the No. 40 mesh sieve.

H. The percentage of wear shall not exceed 30 % after 500 revolutions, when tested in accordance with AASHTO T 96 (Los Angeles Abrasion Test).

I. Aggregates shall have a Flakiness Index and Elongation Index of 35% maximum when tested according to BS EN 933-3 and BS 812-117 standard, respectively.

J. The crushed aggregate base course material shall have a 4-day soaked CBR of not less than 80% when compacted at 100% of Modified Proctor AASHTO T 180 (Method D) and tested in accordance with AASHTO T 193.

K. When tested for soundness in accordance with AASHTO T 104, the material shall not show signs of disintegration and the loss by weight shall not exceed 12 % in the case of the sodium sulphate test and 18 % in the case of the magnesium sulphate test.

L. The portion of aggregate, including any blended material, passing the 0.425 mm (No. 40) mesh sieve shall have a liquid limit (LL) of not more than 25 and plasticity index (PI) of not more than 4 when tested in accordance with AASHTO T 89 and T 90.

M. If additional fine material is required to correct the aggregate gradation, or for adjusting the LL or PI of the fraction passing the 0.425 mm (No. 40) sieve, it shall be uniformly blended and mixed with the aggregate material plant at the crushing plant or by an approved plant. Reworking of the material in-situ to obtain the specified gradation will not be permitted. Additional fine material for these purposes shall be obtained from the crushing of stone, gravel, or natural material.

N. The sand equivalent shall be 50% minimum when tested according to ASTM D2419.

O. The crushed aggregate base course material shall have chloride content of less than 0.8 % and sulphate content of less than 0.50 % when tested in accordance with BS 812-117.

P. The linear shrinkage of the crushed aggregate material shall not exceed 3% when tested according to BS 1377-2 standard.

Q. The aggregate shall not contain more than 1% of clay lumps and friable particle when tested according to ASTM C142/ C142M.

2.2 EQUIPMENT

A. Equipment used to handle, place, spread, moisten, compact, and finish the base course shall be on the site in first-class working condition, and approved by the Engineer before construction is permitted to start.

PART 3 - EXECUTION

3.1 OPERATION AT SOURCES OF SUPPLY

A. All work involved in clearing and grubbing of quarries and pits, including the handling of unsuitable material, shall be performed at Contractor's own expense. The base material shall be obtained from approved sources. The material shall be handled in a manner that shall secure a uniform and satisfactory product.

3.2 SURFACE PREPARATION

A. The aggregate base course shall be placed directly on completed subgrade, preparation and the subgrade surface shall be as specified in Section 312000.

3.3 MIXING AND SPREADING

A. The base course material may be premixed with water, in a pugmill mixing plant or on site. The amount of water added, as determined, shall be such that the material will be uniform and within the optimum moisture content range at the time of compaction.

B. The Engineer may allow other methods of mixing provided such methods(s) do not reduce the standard of work. Demonstrate, in the presence of the Engineer, the ability to attain the requirement given in the Specification.

C. Premixed material shall be placed on the subgrade in a uniform layer not less than 75 mm nor more than 150 mm of compacted thickness, unless the Contractor can prove by successful trial sections that a maximum of 200 mm compacted thickness can achieve the specified degree of compaction in sub-clause 3.4.C.

D. The base course material shall be placed to the required width using a self-propelled spreader or motor grader and shall be delivered such that it is ready for compaction without further shaping.

E. The material shall not be handled in such a way as to cause segregation. If the spreader causes segregation in the material or leaves ridges or other objectionable marks on the surface which cannot be readily eliminated or prevented by adjustment of the spreader operation, the use of such spreader shall forthwith be discontinued and it shall be replaced by a spreader capable of spreading the material in a proper manner.

F. Segregated material shall be removed and replaced with well graded material. "Skin" patching will not be permitted. Only minor surface manipulation and watering to achieve the required surface tolerances will be permitted during the compaction process.

G. Hauling or placement of material will not be permitted when, in the judgement of the Engineer, the weather or surface conditions are such that hauling operations will cause cutting or rutting of subgrade or cause contamination of the base course material.

3.4 COMPACTION

A. Compaction: Plan the sequence of operations so that the least amount of water will be lost by evaporation from uncompleted surfaces. If placing of succeeding layer of material is delayed to the extent that additional water is required to prevent raveling or excessive drying, the application of such water shall be carried out in an approved manner and at Contractor’s own expense.

B. Base course: material shall be compacted by means of approved compaction equipment, progressing gradually from the outside towards the center, with each succeeding pass uniformly overlapping the previous pass.

C. Rolling: Continue until the entire thickness of each base layer is thoroughly and uniformly compacted to 100 %, as per AASHTO T 180 (Method D), maximum density.

1. Final rolling of the completed course shall be by means of an approved self-propelled roller.
2. Rolling shall be accompanied by sufficient blading, to ensure a smooth surface, free from ruts or ridges and having the proper shape.
3. When additional water is required, it shall be applied in an approved manner.

D. Areas Inaccessible to Normal Compaction: Compact by use of portable mechanical tampers until the required standard of compaction is achieved, or to the satisfaction of the Engineer.

E. Each layer shall be completely compacted and approved prior to delivery of materials for the following layer.

F. Prior to placing a following layer, the surface shall be made sufficiently moist as directed, to ensure proper bond between the layers.

G. Edges and Edge Slopes of the base Course: Bladed or otherwise dressed to conform to the lines and dimensions shown on the Drawings and to present straight, neat lines and slopes as free of loose material as practicable.

H. Material which has dried out prior to final compaction, or which has dried and decompacted subsequent to final compaction, shall be watered and recompacted using approved equipment and procedures. If unable to return the material to its original or specified condition with respect to compaction, thickness and surface tolerances, for the final layer only, scarify the material and reconstruct the base course on a re-approved sub-grade surface or subbase course surface to the satisfaction of the Engineer.

3.5 TOLERANCES AND MAINTENANCE OF COMPLETED BASE

A. Compacted and Completed Base Course: Conform to the lines, grades and cross sections as shown on the Drawings.

B. Elevations of the Finished base Course: Checked in the presence of the Engineer at intervals of 20m on straight lines and of 10m on curves, and at intermediate points as directed.

C. Tolerances (for final only): Elevations of finished surface shall not exceed + 10mm or - 15mm.

D. Finished Surface: When tested with a 4.0 m long straightedge, placed parallel to, or at right angles to the centerline, the maximum deviation of the surface from the testing edge between any 2 contact points shall not exceed 12 mm.

E. Specified Tolerances: Areas which exceed shall be corrected by removing the defective sections of base course and reconstructing them or, by scarifying and adding new material and recompacting and finishing to the specified standard.

F. Completion and Acceptance of the base Course: Maintained at Contractor's own expense as follows:

1. The surface shall be broomed, rolled, and otherwise maintained, keeping it free from raveling and other defects until such time as the following course is placed.
2. Water shall be applied at such times and in such quantities as directed.

G. The base shall be sealed with prime coat before it is dried out. If the surface has dried out, then light watering and recompaction may be done before applying prime coat. If full depth is dry, the whole base shall be removed and replaced.

3.6 FIELD QUALITY CONTROL

A. General

1. Testing Laboratory

a. Employ an independent testing agency to perform tests and to submit test reports
b. Be responsible for taking, identifying, and delivering to the test laboratory all test samples called for in this specification. The testing laboratory shall be responsible for the testing. Collect all test results and deliver them to the Engineer in the format and details as specified.

B. Base Course Material: Test in accordance with Table 2 below after mixing with water at the mixing plant or in-situ compaction and if satisfactory shall be approved for use. This approval shall not be deemed to constitute acceptance of the base course for full payment purposes.

C. Compaction: Test in accordance with ASTM D1556/ D1556M (Sand Cone Method) or ASTM D2167 (Rubber balloon Method) or ASTM D6938 (Nuclear Method). The Nuclear Method has to be first calibrated in comparison with Sand Cone Method for at least three sample tests. If there is a significant delay between the construction of any layer and the following layer, the Engineer may require the compaction of the lower layer to be re-verified to ensure that it has not loosened due to traffic, passage of construction equipment, adverse weather conditions or otherwise.

3.7 REQUIRED TESTS AND MINIMUM REPETITION FOR BASE COURSE MATERIAL:

Table 2: Minimum repetition for base course material

(A) Source of Materials		**(B) Control on Site (The Road)**	
Required Tests (A)	**Repetition Required for all Test in (A)**	**Required Tests (B)**	**Repetition Required for all Tests in (B)**
1. Gradation of Material	As requested by the Engineer	1. Proctor	As requested by the Engineer
2. Plasticity Index and liquid limit	1 sample in every 1000 m3	2. Gradation	As requested by the Engineer
3. Abrasion	1 sample in every 1000 m3	3. Plasticity Index and liquid limit	1 sample in every 1000 m3
4. CBR	1 sample in every 1000 m3	4. CBR	1 sample in every 1000 m3
5. Sand equivalent	1 sample in every 500 m3	5. Abrasion	1 sample in every 1000 m3
6. Percentage of fractured Grains/Base course	As requested by the Engineer	6. Sand Equivalent	1 sample in every 500 m3
7. Chloride content (combined aggregate)	1 sample in every 1000 m3	7. Clay lumps & friable Particles	1 sample in every 1000 m3
8. Sulphate content (combined aggregate)	1 sample in every 1000 m3	8. Field Density	1 sample in every 500 m3
9. Flakiness and Elongation (combined aggregate)	1 sample in every 1000 m3	9. Thickness	As requested by the Engineer
10. Linear shrinkage	1 sample in every 1000 m3	-	-

3.8 PROTECTION

A. Do not perform work when the Engineer determines that weather or other conditions are such that construction operations will damage the finished work.

B. Do not haul over aggregate base without approval. Repair damages resulting from occasional routing of equipment over the work.

C. Following the completion of the aggregate base course, all maintenance work necessary to keep the base course in a condition satisfactory for further work shall be performed.

END OF SECTION 321123

SECTION 321216 - ASPHALT PAVING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Hot-mix asphalt paving.
2. Asphalt concrete surface (wearing) course.
3. Asphalt concrete base course.
4. Asphalt prime and tack coats.

B. Provide asphalt concrete pavement for shoulder/protection strip according to the materials, workmanship, and other applicable requirements of the Standard Specifications.

1. Standard Specification: As indicated.

C. Scope of Section:

1. This section covers the specifications and applications of asphalt concrete paving. It covers the case of paving using hot mix asphalt (HMA) having a bitumen binder (or asphalt cement) that is a virgin (conventional/unmodified) asphalt binder.
2. The item entailed under this section shall consist of a course composed of mineral aggregates, asphalt binder, and other additives mixed in a central mixing plant and placed on a prepared course in accordance with these Specifications and shall conform to the lines, grades, thicknesses, and typical cross sections shown on the Drawings.
3. Each layer shall be constructed to the depth, thickness, typical section and elevation required by the Drawings and shall be rolled, finished, and approved before laying of the next layer.

D. Related Requirements:

1. Section 324113.13 “Pavement Demolishing” for demolition of asphalt paving.
2. Section 312000 "Earth Moving" for subgrade preparation and grading.
3. Section 321116.16 "Aggregate Subbase Course" for subbase courses.
4. Section 321123 "Aggregate Base Course" for base courses.

1.3 DEFINITIONS

A. The asphalt concrete surface course (also referred to as AC wearing course) is the upper layer in the flexible pavement of roadways construction consisting of a hot mix of bituminous binder and aggregate conforming to the relevant gradation and other properties specified under this section.

B. The asphalt concrete surface course is the layer underlying the asphalt concrete surface course in roadway, airfield, and dockyard construction consisting of a hot mix of bituminous binder and aggregate conforming to the relevant gradation and other properties specified under this section.

C. Asphalt Concrete (AC), Hot Mix Asphalt (HMA), and Bituminous Mixtures may be used alternately in this Specification noting that all refer to paving using HMA.

1.4 PREINSTALLATION MEETINGS

A. Preinstallation Conference: Conduct conference at Project site to comply with requirements of Division 1 Section "Project Management and Coordination" Review methods and procedures related to asphalt paving including, but not limited to, the following:

1. Review proposed sources of paving materials, including capabilities and location of plant that will manufacture hot-mix asphalt.
2. Review condition of substrate and preparatory work performed by other trades.
3. Review requirements for protecting paving work, including restriction of traffic during installation period and for remainder of construction period.
4. Review and finalize construction schedule for paving and related work. Verify availability of materials, paving Installer's personnel, and equipment required to execute the Work without delays.
5. Review inspection and testing requirements, governing regulations, and proposed installation procedures.
6. Review forecasted weather conditions and procedures for coping with unfavorable conditions.

1.5 ACTION SUBMITTALS

A. Product Data: For each product specified. Include technical data and tested physical and performance properties.

B. Job-Mix Designs: For each job mix proposed for the Works, establish an approved Job Mix Formula (JMF) at least 3 months before planned starting of any asphalt construction works.

C. Submit a new JMF if you change any of the following:

1. Target asphalt binder percentage greater than ± 0.2 percent.
2. Asphalt binder supplier and/or Asphalt plant
3. Combined aggregate gradation
4. Aggregate sources
5. Liquid antistrip producer or dosage.

D. Material Test Reports: Indicate and interpret test results for compliance of materials with requirements indicated.

E. Shop Drawings: Indicate pavement connection details, pavement markings, lane separations, and defined parking spaces. Indicate dedicated handicapped spaces with international graphics symbol.

1.6 INFORMATIONAL SUBMITTALS

A. Qualification Data: For firms and persons specified in the "Quality Assurance" Article to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names, and addresses of engineers and employers, and other information specified or required by Engineer.

B. Material Certificates: Certificates signed by manufacturers certifying that each material complies with requirements.

C. Quality Control (QC) Plan: At least 5 business days prior to the pre-paving meeting, submit a QC plan for the Hot Mix Asphalt (HMA). The QC plan must describe the organization and procedures for:

1. Controlling HMA quality characteristics

2. Taking samples, including sampling locations
3. Establishing, implementing, and maintaining QC
4. Determining when corrective actions are needed
5. Implementing corrective actions
6. Using methods and materials for backfilling core locations

D. The QC plan must address the elements affecting HMA quality, including:

1. Aggregates
2. Asphalt binder
3. Additives
4. Production
5. Transportation.
6. Paving.

1.7 QUALITY ASSURANCE

A. "All products and equipment shall demonstrate compliance with requirements specified in Section 016000 "Product Requirements".

B. Installer Qualifications: Engage an experienced installer who has completed Hot-Mix Asphalt paving similar in material, design, and extent to that indicated for this Project and with a record of successful in-service performance.

C. Manufacturer Qualifications: Engage a firm experienced in manufacturing hot-mix asphalt similar to that indicated for this Project and with a record of successful in-service performance.

D. Testing Agency Qualifications: Demonstrate to Engineer's satisfaction, based on Engineer's evaluation of criteria, that the independent testing agency has the experience and capability to satisfactorily conduct the testing indicated in accordance with Standards, without delaying the Works.

E. Regulatory Requirements: Conform to applicable standards of authorities having jurisdiction for asphalt paving work.

F. Asphalt Paving Publications: Comply with Asphalt Institute’s (AI's) "The Asphalt Handbook", except where other requirements are stipulated.

1.8 DELIVERY, STORAGE AND HANDLING

A. Deliver pavement-marking materials to Project site in original packages with seals unbroken and bearing manufacturer's labels containing brand name and type of material, date of manufacture, and directions for storage.

B. Store pavement-marking materials in a clean, dry, protected location and within temperature range required by manufacturer. Protect stored materials from direct sunlight.

1.9 FIELD/PROJECT CONDITIONS

A. Environmental Limitations: Do not apply asphalt materials if substrate is wet or excessively damp or during wet weather, and when the following conditions are not met:

1. Prime and Tack Coats: Minimum surface temperature of 15 deg C.
2. Asphalt Concrete Base Course: Minimum surface temperature of 15 deg C and rising at time of placement.

3. Asphalt Concrete Surface Course: Minimum surface temperature of 15 deg C and rising at time of placement.

PART 2 - PRODUCTS

2.1 AGGREGATE

A. General: Use materials and gradations that have performed satisfactorily in previous installations.

B. General: Crushed stone, screenings, and mineral filler, with or without sand meeting the specified gradation.

C. The aggregates should have no known history of detrimental pavement staining on exposed surfaces due to ferrous sulfides.

D. Aggregates for use in the asphalt surface layers shall consist of 100% crushed stone from a hard, high quality rock. No mixing of different types of rocks shall be allowed in the same asphalt mix. The Polish Stone value of the coarse aggregate material for use in the asphalt surface layers shall be 45 minimum, when tested according to BS 812-114 standard.

E. Aggregates shall consist of not more than 8 percent of flat elongated pieces according to U.S. Army, Corps of Engineers CRD-C119-91 or ASTM D4791. A flat particle is one having a ratio of width to thickness greater than five. An elongated particle is one having a ratio of length to width greater than five.

F. **Coarse Aggregate** is the portion of the aggregates retained on the No. 4 (4.75 mm) sieve. Aggregate particles shall be clean, hard, durable, and sound. It shall be angular crushed stone or crushed gravel; complying with ASTM D692/D692M and the requirements specified in this section. Crushing shall result in a product such that for coarse aggregates at least 100% by weight shall have 1 (one) fractured faces, a minimum of 85% by weight shall have at least two fractured faces for AC Base Course, and a minimum of 90% by weight shall have at least two fractured faces for AC Surface Course.

G. **Fine Aggregate** is the portion of the aggregates passing the No. 4 (4.75 mm) sieve. Fine aggregates shall consist of clean, sound, tough, durable, and sharp-edged angular shaped aggregates produced by crushing of rock (stone or gravel) and it shall be clean and free of organic matter, clay, clay lumps or deleterious material. Fine aggregates shall comply with requirements of ASTM D1073 and the requirements specified in this section.

H. Passing a stripping test (95% minimum) according to ASTM D3625/ D3625M “Standard Practice for Effect of Water on Bituminous-Coated Aggregate Using Boiling Water”.

I. Coarse and fine aggregates shall be sampled according to ASTM D75. The material requirements of fine and coarse aggregates are listed in Table 1 below:

Table 1: Aggregates requirements

Test	Ratio
Liquid Limit (ASTM D4318)	25 maximum
Plasticity Index (ASTM D4318)	Non-plastic
Loss by Abrasion Test (ASTM C131/ C131M)	30 percent maximum for asphalt base course, and 25 percent Maximum for asphalt surface course
Aggregate Crushing Value (BS 812-110)	25 percent maximum for asphalt base course, and 20 percent maximum for asphalt surface course

Test	Ratio
Soundness Test, Loss of Weight using Sodium Sulfate (5 cycle) (ASTM C88/ C88M)	10 per cent maximum
Soundness Test, Loss of Weight using Magnesium Sulfate (5 cycle) (ASTM C88/ C88M)	10 percent maximum
Fine Aggregate Water Absorption (ASTM C128)	1.0 percent maximum
Coarse Aggregate Water Absorption (ASTM C127)	2.0 percent maximum
Chloride Content (BS 812-117)	0.1 percent maximum
Sulphate content (BS 812-117)	0.3 per cent maximum
Sand Equivalent (ASTM D2419)	50 minimum

J. Aggregate particles shall be clean, hard, durable, and sound. Crushing shall result in a product such that, for particles retained as 4.75mm (No. 4) sieve, at least 100% by weight shall have 1 (one) fractured faces and minimum 85% by weight having at least two fractured faces.

K. Fine aggregates shall be clean and free of organic matter, clay, clay lumps or deleterious material. Clay lumps content shall be tested according to ASTM C142/ C142M.

L. Addition of sand, with the approval of the Engineer, shall be limited to natural sand in a quantity not to exceed 15 percent of the combined weight of course and fine aggregate and mineral filler. The use of wadi, beach or dune sand is not permitted in asphalt concrete mixes.

M. The fine aggregate material for the asphalt surface and base layers shall have a minimum angularity of 45% when tested in accordance with AASHTO T 304-Method A standard.

N. Mineral Filler: Rock or slag dust, hydrated lime or hydrated cement or other inert material complying with ASTM D242/ D242M.

O. The asphalt layers in the Surface Course shall mainly consist of 5 to 7.5 cm thick layers, and those of the Asphalt Base Course shall consist of 7 to 10cm thick layers. The NMAS used in the asphalt mix shall depend on the layer thickness. For guidance, the NMAS shall be as follows:

Table 2: NMAS requirements

Asphalt Layer Thickness, [cm]	NMAS, [mm]
5-6	12.5
6.5-9	19.0
9.5-10	25.0

P. Only for the case of the non-trafficked pavements used in the areas subjected to jet blast, and/or the case of road shoulders pavement, a 4cm thick asphalt surface layer shall be accepted using 12.5mm NMAS.

Q. Combined aggregates meeting the following requirements when tested according to ASTM C136/ C136M:

Table 3: Combined aggregates requirements

Sieve Size (mm)	Minimum % Passing	Maximum % Passing	Minimum % Passing	Maximum % Passing	Minimum % Passing	Maximum % Passing
	12.5mm NMAS		19 mm NMAS		25mm NMAS	
37.5	100	100	100	100	100	100
25.0	100	100	100	100	90	98
19.0	100	100	86	100	68	90
12.5	79	99	69	87	57	78
9.5	68	88	58	78	49	69
4.75	48	68	40	60	34	56
2.36	33	53	25	45	22	42
1.18	20	40	-	-	13	29

Sieve Size (mm)	Minimum % Passing	Maximum % Passing	Minimum % Passing	Maximum % Passing	Minimum % Passing	Maximum % Passing
	12.5mm NMAS		19 mm NMAS		25mm NMAS	
0.85	-	-	15	30	-	-
0.600	14	30	-	-	8	21
0.425	-	-	10	22	-	-
0.300	9	21	-	-	6	14
0.18	-	-	6	15	-	-
0.150	6	16	-	-	4	10
0.075	3	6	2	8	3	6

R. The aggregate material for the asphalt surface and base course layers shall satisfy the below conformity criteria:

Table 4: Aggregate material for the asphalt surface requirements

Conformity Equations	Asphalt Surface Course (12.5mm NMAS)	
	Minimum	Maximum
$\frac{6.25mm(\%) - 2.36mm(\%)}{100\% - 6.25mm(\%)}$	0.5	0.65
$\frac{0.6\,mm\ (\%)}{2.36\,mm\ (\%)}$	0.35	0.5
$\frac{0.15\,mm\ (\%)}{0.6\,mm\ (\%)}$	0.35	0.5
Conformity Equations	**Asphalt Surface/Base Course (19mm NMAS)**	
	Minimum	**Maximum**
$\frac{9.5mm(\%) - 4.75mm(\%)}{100\% - 9.5mm(\%)}$	0.6	0.75
$\frac{1.18\,mm\ (\%)}{4.75\,mm\ (\%)}$	0.35	0.5
$\frac{0.300\,mm\ (\%)}{1.18\,mm\ (\%)}$	0.35	0.5
Conformity Equations	**Asphalt Base Course (25mm NMAS)**	
	Minimum	**Maximum**
$\frac{12.5mm(\%) - 4.75mm(\%)}{100\% - 12.5mm(\%)}$	0.7	0.85
$\frac{1.18\,mm\ (\%)}{4.75\,mm\ (\%)}$	0.35	0.5
$\frac{0.300\,mm\ (\%)}{1.18\,mm\ (\%)}$	0.35	0.5

S. Coarse Aggregate: Sound; angular crushed stone or crushed gravel; complying with ASTM D692/D692M.

T. Fine Aggregate: Sharp-edged natural sand or sand prepared from stone or gravel, or combinations thereof; complying with ASTM D1073.

2.2 ASPHALT MATERIALS

A. Asphalt Cement (Bitumen Binder): ASTM D946/D946M for penetration-graded material; Grade 60-70 (mixing temperature 145 deg C - 165 deg C).

B. Asphalt Cement (Bitumen Binder): ASTM D3381/D3381M for viscosity-graded material.

C. Prime Coat: ASTM D2027/ D2027M; medium-curing cutback asphalt; MC-70.

D. Prime Coat: ASTM D977, emulsified asphalt or ASTM D 2397/D2397M, cationic emulsified asphalt, slow setting, factory diluted in water, of suitable grade and consistency for application.

E. Tack Coat: ASTM D977, emulsified asphalt or ASTM D 2397/D2397M, cationic emulsified asphalt, slow setting, factory diluted in water, of suitable grade and consistency for application.

F. Tack Coat: ASTM D2028/D2028M; rapid curing cutback asphalt; RC-70.

G. Water: Potable.

H. Asphalt material shall be obtained from approved sources, approved by the Engineer on site.

2.3 AUXILIARY MATERIALS

A. Herbicide: Commercial chemical for weed control, registered by Environmental Protection Agency (EPA). Provide granular, liquid, or wettable powder form.

B. Sand: ASTM D1073, Grade Nos. 2 or 3.

C. Paving Geotextile: AASHTO M 288, nonwoven polypropylene; resistant to chemical attack, rot, and mildew; and specifically designed for paving applications.

D. Wheel Stops: Precast, air-entrained concrete, 17.2-MPa minimum compressive strength, approximately 150 mm high, 225 mm wide, and 2150 mm long. Provide chamfered corners and drainage slots on underside and provide holes for anchoring to substrate.

1. Dowels: Galvanized steel, diameter 20 mm, minimum length 250 mm.

E. Liquid Antistrip: Liquid antistrip must be from 0.25 to 1.0 percent by weight of asphalt binder. Do not use liquid antistrip additive as a substitute for asphalt binder. Liquid antistrip total amine value must be 325 minimum, when tested under ASTM D2074. Use only one liquid antistrip type or brand at a time. Do not mix liquid antistrip types or brands.

2.4 MIXES

A. Hot-Mix Asphalt: Provide dense, hot-laid, hot-mix asphalt plant mixes approved by authorities having jurisdiction and designed according to procedures in AI's "Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types, or in accordance with the Marshall method for Asphalt Institute Manual Series MS-2. However, in case the Asphalt mix design is required to follow the Superpave

Mix Design Method, this shall be performed in full compliance with the method stipulated in AASHTO M323 and AI SP-2.

1. Provide mixes with a history of satisfactory performance in geographical area where Project is located.
2. Provide mixes complying with the composition, grading, and tolerance requirements of AASHTO M 156 for the following nominal, maximum aggregate sizes:

    a. Base Course: 19 or 25 mm as per requirements of Table 2 for NMAS.
    b. Surface Course: 12.5mm or 19mm as per requirements of Table 2 for NMAS .

B. Combine the mineral aggregates and asphalt to conform to the following composition limits by weight:

1. Total Mineral Aggregates:

    a. Asphalt Base Course 95.5 to 96.5 percent
    b. Asphalt Surface Course 95.5 to 96.5 percent

2. Asphaltic Binder:

    a. Asphalt Base Course 3.5 to 4.5 percent
    b. Asphalt Surface Course 3.5 to 4.5 percent

C. Asphaltic mixtures with maximum aggregate size of 25 mm shall be tested according to ASTM D6926 (75 blows each face) and shall satisfy the below requirements. For asphaltic mixtures with maximum aggregate size greater than 25mm, testing shall be carried out according to ASTM D5581 (112 blows each face) but in this case the Marshall Mix specified properties shall be reviewed to account for the larger size aggregates to the satisfaction of the Engineer.

Table 5: Asphaltic mixtures requirements

Test Required	**Asphalt Base Course**	**Asphalt Surface Course**
Marshall Stability (N)	10,000	12,000
Flow (mm)	2-3.5	2-4
Stiffness, minimum (N/mm)	4900	4900
Voids in total mix, %VIM	4.0 to 7.0 percent	4.0 to 7.0 percent
Voids in mineral aggregate based on maximum aggregate size, VMA (%)	Min 13 (25mm NMAS) Min 14 (19 NMAS)	Min 14 (19mm NMAS) Min 15 (12.5 NMAS)
Voids Filled with Bitumen, VFB (%)	50-70	60-70
Loss of Marshall Stability by submerging specimens in water at 60°C for 24 h. compared to stability measured after submersion in water at 60°C for 30 minutes.	Max. 25%	Max. 25%
% Air Voids at Refusal*	2 min.	2 min.
Filler/Bitumen ratio	0.8-1.5	0.8-1.4

*Prior to final approval, the proposed job mix, but with a bituminous content at the upper percentage limits shall be compacted to refusal, (400 to 600 blows) and the resulting voids in the mix shall not be less than 2%.

D. Variation from the approved job-mix, based on results of 4 tests, shall not exceed the following:

1. Aggregates passing No. 4 (4.75 mm) and larger……... ± 4 percent
2. Aggregates passing No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (0.6 mm), and No. 50 (0.3 mm)……...± 3 percent
3. Aggregates passing No. 100 (0.15 mm) and No. 200 (0.075 mm)……± 1 percent
4. Asphalt content…….... ± 0.2 percent
5. Temperature of mixing and placing…….± 10 deg C
6. Air voids in total mix……...± 1 percent

E. When tested for resistance to water damage in accordance with AASHTO T 283 "Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage", the asphalt surface course mixture shall have a retained tensile strength greater than or at least equal to 80%. In case the anti-stripping agents are not successful in providing the specified Tensile Strength Ratio, then the Contractor shall consider alternative means, such as the use of hydrated lime to achieve this purpose.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verify that subgrade is dry and in suitable condition to support paving and imposed loads.

B. Proof-roll the aggregate base course using heavy, pneumatic-tired rollers to locate areas that are unstable or that require further compaction.

C. Inspect surfaces on which asphalt materials are to be placed for conformance to the required compaction, grades, and sections.

D. Notify Engineer in writing of any unsatisfactory conditions. Do not begin paving installation until these conditions have been satisfactorily corrected.

3.2 COLD MILLING

A. Clean existing paving surface of loose and deleterious material immediately before cold milling. Remove existing asphalt pavement, including hot-mix asphalt and, as necessary, unbound-aggregate base course, by cold milling to grades and cross sections indicated.

3.3 PATCHING AND REPAIRS

A. All saw-cutting and breaking of defective pavements of any type, cleaning, patching, sealing, or carrying out pavement repair works shall be coordinated with the Engineer through the submission of detailed method statement for every area that needs repair. The method statement should show the extent of patching or repair works, the steps that shall be followed and the materials that shall be used for each type of repair, with due consideration to the applicability of the proposed method and materials to each specific repair case. The execution shall not start before receiving the written approval of the Engineer. The requirements set in Clauses B, C and D below, are for guidance only and shall be coordinated with the approved method statement and with the Engineer on Site.

B. Patching: Saw cut perimeter of patch and excavate defective pavement section to sound base. Recompact new subgrade. Excavate rectangular or trapezoidal patches, extending 300 mm into adjacent sound pavement, unless otherwise indicated. Cut excavation faces vertically.

1. Tack coat faces of excavation and allow to cure before paving.

2. Fill excavation with dense-graded, hot-mix asphalt surface mix and, while still hot, compact flush with adjacent surface.
3. Partially fill excavation with dense-graded, hot-mix asphalt base mix and compact while still hot. Cover asphalt base course with compacted, hot-mix surface layer finished flush with adjacent surfaces.

C. Retain below if surface irregularities of areas to be paved exceed ability of hot-mix paver to correct. Leveling courses are usually applied over existing pavements before overlays or other surface treatments. Revise mix to a base-course mixture when appropriate.

D. Leveling Course: Install and compact leveling course consisting of dense-graded, hot-mix asphalt surface course to level sags and fill depressions deeper than 25 mm in existing pavements.

1. Install leveling wedges in compacted lifts not exceeding 75 mm thick.

E. Crack and Joint Filling: Remove existing filler material from cracks or joints to a depth of 6 mm. Refill with asphalt joint-filling material to restore watertight condition. Remove excess filler that has accumulated near cracks or joints.

1. Tack Coat: Apply according to Article 3.6.

F. For repairing large areas of existing asphalt pavement, refer to Specification Section 320117.

3.4 SURFACE PREPARATION

A. General: Immediately before placing asphalt materials, remove loose and deleterious material from substrate surfaces. Ensure that prepared subgrade is ready to receive paving.

1. Sweep loose granular particles from surface of unbound-aggregate base course. Do not dislodge or disturb aggregate embedded in compacted surface of base course.
2. Remove loose materials from existing asphalt pavement and clean surface using approved mechanical sweepers, blowers, and hand brooms. Remove loose broken or shattered asphaltic material along the edges of existing surfaces. Shape, blade, and broom the exposed subgrade and a sufficient width of shoulder to provide a uniform firm subgrade for the new surface course.
3. Remove loose materials from existing PCC pavement and clean surface using approved mechanical sweepers, blowers, and hand brooms. Shape, blade, and broom the exposed subgrade and a sufficient width of shoulder to provide a uniform firm subgrade for the new surface course.

B. Herbicide Treatment: Apply herbicide according to manufacturer's recommended rates and written application instructions and in compliance with Section 313116. Apply to dry, prepared subgrade or surface of compacted-aggregate base before applying paving materials.

1. Mix herbicide with prime coat when formulated by manufacturer for that purpose.

C. Prime Coat: Apply according to Article 3.6.

D. Control of Traffic: Do not permit unnecessary traffic on the surface after it has been approved to receive asphaltic material.

3.5 TRIAL SECTIONS

A. At the start of plant operation, place a trial section for each Job Mix Formula used. Construct a trial section 100 m long and two paver-widths wide (operating simultaneously), with a longitudinal cold joint. The trial section shall be of the same depth as the course which it represents. The underlying

grade or pavement structure upon which the trial section is to be constructed shall be the same as the remainder of the course represented by the test section. The equipment used in construction of the trial section shall be the same equipment to be used on the remainder of the course represented by the trial section. The trial section shall be placed at locations approved by the Engineer on Site.

B. One random sample shall be taken at the plant, triplicate specimens compacted, and tested for stability, flow, and laboratory air voids. A portion of the same sample shall be tested for theoretical maximum density, aggregate gradation, and asphalt content. Four randomly selected cores shall be taken from the finished pavement mat, and four from the longitudinal joint, and tested for density. Random sampling shall be in accordance with procedures contained in ASTM D3665. The test results shall conform to all specified requirements for work to continue. If all test results meet the specified requirements, the trial section shall remain as part of the project pavement. If test results exceed the specified tolerances, the test section shall be removed and replaced at no cost to the project and another test section shall be constructed.

C. Should the initial trial section prove to be unacceptable, the necessary adjustments to the Job Mix Formula, plant operation, placing procedures, and/or rolling procedures shall be made. A second trial section shall then be placed. Additional trial sections, as required, shall be constructed, and evaluated for conformance to the specifications. Full production shall not begin until an acceptable section has been constructed and accepted.

3.6 PRIME AND TACK COATS

A. General: Prepare a test section of an approved length for determining the rate of application for each type of material. Subsequent test sections may be required, and previously established rate or rates of application may be altered when necessary.

B. Prime Coat: Apply uniformly over surface of compacted aggregate base to a line 200 mm outside edge of pavement line, at a rate of 0.75 to 1.50 L/sq. m. Apply enough material to penetrate and seal, but not flood, surface. Allow prime coat to cure for 48 hours minimum.

1. Apply liquid asphalt at temperatures within the range of 50 to 70 deg C. Reject materials heated to temperatures above 108 deg C.
2. If prime coat is not entirely absorbed within 24 hours after application, spread sand over surface to blot excess asphalt. Use just enough sand to prevent pickup under traffic. Remove loose sand by sweeping before pavement is placed and after volatiles have evaporated.
3. Protect primed substrate from damage until ready to receive paving.

C. Tack Coat: Apply uniformly to existing surfaces of previously constructed asphalt or Portland cement concrete paving and to surfaces abutting or projecting into new, hot-mix asphalt pavement. Apply at a uniform rate of 0.30 to 0.60 L/sq. m of surface.

1. Apply liquid asphalt at temperatures within the range of 50 to 70 deg C. Reject materials heated to temperatures above 108 deg C.
2. Allow tack coat to cure undisturbed before paving.
3. Avoid smearing or staining adjoining surfaces, appurtenances, and surroundings. Remove spillages and clean affected surfaces.
4. Vertical faces of existing pavements such as curbs and gutters should also be sprayed or painted with a uniform coating of approved tack material.

D. Application:

1. Apply by approved pressure distributors. Spray nozzles and spray bar shall be adjusted and frequently checked to ensure uniform distribution. Stop spraying upon clogging or interference of any nozzles and take corrective measures before resuming.
2. Hand sprays will be approved only for priming small patches or areas that cannot be primed by normal operation of the distributor.

3. Application at the junction of spreads shall not be in excess of the specified amount. Squeeze excess from the surface and correct skipped and deficient areas by means of approved hand sprayers.

E. Blotting: When approved, after the material has been applied for 48 hours and has not dried sufficiently, apply a light application of sand as blotter material. Apply blotting material sparingly and only on areas that have not dried.

3.7 PAVING GEOTEXTILE INSTALLATION

A. Apply Tack Coat or Asphalt Binder or Asphalt Cement uniformly to existing pavement surfaces at a rate of (0.8 to 1.2 L/sq. m).

B. Place paving geotextile promptly according to manufacturer's written instructions. Broom or roll geotextile smooth and free of wrinkles and folds. Overlap longitudinal joints (100 mm) and transverse joints (150 mm).

1. Protect paving geotextile from traffic and other damage and place hot-mix asphalt paving overlay the same day.

3.8 ASPHALTIC CONCRETE BATCHING AND MIXING

A. Preparation of Asphalt Cement: Heat asphalt cement within a temperature range of 145 deg C to 165 deg C at the time of mixing. All material heated to more than 204 deg C in storage tanks shall be rejected.

B. Preparation of Mineral Aggregate:

1. Heat and dry aggregates to a temperature after screening of not more than 163 deg C. Reject and remove aggregates from the bins, if they contain sufficient moisture to cause foaming in the mixture, or if their temperature is in excess of 163 deg C.
2. Immediately after heating, screen aggregates into at least 3 sizes and convey into separate bins ready for batching and mixing. When separating into three bins is impractical, the number of separations may be reduced to two with approval. Screen and produce gradations of heated and dried aggregates which are reasonably uniform and result in the production of a mixture as specified.

C. Preparation of Asphaltic Mixture:

1. Introduce aggregates and asphalt cement into the mixture in proportionate amount according to the job-mix formula. The temperature of the asphalt, except for temporary fluctuations, shall be not lower than 32 deg C below the temperature of the aggregate at the time the materials enter the mixer or pug mill.
2. Use the shortest mixing time that will produce a satisfactory mixture based on the procedure for determining the percentage of coated particles described in ASTM D2489/D2489M. The mixing times shall be set to achieve 90 percent of coated particles for base mixtures and 95 percent of coated particles for surface mixtures.
3. Dry mixing time, if required for the batch plants, shall not exceed 10 seconds. Wet mixing time shall not exceed 50 seconds. Timing shall begin at the start of asphalt introduction into the pug mill at batch plants.
4. The length of mixing time for continuous plants shall be determined by the following formula or other approved methods:

$$\text{Mixing time in seconds} = \frac{\text{Pugmill dead capacity in kilos}}{\text{Pugmill output in kilos/second}}$$

D. Do not use petroleum products such as kerosene or diesel fuel to release HMA from trucks, spreaders, or compactors.

E. Preparation of Hot-Mix Asphalt Placement:

1. Apply a prime coat or tack coat to surface on which asphaltic concrete is to be placed, unless otherwise approved.
2. Maintain line and grade control by means of taut reference string lines or other approved methods. If the existing surface is determined to be acceptable, it may be used for control, and the use of the string line waived. If directed, establish, and maintain centerline points

3.9 HOT-MIX ASPHALT PLACING

A. Spread and finish asphaltic concrete true-to-line and grade by means of an automatically controlled paver except that the use of the automatically controlled paver may be waived and a manually controlled paver or hand methods may be used on irregular or other sections when approved.

B. Place the mixture in consecutive, adjacent strips with a minimum width of 3 m except where edge lanes require strips of lesser width. Unless otherwise directed, begin placing along the centerline of crowned sections or on the high side or areas with a one-way slope.

C. Operate the paver at a speed which will give the best results for the type of paver being used and which coordinates satisfactorily with the rate of delivery of the mixture to the paver so as to provide a uniform rate of placement without intermittent operation of the paver. Regulate the speed of the paver to eliminate pulling and tearing of the bituminous mat. Use several pavers adjacent to each other (Echelon Paving) to reduce cold joints as much as possible.

D. Deliver asphaltic concrete to the paver at a temperature between 145 and 165 deg C. Do not use mixtures delivered to the paver at temperatures outside this range.

E. Place asphaltic concrete so that after rolling the nominal thickness will not exceed the range of 70-100 mm for Asphalt Base Course and shall not exceed the range of 50-75 mm for Asphalt Surface Course.

F. Make surface test to check conformity with the specified crown and grade immediately after initial compression. Correct all variations by the removal or addition of materials and by continuous rolling. The finished surface shall not vary by more than the specified tolerances. After the completion of final rolling, retest the smoothness of the course. Immediately correct all humps and depressions exceeding the specified tolerances, as approved. Replace and recompact the pavement where holes are made for test purposes.

3.10 JOINTS

A. Make joints so as to ensure thorough and continuous bond. Construct transverse construction joints free of depressions, with same texture and smoothness as other sections of hot-mix asphalt course.

B. Clean contact surfaces and apply tack coat in previously laid material by cutting the material back vertically for its full depth so as to expose a fresh surface. Transverse joints in one layer shall be offset by at least 600 mm from transverse joints in the previous layer. Transverse joints in adjacent lanes shall be offset a minimum of 3 m.

C. Offset longitudinal joints in successive layers not less than 300 mm.

D. Before placing the fresh mixture against a cut joint or against old pavement, spray or paint the contact surface with a thin uniform coat of liquid asphalt. Where a finishing machine is used, make the longitudinal joint by overlapping the screed on the previously laid material for a minimum width

of 25 mm and depositing a sufficient amount of material so that the joint formed will be smooth and tight.

3.11 COMPACTION

A. Rolling shall begin as soon as the mixture will bear the roller weight without undue displacement. The minimum temperature of the mat at which rolling shall be allowed to start is 120 ºC.

B. After spreading and strike-off, compact the asphaltic concrete to the density specified in Sub-Clause 3.17.C.3. Complete rolling before the asphalt mat temperature drops below 65 ºC.

C. Begin initial or breakdown rolling (using Steel Wheel vibratory roller specifically designed to compact HMA) as soon as the asphaltic concrete will bear the roller without undue displacement. Roll longitudinally, beginning at the low side of the work and proceeding toward the high side, or centerline.

   1. Overlay successive strips by at least one half the drum width. Alternate trips of the roller shall be of different lengths.

D. Prevent adhesion of mixture by moistening the roller drums with water; an excess of water will not be permitted. Do not use petroleum-based fuels or oil on roller drums and pneumatic tires.

E. Follow initial or breakdown rolling by intermediate rolling with an oscillating-type pneumatic-tire roller. The tires must be inflated to 60 psi minimum. Perform finish rolling with tandem steel roller. Select number and size of roller required to obtain the specified density.

F. Operate rollers continuously so that all areas of the pavement will receive substantially equal compaction. Placing will be ordered to stop at any time that proper rolling is not being performed.

G. Repairs: Remove paved areas that are defective or contaminated with foreign materials. Remove paving course over area affected and replace with fresh, hot-mix asphalt. Compact by rolling to specified density and surface smoothness.

H. Protection: After final rolling, do not permit vehicular traffic on pavement until it has cooled and hardened.

I. Erect barricades to protect paving from traffic until mixture has cooled enough not to become marked.

3.12 ASPHALT CURBS

A. Construct hot-mix asphalt curbs over compacted pavement surfaces. Apply a light tack coat unless pavement surface is still tacky and free from dust. Spread mix at minimum temperature of 121 deg C.

   1. Asphalt Mix: Same as pavement surface-course mix.

B. Place hot-mix asphalt to curb cross section indicated or, if not indicated, to local standard shapes, by machine or by hand in wood or metal forms. Tamp hand-placed materials and screed to smooth finish. Remove forms after hot-mix asphalt has cooled.

3.13 CONTACT SURFACES

A. Paint contact surfaces of concrete structures with a thin uniform coating of approved asphaltic material. Place asphaltic concrete uniformly high near contact surfaces so that after compaction it shall be 6 mm above the edge of such structures.

3.14 QUALITY CONTROL AND TESTING

A. General:

1. Testing Laboratory:

a. Employ an independent testing agency to perform the specified quality control tests, test mixes and to submit official test reports.
b. Be responsible for taking, identifying, and delivering to the test laboratory all test samples called for in this Specification. The testing laboratory shall be responsible for the testing. Collect all test results and deliver them to the Engineer in the format and detail as specified.

B. Crowned Surfaces: Test with crowned template centered and at right angle to crown. Maximum allowable variance from template is (6 mm).

3.15 SURFACE TREATMENTS

A. Slurry Seals: wherever shown on drawings, apply slurry coat in a uniform thickness according to ASTM D3910 and allow to cure.

1. Roll slurry seal to remove ridges and provide a uniform, smooth surface.

3.16 WHEEL STOPS

A. Install wheel stops in bed of adhesive as recommended by manufacturer.

B. Securely attach wheel stops to pavement with not less than two galvanized-steel dowels embedded at one-quarter to one-third points. Securely install dowels into pavement and bond to wheel stop. Recess head of dowel beneath top of wheel stop.

3.17 FIELD QUALITY CONTROL

A. Sampling: The job shall be divided into lots of 2000 metric tons of produced Asphalt. Each lot will further be subdivided into four equal sub-lots. One random sample shall be taken from each sub-lot and tested. For aggregate gradation, asphalt content and in-place density tests, samples shall be taken from in-place asphaltic concrete paving. For Marshall Test, samples shall be taken from trucks.

B. Testing: Tests shall be performed in accordance with the following:

1. Marshall Stability and Flow of Bituminous Mixtures: ASTM D6927.
2. Bulk Specific Gravity of Compacted Bituminous Mixture: ASTM D2726/D2726M.

C. Acceptance:

1. The gradation will be acceptable when variation from the approved job mix for the average of four samples is within the limits of tolerances specified.

2. The asphalt content will be acceptable when variation from the approved job mix for the average of four samples is within the limits of tolerances specified.
3. The compaction density for all bituminous courses shall be equal to or greater than 98% of the average Marshall bulk specific gravity for each day's production unless otherwise directed by the Engineer. (90% of the results shall be greater than the lower specification tolerance limit of 96.3%).
4. Surfaces: Refer to Sub-Clause 3.19.B of this specification section.
5. Elevations: Variations from grade line, elevations and cross sections are not to exceed 10 mm above or 6 mm below the elevations shown. Straightedge will be used for testing of transverse irregularities.

D. Surface Smoothness: Finished surface of each hot-mix asphalt course will be tested for compliance with smoothness tolerances (Sub-Clause 3.19. B).

E. In-Place Density: Samples of uncompacted paving mixtures and compacted pavement will be secured by testing agency according to ASTM D979/ D979M.

1. Reference laboratory density will be determined by averaging results from 4 samples of hot-mix asphalt-paving mixture delivered daily to site, prepared according to ASTM D6926, and compacted according to job-mix specifications.
2. Reference maximum theoretical density will be determined by averaging results from 4 samples of hot-mix asphalt-paving mixture delivered daily to site, prepared according to ASTM D2041/ D2041M, and compacted according to job-mix specifications.
3. In-place density of compacted pavement will be determined by testing core samples according to ASTM D1188 or ASTM D 2726/ D2726M.
4. One core sample will be taken for every 800 sq. m or less of installed pavement, but in no case will fewer than 3 cores be taken. Cores shall be reinstated by placing “Repair Cold Asphalt” in the core holes and compacting it with tamping rod to the satisfaction of the Engineer.
5. Field density of in-place compacted pavement may also be determined by nuclear method according to ASTM D2950/D2950M and correlated with ASTM D1188 or ASTM D2726/ D2726M.

F. Determination of Thickness of Courses.

1. Compensate for minor deficiencies in the thickness of any bituminous course in the pavement structure by increasing the thickness of the subsequent bituminous course. After completion of the final (surface) course any deficiencies in the thickness of any course which have not been compensated for by increasing the thickness of a subsequent course, will be considered deficiencies in the final (surface) course.
2. Cylinder core samples shall be taken as specified for in-situ bulk specified gravity core samples.
3. Thickness of bituminous courses shall be determined by average caliper measurement of cores, rounded upwards to the nearest mm.
4. Paved sections to be measured separately shall consist of each 300 lin.m section in each paved strip. The last section in each paved strip shall be 300 m plus the fractional part of 300 m remaining. Other areas such as intersections, entrances, crossovers, ramps, etc. shall be measured as one section and the thickness of each shall be determined separately. Small irregular unit areas may be included as part of another section.
5. One core shall be taken from each section at approved locations and in the presence of the Engineer. When the measurement of the core from any paved section is not deficient by more than 5 mm from the specified thickness, the core will be deemed to be of the specified thickness as shown on the Drawings.
6. When the measurement of the core from any paved section is deficient by more than 5 mm but not more than 20 mm, 2 additional cores spaced at not less than 100 m shall be taken and used together with the first core to determine the average thickness of such section.
7. When the measurement of the core from any paved section is less than the specified thickness by more than 20 mm, the average thickness of such section shall be determined by taking additional cores at not less than 5 m intervals parallel to the centerline in each direction from

the affected location until, in each direction, a core is taken which is not deficient by more than 20 mm. Exploratory cores for deficient thickness will not be used in average thickness determinations.

8. Any deficiencies in the total thickness of bituminous courses shall be subject to a proportional reduction in the volume of final (surface) course measured for payment. Alternatively, construct all at your own expense, a surface course overlay, if practicable in the judgement of the Engineer. Any such overlay shall be a minimum of 40 mm compacted thickness and to the specified standard of the course it is overlaying.
9. If the deficiency in total asphalt layers thickness is from 0 - 3mm, full payment will be made, on condition that deficiencies are not found in more than 10% of the total project. Deficiencies between 3mm and 10mm, 80% of the full payment for the bituminous courses will be made.

G. Surface texture: A texture depth of at least 1.14mm shall be achieved on completion of the asphalt surface course top layer for roadways, as determined by the sand patch test to ASTM E 965.

H. Surface Roughness of Landside roads: The International Roughness Index (IRI) for the landside roads should be carried out for all asphalt wearing course layers. The Contractor should submit for the Engineer's approval the appropriate testing instrument(s) and test methodology for the surface roughness test.

3.18 TESTING FREQUENCY

Table 6: Testing frequency

(A) Source of Materials		**(B) Control on Site**	
Required Tests (A)	**Repetition Required for all Test in (A)**	**Required Tests (B)**	**Repetition Required for all Tests in (B)**
1. Gradation of Material	As requested by Engineer	1. Coring	1 sample in every 800 m^2
2. Quality Testing on the material	1 sample in every 2000 m^3	2. Asphalt content	As requested in the Specification
-	-	3. Bulk specific gravity	As requested in the Specification
-	-	4. Volumetric tests	As requested in the Specification
-	-	5. Pavement density tests	1 sample in every 800 m^2
-	-	6. Smoothness	As requested in the Specification
-	-	7. Plastic Flow	As requested in the Specification
-	-	8. Thickness	As requested in the Specification

3.19 INSTALLATION TOLERANCES

A. Thickness: Compact each course to produce the thickness indicated within the following tolerances:

1. Asphalt Base Course: Plus or minus 10 mm.
2. Asphalt Surface Course: Plus 6 mm, no minus.

B. Surface Smoothness: Compact each course to produce a surface smoothness within the following tolerances as determined by using a 3-m straightedge applied transversely or longitudinally to paved areas:

1. Asphalt Base Course: 6mm.
2. Asphalt Surface Course: 3mm.

3. Crowned Surfaces: Test with crowned template centered and at right angle to crown. Maximum allowable variance from template is 6 mm.

END OF SECTION 321216

SECTION 321313 - CONCRETE PAVING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract, and the Project Requirements, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Exterior Portland Cement Concrete (PCC)/rigid pavement for airfield facilities.

B. Related Requirements:

1. Section 031000 “Concrete Forming and Accessories”, Section 032000 “Concrete Reinforcing”, and Section 033000 "Cast-in-Place Concrete", for general building applications of concrete.
2. Section 321373 "Concrete Paving Joint Sealants" for joint sealants in expansion and contraction joints within concrete paving and in joints between concrete paving and asphalt paving or adjacent construction.
3. Section 312000 “Earth Moving” for subgrade preparation.

1.3 DEFINITIONS

A. Cementitious Materials: Portland cement alone or in combination with one or more of cementitious additives such as fly ash, ground granulated blast-furnace slag, and silica fume.

B. Base Course: Bituminous Base Course, Cement-Treated Base Course or aggregate base course placed beneath the concrete pavement.

1.4 PREINSTALLATION MEETINGS

A. Preinstallation Conference: Conduct conference at Project site to comply with the project requirements.

1. At least 35 days prior to submitting design mixes, review concrete pavement mix design and examine procedures for ensuring quality of concrete materials. Require representatives of each entity directly concerned with concrete pavement to attend, including the following, as applicable:

a. Engineer.
b. Contractor's superintendent.
c. Independent testing agency responsible for concrete design mixes.
d. Ready-mix concrete producer.
e. Concrete subcontractor

1.5 ACTION SUBMITTALS

A. Product data for proprietary materials and items, including reinforcement (wherever applicable) and forming accessories, admixtures, joint systems, curing compounds, dry-shake finish materials, and others if requested by the Engineer.

B. Shop Drawings: Include layout, sections, and joint details.

C. Field Reports:

1. Submit three copies of the following reports directly to Engineer from the testing services:

    a. Test reports and product data verifying the suitability of aggregate (to include source of the aggregate), cement, admixtures, joint filler and sealants, dowels, tie bars, mesh reinforcement, curing material and other materials as requested by Engineer.
    b. Test report on preliminary design of concrete mix: At least 15 days prior to the start of paving operations and after approval of all material to be used in the concrete, submit a mix design showing the proportions and actual flexural strength obtained from the concrete. The mix design shall include a complete list of materials including type; brand; source and amount of cement and admixtures; and copies of test reports.

2. At least 15 days before the commencement of paving operation, submit a detailed method statement, for approval by Engineer.
3. Verification of suitability of base course, in accordance with requirements, prior to placement of pavement.
4. Pour Records (three copies): Record in an approved form, details of every pour of concrete placed in the pavement including date, location of pour, ambient temperature and temperature of concrete at placement, moisture content of aggregate, details of mix, results of tests and details of cores.
5. Weekly Records (three copies): Report covering work carried out the preceding week, to include location of all joints.
6. Monthly Records (three copies): Provide monthly histograms of all 28-day cube or cylinder strengths and accumulative standard deviations and other information, which the Engineer may require concerning placement of the pavement.

1.6 INFORMATIONAL SUBMITTALS

A. Qualification Data: For firms and persons specified in the "Quality Assurance" Article to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names and addresses of engineers and employers, and other information specified.

B. Design Mixes: For each concrete pavement mix. Include alternate mix designs when characteristics of materials, project conditions, weather, test results, or other circumstances warrant adjustments.

C. Samples: 4.5-kg sample of exposed aggregate.

D. Material Test Reports: From a qualified testing agency indicating and interpreting test results for compliance of the following with requirements indicated, based on comprehensive testing of current materials:

E. Material Certificates: Signed by manufacturers certifying that each of the following materials complies with requirements:

1. Cement, Cementitious materials and aggregates.
2. Steel reinforcement and reinforcement accessories.
3. Admixtures.
4. Curing compounds.
5. Applied finish materials.

6. Bonding agent or adhesive.
7. Joint fillers.

F. Photographs or videotape, sufficiently detailed, of existing conditions of adjoining construction and site improvements that might be misconstrued as damage caused by installation or failure of special excavation support and protection systems.

G. Minutes of preinstallation conference.

H. Material Test Report: Indicate and interpret test results for compliance of materials with requirements indicated.

1.7 QUALITY ASSURANCE

A. All materials and equipment shall demonstrate compliance with the project requirements.

B. Codes and Standards: Comply with the Provisions of the following standards, except where more stringent requirements are specified or shown on Drawings:

1. Federal Aviation Administration (FAA) advisory circulars.
2. ACI 211.1, 301, 305.1 and 318.
3. CRSI "Manual of Standard Practice".

C. Material and Installed Work: May require testing and re-testing at any time during progress of work. Tests, including re-testing of rejected material for installed work, shall be done at own expense.

D. Installer Qualifications: An experienced installer who has completed pavement work similar in material, design, and extent to that indicated for this Project and whose work has resulted in construction with a record of successful in-service performance.

E. Manufacturer Qualifications: A firm experienced in manufacturing ready-mixed concrete products complying with ASTM C94/ C94M requirements for production facilities and equipment.

F. Testing Agency Qualifications: An independent testing agency, acceptable to Engineer, qualified according to ASTM C1077 and ASTM E 329 to conduct the testing indicated.

G. Source Limitations: Obtain each type or class of cementitious material of the same brand from the same manufacturer's plant and each aggregate from one source.

H. Equipment and Tools: As necessary for handling materials and performing all parts of the work shall be approved by Engineer as to design, capacity, and mechanical condition. The equipment shall be at the job site before the start of construction operations for examination and approval.

I. Concrete Testing Service: Engage a qualified independent testing agency to perform material evaluation tests, design concrete mixes, and perform field quantity control testing.

J. Mockups: Cast mockups of full-size sections of concrete pavement to demonstrate typical joints, surface finish, texture, color, and standard of workmanship.

1. Build mockups in the location and of the size indicated or, if not indicated, as directed by Engineer.
2. Notify Engineer seven days in advance of dates and times when mockups will be constructed.
3. Obtain Engineer's approval of mockups before starting construction.
4. Maintain approved mockups during construction in an undisturbed condition as a standard for judging the completed pavement.
5. Demolish and remove approved mockups from the site when directed by Engineer.

6. Approved mockups may become part of the completed Works if undisturbed at time of Taking Over.

1.8 FIELD/PROJECT CONDITIONS

A. Protect Finished Pavement: Protect from spatter during concrete placement of adjacent sections.

B. Protect Fresh Concrete: Cover completed fresh concrete with temporary cover as required to protect newly cast pavement from direct sun in hot weather - above 35 deg C - and maintain cover until curing starts.

C. Protect Immature Concrete: Protect from physical shock, movement, thermal shock and cold water.

D. Protect Surfaces: Protect from rain, wind, sun, indentation and physical damage.

E. Traffic Control: Maintain access for vehicular and pedestrian traffic as required for other construction activities.

PART 2 - PRODUCTS

2.1 FORMS

A. Form Materials: Plywood, metal, metal-framed plywood, or other approved panel-type materials to provide full-depth, continuous, straight, smooth exposed surfaces.

1. Use flexible or curved forms for curves of a radius 30 m or less.

B. Form-Release Agent: Commercially formulated form-release agent that will not bond with, stain, or adversely affect concrete surfaces and will not impair subsequent treatments of concrete surfaces.

2.2 STEEL REINFORCEMENT: Refer to relevant parts in Section 033000 “Cast in Place Concrete”.

A. Reinforcement Bars: ASTM A615/ A615M, Grade 60, deformed.

B. Plain Steel Wire: ASTM A1064 / A1064M, cold-drawn steel.

C. Welded Deformed Steel Wire Fabric: ASTM A1064/ A1064M.

D. Joint Dowel Bars: Plain-steel bars, ASTM A615 /A615M, Grade 60. Cut bars true to length with ends square and free of burrs.

E. Dowel Bars: High tensile plain steel bars conforming to BS 4449, ASTM A615/ A165M, ASTM A955/ A955M, and shall be free from burring or other deformation restricting slippage in the concrete. Before delivery to the construction site, a minimum of two-thirds of the length of each dowel bar shall be painted with one coat of zinc-chromate. If plastic or epoxy-coated steel dowels are used, no zinc-chromate coating is required, except when specified for a particular situation on the contract plans. Coated dowels shall conform to the requirements given in AASHTO M254.

F. Tie Bars: ASTM A615/A615M, Grade 60, deformed.

G. Sleeves: Metal, of an approved design to cover 50mm to 75mm of the dowel, with a closed end and with a suitable stop to hold the end of the bar at least 25mm from the closed end of the sleeve. Sleeves shall be of such design that they will not collapse during construction.

H. Hook Bolts: AASHTO M291, Property Class 4.6, internally and externally threaded. Design hook-bolt joint assembly to hold coupling against pavement form and in position during concreting operations, and to permit removal without damage to concrete or hook bolt.

I. Bar Supports: Bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcement bars, welded wire fabric, and dowels in place. Use wire bar type supports complying to CRSI's "Manual of Standard Practice".

1. For exposed-to-view concrete surfaces, where legs of wire bar support contract forms, use CRSI, Class 1 plastic protected, or CRSI Class 2 stainless steel, bar supports.

J. Epoxy Repair Coating: Liquid two-part epoxy repair coating, compatible with epoxy coating on reinforcement.

2.3 CONCRETE MATERIALS

A. General: Use the same brand and type of cementitious material from the same manufacturer throughout the Project, unless otherwise accepted by Engineer.

B. Portland Cement: Conform to ASTM C 150 Type II or BS EN 197-1 Type CEM I 42.5N, C3A content lower than 8%. Do not use cement meeting the requirements of rapid hardening Portland Cement. Use OPC with the heat of hydration not exceeding 325kJ per kg when tested in accordance with ASTM C 186. Do not use OPC with the tricalcium- aluminate (C3A) content less than 4% by weight as tested in accordance with ASTM C 114.

C. Aggregate: Shall conform to the requirements of ASTM C33/ C33M. Aggregates shall consist of crushed stone, crushed or uncrushed gravel, or natural sand. The aggregate shall be composed of sound, tough, durable particles and shall meet the requirements for deleterious substances given in ASTM C33/ C33M or BS EN 12620. The aggregate in any size group shall not contain more than 8 percent by weight of flat or elongated pieces when tested in accordance with ASTM D4791. A flat or elongated particle is one having a ratio between the maximum and the minimum dimensions of a circumscribing rectangular prism exceeding 5 to 1. Uniformly graded, from a single source, with coarse aggregate as follows:

1. Maximum Aggregate Size: 25 mm nominal.
2. Do not use fine or coarse aggregates containing substances that cause spalling.

D. Exposed Aggregate: Selected, hard, and durable; washed; free of material that reacts with cementitious material or causes staining.

E. Reactivity: Fine and Coarse aggregates to be used in PCC on this project shall be tested and evaluated by the Contractor for alkali-aggregate reactivity in accordance with both ASTM C1260 and ASTM C157. Tests must be representative of aggregate sources which will be providing material for production. ASTM C1260 and ASTM C1567 tests may be run concurrently.

F. The aggregates shall have no known history of detrimental pavement staining. Aggregates from steel blast furnace slag is not permitted.

G. Aggregate Gradation:

1. Fine Aggregate: Conform to the requirements of ASTM C33/ C33M. The % fines (material passing #200 sieve) shall not exceed 3%. The sand equivalent of the fine aggregate material shall be 60 minimum when tested according to ASTM D2419 and the specific gravity and % absorption shall be 2.6 minimum and 2% maximum, respectively, when tested according to ASTM C128.

2. Coarse Aggregate: Conform to the requirements of ASTM C33/ C33M, depending on the maximum aggregate size of the material used. The percentage of wear shall be no more than

30% when tested in accordance with ASTM C131/ C131M. The specific gravity and % absorption shall be 2.6 minimum and 2% maximum, respectively, when tested according to ASTM C127.

3. The combined gradation shall be validated in full compliance with FAA 150-5370-10H and considering the requirements of the United States Air Force Engineering Technical Letter (ETL) 97-5: Proportioning Concrete Mixtures with Graded Aggregates for Rigid Airfield Pavements, as directed and approved by the Engineer.

H. Water: Water used in mixing or curing shall be as clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substances injurious to the finished product as possible. Water will be tested in accordance with the requirements of ASTM C1602/C1602M, ASTM C94/C94M. The chloride content shall not exceed 500ppm.

2.4 ADMIXTURES

A. General: Admixtures certified by manufacturer to contain not more than 0.1 percent water-soluble chloride ions by mass of cement and to be compatible with other admixtures.

B. General: The use of any material added to the concrete mix shall be approved by Engineer. Submit certificates indicating that the material to be furnished meets all of the requirements indicated below. In addition, Engineer may require the submittal of complete test data from an approved laboratory showing that the material to be furnished meets all of the requirements of the cited specifications. Subsequent tests will be made of samples taken by Engineer from the supply of the material being furnished or proposed for use on the work to determine whether the admixture is uniform in quality with that approved.

C. Air Entraining Admixtures: Air-entraining admixtures shall meet the requirements of ASTM C260/C260M and shall be added to the mix in the amount necessary to produce the specified air content. The air-entrainment agent and the water reducer admixture shall be compatible.

D. Chemical Admixtures: Water reducing, set-retarding, and set-accelerating admixtures shall meet the requirements of ASTM C494/ C494M.

1. Water-Reducing Admixture: ASTM C494/ C494M, Type A.
2. High-Range, Water-Reducing Admixture: ASTM C494/ C494M, Type F.
3. Water-Reducing and Accelerating Admixture: ASTM C494/ C494M, Type E.
4. Water-Reducing and Retarding Admixture: ASTM C494/ C494M, Type D.

2.5 CURING MATERIALS

A. Absorptive Cover: AASHTO M 182, Class 2, burlap cloth made from jute or kenaf, weighing approximately. 305 g/sq. m dry.

B. Moisture-Retaining Cover: ASTM C171, polyethylene film or white burlap-polyethylene sheet.

C. Water: Potable.

D. Evaporation Retarder: Waterborne, monomolecular film forming, manufactured for application to fresh concrete.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

E. Clear Solvent-Borne Liquid-Membrane-Forming Curing Compound: ASTM C309, Type 1, Class B.

F. Clear Waterborne Membrane-Forming Curing Compound: ASTM C309, Type 1, Class B.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

G. White Waterborne Membrane-Forming Curing Compound: ASTM C 309, Type 2, Class B.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

2.6 RELATED MATERIALS

A. Premolded Joint Filler: Conform to the requirements of ASTM D1751 and shall be punched to admit the dowels where called for on the plans.

1. Expansion- and Isolation-Joint-Filler Strips: ASTM D1751, asphalt-saturated cellulosic fiber.
2. Expansion- and Isolation-Joint-Filler Strips: ASTM D1752, cork or self-expanding cork.
3. Expansion- and Isolation-Joint-Filler Strips: ASTM D 1751, asphalt-saturated cellulosic fiber, or ASTM D1752, cork or self-expanding cork.

B. Joint Filler: Furnished in a single piece for the full depth and width required for the joint, unless otherwise specified by Engineer. When the use of more than one piece is authorized for a joint, the abutting ends shall be fastened securely and held accurately to shape by stapling or other positive fastening means satisfactory to Engineer.

C. Joint Sealer: Meet the requirements of Division 32 Section 321373 “Concrete Paving Joint Sealants” of the specification and shall be of the type(s) specified on drawings.

D. Coloring Agent: ASTM C979/ C979M, synthetic mineral-oxide pigments or colored water-reducing admixtures; color stable, nonfading, and resistant to lime and other alkalis.

1. Color: As indicated by manufacturer's designation.
2. Color: Match Engineer’s sample.
3. Color: As selected by Engineer from manufacturer's full range.

E. Bonding Agent: ASTM C 1059 /C1059M, Type II, non-redispersible, acrylic emulsion or styrene butadiene.

F. Epoxy Bonding Adhesive: ASTM C881/ C881M, two-component epoxy resin, capable of humid curing and bonding to damp surfaces, of class and grade to suit requirements, and as follows:

1. Type II, non-load bearing, for bonding freshly mixed concrete to hardened concrete.
2. Types I and II, non-load bearing, for bonding hardened or freshly mixed concrete to hardened concrete.
3. Types IV and V, load bearing, for bonding hardened or freshly mixed concrete to hardened concrete.

G. Chemical Surface Retarder: Water-soluble, liquid set retarder with color dye, for horizontal concrete surface application, capable of temporarily delaying final hardening of concrete to a depth of 3 to 6 mm.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

H. Pigmented Mineral Dry-Shake Hardener: Factory-packaged, dry combination of Portland Cement, graded quartz aggregate, color pigments, and plasticizing admixture. Use color pigments that are finely ground, nonfading mineral oxides interground with cement.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

I. Colored Dry-Shake Hardener: Factory-packaged dry combination of Portland cement, graded quartz aggregate, coloring pigments, and plasticizing admixture. Use coloring pigments that are finely ground, nonfading mineral oxides interground with cement.

1. Color Hardener.
2. Color: As indicated by manufacturer's designation.
3. Color: Match Engineer’s samples.
4. Color: As selected by Engineer from manufacturer's full range.

2.7 DETECTABLE WARNING MATERIALS

A. Detectable Warning Stamp: Semi-rigid polyurethane mats with formed underside capable of imprinting detectable warning pattern on plastic concrete; perforated with a vent hole at each dome.

1. Manufacturers: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.
2. Size of Stamp: One piece matching detectable warning area shown on Drawings

B. Liquid Release Agent: Manufacturer's standard, clear, evaporating formulation designed to facilitate release of stamp mats.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

2.8 WHEEL STOPS

A. Wheel Stops: Precast, air-entrained concrete,17.2-MPa minimum compressive strength, as per the dimensions shown on the Drawings. Provide chamfered corners and drainage slots on underside and holes for anchoring to substrate.

1. Dowels: Galvanized steel, 20 mm in diameter, 250 mm minimum length.

B. Wheel Stops: Solid, integrally colored, 96 percent recycled HDPE, or commingled postconsumer and postindustrial recycled rubber or plastic; UV stabilized; as per the dimensions shown on the Drawings. Provide chamfered corners and drainage slots on underside and holes for anchoring to substrate.

1. Color: As indicated on the Drawings.
2. Dowels: Galvanized steel, 20 mm in diameter, 250 mm minimum length.
3. Adhesive: As recommended by wheel stop manufacturer for application to concrete pavement.

2.9 CONCRETE MIXES

A. Prepare design mixes, proportioned according to ACI 211.1 and ACI 301, for each type and strength of normal-weight concrete determined by laboratory trial mixes.

B. Use a qualified independent testing agency for preparing and reporting proposed mix designs for the trial batch method.

1. Do not use Employer's field quality-control testing agency as the independent testing agency.

2. The laboratory used to develop the concrete mix shall be accredited in accordance with ASTM C1077.

C. Proportion mixes to provide concrete with the following properties using test specimens prepared in accordance with ASTM C31/ C31M and tested with ASTM C78/ C78M:

1. Cement Concrete Pavement Layer:

a. Flexural Strength (28 Days): 5.0 MPa. Flexural strength test specimens shall be prepared in accordance with ASTM C192 and tested in accordance with ASTM C78.
b. Compressive Strength (28 days): 40 Mpa
c. The minimum cementitious material shall be adequate to ensure a workable, durable mix.
d. The minimum cementitious material content shall be 380 kg per cubic meter. The ratio of water to cementitious material, including free surface moisture on the aggregates but not including moisture absorbed by the aggregates shall not be more than 0.4 by weight.
e. Slump Limit:

1) The mix determined shall be workable concrete having where the slump should be determined according to ASTM C143.

2) The allowable slump should not to exceed 2 inches (50 mm) for slip-form placement. For fixed-form placement, the slump shall not exceed 3 inches (75 mm). For hand placement, the slump shall not exceed 4 inches (100 mm).

f. Absorption and Permeability tests on hardened concrete: Water Absorption test to BS 1881-122 standard and Depth of Penetration Permeability test to BS EN 12390-8 standard should be carried out on hardened concrete. The mean water absorption of the tested concrete shall not exceed 2% and the depth of penetration shall not exceed 15 mm.

2. Lean Concrete Base Course Layer:
a. Compressive Strength (28 days): 14 Mpa
b. Minimum Cement content: 250 kg per cubic meter.
c. Maximum water to cement ratio: 0.5.
d. Maximum Air content: 2%.
e. Slump Limit: The mix determined shall be workable concrete having a slump for side-form concrete between 25 mm and 50 mm as determined by ASTM C143.
f.

D. Cementitious Materials: Limit percentage, by weight, of cementitious materials other than Portland cement (if used) in concrete as follows:

1. Fly Ash: 25-35%.
2. Ground Granulated Blast-Furnace Slag: 50-60%

E. Air Entraining: Air-entraining admixture shall be added in such a manner that will insure uniform distribution of the agent throughout the batch. The air content of freshly mixed air-entrained concrete shall be based upon trial mixes with the materials to be used in the work adjusted to produce concrete of the required plasticity and workability. The percentage of air-entrainment in the mix shall be in accordance with the percentages specified under sub-clause F below plus or minus 1-1/2

percentage points. Air content shall be determined by testing in accordance with ASTM C231/ C231M.

F. Add air-entraining admixture at manufacturer's prescribed rate to result in concrete at point of placement having an air content of 3% for the 25mm Maximum Aggregate Size or 3.5% for the 19mm Maximum Aggregate Size for mild exposures.

G. Chemical Admixtures: Water-reducing and set-controlling admixtures shall be added to the mix in the manner recommended by the manufacturer and in the amount necessary to comply with the specification requirements. Tests shall be conducted on trial mixes, during the mix design, in accordance with ASTM C494/ C494M.

H. Coloring Agent: Add coloring agent to mix (if required) according to manufacturer's written instructions.

I. Slip-form Construction: A high degree of uniformity in the plastic concrete is required. Caution should be exercised in establishing the air-entrainment percentage, as excessive air entrainment will aggravate edge slumping and insufficient air entrainment will result in poor concrete durability. Some edge slump of the wet concrete behind the side form on the paving machine will occur, even with low slump concrete. This may continue, though very slowly, until initial set has taken place.

2.10 CONCRETE MIXING

A. Ready-Mixed Concrete: Comply with requirements and with ASTM C94/ C94M and ASTM C1116 /C1116M. Furnish batch certificates for each batch discharged and used in the Works.

1. When air temperature is between 30 deg C and 32 deg C, reduce mixing and delivery time from 1-1/2 hours to 75 minutes; when air temperature is above 32 deg C, reduce mixing and delivery time to 60 minutes.

B. Project-Site Mixing: Comply with requirements and measure, batch, and mix concrete materials and concrete according to ASTM C94/ C94M. Mix concrete materials in appropriate drum-type batch machine mixer.

1. For mixers of 0.76 cu. m or smaller capacity, continue mixing at least one and one-half minutes, but not more than five minutes after ingredients are in mixer, before any part of batch is released.
2. For mixers of capacity larger than 0.76 cu. m, increase mixing time by 15 seconds for each additional 0.76 cu. m.
3. Provide batch ticket for each batch discharged and used in the Works, indicating Project identification name and number, date, mix type, mix time, quantity, and amount of water added.

C. Concrete:

1. May be mixed at the work site, in a central mix plant or in truck mixers. The mixer shall be of an approved type and capacity. Mixing time shall be measured from the time all materials, except water, are emptied into the drum.
2. Ready-mixed concrete shall be mixed and delivered in accordance with the requirements of ASTM C94/ C94M, except that the minimum required revolutions of the mixing speed for transit mixed concrete may be reduced to not less than that recommended by the mixer manufacturer.
3. The number of revolutions recommended by the mixer manufacturer shall be indicated on the manufacturer's serial plate attached to the mixer.
4. Furnish test data acceptable to Engineer verifying that the make and model of the mixer will produce uniform concrete conforming to the provisions of ASTM C94/ C94M at the reduced number of revolutions shown on the serial plate.

D. When mixed at the work site or in a central mixing plant, the mixing time shall not be less than 50 seconds nor more than 90 seconds. Mixing time ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein.

E. Mixer:

1. Operated at the drum speed as shown on the manufacturer's nameplate on the approved mixer. Any concrete mixed less than the specified time shall be discarded at own expense.
2. The volume of concrete mixed per batch shall not exceed the mixer's nominal capacity in cubic meters, as shown on the manufacturer's standard rating plate on the mixer.
3. An overload up to 10 percent above the mixer's nominal capacity may be permitted provided concrete test data for segregation and uniform consistency are satisfactory and provided no spillage of concrete takes place.

F. Batch: Charged into the drum so that a portion of the mixing water shall enter in advance of the cement and aggregates. The flow of water shall be uniform, and all water shall be in the drum by the end of the first 15 seconds of the mixing period. The throat of the drum shall be kept free of such accumulations as may restrict the free flow of materials into the drum.

G. Mixed Concrete:

1. Central mixing plant concrete shall be transported in truck mixers, truck agitators, or non-agitating trucks.
2. The time elapsing from the time water is added to the mix until the concrete is deposited in place at the work site shall not exceed 30 minutes when the concrete is hauled in non-agitating trucks, nor 45 minutes when the concrete is hauled in truck mixers or truck agitators. All these operations must be performed within 45 minutes after the initial mixing operations and the water-cement ratio must not be exceeded.
3. Admixtures for increasing the workability or for accelerating the set will be permitted only when specified for in the contract.

2.11 LIMITATIONS OF MIXING:

A. No concrete shall be mixed, placed, or finished when the natural light is insufficient, unless an adequate and approved artificial lighting system is operated.

B. Unless authorized in writing by Engineer, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches 4 deg. C and shall not be resumed until an ascending air temperature in the shade and away from artificial heat reaches 2 deg C.

C. When concreting is authorized during cold weather the temperature of the mixed concrete shall not be less than 10 deg. C at the time of placement in the forms.

D. During periods of hot weather when the maximum daily air temperature exceeds 30 deg C, the following precautions should be taken: the forms and/or the underlying material shall be sprinkled with water immediately before placing the concrete. The concrete shall be placed at the coolest temperature practicable, and in no case shall the temperature of the concrete when placed exceed 32 deg. C. The aggregates and/or mixing water shall be cooled as necessary to maintain the concrete temperature at or not more than the specified maximum. Refer to ACI 305R “Guide to Hot Weather Concreting”.

PART 3 - EXECUTION

3.1 PREPARATION

A. Proof-roll prepared subbase surface to check for unstable areas and verify need for additional compaction. Proceed with pavement only after nonconforming conditions have been corrected and subgrade is ready to receive pavement.

B. Remove loose material from compacted subbase surface immediately before placing concrete.

3.2 EDGE FORMS AND SCREED CONSTRUCTION

A. Set, brace, and secure edge forms, bulkheads, and intermediate screed guides for paving to required lines, grades, and elevations. Install forms to allow continuous progress of work and so that forms can remain in place at least 24 hours after concrete placement.

B. Forms shall be securely set so that they can withstand impacts and vibration of consolidating and finishing equipment without visible spring or settlement. Extend flange braces on the base outward for not less than two thirds of the height of the form. Remove bent, twisted or broken forms, and forms with damaged top surfaces. Use of repaired forms only with inspection and approval. Built-up forms will not be allowed, unless specifically approved. The top faces of forms are not to vary from a true plane by more than 3 mm in 3m. The upstanding leg shall be perpendicular to the base and is not to vary horizontally from true alignment by more than 6 mm at any point. The ends of abutting sections lock together tightly for secure setting. Local defects, such as kinks in steel forms, will not be allowed.

C. Setting: Forms shall be set ahead of concrete placement and staked into place with at least three pins for each 3 m section. A pin shall be placed at each side of every joint. Form sections shall be tightly locked and free from movement in any direction. Excessive settlement or springing from operation of the finishing machine will not be allowed. Forms shall be cleaned and oiled before concrete placement.

1. The alignment and grade elevations of the forms shall be checked, and corrections made immediately before placing concrete. Reset and recheck forms when they have been disturbed, or when the grade has become unstable.

D. Clean forms after each use and coat with form release agent as required to ensure separation from concrete without damage.

E. Removal: Do not remove forms until the concrete has set for at least 12 hours, unless otherwise approved or where auxiliary forms are used temporarily in widened areas. Remove forms carefully to avoid damaging the pavement, and after removal, the side of the slab shall be cured by the method specified in Article 3.9.

3.3 STEEL REINFORCEMENT

A. General: Comply with CRSI's "Manual of Standard Practice" for fabricating reinforcement and with recommendations in CRSI's "Placing Reinforcing Bars" for placing and supporting reinforcement.

B. Clean reinforcement of loose rust and mill scale, earth, or other bond-reducing materials.

C. At the time concrete is placed the reinforcing bars shall be free of mud, oil or other organic matter that may adversely affect or reduce bond. Reinforcing steel with rust, mill scale, or a combination of both will be considered satisfactory, provided the minimum dimensions, weight, and tensile

properties of a hand wire-brushed test specimen are not less than the applicable ASTM specification requirements.

D. Accurately position, support, and secure reinforcement against displacement by formwork, construction, or concrete placement operations. Locate and support reinforcing bars by metal chairs, runners, bolsters, spacers, and hangers, as required.

E. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position during concrete operations. Set wire ties so ends are directed into concrete, not toward exposed concrete surfaces. Maintain minimum cover to reinforcement.

F. Install welded wire fabric in lengths as long as practicable. Lap adjoining pieces at least one full mesh, and lace splices with wire. Offset laps of adjoining widths to prevent continuous laps in either direction.

G. Install fabricated bar mats in lengths as long as practicable. Handle units to keep them flat and free of distortions. Straighten bends, kinks, and other irregularities, or replace units as required before placement. Set mats for a minimum 50-mm overlap to adjacent mats.

3.4 PLACEMENT OF REINFORCEMENT

A. Reinforced Concrete Pavement: Comply with Concrete Reinforcing Steel Institute's recommended practice for "Placing Reinforcing Bars", for details and methods of reinforcement placement and supports, and as herein specified:

1. At the time concrete is placed the reinforcing bars shall be free of mud, oil or other organic matter that may adversely affect or reduce bond. Reinforcing steel with rust, mill scale, or a combination of both will be considered satisfactory, provided the minimum dimensions, weight, and tensile properties of a hand wire-brushed test specimen are not less than the applicable ASTM specification requirements.
2. Accurately position, support, and secure reinforcement against displacement by formwork, construction, or concrete placement operations. Locate and support reinforcing bars by metal chairs, runners, bolsters, spacers, and hangers, as required.
3. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position during concrete placement operations. Set wire ties so ends are directed into concrete, not toward exposed concrete surfaces.
4. Install welded wire fabric in as long lengths as practicable. Lap adjoining pieces at least one full mesh and lace splices with wire. Offset end laps in adjacent widths to prevent continuous laps in either direction.

3.5 JOINTS

A. General: Construct construction, isolation, and contraction joints and tool edgings true to line with faces perpendicular to surface plane of concrete. Construct transverse joints at right angles to centerline, unless otherwise indicated.

1. When joining existing pavement, place transverse joints to align with previously placed joints, unless otherwise indicated.

B. Construction Joints: Set construction joints at side and end terminations of pavement and at locations where pavement operations are stopped for more than one-half hour, unless pavement terminates at isolation joints.

1. Provide preformed galvanized steel or plastic keyway-section forms or bulkhead forms with keys, unless otherwise indicated. Embed keys at least 38 mm into concrete.
2. Continue reinforcement across construction joints, unless otherwise indicated. Do not continue reinforcement through sides of pavement strips, unless otherwise indicated.

3. Provide tie bars at sides of pavement strips where indicated.
4. Use a bonding agent at locations where fresh concrete is placed against hardened or partially hardened concrete surfaces.
5. Use epoxy bonding adhesive at locations where fresh concrete is placed against hardened or partially hardened concrete surfaces.

C. Isolation Joints: Form isolation joints of preformed joint-filler strips abutting concrete curbs, catch basins, manholes, inlets, structures, walks, other fixed objects, and where indicated.

1. Locate expansion joints at intervals indicated on drawings.
2. Extend joint fillers full width and depth of joint.
3. Terminate joint filler less than 12 mm or more than 25 mm below finished surface if joint sealant is indicated.
4. Place top of joint filler flush with finished concrete surface if joint sealant is not indicated.
5. Furnish joint fillers in one-piece lengths. Where more than one length is required, lace or clip joint-filler sections together.
6. Protect top edge of joint filler during concrete placement with metal, plastic, or other temporary preformed cap. Remove protective cap after concrete has been placed on both sides of joint.

D. Longitudinal and Transverse Joints: Constructed as indicated on the plans and in accordance with the following requirements:

1. All joints shall be constructed true to line with their faces perpendicular to the surface of the pavement.
2. Joints shall not vary more than 12mm from a true line or from their designated position.
3. The vertical surface of the pavement adjacent to all expansion joints shall be finished to a true plane and edged to a radius of 6mm or as shown on the plans.
4. The surface across the joints shall be tested with a 3m straightedge as the joints are finished and any irregularities in excess of 6mm shall be corrected before the concrete has hardened.
5. Transverse joints shall be at right angles to the centerline of the pavement and shall extend the full width of the slab.
6. The transverse joints in succeeding lanes shall be placed in line with similar joints in the first lane. All joints shall be so prepared, finished, or cut to provide a groove of the width and depth shown on the plans.

E. Slip-Form Construction: Transverse joints with dowels will require particular care to ensure the dowels are accurately placed and not disturbed during concrete placement.

1. Transverse dowels will require use of an apparatus to firmly hold the dowels perpendicular to the joint and parallel to the slab surface.
2. During the concrete placement operation, it is advisable to place plastic concrete directly on the dowel assembly immediately prior to passage of the paver to help maintain dowel alignment.

F. Tie Bars: Deformed bars installed principally in longitudinal joints as shown on the plans.

1. Tie bars shall be placed at right angles to the centerline of the concrete slab and shall be spaced at intervals shown on Drawings.
2. Tie bars shall be held in position parallel to the pavement surface and midway between the surfaces of the slab.
3. When tie bars extend into an unpaved lane, they may be bent at right angles against the form at longitudinal construction joints, unless threaded bolt or other assembled tie bars are specified.
4. Tie bars shall not be painted, greased, or enclosed in sleeves.

G. Dowel Bars: Dowel bars or other load-transfer units of an approved type shall be placed across transverse or other joints in the manner as specified on the plans.

1. They shall be of the dimensions and spacing as shown and held rigidly in the middle of the slab depth in the proper horizontal and vertical alignment by an approved assembly device to be left permanently in place.
2. The dowel or load-transfer and joint devices shall be rigid enough to permit complete assembly as a unit ready to be lifted and placed into position.
3. A metal or other type dowel expansion cap of sleeve shall be furnished for each dowel bar used with expansion joints.
4. These caps shall be substantial enough to prevent collapse and shall be placed on the ends of the dowels as shown on the plans.
5. The caps or sleeves shall fit the dowel bar tightly and the closed end shall be watertight.
6. The portion of each dowel painted with rust preventative paint and shall be thoroughly coated with asphalt MC-70, or an approved lubricant, to prevent the concrete from binding to that portion of the dowel.

H. Install dowel bars and support assemblies at joints where indicated. Lubricate or asphalt-coat one-half of dowel length to prevent concrete bonding to one side of joint.

I. Joints Installation:

1. The top of an assembled joint device shall be set at the proper distance below the pavement surface and the elevation shall be checked. Such devices shall be set to the required position and line and shall be securely held in place by stakes or other means during the pouring and finishing of the concrete. The pre-molded joint material shall be placed and held in a vertical position; if constructed in sections, there shall be no offsets between adjacent units. Dowel bars shall be checked for exact position and alignment as soon as the joint device is staked in place, and the device shall be tested to determine whether it is firmly supported. The maximum permissible tolerance on dowel bar alignment in each plane, horizontal and vertical, shall not exceed 2 percent or 6mm per 300 mm of a dowel bar. The most effective way to obtain proper alignment is with well-fabricated dowel baskets and dowel assemblies.
2. When joints in concrete pavements are sawed, the joints shall be cut as shown on the plans. The circular cutter shall be capable of cutting a groove in a straight line and shall produce a slot at least 3mm wide so as to provide proper shape factor W/D for optimum performance in accordance with the manufacturer recommendations as shown on the plans. The groove edges shall be 6mm by 6mm chamfered or smoothed by a radius of 6mm to form a “bull nose” shape, depending on the type of joint and as shown on the drawings. When shown on the plans or required by the specifications, the top portion of the slot groove shall be widened by means of a second shallower cut or by suitable and approved beveling to provide adequate space for joint sealers. Sawing of the joints shall commence as soon as the concrete has hardened sufficiently to permit cutting without chipping, spalling, or tearing. Sawing shall be carried on both during the day and night as required. The joints shall be sawed at the required spacing consecutively in sequence of the concrete placement, unless otherwise approved by Engineer.

J. Contraction Joints: Form weakened-plane contraction joints, sectioning concrete into areas as indicated. Construct contraction joints for a depth equal to at least one-fourth of the concrete thickness, as follows:

1. Grooved Joints: Form contraction joints after initial floating by grooving and finishing each edge of joint with groover tool to the radius shown on drawings. Repeat grooving of contraction joints after applying surface finishes. Eliminate groover marks on concrete surfaces.
2. Sawed Joints: Form contraction joints with power saws equipped with shatterproof abrasive or diamond-rimmed blades. Cut joints into concrete to the width shown on drawings, when cutting action will not tear, abrade, or otherwise damage surface and before developing random contraction cracks.

K. Longitudinal Joints:

1. Construction Type: Longitudinal construction joints necessary for lane construction shall be formed against suitable side forms as indicated in the plans. Wooden forms may be used under special conditions, when approved by Engineer. Where butt-type joints with dowels are designated, the dowels for this type shall be painted and greased. The edges of the joint shall be finished with a grooving tool or edging tool, and a space or slot shall be formed along the joint of the dimensions, as indicated, to receive the joint sealing material. Longitudinal construction joints shall be sawed to provide a groove at the top conforming to the details and dimensions indicated on the plans. Provisions shall be made for the installation of tie bars as noted on the plans.
2. Contraction or Weakened - Plane Type: Longitudinal groove formed or sawed in the top of the slab shall be installed where indicated on the drawings. The groove shall be formed in the plastic concrete with suitable tools or material to obtain the width and depth specified, or it shall be sawed with approved equipment in the hardened concrete to the dimensions required. When the groove is formed in plastic concrete, it shall be true to line with not more than 6mm variation in 3m; it shall be uniform in width and depth; and the sides of the groove shall be finished even and smooth with an edging tool. If an insert material is used, the installation and edge finish shall be according to the manufacturer's instructions. The sawed groove shall be straight and of uniform width and depth. In either case, the groove shall be clean cut so that spalling will be avoided at intersections with transverse joints. Tie bars shall be installed across these joints where indicated on the plans.
3. Expansion Type: Longitudinal expansion joints shall be installed as indicated on the plans. The pre-moulded filler, of the thickness as shown on the plans, shall extend for the full depth and width of the slab at the joint, except for space for sealant at the top of the slab. The filler shall be securely staked or fastened into position perpendicular to the proposed finished surface. A metal cap shall be provided to protect the top edge of the filler and to permit the concrete to be placed and finished. After the concrete has been placed and struck off, the cap shall be carefully withdrawn leaving the space over the pre-moulded filler. The edge of the joint shall be finished and tooled while the concrete is still plastic.

L. Transverse Joints:

1. Expansion Type:

    a. Transverse expansion joints shall be installed at the locations and spacing as shown on the plans. The joints shall be installed at right angles to the centerline and perpendicular to the surface of the pavement. The joints shall be installed and finished to insure complete separation of the slabs. Expansion joints shall be of a pre-moulded type conforming to these specifications and with the plans and shall be the full width of the pavement strip.
    b. All concrete shall be cleaned from the top of the joint material. Before the pavement is opened to traffic, this space shall be swept clean and filled with approved joint sealing material.
    c. All devices used for the installation of expansion joints shall be approved by Engineer. They shall be easily removable without disturbing the concrete and held in proper transverse and vertical alignment. Immediately after forms are removed, any concrete bridging the joint space at the ends shall be removed for the full width and depth of the joint.
    d. When specified, expansion joints shall be equipped with dowels of the dimensions and at the spacing and location indicated on the plans. The dowels shall be firmly supported in place and accurately aligned parallel to the subgrade and the centerline of the pavement by means of a dowel assembly, which will remain in the pavement and will ensure that the dowels are not displaced during construction.

2. Contraction Type: Transverse contraction joints, weakened-plane joints, or both, shall be installed at the locations and spacing as shown on the plans. These joints will be installed by forming a groove or cleft in the top of the slab while the concrete is still plastic or by sawing a groove into the concrete surface after the concrete has hardened in the same manner as specified. Dowel bar assemblies shall be installed as shown on the plans.

3. Construction Type: Transverse construction joints shall be installed at the end of each day's placing operations and at any other points within a paving lane when concrete placement is interrupted for more than 30 minutes or it appears that the concrete will obtain its initial set before fresh concrete arrives. When the installation of the joint can be planned in advance, it shall be located at a contraction or expansion joint. The joint shall not be allowed within 2500 mm of a regular spaced transverse joint. If the pouring of the concrete has been stopped, causing a joint to fall within this limit, it shall not be installed, and the fresh placed concrete shall be removed back to the 2500 mm limit.

M. Edging: Tool edges of pavement, gutters, curbs, and joints in concrete after initial floating with an edging tool to the radius shown on drawings. Repeat tooling of edges after applying surface finishes. Eliminate tool marks on concrete surfaces.

3.6 CONDITIONING OF UNDERLYING COURSE, SLIP-FORM CONSTRUCTION:

A. The base course on which the pavement will be placed shall extend approximately 900 mm beyond the paving machine track to support the paver without any noticeable deformation. Where necessary, the base course will be extended at own expense.

B. If damage occurs to the base course, it shall be corrected full depth, or the damaged areas filled with concrete integral with the pavement. If traffic is allowed to use the prepared grade, the grade shall be checked and corrected immediately before the placement of concrete.

C. The prepared grade shall be well moistened with water, without saturating, immediately ahead of concrete placement to prevent rapid loss of moisture from concrete. In cold weather the underlying base course shall be protected so that it will be entirely free of frost when concrete is placed.

3.7 CONDITIONING OF UNDERLYING COURSE, SIDE-FORM CONSTRUCTION:

A. Prepared Grade: Well moistened with water, without saturating, immediately ahead of concrete placement to prevent rapid loss of moisture from the concrete.

B. If damage occurs to the base course, it shall be corrected full depth, or the damaged areas filled with concrete integral with the pavement.

C. A multiple-pin template weighing not less than 454 kg per 6 m or other approved template shall be provided and operated on the forms immediately in advance of the placing of the concrete. The template shall be propelled only by hand and not attached to a tractor or other power unit. Templates shall be adjustable so that they may be set and maintained at the correct contour of the underlying course. The adjustment and operation of the template shall be such as will provide an accurate re-test of the grade before placing the concrete thereon. All excess material shall be removed. Low areas may be filled with concrete integral with the pavement.

3.8 HANDLING, MEASURING, AND BATCHING MATERIAL

A. Batch Plant Site: Layout, equipment, and provisions for transporting material shall assure a continuous supply of material to the work.

B. Stockpiles: Built up in layers of not more than 900 mm in thickness. Each layer shall be completely in place before beginning the next layer and shall not be allowed to "cone" down over the next lower layer. Aggregates from different sources and of different grading shall not be stockpiled together. Improperly placed stockpiles will not be accepted by Engineer.

C. Aggregates: Handled from stockpiles or other sources to the batching plant in such manner to secure the specified grading of the material. Aggregates that have become segregated or mixed with earth

or foreign material shall not be used. All aggregates produced or handled by hydraulic methods, and washed aggregates, shall be stockpiled or binned for draining at least 12 hours before being batched.

D. Cement: Stored in weather tight structures with raised floors or in suitable silos. Different consignments of bagged cement shall be used separately and in the order of delivery. If, for any reason, cement becomes partially set or contains lumps of caked cement, it shall be rejected. Cement salvaged from discarded or used bags shall not be used. Also, cement manufactured more than twelve months prior to proposed use on site shall not be used.

E. Aggregate: Fine and coarse aggregate shall be separately weighed into hoppers in the respective amounts set by Engineer in the job mix. Cement shall be measured by weight. Separate scales and hopper, with a device to positively indicate the complete discharge of the batch of cement into the batch box or container, shall be used for weighing the cement.

F. When required by the contract or when permitted, batching plants shall be equipped to proportion aggregates and bulk cement, by weight, automatically using interlocked proportioning devices of an approved type.

G. Water: Measured either by volume or by weight. The accuracy of measuring the water shall be within plus or minus 1 percent of required amounts. Unless the water is to be weighed, the water-measuring equipment shall include an auxiliary tank from which the measuring tank shall be filled. The measuring tank shall be equipped with an outside tap and valve to provide for checking the setting, unless other means are provided for readily and accurately determining the amount of water in the tank. The volume of the auxiliary tank shall be at least equal to that of the measuring tank.

H. Methods and equipment for adding air-entraining agent or other admixtures to the batch, when required, shall be approved by Engineer. All admixtures shall be measured into the mixer with an accuracy of plus or minus 3 percent.

3.9 CONCRETE PROTECTION AND CURING

A. General: Protect concrete against loss of moisture and rapid temperature changes for at least seven days from beginning of the curing operation. Unhardened concrete shall be protected from rain and flowing water. All equipment needed for adequate curing and protection of the concrete shall be on hand, ready to use before concrete placement beings. A standby water truck capable of dispensing a fine spray of water shall be continuously available during paving operations to keep the concrete moist until the curing compound has been applied. Provide protection as necessary to prevent cracking of the pavement due to temperature changes during the curing period.

B. Membrane Curing: Apply a uniform coating of white pigmented-type membrane curing compound to the entire exposed surface of the concrete by means of an approved automatic spraying machine as soon after finished as free water has disappeared from the finished surface. Coated formed surfaces immediately after the forms are removed and in no case longer than one hour after removal of forms. Do not allow concrete to dry before the application of the membrane. Moisten the surface of the concrete with a fine spray of water and apply curing compound as soon as the free water disappears, if any drying has occurred. The spraying machine shall be self-propelled and ride on the side forms, or previously constructed pavement straddling the newly paved lane. The machine is to have one or more spraying nozzles that can be controlled and operated to cover the pavement surface completely and uniformly with the required amount of curing compound. Thoroughly and continuously agitated curing compound in the drum used for the spraying operation mechanically throughout the full depth of the drum during application. Air agitation may be used only to supplement mechanical agitation. Provide sufficient spraying pressure to produce a fine spray as necessary to cover the surface thoroughly and completely with a uniform film. Maintain spray equipment in good mechanical condition and provide adequate wind guard to the spray nozzle. Apply curing compound with an overlapping coverage that will give a two-coat application at a coverage rate of not more than 0.1 L/sq. m for each coat or as recommended by the manufacturer. The application of curing compound by hand-operated pressure sprayers will be permitted only on odd widths or shapes of slabs as approved, and on concrete surfaces exposed by removal of forms.

Apply the second coat, when application is made by hand-operated sprayer, in a direction approximately at right angles to the direction of the first coat. The compound is to form a uniform, continuous, cohesive film that will not check, crack or peel, and is free of pinholes and other discontinuities. Apply an additional coat, if pinholes, abrasions or other discontinuities exist, to the affected areas within 30 minutes. Respray concrete surfaces that are subjected to heavy rainfall or abrasive windblown sand within three hours after the curing compound has been applied as specified above. Respray areas where the curing membrane is damaged by subsequent construction operations within the curing period.

1. Precautions shall be taken to ensure that concrete is properly cured at sawed joints, but that no curing compound enters the joints. Tightly seal top of joint opening and joint groove at exposed edges before concrete adjacent to the joint is resprayed. Sealing joint groove by using method that will prevent loss of moisture from the joint during the specified curing period.
2. Provide approved standby facilities for during concrete pavement at an accessible location at the jobsite for use in the event of mechanical failure of the spraying equipment, or other conditions that might prevent correct application of curing compound at the proper time.
3. Protect concrete surfaces to which curing compounds have been applied during the curing period from pedestrian and vehicular traffic except as required of joint-sawing operations and surface testing, and from any other possible damage to the continuity of the membrane.

C. Protection: Protect pavement and its appurtenances from damage caused by all traffic. The Engineer will decide when the pavement may be cleaned and opened to traffic, but not earlier than 14 days after concrete placing. Protect freshly placed concrete from premature drying and excessive cold or hot temperatures. Comply with the recommendations of ACI 306R for cold weather protection and ACI 305R for hot weather protection during curing.

3.10 CONCRETE PLACEMENT

A. Inspection: Before placing concrete, inspect and complete formwork installation, reinforcement steel, and items to be embedded or cast in. Notify other trades to permit installation of their work.

B. Moisten subbase to provide a uniform dampened condition at the time concrete is placed. Do not place concrete around manholes or other structures until they are at the required finish elevation and alignment.

C. Comply with requirements and with recommendations in ACI 304R for measuring, mixing, transporting, and placing concrete.

D. Do not add water to concrete during delivery, at Project site, or during placement.

E. Deposit and spread concrete in a continuous operation between transverse joints. Do not push or drag concrete into place or use vibrators to move concrete into place.

F. Consolidate concrete by mechanical vibrating equipment supplemented by hand-spading, rodding, or tamping. Use equipment and procedures to consolidate concrete according to recommendations in ACI 309R.

1. Consolidate concrete along face of forms and adjacent to transverse joints with an internal vibrator. Keep vibrator away from joint assemblies, reinforcement, or side forms. Use only square-faced shovels for hand-spreading and consolidation. Consolidate with care to prevent dislocating reinforcement, dowels, and joint devices.

G. Place concrete in two operations; strike off initial pour for entire width of placement and to the required depth below finish surface. Lay welded wire fabric or fabricated bar mats (if any) immediately in final position. Place top layer of concrete, strike off, and screed.

1. Remove and replace portions of bottom layer of concrete that have been placed more than 15 minutes without covered by top layer or use bonding agent if approved by Engineer.

H. Following the placing of the concrete, it shall be struck off to conform to the cross section shown on the plans and to an elevation such that when the concrete is properly consolidated and finished, the surface of the pavement shall be at the elevation shown on the plans.

I. Screed pavement surfaces with a straightedge and strike off. Commence initial floating using bull floats or derbies to form an open textured and uniform surface plane before excess moisture or bleed water appears on the surface. Do not further disturb concrete surfaces before beginning finishing operations or spreading dry-shake surface treatments.

J. Curbs and Gutters: When automatic machine placement is used for curb and gutter placement, submit revised mix design and laboratory test results that meet or exceed requirements. Produce curbs and gutters to required cross section, lines, grades, finish, and jointing as specified for formed concrete. If results are not approved, remove and replace with formed concrete.

K. Side Form Method:

1. The concrete shall be deposited on the moistened grade to require as little re-handling as possible. Unless truck mixers, truck agitators, or non-agitating hauling equipment are equipped with means for discharge of concrete without segregation of the materials, the concrete shall be unloaded into an approved spreading device and mechanically spread on the grade to prevent segregation of the materials. Placing shall be continuous between transverse joints without the use of intermediate bulkheads. Necessary hand spreading shall be done with shovels - not rakes. Workmen shall not be allowed to walk in the freshly mixed concrete with boots or shoes coated with earth or foreign substances.
2. When concrete is to be placed adjoining a previously constructed lane of pavement and when mechanical equipment will be operated upon the existing lane of pavement, the concrete shall be at least 7 days old and at a flexural strength approved by Engineer.
3. Concrete shall be thoroughly consolidated against and along the faces of all forms and along the full length and on both sides of all joint assemblies by means of vibrators inserted in the concrete. Vibrators shall not be permitted to come in contact with a joint assembly, the grade, or a side form. In no case shall the vibrator be operated longer than 15 seconds in any one location, nor shall the vibrators be used to move the concrete.
4. Concrete shall be deposited as near to expansion and contraction joints as possible without disturbing them but shall not be dumped from the discharge bucket or hopper onto a joint assembly unless the hopper is well centered on the joint assembly.
5. Should any concrete materials fall on or be worked into the surface of a completed slab, they shall be removed immediately by approved methods.

L. Slip-Form Method:

1. The concrete shall be placed with an approved crawler-mounted, slip-form paver designed to spread, consolidate, and shape the freshly placed concrete in one complete pass of the machine so that a minimum of hand finishing will be necessary to provide a dense and homogeneous pavement in conformance with requirements of the plans and specifications. The concrete should be placed directly on top of the joint assemblies to prevent them from moving when the paver moves over them. Side forms and finishing screeds shall be adjustable to the extent required to produce the specified pavement edge and surface tolerance. The side forms shall be of dimensions, shape, and strength to support the concrete laterally for a sufficient length of time so that no appreciable edge slumping will occur. Final finishing shall be accomplished while the concrete is still in the plastic state.
2. It is the intent of the specification to produce a high quality, dense, long lasting, and smooth pavement suitable for the high-speed operations of roughness-sensitive heavy jet aircraft. This requires that all joints, and particularly all longitudinal joints, meet the specified tolerance throughout their length. In the event that slumping or sloughing occurs behind the paver or if there are any other structural or surface defects, which, in the opinion of Engineer, cannot be corrected within permissible tolerances, Engineer may halt paving operations until

proper adjustment of the equipment or procedures have been made. In the event that satisfactory procedures and pavement are not achieved after not more than 600 m of single lane paving, the balance of the work shall be completed with the use of standard metal forms and the formed method of placing and curing.

M. Slip-Form Pavers: When automatic machine placement is used for pavement, submit revised mix design and laboratory test results that meet or exceed requirements. Produce pavement to required thickness, lines, grades, finish, and jointing as required for formed pavement.

1. Compact subbase and prepare subgrade of sufficient width to prevent displacement of paver machine during operations.

N. When adjoining pavement lanes are placed in separate pours, do not operate equipment on concrete until pavement has attained 85 percent of its 28-day compressive strength.

O. Hot-Weather Placement: Place concrete according to recommendations in ACI 305R and as follows when hot-weather conditions exist:

1. Cool ingredients before mixing to maintain concrete temperature at time of placement below 32 deg C. Chilled mixing water or chopped ice may be used to control temperature, provided water equivalent of ice is calculated to total amount of mixing water. Using liquid nitrogen to cool concrete is subject to the approval of the Engineer.
2. Cover reinforcement steel with water-soaked burlap so steel temperature will not exceed ambient air temperature immediately before embedding in concrete.
3. Fog-spray forms, reinforcement steel, and subgrade just before placing concrete. Keep subgrade moisture uniform without standing water, soft spots, or dry areas.
4. Concreting shall not be permitted when the rate of evaporation exceeds 1.0 kg/m2/hr. (ACI 305R "Guide to Hot Weather Concreting").

3.11 CONCRETE FINISHING

A. General: Wetting of concrete surfaces during screeding, initial floating, or finishing operations is prohibited.

B. Float Finish: Begin the second floating operation when bleed-water sheen has disappeared, and the concrete surface has stiffened sufficiently to permit operations. Float surface with power-driven floats, or by hand floating if area is small or inaccessible to power units. Finish surfaces to true planes. Cut down high spots and fill low spots. Refloat surface immediately to uniform granular texture.

1. Burlap Finish: Drag a seamless strip of damp burlap across float-finished concrete, perpendicular to line of traffic, to provide a uniform, gritty texture.
2. Medium-to-Fine-Textured Broom Finish: Draw a soft bristle broom across float-finished concrete surface perpendicular to line of traffic to provide a uniform, fine-line texture.
3. Medium-to-Coarse-Textured Broom Finish: Provide a coarse finish by striating float-finished concrete surface 1.6 to 3 mm deep with a stiff-bristled broom, perpendicular to line of traffic.

3.12 FINAL STRIKE-OFF, CONSOLIDATION AND FINISHING

A. Sequence: The sequence of operations shall be the strike-off and consolidation, floating and removal of laitance, straight edging, and final surface finish. The addition of superficial water to the surface of the concrete to assist in finishing operations generally will not be permitted. If the application of water to the surface is permitted, it shall be applied as a fog spray by means of approved spray equipment.

B. Strike-Off of Concrete: Following the placing of the concrete, it shall be struck off to conform to the cross section shown on the plans and to an elevation such that when the concrete is properly consolidated and finished, the surface of the pavement shall be at the elevation shown on the plans.

C. Finishing at Joints:

1. The concrete adjacent to joints shall be compacted or firmly placed without voids or segregation against the joint material; it shall be firmly placed without voids or segregation under and around all load-transfer devices, joint assembly units, and other features designed to extend into the pavement.
2. Concrete adjacent to joints shall be mechanically vibrated. After the concrete has been placed and vibrated adjacent to the joints, the finishing machine shall be operated in a manner to avoid damage or misalignment of joints.
3. If uninterrupted operations of the finishing machine, to, over, and beyond the joints, cause segregation of concrete, damage to, or misalignment of the joints, the finishing machine shall be stopped when the screed is approximately 200mm from the joint.
4. Segregated concrete shall be removed from the front of and off the joint, the screed shall be lifted and set directly on top of the joint, and the forward motion of the finishing machine shall be resumed. Thereafter, the finishing machine may be run over the joint without lifting the screed, provided there is no segregated concrete immediately between the joint and the screed or on top of the joint.

D. Machine Finishing:

1. The concrete shall be spread as soon as it is placed, and it shall be struck off and screeded by an approved finishing machine. The machine shall go over each area as many times and at such intervals as necessary to give the proper consolidation and to leave a surface of uniform texture.
2. Excessive operation over a given area shall be avoided. When side forms are used, the tops of the forms shall be kept clean by an effective device attached to the machine, and the travel of the machine on the forms shall be maintained true without lift, wobbling, or other variation tending to affect the precision finish. During the first pass of the finishing machine, a uniform ridge of concrete shall be maintained ahead of the front screed for its entire length.
3. When in operation, the screed shall be moved forward with a combined longitudinal and transverse shearing motion, always moving in the direction in which the work is progressing, and so manipulated that neither end is raised from the side forms during the striking-off process. If necessary, this shall be repeated until the surface is of uniform texture, true to grade and cross section, and free from porous areas.

E. Hand Finishing:

1. Hand finishing methods will not be permitted, except under the following conditions:

    a. In the event of breakdown of the mechanical equipment, hand methods may be used to finish the concrete already deposited on the grade.
    b. In areas of narrow widths or of irregular dimensions where operation of the mechanical equipment is impractical.

2. Concrete, as soon as placed, shall be struck off and screeded. An approved portable screed shall be used. A second screed shall be provided for striking off the bottom layer of concrete when reinforcement is used.
3. The screed for the surface shall be at least 600 mm longer than the maximum width of the slab to be struck off. It shall be of approved design, sufficiently rigid to retain its shape, and shall be constructed either of metal or of other suitable material covered with metal. Consolidation shall be attained by the use of a suitable vibrator.

F. Floating: After the concrete has been struck off and consolidated, it shall be further smoothed, trued, and consolidated by means of a longitudinal float, using approved hand or machine methods.

G. Straight-Edge Testing and Surface Correction:

1. After the pavement has been struck off and consolidated and while the concrete is still plastic, it shall be tested for trueness with a 4.8m straightedge. Furnish and use an accurate 4.8m straightedge swung from handles 900 mm longer than one-half the width of the slab.
2. The straightedge shall be held in contact with the surface in successive positions parallel to the centerline and the whole area gone over from one side of the slab to the other, as necessary. Advancing shall be in successive stages of not more than one-half the length of the straightedge. Any excess water and laitance shall be removed from the surface of the pavement.
3. Any depressions shall be immediately filled with freshly mixed concrete, struck off, consolidated, and refinished. High areas shall be cut down and refinished.
4. Special attention shall be given to assure that the surface across joints meets the requirements for smoothness. Straightedge testing and surface corrections shall continue until the entire surface is found to be free from observable departures from the straightedge and until the slab conforms to the required grade and cross section.
5. The use of long-handled wood floats shall be confined to a minimum; they may be used only in emergencies and in areas not accessible to finishing equipment.

3.13 SPECIAL FINISHES

A. Monolithic Exposed Aggregate Finish: Expose coarse aggregate to pavement surfaces as follows:

1. Immediately after floating, spray-apply chemical surface retarder to pavement according to manufacturer's written instructions.
2. Cover with plastic sheeting, sealing laps with tape, and remove when ready to continue finishing operations.
3. Without dislodging aggregate, remove excess mortar by lightly brushing surface with a stiff, nylon bristle broom.
4. Fine-spray surface with water and brush. Repeat water flushing and brushing cycle until cement film is removed from aggregate surfaces to depth required.

B. Seeded Exposed Aggregate Finish: Immediately after floating, broadcast a single layer of aggregate uniformly onto the pavement surface. Tamp seeded aggregate into plastic concrete, and float to entirely embed aggregate with mortar cover of 1.6 mm.

1. Spray-apply chemical surface retarder to pavement according to manufacturer's written instructions.
2. Cover pavement surface with plastic sheeting, sealing laps with tape, and remove when ready to continue finishing operations.
3. Without dislodging aggregate, remove excess mortar by lightly brushing surface with a stiff, nylon bristle broom.
4. Fine-spray surface with water and brush. Repeat water flushing and brushing cycle until cement film is removed from aggregate surfaces to depth required.

C. Slip-Resistant Aggregate Finish: Before final floating, apply slip-resistant aggregate finish to pavement surfaces according to manufacturer's written instructions and as follows:

1. Uniformly spread 12 kg/10 sq. m of dampened nonslip aggregate over the surface. Tamp aggregate flush with surface using a steel trowel, but do not force below surface.
2. After curing, lightly work surface with a steel wire brush or an abrasive stone, and water to expose nonslip aggregate.

D. Rock-Salt Finish: After initial floating, uniformly seed 0.2 kg/10 sq. m over the concrete surface.

1. Cover surface with 0.025-mm thick polyethylene sheet and remove when concrete has hardened and seven-day curing period has elapsed.
2. Embed rock salt into plastic concrete, power float concrete, and trowel finish.

3. After seven-day curing period, saturate concrete with water and broom-sweep surface to dissolve remaining rock salt.

E. Colored Dry-Shake Hardener Finish: After initial floating, apply colored dry-shake materials to pavement surfaces according to manufacturer's written instructions and as follows:

1. Uniformly apply colored dry-shake materials at a rate of 49 kg/10 sq. m, unless greater amount is recommended by manufacturer to match pavement color required.
2. Uniformly distribute approximately two-thirds of colored dry-shake material over the concrete surface with mechanical spreader and embed by power floating. Follow power floating with a second shake application, uniformly distributing remainder of dry-shake material to ensure uniform color and embed by power floating.
3. After final floating, apply a hand-trowel finish followed by a broom finish to concrete. Cure concrete with curing compound recommended by dry-shake material manufacturer. Apply curing compound immediately after final finishing.

3.14 SURFACE TEXTURE:

A. The surface of the pavement shall be finished as designated below for all newly constructed concrete pavements. It is important that the texturing equipment not tear or unduly roughen the pavement surface during the operation. The texture shall be uniform in appearance and approximately 2 mm in depth. Any imperfections resulting from the texturing operation shall be corrected to the satisfaction of the Engineer.

B. Brush or Broom Finish:

1. A brush or broom finish shall be applied to all newly constructed concrete pavements when the water sheen has practically disappeared.
2. The equipment shall operate transversely across the pavement surface.
3. It is important that the texturing equipment not tear or unduly roughen the pavement surface during the operation.

3.15 SKID RESISTANT SURFACES:

A. Wire Combing: A skid resistant surface shall be provided by wire combing in plastic concrete. The wire combing technique shall use steel combs or tines of various dimensions to form groove-like texture in the plastic concrete pavement and shall provide grooves that are approximately 3 mm by 3 mm spaced 13 mm center-to-center.

3.16 SURFACE TEST:

A. As soon as the concrete has hardened sufficiently, the pavement surface shall be tested with a 4.8 m straightedge or another specified device. Areas in a slab showing high spots of more than 6 mm but not exceeding 12 mm in 4.8 m shall be marked and immediately ground down with an approved grinding machine to an elevation that will fall within the tolerance of 6 mm or less. Where the departure from correct cross section exceeds 12 mm, the pavement shall be removed and replaced at own expense when so directed by Engineer.

B. Any area or section so removed shall not be less than 3 m in length nor less than the full width of the lane involved. When it is necessary to remove and replace a section of pavement, any remaining portion of the slab adjacent to the joints that is less than 3 m in length shall also be removed and replaced.

C. Surface texture: Surface texture shall be determined by the sand patch test to ASTM E 965. The recommended average texture depth to provide good skid-resistance for newly constructed

pavements is 0.045 inch (1.14 mm). A lower value indicates a deficiency in macrotexture that will require correction as the surface deteriorates.

3.17 REMOVING FORMS

A. Unless otherwise specified, forms shall not be removed from freshly placed concrete until it has set for at least 12 hours, except where auxiliary forms are used temporarily in widened areas. Forms shall be removed carefully to avoid damage to the pavement. After the forms have been removed, the sides of the slab shall be cured. Major honeycombed areas shall be considered as defective work and shall be removed and replaced. Any area or section so removed shall not be less than 3 m in length nor less than the full width of the lane involved. When it is necessary to remove and replace a section of pavement, any remaining portion of the slab adjacent to the joints that is less than 3 m in length shall also be removed and replaced.

3.18 SEALING JOINTS

A. The joints in the pavement shall be sealed as shown on Drawings and as specified in Section 321373.

3.19 OPENING TO TRAFFIC

A. Opening to Construction Traffic: The pavement shall not be opened to construction traffic until test specimens moulded and cured in accordance with ASTM C31 have attained 75% of the specified flexural strength at 28-days when tested in accordance with ASTM C78. If such tests are not conducted, the pavement shall not be opened to traffic until 14 days after the concrete was placed. Prior to opening the pavement to construction traffic, all joints shall either be sealed or protected from damage to the joint edge and intrusion of foreign materials into the joint. As a minimum, backer rod or tape may be used to protect the joints from foreign matter intrusion.

B. Opening to Air Traffic Operations in case of active/operational airports: Prior to reopening rigid pavements to air traffic operations, inspection and testing of the work areas must be performed. The quality control program should be used to determine that the in-place concrete has reached the specified strength at 28-days to take traffic. Thus, in cases of time constraints and the need to reopen areas to aircraft traffic in timely manner, it is required to have the samples taken from newly casted PCC and to be field cured, and to check the strength at the time of opening the pavement to traffic to ensure that it has reached 100% of the specified strength. Field curing has to be done in accordance with ASTM C31, with particular reference to Clauses 4.3 and 10.2.

3.20 PAVEMENT TOLERANCES

A. Comply with tolerances of ACI 117 and as follows:

1. Elevation: 6 mm.
2. Thickness: Plus 9 mm, minus 6 mm.
3. Surface: Gap below 3-m long, unleveled straightedge not to exceed 6 mm.
4. Lateral Alignment and Spacing of Tie Bars and Dowels: 25 mm.
5. Vertical Alignment of Tie Bars and Dowels: 6 mm.
6. Alignment of Tie-Bar End Relative to Line Perpendicular to Pavement Edge: 13 mm.
7. Alignment of Dowel-Bar End Relative to Line Perpendicular to Pavement Edge: Length of dowel 6 mm per 300 mm.
8. Joint Spacing: 75 mm.
9. Contraction Joint Depth: Plus 6 mm, no minus.
10. Joint Width: Plus 3 mm, no minus.

B. Extreme care must be exercised in all phases of the operation to assure the pavement will pass the specified tolerances. The following tolerances are applicable:

1. Lateral deviation from established alignment of the pavement edge shall not exceed plus or minus 30 mm in any lane.
2. Vertical deviation from established grade shall not exceed plus or minus 12 mm at any point.
3. Surface smoothness deviations shall not exceed 6 mm from a 4.8 m straightedge placed in any direction, including placement along and spanning any pavement joint or edge.

3.21 WHEEL STOPS

A. Securely attach wheel stops into pavement with not less than two galvanized steel dowels embedded in holes cast into wheel stops. Firmly bond each dowel to wheel stop and to pavement. Extend upper portion of dowel 125 mm into wheel stop.

3.22 FIELD QUALITY CONTROL

A. Slump: One test at point of discharge for each day's pour of concrete. Additional tests when concrete consistency seems to have changed.

B. Concrete Temperature: Test hourly when air temperature is 4 deg C and below, and when 27 deg C and above, and each time a set of flexural test beams are made.

C. Flexural Strength:

1. Flexural test beams shall be made for each day's pour exceeding 4 cu.m, plus additional sets for each 40 cu.m over and above the first 20 cu. m. Each group of test beams shall be moulded from the same batch of concrete and shall consist of a sufficient number of specimens to provide two flexural strength tests at each test age. The specimens shall be made in accordance with ASTM C31/C31M. However, at the start of paving operations and when the aggregate source, aggregate characteristics, or mix design is changed, additional groups of test beams may be required until Engineer is satisfied that the concrete mixture being used complies with the strength requirements of these specifications. Test ages will be 7 days and 28 days.

2. The flexural strength of the concrete shall meet the following requirements:

    a. The average of any 4 consecutive strength tests, tested at the end of 28 days, shall have an average flexural strength equal to or greater than the specified flexural strength.
    b. Not more than 20 percent of the beams tested at the end of 28 days shall have a flexural strength less than the specified strength.
    c. No specimen shall have a flexural strength less than 90% of the specified flexural strength.

3. Specimens, which are obviously defective, shall not be considered in the determination of the strength. When it appears that the test specimens will fail to conform to the requirements for strength, Engineer shall have the right to order changes in the concrete sufficient to increase the strength to meet the requirements. When a satisfactory relationship between 7-days and 28-day strengths has been established and approved, the 7-day test results may be used as an indication of the 28-day strengths. However, the 7-day test results will not replace the results of the 28-day tests if the 28-day results fall below the requirements.

D. Testing Agency: Engage a qualified independent testing and inspection agency to sample materials, perform tests, and submit test reports during concrete placement according to requirements specified in this Article.

E. Testing Services: Testing shall be performed according to the following requirements:

1. Sampling Fresh Concrete: Representative samples of fresh concrete shall be obtained according to ASTM C172/C172M, except modified for slump to comply with ASTM C 94/ C94M.
2. Slump: ASTM C143/C143M; one test at point of placement for each flexural and/or compressive-strength test, but not less than one test for each day's pour of each type of concrete. Additional tests will be required when concrete consistency changes.
3. Air Content: ASTM C231/C231M, pressure method; one test for each flexural and/or compressive strength test, but not less than one test for each day's pour of each type of air-entrained concrete.
4. Concrete Temperature: ASTM C1064/C1064M; one test hourly when air temperature is 4.4 deg C and below and when 27 deg C and above, and one test for each set of flexural and/or compressive-strength specimens.
5. Compression Test Specimens: ASTM C31/C31M; one set of four standard cylinders for each compressive-strength test, unless otherwise indicated. Cylinders shall be molded and stored for laboratory-cured test specimens unless field-cured test specimens are required.
6. Compressive-Strength Tests: ASTM C39/C39M; one set for each day's pour of each concrete class exceeding 4 cu. m, but less than 19 cu. m, plus one set for each additional 38 cu. m. One specimen shall be tested at 7 days and two specimens at 28 days; one specimen shall be retained in reserve for later testing if required.
7. When frequency of testing will provide fewer than five compressive-strength tests for a given class of concrete, testing shall be conducted from at least five randomly selected batches or from each batch if fewer than five are used.
8. When total quantity of a given class of concrete is less than 38 cu. m, Engineer may waive compressive-strength testing if adequate evidence of satisfactory strength is provided.
9. When strength of field-cured cylinders is less than 85 percent of companion laboratory-cured cylinders, current operations shall be evaluated, and corrective procedures shall be provided for protecting and curing in-place concrete.
10. Strength level of concrete will be considered satisfactory if averages of sets of three consecutive compressive-strength test results equal or exceed specified compressive strength and no individual compressive-strength test result falls below specified compressive strength by more than 3.4 MPa.
11. Water Absorption and Depth of Penetration Testing: BS 1881-122 and BS EN 12390-8; minimum of four standard cylinders shall be obtained at the start of concreting works for each permeability test, unless otherwise indicated by the Engineer.

F. Test results shall be reported in writing to Engineer, concrete manufacturer, and Contractor within 24 hours of testing. Reports of compressive-strength tests shall contain Project identification name and number, date of concrete placement, name of concrete testing agency, concrete type and class, location of concrete batch in pavement, design compressive strength at 28 days, concrete mix proportions and materials, compressive breaking strength, and type of break for both 7- and 28-day tests.

G. Nondestructive Testing: Impact hammer, sonoscope, or other nondestructive device may be permitted by Engineer but will not be used as the sole basis for approval or rejection.

H. Additional Tests: Testing agency shall make additional tests of the concrete when test results indicate slump, air entrainment, concrete strengths, or other requirements have not been met, as directed by Engineer. Testing agency may conduct tests to determine adequacy of concrete by cored cylinders complying with ASTM C 42/ C42M, or by other methods as directed.

3.23 PROTECTION AND REPAIRS

A. Protect concrete from damage. The Contractor shall protect the pavement and its appurtenances against any traffic and traffic caused by the Contractor’s employees and agents until accepted by the Engineer. This shall include watchmen to direct traffic and the erection and maintenance of warning signs, lights, pavement bridges, crossovers, and protection of unsealed joints from intrusion of foreign material,

B. Exclude traffic from pavement for at least 14 days after placement. When construction traffic is permitted, maintain pavement as clean as possible by removing surface stains and spillage of materials as they occur.

C. Prior to opening the pavement to construction traffic, all joints shall either be sealed or protected from damage to the joint edge and intrusion of foreign materials into the joint. As a minimum, backer rod or tape may be used to protect the joints from foreign matter intrusion.

D. Remove and replace concrete pavement that is broken, damaged, or defective, or does not meet requirements in this Section.

E. Damaged pavements shall be removed and replaced at the Contractor's expense. Slabs shall be removed to the full depth, width, and length of the slab as directed by the Engineer, at the Contractor's expense. Spalls along joints shall be repaired as specified. Removal of partial slabs is not permitted. Removal and replacement shall be full depth, shall be full width of the slab, and the limit of removal shall be normal to the paving lane and to each original transverse joint.

F. Aggregates, rubble, or other similar construction materials shall not be placed on airfield pavements.

G. Drill test cores where directed by Engineer when necessary to determine magnitude of cracks or defective areas. Fill drilled core holes in satisfactory pavement areas with Portland cement concrete bonded to pavement with epoxy adhesive.

H. Maintain concrete pavement free of stains, discoloration, dirt, and other foreign material. Sweep concrete pavement not more than two days before date scheduled for Taking Over inspections.

I. Repair of cracks shall not be allowed if in the opinion of the Engineer the overall condition of the pavement indicates that such repair is unlikely to achieve an acceptable and durable finished pavement. No repair of cracks shall be allowed in any panel that demonstrates segregated aggregate with an absence of coarse aggregate in the upper 1/8 inch (3 mm) of the pavement surface.

1. **Shrinkage cracks.** Shrinkage cracks which do not exceed one-third of the pavement depth shall be cleaned and either high molecular weight methacrylate (HMWM) applied; or epoxy resin (Type IV, Grade 1) pressure injected using procedures recommended by the manufacturer and approved by the Engineer. Sandblasting of the surface may be required following the application of HMWM to restore skid resistance. Care shall be taken to ensure that the crack is not widened during epoxy resin injection. All epoxy resin injection shall take place in the presence of the Engineer. Shrinkage cracks which exceed one-third the pavement depth shall be treated as full depth cracks.

2. **Slabs with cracks through interior areas.** Interior area is defined as that area more than 150 mm from either adjacent original transverse joint. The full slab shall be removed and replaced at no cost to the Owner, when there are any full depth cracks, or cracks greater than one-third the pavement depth, that extend into the interior area.

3. **Cracks close to and parallel to joints.** All full-depth cracks within 150 mm either side of the joint and essentially parallel to the original joints, shall be treated as follows:

a. **Full depth cracks and original joint not cracked.** The full-depth crack shall be treated as the new joint and the original joint filled with an epoxy resin.
- Full-depth crack. The joint sealant reservoir for the crack shall be formed by sawing to a depth of 19 mm, ±2 mm, and to a width of 16 mm, 3 mm. The crack shall be sawed with equipment specially designed to follow random cracks. Any equipment or procedure which causes raveling or spalling along the crack shall be modified or replaced to prevent raveling or spalling. The joint shall be sealed with sealant in accordance with P-605 or as directed by the Engineer.
- Original joint. If the original joint sealant reservoir has been sawed out, the reservoir and as much of the lower saw cut as possible shall be filled with epoxy resin, Type IV, Grade 2, thoroughly tooled into the void using approved procedures.

If only the original narrow saw cut has been made, it shall be cleaned and pressure injected with epoxy resin, Type IV, Grade 1, using approved procedures. Where a parallel crack goes part way across paving lane and then intersects and follows the original joint which is cracked only for the remained of the width, it shall be treated as specified above for a parallel crack, and the cracked original joint shall be prepared and sealed as originally designed.

b. **Full depth cracks and original joint cracked.** If there is any place in the lane width where a parallel crack and a cracked portion of the original joint overlap, the entire slab containing the crack shall be removed and replaced.

4. **Removal and replacement of full slabs.** Make a full depth cut perpendicular to the slab surface along all edges of the slab with a concrete saw cutting any dowels or tie-bars. Remove damaged slab protecting adjacent pavement from damage. Damage to adjacent slabs may result in removal of additional slabs as directed by the Engineer at the Contractor's expense. The underlying material shall be repaired, re-compacted and shaped to grade. Dowels of the size and spacing specified for other joints in similar pavement on the project shall be installed along all four (4) edges of the new slab. Placement of concrete shall be as specified for original construction. The joints around the new slab shall be prepared and sealed as specified for original construction.

5. Spalls along joints.

a. Spalls less than one inch wide and less than the depth of the joint sealant reservoir, shall be filled with joint sealant material.

b. Spalls larger than one inch and/or deeper than the joint reservoir, but less than ½ the slab depth, and less than 25% of the length of the adjacent joint shall be repaired as follows:

i. Make a vertical saw cut at least one inch (25 mm) outside the spalled area and to a depth of at least 2 inches (50 mm). Saw cuts shall be straight lines forming rectangular areas surrounding the spalled area.

ii. Remove unsound concrete and at least 1/2 inch (12 mm) of visually sound concrete between the saw cut and the joint or crack with a light chipping hammer.

iii. **iii.** Clean cavity with high-pressure water jets supplemented with compressed air as needed to remove all loose material.

iv. **iv.** Apply a prime coat of epoxy resin, Type III, Grade I, to the dry, cleaned surface of all sides and bottom of the cavity, except any joint face.

v. **v.** Fill the cavity with low slump concrete or mortar or with epoxy resin concrete or mortar.

vi. **vi.** An insert or other bond-breaking medium shall be used to prevent bond at all joint faces.

vii. **vii.** A reservoir for the joint sealant shall be sawed to the dimensions required for other joints, or as required to be routed for cracks. The reservoir shall be thoroughly cleaned and sealed with the sealer specified for the joints.

c. Spalls deeper than 1/2 of the slab depth or spalls longer than 25% of the adjacent joint require replacement of the entire slab.

3.24 TESTING STANDARDS AND CODES

AASHTO M 182	Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats
AASHTO M254	Standard Specification for Corrosion-Resistant Coated Dowel Bars
AASHTO M291	Standard Specification for Carbon and Alloy Steel Nuts

ACI 117	Specification for Tolerances for Concrete Construction and Materials and Commentary
ACI 211.1	Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 301	Specifications for Concrete Construction
ACI 304R	Guide for Measuring, Mixing, Transporting, and Placing Concrete
ACI 305.1	Specification for Hot Weather Concreting
ACI 305R	Guide to Hot Weather Concreting
ACI 306R	Guide to Cold Weather Concreting
ACI 309R	Guide for Consolidation of Concrete
ACI 318	Building Code Requirements for Structural Concrete and Commentary
ASTM A615/ A615M	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
ASTM A955/ A955M	Standard Specification for Deformed and Plain Stainless Steel Bars for Concrete Reinforcement
ASTM A1064 / A1064M	Standard Specification for Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
ASTM C31/ C31M	Standard Practice for Making and Curing Concrete Test Specimens in the Field
ASTM C33/ C33M	Standard Specification for Concrete Aggregates
ASTM C39/C39M	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C 42/ C42M	Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C78/ C78M	Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C94/ C94M	Standard Specification for Ready-Mixed Concrete
ASTM C114	Standard Test Methods for Chemical Analysis of Hydraulic Cement
ASTM C127	Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
ASTM C128	Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate
ASTM C131/ C131M	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C143/C143M	Standard Test Method for Slump of Hydraulic-Cement Concrete

ASTM C150	Standard Specification for Portland Cement
ASTM C157	Standard Test Method for Length Change of Hardened Cement Mortar and Concrete
ASTM C171	Standard Specification for Sheet Materials for Curing Concrete
ASTM C172/C172M	Standard Practice for Sampling Freshly Mixed Concrete
ASTM C186	Standard Test Method for Heat of Hydration of Hydraulic Cement (Withdrawn 2019)
ASTM C192	Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
ASTM C231/ C231M	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C260/C260M	Standard Specification for Air-Entraining Admixtures for Concrete
ASTM C309	Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C494/ C494M	Standard Specification for Chemical Admixtures for Concrete
ASTM C881/ C881M	Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete
ASTM C979/ C979M	Standard Specification for Pigments for Integrally Colored Concrete
ASTM C1059/C1059M	Standard Specification for Latex Agents for Bonding Fresh To Hardened Concrete
ASTM C1064/C1064M	Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C1077	Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
ASTM C1116/C1116M	Standard Specification for Fiber-Reinforced Concrete
ASTM C1260	Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
ASTM C1567	Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
ASTM C1602/C1602M	Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
ASTM D1751	Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)
ASTM D1752	Standard Specification for Preformed Sponge Rubber, Cork, and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction
ASTM D2419	Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate

ASTM D4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
ASTM E329	Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection
ASTM E965	Standard Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique
BS 1881-122	Testing Concrete. Method for determination of water absorption
BS 4449	Steel for the reinforcement of concrete - Weldable reinforcing steel - Bar, coil and decoiled product - Specification
BS EN 197-1	Cement Part 1: Composition, specifications and conformity criteria for common cements
BS EN 12390-8	Testing hardened concrete. Depth of penetration of water under pressure
BS EN 12620	Aggregates for concrete
FAA 150-5370-10H	Standard Specifications for Construction of Airports

END OF SECTION 321313

SECTION 321373 - CONCRETE PAVING JOINT SEALANTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract, and the Project Requirements, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Cold-applied joint sealants.
2. Cold-applied, jet-fuel-resistant joint sealants.
3. Hot-applied joint sealants.
4. Hot-applied, jet-fuel-resistant joint sealants.
5. Expansion, construction, and contraction joints within cement concrete pavement.
6. Joints between cement concrete and asphalt pavement.

B. Related Requirements:

1. Section 079200 "Joint Sealants" for sealing non-traffic and traffic joints in locations not specified in this Section.
2. Section 321216.30 "Asphalt Paving for Airfield" for constructing joints between concrete and asphalt pavement.
3. Section 321313 "Concrete Paving" for constructing joints in concrete pavement.

1.3 DEFINITIONS

A. Joint sealant is a material that absorbs movement of incompressible material into the joint system and minimizes infiltration of surface water. Secondarily, sealants are also purported to reduce the potential for dowel bar corrosion by reducing entrance of de-icing chemicals (wherever applicable).

B. Joint Sealers are produced and installed to establish and maintain watertight and airtight continuous seals.

1.4 ACTION SUBMITTALS

A. Samples for Initial Selection Purposes: Manufacturer’s standard bead samples consisting of strips of actual products showing full range of colors available, for each product exposed to view.

B. Samples for Verification: For each type and color of joint sealant required. Install joint-sealer samples in 6-mm wide joints formed between two 150-mm long strips of material matching the appearance of exposed surfaces adjacent to joint sealants.

1.5 INFORMATIONAL SUBMITTALS

A. Product Certificates: Signed by manufacturers of joint sealants certifying that products furnished comply with requirements and are suitable for the use indicated.

B. Qualification Data: For firms and persons specified in "Quality Assurance" Article to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names, and addresses of engineers and employers, and other information specified or required by Engineer.

C. Compatibility and Adhesion Test Reports: From joint elastomeric sealant manufacturer indicating the following:

1. Materials forming joint substrates and elastomeric backer materials have been tested for compatibility and adhesion with joint sealants.
2. Interpretation of test results and written recommendations for primers and substrate preparation needed for adhesion.

D. Product Test Reports: From a qualified testing agency indicating joint sealants comply with requirements, based on comprehensive testing of current product formulations.

E. Preconstruction Field Test Report: Indicating which products and joint preparation methods demonstrated acceptable adhesion to joint substrates.

1.6 QUALITY ASSURANCE

A. All products, material, and equipment shall demonstrate compliance with requirements specified in the project requirements.

B. Installer Qualifications: An experienced installer who has specialized in installing joint sealants similar in material, design, and extent to those indicated for this Project and whose work has resulted in joint-sealant installations with a record of successful in-service performance.

C. Source Limitations: Obtain each type of joint sealant through one source from a single manufacturer.

D. Product Testing: Obtain test results for "Product Test Reports" mentioned in Sub-Article 1.5.D above from a qualified testing agency, based on testing current sealant formulations within a 36-month period.

1. Testing Agency Qualifications: An independent testing agency qualified according to ASTM C1021.
2. Sampling and testing of joint sealing material shall be in accordance with ASTM D3569.

E. Product Testing: Provide comprehensive test data for each type of joint sealer based on tests conducted by a qualified independent testing laboratory on current product formulations within a 24-month period preceding date of submittal of test results to Engineer.

1. Test elastomeric sealants for compliance with requirements specified by reference to ASTM C 920. Include test results for hardness, stain resistance, adhesion, and cohesion under cyclic movement (per ASTM C719), low-temperature flexibility, modulus of elasticity at 100 percent strain, effects of heat aging, and effects of accelerated weathering.
2. For all exterior sealant systems, furnish test results performed on joint sealers after they have cured 1 year.

F. Preconstruction Compatibility and Adhesion Testing: Submit to joint sealant manufacturer, for testing indicated below, samples of materials that will contact or affect joint sealants.

1. Use manufacturer's standard test methods to determine whether priming and other specific joint preparation techniques are required to obtain rapid, optimum adhesion of joint sealants to joint substrates.

a. Perform tests under environmental conditions replicating those that will exist during installation.

2. Submit not less than nine pieces of each type of material, including joint substrates, shims, joint-sealant backer materials, secondary seals, and miscellaneous material.
3. Schedule sufficient time for testing and analyzing results to prevent delaying the Works.
4. Investigate materials failing compatibility or adhesion tests and obtain joint sealer manufacturer's written recommendations for corrective measures, including use of specially formulated primers.
5. Testing will not be required if joint sealant manufacturer submits joint preparation data that are based on previous testing of current sealant products for adhesion to, and compatibility with, joint substrates and other materials matching those submitted.

G. Preconstruction Field Testing: Prior to installation of joint sealants, field-test their adhesion to joint substrates as follows:

1. Locate test joints where indicated or, if not indicated, as directed by Engineer.
2. Conduct field tests for each application indicated below:

a. Each type of elastomeric sealant and joint substrate indicated.
b. Each type of non-elastomeric sealant and joint substrate indicated.

3. Arrange for tests to take place in presence of Engineer.
4. Test Method: Test joint sealers by hand pull method described below:

a. Install joint sealants in 1500mm joint lengths using same materials and methods for joint preparation and joint sealant installation required for completed Works. Allow sealants to cure fully before testing.
b. Make knife cuts as follows: A horizontal cut from one side of joint to the other followed by 2 vertical cuts approximately 50mm long at side of joint and meeting horizontal cut at top of 50mm cuts. Place a mark 25 mm from top of 50 mm piece.
c. Use fingers to grasp 50mm piece of sealant just above 25mm mark; pull firmly down at a 90-degree angle or more while holding a ruler alongside of sealant. Pull sealant out of joint to the distance recommended by sealant manufacturer for testing adhesive capability, but not less than that equaling specified maximum movement capability in extension; hold this position for 10 seconds.

5. Report whether or not sealant in joint connected to pull out portion failed to adhere to joint substrates or tore cohesively. Include data on pull distance used to test each type of product and joint substrate.
6. Evaluation of Field Test Results: Sealants not evidencing adhesive failure from testing, in absence of other indications of noncompliance with requirements, will be considered satisfactory. Do not use sealants, which fail to adhere to joint substrates during testing.

H. Field-Constructed Mock-Ups: Prior to installation of joint sealers, apply elastomeric sealants to the following selected pavement joints as indicated below for further verification of colors selected from sample submittals and to represent completed work for qualities of appearance, materials, and application:

1. Joints in field-constructed mock-ups of assemblies specified in other sections, which are indicated to receive elastomeric joint sealants specified in this section.
2. Retain mock-ups during construction as standard for judging completed construction

1.7 DELIVERY, STORAGE AND HANDLING

A. Deliver materials to Project site in original unopened containers or bundles with labels indicating manufacturer, product name and designation, color, expiration date, pot life, curing time, and mixing instructions for multi-component materials.

B. Store and handle materials to comply with manufacturer's written instructions to prevent their deterioration or damage due to moisture, high or low temperatures, contaminants, or other causes.

1.8 PROJECT CONDITIONS

A. Environmental Limitations: Do not proceed with installation of joint sealants under any of the following conditions:

1. When ambient and substrate temperature conditions are outside limits permitted by joint sealant manufacturer.
2. When joint substrates are wet due to rain, condensation, or other causes.
3. Where joint widths are less than those allowed by joint-sealant manufacturer for applications indicated.
4. Where contaminants capable of interfering with adhesion have not yet been removed from joint substrates.

B. Traffic Control: Maintain access for vehicular and pedestrian traffic as required for other construction activities.

PART 2 - PRODUCTS

2.1 MATERIALS, GENERAL

A. Compatibility: Provide joint sealants, backing materials, and other related materials that are compatible with one another and with joint substrates under conditions of service and application, as demonstrated by joint sealant manufacturer based on testing and field experience.

B. Colors of Exposed Joint Sealants: Match Engineer's samples.

C. Colors of Exposed Joint Sealants: As indicated by referencing manufacturer's designations.

D. Colors of Exposed Joint Sealants: As selected by Engineer from manufacturer's full range for this characteristic.

2.2 ELASTOMERIC JOINT SEALANTS

A. ASTM D5893/D5893M, Type NS.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

B. Single-Component, Self-Leveling, Silicon- Joint Sealant for Concrete: ASTM D5893/D5893M, Type SL.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of Engineer.

C. Multi-component, Pourable, Traffic-Grade, Urethane Joint Sealant for Concrete: ASTM C920, Type M, Grade P, Class 25, for Use T.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of Engineer.

2.3 COLD-APPLIED, JET-FUEL-RESISTANT JOINT SEALANTS

A. Sealants, Cold-Applied, Elastomeric, Jet-Fuel-Resistant type, for Portland Cement Concrete Pavements.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of Engineer.

B. Jet-Fuel-Resistant, Multicomponent, Pourable, Traffic-Grade, Modified-Urethane Joint Sealant for Concrete: ASTM C920, Type M, Grade P, Class 12-1/2, for Use T.

1. Products: Subject to compliance with requirements, [provide available products that may be incorporated into the Works, to the approval of the Engineer].

C. Jet-Fuel-Resistant, Multicomponent, Pourable, Traffic-Grade, Modified-Urethane Joint Sealant for Concrete: ASTM C920, Type M, Grade P, Class 25, for Use T.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

D. ASTM D2628 - Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements.

1. For preformed joint sealer, the manufacturer shall certify that the performed seal will exert a minimum pressure of 21 kPa when compressed to 80 percent of nominal width and a maximum of 172 kPa when compressed to 50 percent of nominal width.
2. Lubricant: Lubricant for installation of preformed joint seal shall be a one-component polychloroprene compound containing only soluble phenolic resins blended together with anti-oxidants and acid acceptors in aromatic hydrocarbon solvent mixture and shall meet the following requirements:

Table1: Lubricant requirements

Average weight per gallon	Requirements 3.54 [kg]	Standard
Solids content	22-28 [percent by weight]	ASTM D1644 (Method A)
Film strength	15.86 min. [Mpa]	ASTM D412
Elongation	750 min. [percent]	ASTM D412

3. Each shipment of lubricant shall be delivered to the jobsite in the manufacturer's original sealed container. Each container shall be marked with the manufacturer's name, batch or lot number, and the date of manufacture and shall be accompanied by the manufacturer's certification stating that the lubricant meets the requirements of the specification.
4. This lubricant shall be stored at a temperature between 10° C and 30° C and shall be used within 270 days of its manufacture.

E. Federal Specification SS-S-200–Joint Sealants, Cold-Applied, Two-Component, Jet Blast Resistant for Portland Cement Concrete Pavements Type M (Machine Application – Fast Curing)

2.4 HOT-APPLIED JOINT SEALANTS:

A. Hot-Applied, Single-Component Joint Sealant for Concrete and Asphalt: ASTM D6690, Types I, II, and III.

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

2.5 HOT-APPLIED, JET-FUEL-RESISTANT JOINT SEALANTS

A. Jet-Fuel-Resistant, Single-Component Joint Sealant for Concrete and/or for Tar Concrete. ASTM D7116 type I, II, or III

1. Products: Subject to compliance with requirements, provide available products that may be incorporated into the Works, to the approval of the Engineer.

2.6 JOINT-SEALANT BACKER MATERIALS

A. General: Provide joint-sealant backer materials that are non-staining; are compatible with joint substrates, sealants, primers, and other joint fillers; and are approved for applications indicated by joint sealant manufacturer based on field experience and laboratory testing.

B. Plastic Foam Joint Fillers: Preformed, compressible, resilient, non-waxing, non-extruding strips of flexible, non-gassing plastic foam of material indicated below; nonabsorbent to water and gas; and of size, shape and density to control sealant depth and otherwise contribute to producing optimum sealant performance.

1. Either open-cell polyurethane foam or closed-cell polyethylene foam, unless otherwise indicated, subject to approval of sealant manufacturer.

C. Bond-Breaker Tape: Polyethylene tape or other plastic tape as recommended by sealant manufacturer for preventing sealant from adhering to rigid, inflexible joint filler materials or joint surfaces at back of joint where such adhesion would result in sealant failure. Provide self-adhesive tape where applicable.

D. Round Backer Rod for Hot-Applied Sealants: ASTM D 5249, Type 1, of diameter and density required to control sealant depths and prevent bottom-side adhesion of sealant.

E. Backer Strips for Hot-Applied Sealants: ASTM D5249; Type 2; of thickness and width required to control sealant depths, prevent bottom-side adhesion of sealant, and fill remainder of joint opening under sealant.

F. Rod back-up material and bond-breaker material shall be as recommended by joint sealant manufacturer.

2.7 PRIMERS

A. Primers: Product recommended by joint sealant manufacturer where required for adhesion of sealant to joint substrates indicated, as determined from preconstruction joint- sealant-substrate tests and field tests.

2.8 ACCESSORIES

A. Cleaners for Nonporous Surfaces: Provide non-staining, chemical cleaners of type which are acceptable to manufacturers of sealants and sealant backing materials, which are not harmful to substrates and adjacent nonporous materials, and which do not leave oily residues or otherwise have a detrimental effect on sealant adhesion or in-service performance.

B. Masking Tape: Provide non-staining, nonabsorbent type compatible with joint sealants and to surfaces adjacent to joints.

C. Accessory Materials for Fire-Stopping Sealants: Provide forming, joint fillers, packing and other accessory materials required for installation of fire-stopping sealants as applicable to installation conditions indicated.

2.9 JOINT CLEANING EQUIPMENT

A. Equipment used for cleaning the joints shall consist of, but not be limited to, the following items.

B. Concrete Saw: The concrete saw shall be a self-propelled power saw with diamond or abrasive blades designed for sawing hardened concrete without damaging the sides, bottom, or top edges. Blades may be single or gang-type with one or more blades mounted in tandem for fast cutting. All blades shall be of the proper hardness for the concrete being sawed. The saw shall be adequately powered and capable of cutting to the specified width and depth with not more than two passes of the saw through the joints.

C. Sandblasting: Sandblasting equipment shall be standard commercial type capable of effectively scaling off any foreign material which may prevent proper bond of the new sealer. The compressor used for sandblasting shall provide air at a pressure of not less than 620 kPa and a minimum volume of 4.25 cu. m per minute at the nozzle. It shall be equipped with a moisture trap that effectively trap moisture and provide relatively dry air and not preventing free flow of sand. A dial gage indicating the air pressure shall be installed in a clearly visible location. A flexible hose of the proper diameter and of sufficient length shall be an integral part of the equipment. The nozzle shall be of a diameter in proper relation to the width of the joint and equipped with a guide that maintains the nozzle at a constant height, alignment, and angle of inclination. The guide shall be fabricated to allow adjustments in height and angle of inclination of the nozzle to secure the desired results.

D. Air Compressor: The air compressor shall be portable arid, oil free, capable of blowing out sand and other objectionable materials from the joints. This equipment shall meet the same capacity requirements as specified for the compressor for the sandblasting equipment. The compressor shall be equipped with sufficient hose of adequate capacity and nozzles of proper size for joint to be cleaned.

E. Vacuum Sweeper: The vacuum pickup sweeper shall be self-propelled and capable of completely removing all loose joint material, concrete slurry from the joints after sawing, and debris from the pavement surface. A sweeper of adequate capacity or a sufficient number of sweepers shall be provided to maintain the work area to the cleanliness standards required on airfield pavements.

2.10 OTHER ACCESSORIES

A. Cleaners for Nonporous Surfaces: Provide non-staining, chemical cleaners of type which are acceptable to manufacturers of sealants and sealant backing materials, which are not harmful to substrates and adjacent nonporous materials, and which do not leave oily residues or otherwise have a detrimental effect on sealant adhesion or in-service performance.

B. Masking Tape: Provide non-staining, nonabsorbent type compatible with joint sealants and to surfaces adjacent to joints.

C. Accessory Materials for Fire-Stopping Sealants: Provide forming, joint fillers, packing and other accessory materials required for installation of fire-stopping sealants as applicable to installation conditions indicated.

2.11 APPLICATION EQUIPMENT FOR HOT-POURED SEALER

A. Applicators used for heating and installing the sealing materials shall be of the mobile type and equipped with a double-wall agitator-type kettle with suitable oil-type extruding device with nozzle or nozzles shaped for insertion in the joints to be filled, positive temperature devices for controlling

the temperature of oil bath and sealer, and a recording thermometer for recording the temperature of the sealer. The applicator unit shall be designed so that the sealer may be circulated in the inner kettle when not in use and capable of completely filling the joint with the sealer without formation of voids or entrapped air. The applicator wand shall be insulated all the way to the nozzle and maintained in a satisfactory working condition.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine joints indicated to receive joint sealants, with Installer present, for compliance with requirements for joint configuration, installation tolerances, and other conditions affecting joint-sealant performance.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. General:

1. Final cleaning operations shall not proceed in advance of sealing operations by more than one working day, except as otherwise approved by the Engineer. Joints shall be thoroughly cleaned of all laitance, curing compound, dirt, and other foreign material. Cleaning procedures that cause excessive spalling along joints, as determined by the Engineer, shall not be used. Make changes in method of cleaning or equipment utilized as required to eliminate spalling. Concrete faces and the pavement surfaces extending approximately 13 mm from the joint edges shall be refaced by sandblasting. Sandblasting shall be continued until the joint surface and edges are clean and have etched surfaces. The joint shall be completely free of dust, dirt, and any other material that might prevent bonding of the sealer. After the sandblasting operation and immediately before the sealer is placed, the joints shall be thoroughly blown out by means of an air jet supplied by an air compressor meeting the requirements specified. Compressed air may be used at any time during the cleaning operations. However, to ensure removal of all loose material, a jet of compressed air is required immediately ahead of pouring operations, but in no case precede pouring by more than 30 minutes. Debris pick-up and disposal shall be a continuous process during cleaning operations, and the pavement surface be thoroughly cleaned immediately prior to sealing operations with a vacuum sweeper supplemented with hand brooms and tools, as required. Dispose of debris as directed.
2. Curing tape, masking tape or other approved bond-breaker shall be installed in each joint as shown on the Drawings. Submit the bond-breaker to the Engineer for approval prior to placing any joint seal material. The bond-breaker shall be installed in the joints without being stretched or damaged.

B. Joint Priming: Prime joint substrates where indicated or where recommended in writing by joint sealant manufacturer, based on preconstruction joint-sealant-substrate tests or prior experience. Apply primer to comply with joint sealant manufacturer's recommendations. Confine primers to areas of joint-sealant bond; do not allow spillage or migration onto adjoining surfaces.

C. Time of Application: Joint shall be sealed as soon after completion of the curing period as feasible and before the pavement is opened to traffic, including construction equipment. The pavement temperature shall be above 4 deg C at the time of installation of the preformed joint seal and above 10 deg C at the time of installation of the joint seal of material.

D. Sawing Joints: Saw joints with a concrete saw to the depth and width shown within a tolerance of plus or minus 1.5 mm. After sawing, joints shall present a straight rectangular opening with vertical sides.

E. Widening Cracks by Sawing: Random cracks shall be prepared for sealing as determined by the Engineer. The top of all random cracks shall be grooved to a depth of 20 mm and a width of not less than 10 mm and not more than 15 mm by means of a rotary-cutting type grooving machine. The grooving tool shall be capable of following closely the path of the crack and of widening the top of the crack to the required section without spalling or otherwise damaging the concrete. The side walls of cracks after cutting shall be vertical.

F. Sandblast Cleaning: Concrete joint faces and the pavement surfaces extending 13 mm from the joint edges shall be sandblast cleaned. Use a multiple-pace technique until the surfaces are free of saw cutting fines that might prevent bonding of the sealant to the concrete. After final cleaning and immediately prior to sealing, the joints shall be blown out with compressed air and left completely free of sand and water.

3.3 INSTALLATION OF JOINT SEALANTS

A. General:

1. Comply with joint sealant manufacturer's written installation instructions applicable to products and applications indicated unless more stringent requirements apply.
2. No Joint sealer shall be installed until the joints to be sealed have been inspected and approved. A bond-breaker shall be installed in the bottom of all joints just prior to pouring. Pouring of the joints shall be done in a neat, workmanlike manner. The joint sealing compound shall be applied into the joints by extending the material to fill the joints uniformly solid from bottom to top.

B. Sealant Installation Standard: Comply with recommendations of ASTM C1193 for use of joint sealants as applicable to materials, applications, and conditions indicated.

C. Install backer materials of type indicated to support sealants during application and at position required to produce cross-sectional shapes and depths of installed sealants relative to joint widths that allow optimum sealant movement capability.

1. Do not leave gaps between ends of backer materials.
2. Do not stretch, twist, puncture, or tear backer materials.
3. Remove absorbent backer materials that have become wet before sealant application and replace them with dry materials.

D. Install sealants by proven techniques to comply with the following and at the same time backings are installed:

1. Place sealants so they directly contact and fully wet joint substrates.
2. Completely fill recesses provided for each joint configuration.
3. Produce uniform, cross-sectional shapes and depths relative to joint widths that allow optimum sealant movement capability.

E. Tooling of Nonsag Sealants: Immediately after sealant application and before skinning or curing begins, tool sealants according to requirements specified below to form smooth, uniform beads of configuration indicated; to eliminate air pockets; and to ensure contact and adhesion of sealant with sides of joint.

1. Remove excess sealants from surfaces adjacent to joint.
2. Use tooling agents that are approved in writing by joint sealant manufacturer and that do not discolor sealants or adjacent surfaces.

F. Provide joint configuration to comply with joint sealant manufacturer's written instructions, unless otherwise indicated.

G. Provide recessed joint configuration for silicone sealants of recess depth and at locations indicated.

H. The joints shall be filled to 6 mm of the top of the pavement as shown, without formation of voids or entrapped air using the type of equipment specified.

I. Excess sealer or sealer that has been inadvertently spilled shall be removed from the pavement by approved methods and discarded.

J. Traffic shall not be allowed for 24 hours over pavement, except as approved. Use of gravity methods of application and pouring pots will not be allowed except as approved.

K. Hot Poured Sealants:

1. The joint sealant shall be applied solid, uniformly from bottom to top and shall be filled without formation of entrapped air or voids.
2. A backing material shall be placed as shown on the plans and shall be non-adhesive to the concrete or the sealant material.
3. The heating kettle shall be an indirect heating type, constructed as a double boiler. A positive temperature control and mechanical agitation shall be provided. The sealant shall not be heated to more than 11 deg. C below the safe heating temperature. The safe heating temperature can be obtained from the manufacturer's shipping container.
4. A direct connecting pressure type extruding device with nozzles shaped for insertion into the joint shall be provided.
5. Any sealant spilled on the surface of the pavement shall be removed immediately.
6. Backup materials and bond breakers should be compatible with the sealant, should not adhere to the sealant, should be compressible without extruding the sealant, and should recover to maintain contact with the joint faces when the joint is open.

L. Cold Applied Sealants: Cold applied joint sealing compound shall be applied by means of pressure equipment that will force the sealing material to the bottom of the joint without spilling the material on the surface of the pavement. A backing material shall be placed as shown on the plans and shall be non-adhesive to the concrete or the sealant material. Sealant which does not bond to the concrete surface of the joint walls, contains voids, or fails to set to a tack-free condition will be rejected and replaced by the Contractor at no additional cost. Before sealing the joints, the Contractor shall demonstrate that the equipment and procedures for preparing, mixing, and placing the sealant will produce a satisfactory joint seal. This shall include the preparation of two small batches and the application of the resulting material.

M. Preparation of Joint Sealing Material (Hot-Poured Sealer): Sealer shall not be heated in excess of the safe heating temperature recommended by the manufacturer as shown on sealer container. Any sealer that has been overheated or has remained in the applicator at the end of the day's operation shall be withdrawn and disposed of.

N. Weather Limitations: The concrete at the joint shall be surface dry, and the atmospheric and pavement temperature above 10 deg C at time of application of the sealing material. No sealant shall be applied in foggy or rainy weather.

O. Approval of Sealed Joints: Any joints that do not meet the requirements as determined by the Engineer shall be corrected by removing the sealer and resealing the joints in a satisfactory manner.

P. Preformed Elastomeric Joint Seals:

1. Preformed joint sealer shall be placed using equipment capable of installing the sealer in the upright position, without cutting, nicking, distorting, or otherwise damaging the seal.
2. Lubricant shall be applied to the concrete or the preformed seal, or both, and the seal shall be installed in a substantially compressed condition and at the depth below the surface of the pavement as shown in the plans.
3. The method of installation shall be such that the joint sealer will not be stretched more than 5 percent of the minimum theoretical length or compressed more than 2 percent.
4. The method of installation shall be checked for stretching or compression, using transverse joint sealer. The check shall consist of installing sealer in five joints of at least 7.5 m in

length, removing the sealer immediately after installation, and checking the length. This check may be modified by pre-marking or precutting the sealer to length prior to installation if this is compatible with the equipment being used.

5. If the measured length of any of these five sealers indicated that the sealer is stretched or compressed beyond these limits, the installation shall be modified to correct the situation.
6. Once satisfactory sealing operations have started, one joint length per every hundred shall be removed and checked.
7. If the limits are exceeded, the joint sealers on either side should be removed until the condition disappears. The affected joints shall be resealed in a satisfactory manner at own cost, and the method of installation shall be checked again for satisfactory procedure.
8. The seal shall be installed in the longest practicable lengths in longitudinal joints and shall be cut at the joint intersections for continuous installation of the seal in the transverse joints.

3.4 TRIAL JOINT INSTALLATION

A. Preliminary to sealing of joints for the entire project, a length of at least 50 m of joint in an approved location shall be cleaned and prepared, and the joint filled with sealant material in the manner proposed for completion of the entire Project. This section shall be inspected prior to continuing work to determine that the installation satisfactorily meets all requirements. If the trial installation is not satisfactory, the material shall be removed and an additional 50 m length of joint shall be cleaned, prepared, filled, and inspected. Following approval of a trial installation, all other joint grooves shall be cleaned, prepared, and filled in a similar manner, subject to the approval of the Engineer.

3.5 CLEANING

A. Clean off excess sealants or sealant smears adjacent to joints as the Work progresses by methods and with cleaning materials approved by manufacturers of joint sealants and of products in which joints occur.

3.6 PROTECTION

A. Protect joint sealants during and after curing period from contact with contaminating substances and from damage resulting from construction operations or other causes so sealants are without deterioration or damage at time of Taking Over. If, despite such protection, damage or deterioration occurs, cut out and remove damaged or deteriorated joint sealants immediately so installations with repaired areas are indistinguishable from the original work.

3.7 PAVEMENT-JOINT-SEALANT SCHEDULE

A. Joint-Sealant Application: Joints within cement concrete pavement.

1. Joint Location:

    a. Expansion and isolation joints in cast-in-place concrete pavement.
    b. Contraction joints in cast-in-place concrete slabs.
    c. Other joints as indicated.

2. Silicone Joint Sealant for Concrete: Single component, non-sag, or Single component, self-leveling, as approved by the Engineer.
3. Urethane Joint Sealant for Concrete: Multi-component, pourable, traffic-grade, as approved by the Engineer.
4. Hot-Applied Joint Sealant for Concrete: [Single component, as approved by the Engineer.
5. Joint-Sealant Color: As indicated by manufacturer's designations and Match Engineer's sample, as approved by the Engineer.

B. Joint-Sealant Application: Fuel-resistant joints within cement concrete pavement.

1. Joint Location:

a. Expansion and isolation joints in cast-in-place concrete pavement.
b. Contraction joints in cast-in-place concrete slabs.
c. Other joints as indicated.

2. Jet-Fuel-Resistant, Modified-Urethane Joint Sealant for Concrete: Single-component, pourable, traffic-grade or Multi-component, pourable, traffic-grade, Class 12-1/2 or Multi-component, pourable, traffic-grade, Class 25, as approved by the Engineer.
3. Hot-Applied, Jet-Fuel-Resistant, Joint Sealant for Concrete: Single component, as approved by the Engineer.

C. Joint-Sealant Application: Joints between cement concrete and asphalt pavement.

1. Joint Location:

a. Joints between concrete and asphalt pavement.
b. Joints between concrete curbs and asphalt pavement.
c. Other joints as indicated.

2. Hot-Applied Joint Sealant for Concrete and Asphalt: Single component, as approved by the Engineer.
3. Joint-Sealant Color: As indicated by manufacturer's designations and Match Engineer's sample, as approved by the Engineer.

D. Joint-Sealant Application: Fuel-resistant joints between cement concrete and Asphalt concrete pavement.

1. Joint Location:

a. Joints between concrete and Asphalt concrete pavement.
b. Joints between concrete curbs and Asphalt concrete pavement.
c. Other joints as indicated.

2. Hot-Applied, Jet-Fuel-Resistance Joint Sealant for Concrete and Asphalt Concrete: Single component, as approved by the Engineer.
3. Joint-Sealant Color: As indicated by manufacturer's designations and Match Engineer's sample, as approved by the Engineer.

3.8 WARRANTY ON THE EXECUTED JOINT SEALANT

A. The Contractor and his Supplier shall provide a minimum of 5-year warranty on the executed pavement joint sealant, whereby they will be held liable for any drying-out, hardening, loosening of elasticity, foaming, flow or spillage on the adjacent surface with time, and/or any sort of disintegration or damage that is not induced by other entities. If any of these defects is exhibited by the executed joint sealant during this warranty period, it shall be removed and replaced at the Contractor’s own cost.

3.9 TESTING STANDARDS AND CODES

ASTM C719	Standard Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants Under Cyclic Movement (Hockman Cycle)
ASTM C920	Standard Specification for Elastomeric Joint Sealants
ASTM C1021	Standard Practice for Laboratories Engaged in Testing of Building Sealants
ASTM C1193	Standard Guide for Use of Joint Sealants
ASTM D412	Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
ASTM D1644	Standard Test Methods for Nonvolatile Content of Varnishes
ASTM D2628	Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements
ASTM D3569	Standard Specification for Joint Sealant, Hot-Applied, Elastomeric, Jet-Fuel-Resistant-Type for Portland Cement Concrete Pavements
ASTM D5249	Standard Specification for Backer Material for Use with Cold- and Hot-Applied Joint Sealants in Portland-Cement Concrete and Asphalt Joints
ASTM D5893/D5893M	Standard Specification for Cold-Applied, Single-Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements
ASTM D6690	Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements
ASTM D7116	Standard Specification for Joint Sealants, Hot Applied, Jet Fuel Resistant Types, for Portland Cement Concrete Pavements

END OF SECTION 321373

SECTION 321723.13 - AIRFIELD PAVEMENT MARKINGS

PART 1- GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Particular Conditions of Contract and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section is applicable to pavement marking works to be executed within the airside areas of the Airport related to: runways, taxiways and taxi-lanes, aprons, staging areas, roads, etc. unless otherwise indicated.

B. This Section includes the following:
   1. Waterborne paint

C. Paint shall be supplied in No 37925 white, No. 33538 or 33655 yellow, 31136 Red, 37038 black and pink one-part 31136 to two parts 37925 complying with Federal Standard No. 595.

D. Waterborne or solvent based paint should be used to outline a boarder at least 150 mm wide around markings on all light-colored pavements. Preformed thermoplastic markings shall have a non-reflectorized black boarded integral to the marking.

E. Related Sections include the following:

   1. Section 321216 “Asphalt paving”.

   2. Section 321373 “Concrete paving joint sealants”.

1.3 SUBMITTALS

A. Product Data: For each type of product indicated, include technical data and tested physical and performance properties.

B. Qualification Data: For manufacturer.

C. Material Test Reports: For each type of material, verifying compliance with physical and chemical requirements of these specifications.

D. Material Certificates: For each type of product indicated, signed by the manufacturers.

1.4 QUALITY ASSURANCE

A. Manufacturer Qualifications: A qualified manufacturer.

B. Installer Qualifications: An experienced installer who has completed pavement marking work similar in material, design and extent to that indicated for this project and whose work has resulted in construction with a record of successful in-service performance.

C. Testing Agency Qualifications: An independent testing agency, acceptable to authorities having jurisdiction, qualified according to ASTM C 1077 and ASTM E 329 to conduct the testing indicated, as documented according to ASTM E 548.

D. Maintenance of Traffic: The performance of work in the controlled zones of airfields shall be coordinated with the Contractor and Airport Operator. Verbal communications shall be maintained with the control tower before and during work in the controlled zones of the airfield. The control

tower shall be advised when the work is completed. A radio for this purpose shall be provided by the Contractor and approved by the Airport Operator.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Deliver all materials to project site in original packages with seals unbroken and bearing manufacturer's labels containing brand name and type of material, date of manufacture, and directions for storage.

B. Store pavement marking materials in a clean, dry, protected location within temperature range required by manufacturer. Protect stored materials from direct sunlight.

1.6 PROJECT CONDITIONS

A. Environmental Limitations: Apply pavement-marking paint only if the following conditions are present:

1. When the pavement surface is dry and free of dirt, existing paint lines, curing compound, grease, oil, moisture, loose or unsound layers, and any other material.
2. When the weather is not misty or windy.
3. Surface temperatures above 7 deg. C.
4. The Engineer will determine the suitability of the weather.

PART-2 PRODUCTS

2.1 PAINT MATERIALS

A. Waterborne Paint

1. Paint shall meet the requirements of Federal Specification TT-P-1952F, Type III. The nonvolatile portion of the vehicle for all paint types shall be composed of a 100% acrylic polymer as determined by infrared spectral analysis The acrylic resin for Type III shall be 100 percent cross linking acrylic as evidenced by infrared peaks at wavelengths 1568, 1624, and 1672 cm-l with intensities equal to those produced by an acrylic resin known to be 100 percent cross linking.

B. Retro-reflective Semi Flush Pavement Markers

1. Retro-reflective semi flush pavement markers shall be plain prismatic markers.
2. Color indication shall be yellow.
3. Colormetric characteristics may be tested and approved base on chromaticity requirements specified in accordance with AC 150/5345-39D.
4. The shell material shall conform to Federal Specification L-P-380, plastic molding material mathacrylate, Type 1, Class 3.
5. The fabrication of the shell shall be as specified in AC 150/5345-39D.
6. The base of the marker shall not deviate from a flat surface by more than 2 mm, shall be rough textured, and free from gloss or substances, which may reduce its bond to the adhesive.
7. Markers shall have adequate area to dissipate the loading specified in 4.2.7 of AC 150/5345-39D and to provide for secure bonding to the pavement.

PART 3 - EXECUTION

3.1 SURFACE PREPARATION

A. Remove loose particles, dirt, tar, grease, and other deleterious materials from the surface to be marked. Where necessary, the surface shall be wet with a water jet and scrubbed to dislodge all foreign material without damaging the surface.

B. Where markings are placed on Portland cement concrete pavement less than 1 year old, clean the pavement of all residue and curing compounds.

C. Completely remove by sand blasting, hydroblasting or any equipment necessary existing pavement markings that are being replaced with new pavement marking.

D. Any work placed in violation of the above conditions, or damage due to water or rain within 30 minutes after application, shall be removed without additional compensation.

3.1.1 Pretreatment for early painting

A. When early painting is required on rigid pavements, apply a pretreatment with an aqueous solution, containing 3 percent phosphoric acid and 2 percent zinc chloride, to prepare pavement areas prior to painting.

3.2 MIXING

A. Mechanical Mixers: Shall be used to mix paint. Prior to applying, the paint shall be mixed a sufficient length of time to thoroughly mix the pigment and vehicle together, and shall be kept thoroughly agitated during its application.

3.3 APPLICATION EQUIPMENT

A. Mechanical means shall be used to paint traffic stripes and pavement markings and to apply the glass beads for traffic stripes.

B. Equipment used in the application of traffic stripes and pavement markings shall produce stripes and pavement markings of uniform quality that conform to the specified requirements.

C. Stencils and Hand Spray Equipment: Shall be used to paint pavement markings, Stencils shall conform to the dimensions shown on the plans.

D. The striping machine shall be capable of accurately superimposing succeeding coats of traffic paint upon the first coat and upon existing stripes at a speed of at least 8km/h.

E. Striping Machine: Consist of a rubber-tired vehicle that is maneuverable to the extent that straight lines can be followed and normal curves can be made in true arcs. It shall be capable of applying traffic paints and glass beads at the rates specified. The stripping machine shall be equipped with the following:

1. A pointer or sighting device not less than 1.5m long and extending from the front of the machine.
2. A pointer or sighting device extending from the side of the machine to gauge the distance from the centerline for painting shoulder stripes.
3. A positive acting cutoff device to prevent depositing paint in gaps of broken stripes.
4. Shields or an adjustable air curtain for line control.
5. Pressure regulators and gages (if pneumatically operated) that are in full view of the operator.
6. A paint strainer in the paint supply line.
7. A paint storage tank with a mechanical agitator that operates continuously during painting operations.

8. A glass bead dispenser located behind the paint applicator nozzle and which is controlled simultaneously with the paint applicator nozzle.
9. Calibrated rods for measuring the volumes of paint and glass beads in the paint and glass bead tanks.

F. Spray Equipment: Proper type and of adequate capacity for the work. Air atomized spray equipment shall be equipped with oil and water extractors and pressure regulators and shall have adequate air volume and compressor recovery capacity. Spray gun tip needle assemblies and orifices shall be of the proper sizes.

F. Where the configuration or location of a traffic stripe is such that the use of a striping machine is unsuitable, traffic paint and glass beads may be applied by other methods and equipment approved by Engineer. Engineer will determine if the striping machine is unsuitable for a particular use.

3.4 SETTING OUT

A. On those sections of pavement where no previously applied markings are available to serve as a guide, the proposed markings shall be laid out in advance of the paint application. Control points shall be spaced at such intervals as will ensure accurate location of all markings. The Contractor shall provide an experienced technician to supervise the location, alignment, layout, dimensions, and application of the paint.

3.5 PAINTING APPLICATION

A. Markings shall be applied at the locations and to the dimensions and spacing shown on the plans. Paint shall not be applied until the layout and condition of the surface have been approved by the Engineer.

B. the paint shall be mixed in accordance with the manufacturer's instructions and applied to the pavement with marking machine at the rate shown in Table 1 below. The addition of thinner will not be permitted. A period of time shall elapse between the placement of bituminous surface course or concrete and the application of the paint in accordance with the manufacturer's recommendations.

C. Prior to the full application of airfield markings, the Contractor shall produce a test strip in the presence of the Engineer. The test strip shall include the application of minimum of 4 liters of paint and application of 15.9 kg of Type I/22.7 kg of Type III glass beads. The test strip shall be used to establish thickness/darkness standard for all markings. The test strip shall cover no more than the maximum area prescribed in Table 1 (e.g. for 19 liters of waterborne paint shall cover no more than 53.4 sq. m.).

Table 1 – Application Rates for Paint and Glass Beads

Paint Type	**Paint** **Sq. m per liter (m^2/l)**	**Glass Beads, Type III** **Kg per liter of paint (kg/l)**
Waterborne Type III	2.2 max	1.0 min

Note: Type III beads shall not be applied to Red or Pink paint

D. The edges of the markings shall not vary from a straight line more than 12mm in 15m and the dimensions and spacing shall be within the following tolerances:

Dimensions and Spacing	**Tolerance**
910 mm or less	12 mm
Greater than 910 mm to 1.85 m	25 mm
Greater than 1.85 m to 18.3 m	50 mm
Greater than 18.3 m	76 mm

Glass spheres shall be distributed to the surface of the marked areas immediately after application of the paint. A dispenser shall be furnished which is properly designed for attachment to the marking machine and suitable for dispensing glass spheres. Glass beads shall adhere to the cured paint or all marking operations shall cease until corrections are made.

E. The Contractor shall furnish certified test reports for the materials shipped to the project. The reports shall not be interpreted as a basis for final acceptance. The Contractor shall notify the Engineer upon arrival of a shipment of paint to the job site. All emptied containers shall be returned to the paint storage area for checking by the Engineer. The containers shall not be removed from the airport or destroyed until authorized by the Engineer.

3.6 PROTECTION OF MARKINGS

A. After application of the paint, all markings shall be protected from damage until the paint is dry. All surfaces shall be protected from disfiguration by spatter, splashes, spillage, or drippings of paint.

3.7 REMOVAL OF EXISTING AIRFIELD MARKINGS

A. Where it is necessary to remove existing markings, the material shall be completely removed by sand blasting, waterblasting or other abrasive methods.

B. Care shall be taken to avoid damaging the wearing course surface during this operation.

C. Any damage caused to the wearing course shall be made good to the satisfaction of the engineer.

D. The painting over old markings with black paint shall not be permitted.

3.7 FIELD QUALITY CONTROL

A. Paint Marking Material: Tested prior to use and the manufacturer shall provide a certificate of compliance. The certificate shall certify that the paint marking material complies with the specifications.

END OF SECTION 321723.13

SECTION 324113.13 - PAVEMENT DEMOLISHING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including Conditions of Contract, and the Project Requirements, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Removal, wholly or in part, and satisfactory disposal of existing concrete and/or asphalt pavement layers, and any cement or bitumen stabilized base course in the designated areas shown on the Drawings. It shall also include the salvaging of designated materials and backfilling the resulting holes where and as instructed by the Engineer.
2. The Contractor shall examine the Site and carry out a precondition survey to record all obstructions and utilities and site inventory at the commencement of the Works and prior to demolishing or milling off.

B. Related Sections:

1. Section 321216.30 “Asphalt Paving for Airfield”

1.3 DEFINITIONS

A. Remove: Detach items from existing construction and legally dispose of them off-site unless indicated or directed to be removed and salvaged or removed and re-used.

B. Remove and Salvage: Carefully detach from existing construction, in a manner to prevent damage, and store for reuse.

C. Existing to Remain: Existing items of construction that are not to be removed and that are not otherwise indicated to be removed, removed and salvaged, or removed and re-used.

1.4 PREINSTALLATION MEETINGS

A. Predemolition Conference: Conduct conference at Project site to comply with the project requirements. Review methods and procedures related to pavement demolition including, but not limited to, the following:

1. Inspect and discuss condition of construction to be demolished.
2. Review and establish extent of any 'restricted' areas of demolition.
3. Review and finalize pavement demolition schedule and verify availability of demolition personnel, equipment, and facilities needed to make progress and avoid delays.
4. Review and finalize protection requirements.
5. Review procedures for noise control and dust control.
6. Review procedures for protection of adjacent structures.
7. Discuss existing utilities and subsurface conditions.
8. Review coordination with temporary controls and protections.
9. Review items to be salvaged and returned to Employer.

1.5 ACTION SUBMITTALS

A. Existing Conditions: Documentation of existing adjoining construction, services, utilities and fuel lines, concrete pavement slabs and site improvements that establishes preconstruction conditions that might be misconstrued as damage caused by demolishing works.

B. Record Drawings: Identifying and accurately showing locations of capped utilities and other subsurface structural, electrical, and mechanical conditions, to ensure that the existing services are kept in a safe and stable condition for the duration of the Works.

C. Structures and installations to be demolished shall be surveyed by the Contractor and sketches of these structures and installations shall be submitted to the Engineer, to establish exposed constructional dimensions and details. This information shall be used by the Engineer to confirm the scope of the demolition and the materials or equipment to be recovered.

D. The Contractor shall submit to the Engineer's approval the method of pavement demolition works including the sequence of operations and any special procedural requirements not less than seven days from the start of the execution works.

1.6 INFORMATIONAL SUBMITTALS

A. Engineering Survey: Submit engineering survey of condition of existing pavement, as directed by the Engineer.

B. Schedule of Pavement Demolition Activities: Indicate the following:

1. Detailed sequence of demolition and removal work, with starting and ending dates for each activity.
2. Permanent or temporary interruption of utility services.
3. Coordination for shutoff, capping, re-routing and continuation of utility services.
4. Coordination of Employer's continuing on-site operations, including occupancy or partial use of premises, if any.

C. Predemolition Photographs or Videotape: Show existing conditions of adjoining construction and site improvements, including finish surfaces, that might be misconstrued as damage caused by pavement demolition operations. Submit before works begins.

D. Survey for existing pavement: submit a survey for existing pavement to be demolished in case As-Built drawings are not available.

E. Submit No Objection Certificates "NOC" from all end-users, concerned authorities and utility providers prior to proceed with demolition works.

F. Submit method statement, Work Notification to the Engineer's review and approval.

1.7 CLOSEOUT SUBMITTALS

A. Inventory: After pavement demolition is complete, submit lists of items that have been removed and salvaged or removed for re-use.

1.8 QUALITY ASSURANCE

A. Equipment shall demonstrate compliance with the project requirements.

B. Preinstallation Conference: Conduct conference at Project site prior to commencing pavement demolishing operations.

C. Demolition Firm Qualifications: An experienced firm that is specialized in demolition work similar in material and extent to that indicated for this Project.

D. Professional Engineer Qualifications: A professional engineer who is legally registered and qualified to practice in jurisdiction where Project is located and who is experienced in providing engineering services of the kind indicated.

E. Regulatory Requirements: Before beginning demolition, comply with notification regulations of authorities having jurisdiction. Comply with hauling, including means and methods of transport, and disposal regulations of authorities having jurisdiction.

1.9 FIELD/PROJECT CONDITIONS

A. Traffic: Minimize interference with adjoining airfield facilities, and other adjacent occupied or used facilities during demolishing operations.

1. Do not close or obstruct streets, walks, or other adjacent occupied or used facilities without permission from the Engineer and authorities having jurisdiction.
2. Provide alternate routes around closed or obstructed traffic ways if required by the Engineer or authorities having jurisdiction.

B. Protection of Existing Improvements: Provide protections necessary to prevent damage to existing improvements indicated or directed to remain in place. Restore damaged improvements to their original condition, to the satisfaction of the Engineer.

C. A No objection certificate (N.O.C) shall be obtained from the concerned authorities prior to the start of any demolishing works.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION

3.1 MATERIAL OWNERSHIP

A. Except for materials indicated or directed to be stockpiled or otherwise remain the Employer’s property, demolished materials shall become the Contractor's property and shall be removed from Project site.

3.2 GENERAL

A. The Contractor’s removal operation shall be controlled to not damage adjacent pavement structure, and base material, cables, utility ducts, pipelines, or drainage structures which are to remain under the pavement.

B. The Contractor shall raze, remove and dispose off old pavement of different types to depths as indicated on the drawings, for the portions which are within the Limit of Work. All designated material shall be removed, without causing unnecessary damage.

C. Unusable perishable material shall be disposed of in accordance with the applicable laws and regulations. Non-perishable material may be disposed of off the Site, provided permission of the respective property owners has been obtained in writing to dump such materials on their land.

D. Cavities left by pavement removal shall be filled to the level of the surrounding ground and, if within the prism of construction, shall be compacted as specified for Subgrade Construction under Section 321000.

3.3 REMOVAL OF LIGHTING EQUIPMENT

A. The Contractor shall remove the airfield lighting equipment (fixtures, accessories and the like) before removal of the existing pavements layers.

3.4 PROTECTION OF EXISTING UTILITIES

A. The Contractor shall be responsible for supporting and protecting existing Utilities that are to remain in place, for the duration of the Contract and shall provide all necessary Temporary Works in this respect. Any damage caused to Utilities and attributable to the Contractor shall be repaired at his expense.

B. The Contractor shall be responsible for and shall ensure that pavement removal operations must be completed without applying extreme vibration and heavy loading that may damage the existing underground utilities.

3.5 STOCKPILING PAVEMENT DEMOLISHED MATERIAL

A. During the recovery and stockpiling operations, asphalt pavement containing soil or other debris shall be kept separate from recovered pavement which does not contain soil or other debris.

B. Existing pavement to be recovered shall be removed and stockpiled by methods which will minimize losses and prevent it being contaminated with other materials. The Contractor shall ensure that the stockpiled material is relatively free of soil and other matter.

3.6 CLEANING

A. Clean adjacent structures and improvements of dust, dirt, and debris caused by pavement demolition operations. Return adjacent areas to condition existing before pavement demolition operations began.

1. Clean nearby areas and pavements of debris caused by debris transport.

END OF SECTION 324113.13

SECTION 344314 – AIRFIELD GROUND LIGHTING EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract apply to this Section.

1.2 SUMMARY

A. Section includes airfield ground lighting and associated auxiliary equipment including but not limited to lighting fixtures, isolating transformers, airfield lighting cables, connectors, Constant Current Regulators (CCRs circuit cutouts, earthing installations, bases, poles/masts, mounting accessories, and non-illuminated airfield guidance signs.

B. Conflicts

1. Drawings and specifications are to be used in conjunction with one another and to supplement one another. In general, the specifications determine the nature and quality of the materials and tests, and the drawings establish the quantities, details, and give characteristics of performance that should be adhered to in the installation of the system components.

2. These specifications and the project drawings are complimentary, and what is called for in either of these shall be binding as though called for by both. Should any conflict arise between the drawings and specifications, such conflict shall be brought to the attention of the Engineer for resolution. If the Contractor fails to contact the Engineer in writing of any conflict between the specifications and the project drawings, the Contractor shall be subject to re-work the area of conflict at the Contractor's cost.

3. Clarification with the Employer and/or Employer's Representative or Consultant about items of conflict shall be made prior to the ordering and installation.

1.3 REFERENCE STANDARDS

A. The latest published edition of a reference shall be applicable to this Project unless identified by a specific edition date/revision.

B. The publications listed below form a part of this specification. The publications are referred to in the text by basic designation only.

C. Specific reference in specifications to codes, rules, regulations, standards, manufacturer's instructions, or requirements of regulatory agencies shall mean reference to the latest printed edition of each.

D. Codes and Standards: All materials, installation and workmanship shall comply with the applicable requirements and standards addressed within the latest edition of the following references:

1. Local Standard (Lebanese Civil Aviation Regulations).

2. ICAO, Annex 14, Aerodromes, International Standards and Recommended Practices 9th edition

3. ICAO, Aerodrome Design Manual, Visual Aids - Part 4, Doc. 9157-AN/901 5th edition amendment 1

4. ICAO, Aerodrome Design Manual, Electrical Systems - Part 5, Doc. 9157-AN/901 2nd Edition, 2017 (Amendment no. 1 dated 20/1/20)

5. ICAO, Aerodrome Design Manual, Frangibility - Part 6, Doc. 9157-AN/901 1st Edition, 2006

6. ICAO, Airport Services Manual, Airport Operational Services - Part 8, Doc. 9137-AN/898. 1st Edition

7. FAA, Advisory Circulars (AC), as referred to within the Specifications, including but not limited to:
   a. FAA, AC 150/5340-30J, 2018, Design and Installation Details for Airport Visual Aids.

E. Local regulations and standards, where enforced and relevant, are to have precedence over the International Standards.

F. ICAO Standards are to have precedence over FAA Standards.

1.4 CLIMATIC CONDITIONS

A. Climatic Conditions At Project Site:

1. Altitude: 10m AMSL
2. Maximum temperature: 36 deg. C
3. Minimum temperature: 7 deg. C
4. Maximum relative humidity: 100 percent.

B. The equipment shall be designed for outdoor installation and operate in a temperature range of –40° to +55° C, as well as to the effect of indirect radiation, and in a relative humidity of 100%.

C. Where design and operating conditions, different from the above are required for particular equipment, they are described in the specification of the equipment concerned.

D. Equipment, apparatus, material accessories installed outdoors shall be corrosion and salinity proof. UV stabilized requirement shall be applied for outdoor installations and their surface finish and due certification be provided by manufacturer as necessary. Unless otherwise stated in the relevant specification section, the following degrees of protection to IEC 529 (BS EN 60529) shall be applied for all outdoor equipment:

1. Smaller devices/panels to be IP-65.
2. Panels/equipment shall be IP-54.

1.5 SUBMITTALS

A. Installation plans, schedules, calculations and connection diagrams for the airfield lighting equipment, including all equipment.

B. Acceptance inspection and testing plan, including procedures for airfield lighting equipment inspection and testing to ensure proper installation and operation.

C. Manufacturer’s drawings, including drawings necessary for the installation. and electrical connections of electrical equipment or devices furnished.

D. Point-wise compliance statement to the specifications, duly signed by the manufacturer/ manufacturer authorized representative and by the contractor, along with supporting documentation (third party certificates, catalogues, calculations and the like) proving the compliancy statement.

E. Technical Data: Submit data for approval, including catalogues, detailed literature, manufacturer name, catalogue number, ordering reference/number, rating, specification, overall dimensions and special features, as applicable for each item.

F. Guarantee to supply spares for the complete Airfield Lighting System Equipment for a minimum period of ten years from the date of Taking Over.

G. The AGL Contractor shall prepare all shop drawings required for the installation, testing/commissioning and maintenance of the AGL installations. These drawings shall consist of, but not limited to the following:

1. AGL layout drawings,

2. AGL cable routing drawings for the individual circuits,

3. AGL wiring drawings for each circuit,

4. AGL fixtures legend sheet and the quantity of each type of fixtures installed at site.

H. All drawings shall use standard colored legends and suitably sized with relevant information. The drawings and texts used shall be easily readable. All Drawings shall be as per Employer's standards and shall meet Employer requirements.

I. The AGL Contractor/Supplier shall submit the full details for the following:

1. Isolating transformers sizing calculations to show that the selected isolating transformers can cater for the cable losses, fixture load, and the ILCM unit(s). Typical calculations are to be submitted for typical cable lengths for each type/application of airfield lighting. A spare capacity of 10% of their nominal rating shall be considered for all isolating transformers without any saturation for the isolating transformers.

2. CCR sizing calculations showing that the selected CCR's selection can cater for the cable losses, isolating transformer losses, loads and electrical characteristics (both transient and continuous including inrush currents) of the fixtures all other factors on the series circuit. A spare capacity of 25% of their nominal rating shall be considered for all CCR's.

3. Changes to the system or civil works.

J. Contractor is to submit site acceptance sheets based on supplier recommendations for accepting the equipment on site.

K. Contractor is to submit a safety assessment document for all equipment supplied under the project.

L. Contractor is to provide complete technical information deemed necessary by the Employer/Engineer, for the equipment/system. including the equipment and software used for commissioning, testing or troubleshooting.

M. The AGL contractor shall provide the complete database of the installed AGL equipment/fixtures, circuits, etc. with extensive technical details/catalogues/manuals.

N. Third Party Test Reports and Certificates , to prove compliance with ICAO , FAA and IEC Standards, for each type of the following equipment:

1. Airfield lighting fixtures.

2. Airfield guidance signs.

3. Airfield lighting cables and connectors.

4. Series isolating transformers.

5. Constant current regulator.

6. Frangible couplings.

O. All third party documents (certificates, test reports…) shall show the third party company name, contact details, date of testing, date of issue, model number of the subject product and document number and revision.

P. Contractor to submit the details for the earthing/counterpoise system for engineer's approval prior to execution on site.

1.6 QUALITY ASSURANCE

A. All work shall be in accordance with requirements of Contract Specifications- Electrical Sections, and other applicable Sections as well as ICAO regulations.

1. Installer qualifications: Engage an experienced installer who is an authorized representative of airfield lighting system manufacturers to perform the necessary works with history of large-scale installations worldwide, especially in the Middle East.

2. Contractor qualifications: Engage a firm fully experienced in designing and installation of airfield lighting systems and related control & monitoring Systems complying with the requirements of these specifications. Contractor shall submit details of Airports where similar installations have been executed, including the date of installation and the years of operation.

3. Comply with contractors and manufacturers approved quality assurance plans.

B. The Contractor/Supplier of the lighting fixtures is to be responsible for any contradiction with ICAO requirements concerning the selection of the AGL fixtures as far as construction, characteristics and/or application, taking into consideration the FAA circulars, irrespective of any error that may appear on drawings or in the specification herein. In other words, ICAO recommendations are to be over-ruling over the drawings and specification, and the Contractor is to advise the Engineer prior to handling such erratic materials.

C. Contractor is to perform on-site testing of the illumination levels produced by the lighting fixtures to confirm compliance with ICAO Regulations. Contractor is to cater for all corrective measures and repeat all necessary areas/measures which do not comply with the regulations until the levels achieved are approved by the Engineer.

D. The Contractor shall deliver complete and operable airfield lighting system products that comply with the minimum performance and availability requirements, notwithstanding any errors or omissions in these specifications or drawings which may otherwise render such performance/availability results uncertain or impossible. The contractor shall resolve all such discrepancies before proceeding with the work.

E.

F. Bases for lighting fixtures together with corresponding application for each lighting fixture type selected by the Contractor are to be submitted for approval by the Engineer before purchase of materials is initiated.

G. The Drawings are indicative showing the requirements for the airfield lighting layouts and the related civil works; it shall be the Contractor's responsibility to check the Drawings and to revise them to satisfy the system performance required by the airfield equipment supplier and considering any existing site constraints or utilities. A compliance sheet should be submitted showing in details the proposed changes to the civil works and all other system components along with a justification for these changes.

H. The Contractor to ensure that the procured AGL lighting fixtures are fully compatible with the procured infrastructure (Bases, Constant Current Regulators,). Any interface or component needed to ensure compatibility is considered to be part of the Contract and are deemed to be included without any extra cost.

I. The contractor is responsible for the development of method statements and site mockups in accordance with the specified requirements.

Method Statements:

1. The contractor shall prepare comprehensive method statements outlining the step-by-step procedures for the installation, testing, and commissioning of the airfield ground lighting installations.
2. These method statements must adhere to industry best practices, safety standards, and any relevant regulations. Clear and detailed explanations of each phase, including potential risks and mitigation strategies, should be included.

1.7 MANUFACTURER'S SUPPORT

A. Warranty

1. Warranties to comply with respective closeout procedures specification requirements.

2. The AGL equipment manufacturer to warrant against defects in workmanship and hardware for the equipment specified in this section and in a minimum period of 2 year from the date of the Taking-Over Certificate for the While of the Works of the project (and not from any interim Milestone dates, any partial handover of the Works or sectional completion of any kind).

3. Should there be the requirement for partial or Sectional Completion of the Works, the Employer shall require additional front-end warranty cover accordingly at no additional cost to the Employer. The Contractor shall follow the template wording given.

4. Full detail of the warranties to be provided for review and approval.

5. All AGL components shall be guaranteed for a period in accordance with employer's general requirements against defects.

6. All sign legend panels to be guaranteed against any deterioration for five years.

B. Technical Support:

1. The AGL equipment manufacturer shall provide the following minimum technical support during the warranty period:

   a. Technical Phone assistance.

   b. Technical Support via telephone.

   c. Onsite Technical field support as required.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

A. All materials provided by the Contractor shall be new unused material/products suitable for the intended service and level of operations in accordance with the requirements specified herein.

B. All materials shall have tests to check their ability to withstand corrosion and the results of these tests shall be submitted for approval.

C. Grounding of Airfield Lighting Installations

1. A grounding counterpoise system is to be installed along all the new AGL installations.

2. Grounding Electrodes
   a. Ground rod type and diameter to be chosen based on local country codes and practices.
   b. Ground Rod: 14 or 16d mm diameter high strength, low carbon steel core of high tensile strength (600 N/mm2), with 99.99% pure electrolytic copper molecularly bonded into steel core, 0.25 mm minimum thickness. Driving head is to be high strength steel. Couplings are to be long length silicon bronze, internally threaded. Threads are to be rolled onto rod to ensure uniform layers of copper and strength. Earth rod is to be complete with couplings, head and bolted connector of sufficient size, and number of bolted clamps to connect all cables terminated thereto.
      1) Minimum Length of Rod: 2.4 m, extendible to obtain required earth resistance.
   c. Earth Pit: Precast, square or circular section concrete handhole (minimum 450 mm internal diameter), with concrete cover, and extending to about 150 mm below top of earth rod. Earth pit is to be provided for each earth rod where connected to an earthing conductor. Cover is to have inset brass plate with inscription 'Earth Pit - Do Not Remove'.

3. A ground bare copper wire (counterpoise), 16mm minimum size, shall be run above the series circuit cables. All equipment and structures associated with electrical systems to be connected to this wire. An earthing wire shall be securely attached to each light fixture base. The counterpoise wire shall also be securely attached to copper or copper-clad ground rods around the entire circuit. The ground rods shall be of the length and diameter specified in the plans, but in no case shall they be less than 240 cm long nor less than 15 mm in diameter.

4. A ground wire (counterpoise) shall be run above the primary airfield ground lighting cables and shall comply with the following:

   a. The ground wire (counterpoise) shall be 1C, 16mm², bare copper ground conductor.

   b. Where counterpoise conductors are to be installed and where soil conditions would adversely affect bare copper wire, thermoplastic wire conforming to Fed. Spec J-C30 Type TW,600 might be used.

   c. The counterpoise cable/conductor to be pulled in 32mm UPVC duct centrally located over the top row of airfield lighting ducts at a sufficient height to ensure a 90-degree zone of protection (45 degrees on each side of the vertical) in-line with ICAO Part 5 requirements.

   d. It is to connect to a grounding strip inside each airfield lighting manhole, a second grounding to be added/installed in the manhole only if required.

e. It is to be earthed at every 150m to 300 m maximum following the existing practice in the airfield, via copper ground rods, 19mm diameter, 3m long each (length may vary).

f. Additional earth rods shall be installed to ensure a maximum resistance of 6 ohms.

5. The following AGL equipment shall be connected to the grounding counterpoise system:

a. The secondary side of isolating transformers.

b. The primary cables screen/shield.

c. Each shallow base/inset light fixture.

d. The supports and housing of each elevated light fixture.

D. Airfield Lighting Network:

1. Airfield lighting network and related civil works to comply with relevant Specification Section.

2.2 MATERIALS AND EQUIPMENT

A. The following equipment and materials are specified in this document:
1. Runway End Inset Lights
2. Threshold Inset Lights
3.
4. Runway Guard Elevated Lights
5. PAPI Unit
6. Airfield Guidance Signage
7. Adhesive Compounds, Two-Component For Sealing Wire And Lights In Pavement
8. Epoxy Mortar For Filling Cable Saw-Cuts In Portland Cement Concrete Pavement (for use in temporary installations only, subject to the Approval of the Employer)
9. Airfield Lighting Cables
   a. Airfield Lighting Primary Cables
   b. Airfield Lighting Secondary Cables
10. Isolating Transformers
11. Constant Current Regulators
12.
13. Light Bases

2.3 AIRFIELD LIGHTING FIXTURES GENERAL REQUIREMENTS

A. Airfield Lighting (AGL) fixtures are to be of the types listed and as specified hereafter and/or shown on the drawings.

B. AGL fixtures shall be selected of the Halogen or the LED type as specified.

C. AGL fixtures parts are to withstand the project ambient temperatures and environmental conditions and are to resist to the stresses occurring in the airfield and to all the liquid agents which could be found in the airfield.

D. AGL fixtures performance and characteristics shall be certified and approved to comply with the International Regulations mentioned herein, as follows:

1. AGL fixtures shall fully comply with ICAO requirements.

2. Photometric outputs of airfield lighting fixtures shall comply with ICAO Annex 14 Chapter 5 and Appendix 2.

3. Color outputs for airfield lighting fixtures shall comply with ICAO Annex 14 Chapter 5 and Appendix 1.

4. AGL fixtures shall comply with equivalent FAA type fixtures, and IEC/TS-61827, as far as their construction qualities are concerned, except where otherwise stated in ICAO and/or in this Specification Section.

E. AGL fixtures design shall allow for easy maintenance.

F. AGL fixtures shall be fully corrosion proof. Body parts shall be made of aluminum alloys.

G. All screws, washers, nuts and hardware are to be made of plain stainless steel. All screws shall be equipped with non-losable locking devices.

H. Aluminum is not to be used for current carrying parts, nor be in contact with any metal other than stainless steel.

I. Reflectors are to be constructed of high purity aluminum polished and protected by anodic oxidation of 4 to 5 microns thickness. Aluminum used for optical reflectors is to have a purity level of better than 99.9%.

J. Front glasses, lenses, refractors, and prisms are to be manufactured with highest quality heat resistant glass capable of resisting maximum thermal and dynamic stresses met with in service under all the specified project climatic conditions.

K. All optical components are to be fixed so as not to be misadjusted during fixtures servicing. No internal adjustment of the optical components shall be needed after re-lamping or servicing. All optical components must be keyed so that they may not be reassembled incorrectly.

L. Separate color filters outside the fittings are not to be used.

M. Each AGL fixture shall be furnished with feeder lead(s), minimum 450mm length, with factory molded connector(s) as follows:

1. Omnidirectional and unidirectional AGL fixtures shall be equipped with one number feeder lead (unless otherwise stated here after).

2. Bidirectional AGL fixtures shall be equipped with one or two feeder leads as stated here after for each type of AGL fixture.

N. Inset AGL fixtures shall comply with the following:

1. Inset lights are to be designed for high intensity and frequency of aircrafts operations. Inset lights are to resist the stresses, and static/dynamic loads imposed by the impact and rollover of the airport's fleet mix aircrafts under all the specified project climatic conditions. Moreover, inset lights are to resist the static and dynamic loads of the airport fleet mix aircrafts and the airport vehicles when standing, rolling or turning without damage to the light or to the aircraft/vehicle tires.

2. Inset lights body parts are to be constructed of heavy duty, high tensile strength aluminum alloy, and to comply with the following:
   a. Cover made of drop forged aluminum alloy (casted covers may be approved subject to Engineer review and approval).
   b. Housing made of casted aluminum alloy.
   c. Inner cover (if any) made of aluminum alloy.
   d. Optical sub-assembly plate (if any) made of aluminum alloy.

3. Inset lights shall have interchange ability of parts, such as body parts, prisms, and reflectors.

4. The inset lights components are to be assembled using sealing rings/gaskets resisting to the dynamic stresses occurring in the airfield and to the salt water, kerosene, oil and cleaning, fire-fighting or de-icing chemicals which could be found in the airfield, as well as to their residues. The load forces subjected to the fixtures from the aircrafts/vehicles wheels should never be transmitted through the gaskets of these lights but through metal to metal contact.

5. Inset lights shall have minimum ingress protection of IP-67 or higher.

6. The surface temperature of the inset light shall not exceed 160°C when the fixture is operating at maximum intensity while covered by an aircraft tire for a period of 10 minutes.

7. Inset unidirectional lights are to be provided with light openings in only one direction. Blank filters are not accepted.

8. The prisms shall be sealed using gaskets and tightened by internal screws to ensure water tightness of the fixtures. Prisms shall be user-replaceable without making use of sealing compound (use of sealing compound may be approved subject to Engineer review and approval).

9. Feeder lead(s) shall be each 2 core cable, with 4.0mm² conductor cross section, passing through compression gland(s) at the entry, with factory molded 2-pole plug(s) in accordance with FAA L-823, type II, class A, Style 1 as per Figure 1(a) of AC 150/5345-26.

10. Inset lights housing are to be furnished with built-in:

    a. External earth terminal.

    b. Pressure relief plug that also serves to install valve for water tightness test.

11. Inset lights shall be of “Toe-in” type where required by ICAO for the subject application.

12. Inset lights shall be installed in 8inch or 12inch shallow base cans as specified here after for each type of AGL fixture.

13. Inset lights shall receive a painting to indicated the color of the light output. This paint shall be applied on the body in front of the lenses.

O. Elevated AGL fixtures shall comply with the following:

1. Elevated lights body parts are to be made of aluminum alloy casting.

2. Elevated lights are to be compact, lightweight and streamline in order to minimize drag to wind and jet blast and stresses on poles/masts.

3. Elevated lights and/or their mounting accessories are to be equipped with adjustable mechanism allowing horizontal and vertical angle adjustment.

4. Aluminum is not to be use for current carrying parts, nor be in contact with any metal other than stainless steel.

5. Elevated lights shall have minimum ingress protection of IP-65 or higher, unless otherwise stated in the relevant specification section.

6. Screws, latches and other fixing hardware that have to be removed for servicing the light in the field shall be of the captive type.

7. Front glass sealed with weatherproof high temperature poly-chloroprene (neoprene) gasket. Front glass is to be held in captive aluminum alloy ring.

8. All supports of elevated lights are to be frangible. Mounting of all elevated lights shall comply with latest edition of ICAO Design Manual Part 6 Frangibility.

9. Housing, front glass ring and slip fitter are to be protected by a stove baked, aviation yellow polyester gloss paint deposited by an electrostatic process, after prior anti corrosion treatment (phosphating or other equal treatment).

10. Feeder lead(s) shall be each 2 core cables, flexible, with 4.0mm² conductors cross section, passing through compression gland at its entry, with one factory molded 2-pole plug(s) in accordance with FAA L-823, type II, class A, style 1 as per Figure 1(a) of AC 150/5345-26. Feeder cables shall be mechanically protected for its whole run and shall be pulled inside the mounting pole/mast.

2.4 HALOGEN FIXTURES GENERAL REQUIREMENTS

A. Halogen fixtures shall use pre-focused quartz-halogen lamps with minimum 1000 hrs average lifetime at full intensity, held firmly and precisely into the aluminum reflector.

B. Fixtures with multiple lamps per side shall be equipped with short circuiting device (film disk cut out) for each lamp allowing the other lamp(s) to be kept operational if the first one fails.

C. The number and rating of halogen lamps within each fixture shall be as follows:

1.	Runway Threshold Inset Lights:	1x105W or 2x105W as needed to achieve ICAO photometric requirements;
2.	PAPI units:	2x200W.
3.	Runway End Inset Lights;	1x105W.

D. Required fixture color shall be achieved by colored optical parts. Correlated color temperatures and chromaticity coordinates values shall be as per ICAO required values.

E. Halogen fixtures shall be rated for continuous and trouble-free operation at the project environmental conditions for exterior environment, under direct sunlight.

2.5 LED FIXTURES GENERAL REQUIREMENTS

A. LED fixture (including light fixtures and signs) useful lifetime shall be greater than 50,000 hours before reaching the L80 lumen output degradation point with no catastrophic failures at the project environmental conditions specified in Article for exterior environment, under direct sunlight, and at full intensity.

B. Required fixture color shall be achieved by colored LEDs (for elevated fixtures, colors achieved by the use of colored front glass may be accepted subject to Engineer review and approval). Correlated color temperatures and chromaticity coordinates values shall be as per ICAO required values.

C. LED efficacy shall be minimum 100lm/W or higher.

D. The overall AFL fixture power consumption shall not exceed the following:

1. Runway Guard Elevated Light: 50W;

E. Each individual LED chip shall be fitted with its own refractor optic, thus providing a controlled efficient light output as required for the application.

F. LED fixtures shall be rated for continuous and trouble-free operation at the project environmental conditions specified in Article 1.4 for exterior environment, under direct sunlight.

G. The LED modules shall be mounted on heavy duty heat sinks to ensure highly efficient heat dissipation. The design of the primary heat sinks shall be such that there is a direct thermal path from the led junctions to the atmosphere thus providing a thermal conductivity effect through the life of the luminaire. The heat sinks shall be propriety and designed by the lighting manufacturer to enable the luminaires to work efficiently in the Airport climatic conditions. The primary heat sinks shall be provided with a ventilation arrangement allowing heat to be dissipated to the atmosphere but preventing collection of debris on the heat sinks.

H. The LED driving current shall be selected and guaranteed to ensure that the complete LED components (chip, module, driver…) does not exceed the designed optimal temperature during the lifetime of the fixture, under the project's environmental conditions.

I. LED drivers shall be of the 6.6A constant current type as detailed in the specification and/or shown in drawings. LED drivers shall be of the built-in type, and shall have the possibility to be replaced separately. LED drivers shall be compliant with the electrical requirements of latest edition of FAA EB-67. LED drivers shall conform to the following:

1. Drivers shall have a minimum efficiency of 70% or higher
2. Continuous and trouble-free operation at the project environmental conditions specified in Article for exterior environment, under direct sunlight.
3. Drivers shall meet the limits of harmonic current emissions defined in IEC 61000-3-2.
4. Drivers to have over-heat thermal protection for operation under ambient temperature greater than that specified in in Article 1.4 for exterior environment, under direct sunlight.

J. The True Power Factor (TPF) of all LED fixtures shall not be less than 0.7 when measured at the primary leads of the isolating transformer (feeding this fixture). The TPF measurement must be done over the frequency bandwidth range of at least 100kHz using a pure sine wave source. The power facture measurement must be True Power Factor and not displacement Power Factor.

K. Surge, overcurrent and overvoltage protection shall be provided on all drivers.

L. It shall be possible to detect totally or partially failed LED components in the LED fixtures as per latest edition of FAA EB-67. A failed LED module shall be detected as an open secondary by the addressable RCMU.

M. The starting or switching of LED fixtures on the CCRs shall not cause shutdown or overloading of the CCR. The LED fixtures supplier shall provide all necessary

documentation to prove that, and shall bare all responsibility of replacing the AFL fixtures (in their entirety) in case of shutdown or overloading of CCRs at fixtures startup or switching.

N. The LED fixtures shall be compatible for control & monitoring from the Single Lamp Control & Monitoring System proposed for the Airport. Coordination with the Airfield Lighting Control and Monitoring System Supplier (if different from the AFL equipment/fixtures supplier) is deemed to be included in the scope in order to ensure a fully compatible system.

O. The AFL fixtures shall support immediate detection of internal faults.

P. The intensity ratio (Dimming Curve) of LED light sources shall match with the conventional incandescent/halogen light behavior. The dimming curve and allowed tolerances shall be in according with FAA Engineering Brief EB-67.

Q. The power consumption shall reduce proportionally with the decreasing dimming level.

R. The LED driver for the AFL fixtures shall ensure no flickering will be visible to human at all brightness steps.

The triggering of Fail Open on the device shall not occur when magnets or iron objects rolls over the light, or when emergency generators are switched on

2.6 RUNWAY END INSET LIGHTS

A. Inset, high intensity, unidirectional, red, runway end light is to provide the ICAO photometric performance parameters for use in CAT I, II and III conditions, in accordance with ICAO Annex 14 Chapter 5, Appendix 1and Appendix 2 Figure A2-8.

B. It is to comply with FAA type L850-D(L) (AC 150/5345 - 46) and IEC/TS-61827 as far as its construction qualities are concerned, except where otherwise stated in ICAO and/or in this Specification Section.

C. It is to comply with the general requirements listed in Article “AIRFIELD LIGHTING FIXTURES GENERAL REQUIREMENTS” of this Specification Section, in addition to the following:

1. Mounting system is to comprise a 12” shallow base.

2. Total height above finished grade is not to exceed 6.5mm.

3. The light shall use, as far as possible, the same main components (body parts, prisms, reflectors) as those of the approach, threshold, threshold wing bar, runway edge inset lights to minimize the quantity of spare parts.

D. Halogen components shall comply with the requirements listed in Article “HALOGEN FIXTURES GENERAL REQUIREMENTS” of this Specification Section.

2.7 THRESHOLD INSET LIGHTS

A. Inset, high intensity, unidirectional, green, threshold light is to provide the ICAO photometric performance parameters for use in CAT I, II and III conditions in accordance with ICAO Annex 14 Chapter 5, Appendix 1 and Appendix 2 Figure A2-3.

B. It is to comply with FAA type L850-E(L) (AC 150/5345 - 46) and IEC/TS-61827 as far as its construction qualities are concerned except when otherwise stated in ICAO and/or in this Specification Section.

C. It is to comply with the general requirements listed in Article "AIRFIELD LIGHTING FIXTURES GENERAL REQUIREMENTS" of this Specification Section, in addition to the following:

1. Mounting system is to comprise a 12" shallow base.

2. Total height above finished grade is not to exceed 6.5mm.

3. The light shall use, as far as possible, the same main components (body parts, prisms, reflectors,) as those of the approach, threshold wing bar, runway end and edge inset lights to minimize the quantity of spare parts.

D. Halogen components shall comply with the requirements listed in Article "HALOGEN FIXTURES GENERAL REQUIREMENTS" of this Specification Section.

2.8 RUNWAY GUARD ELEVATED LIGHTS

A. Elevated, high intensity, yellow (wig wag), runway guard light is to provide ICAO photometric performance parameters, for use in day in accordance with ICAO, Annex 14, Chapter 5, Configuration A, Appendix 1 and Appendix 2 Figure A2-25.

B. It is to comply with FAA type L-804(L) (AC 150/5345 - 46) and IEC/TS-61827 as far as its construction qualities are concerned except when otherwise stated in ICAO and/or in this Specification Section.

C. It is to comply with the general requirements listed in Article "AIRFIELD LIGHTING FIXTURES GENERAL REQUIREMENTS" of this Specification Section, in addition to the following:

1. The fixture shall be formed by two light assemblies surrounded by a low luster black face plate and independent visors, to reduce the amount of incident sunlight in order to maximize the contrast during on-off cycle.

2. The mounting system shall include a flexible stainless steel tether that will prevent the fixture from being blown onto neighboring taxiways or runways in case the mounting system breaks.

3. The frangible coupling and mounting system shall ensure a breaking point (yield point) at no more than 38mm above the surrounding finished pavement level.

4. It is to be equipped with an adjustable mechanism allowing horizontal (from -20° to +20° in increments of maximum 5°) and vertical (from 0 to 20° above horizontal) angle adjustment.

5. The flash rate shall be in alternating flashes of 45 to 50 flashes per minute per light assembly. Flashing rate shall be controlled and monitored from dual channel addressable control units.

6. It shall have two feeder leads, one for each light assembly.

7. It shall continue to work on one light assembly if the other light assembly is out of service.

D. LED components shall comply with the requirements listed in Article "LED FIXTURES GENERAL REQUIREMENTS" of this Specification Section.

2.9 PAPI UNIT

A. The PAPI unit is to provide the ICAO photometric performance parameters for use in Cat I, II & II in accordance with:

1. Annex 14, Chapter 5, Paragraphs 5.3.5.23 up to 5.3.5.45.

2. Annex 14, Appendix 1, and Appendix 2 Figure A2-23.

3. Aerodrome Design Manual Part 4 - Visual Aids, Chapter 8, Section 8.3.

B. It is to comply with FAA type L880(L), Style B, Class I (AC 150/5345-28) and IEC/TS-61827 as far as its construction qualities are concerned except when otherwise stated in ICAO and/or in this Specification Section.

C. It is to comply with the general requirements listed in Article "AIRFIELD LIGHTING FIXTURES GENERAL REQUIREMENTS" of this Specification Section, except where in contradiction with the following:

1. Lightweight aluminum housing bearing all the optical components.

2. Single cover made of lightweight aluminum with pad lockable latches.

3. Two or Three optical groups, fixed on an optical frame, consisting each of:

a. Light assembly.

b. Red dichroic filter.

c. High quality lens providing a constant transition zone which is not to exceed 3 minutes of arc, over the full beam width.

d. Fixation accessories

4. A removable hardened front glass protecting the lenses.

5. Heat resistant gaskets for cover and front glass.

6. Three or Four adjustable stainless steel mounting legs allowing the accurate setting of the unit. These legs are to allow the adjustment in elevation of the unit between 2 and 8 degrees, and allow the adjustment of the height of the axis of the beam above the mounting concrete slab between 50 and 95 cm.

7. Site adjustment of beam shall be made by means of a clinometer.

8. Mounting system is to be secured by means of breakable couplings having 2 inch 11 TPI (Thread Per Inch) male thread for fixing to mounting flanges

9. PAPI unit shall have one feeder lead for each optical group. Feeder leads shall be protected by a stainless steel reinforced flexible conduit for its run outside the PAPI unit, down to the transformer housing.

10. The PAPI unit is to be compact in order to afford a minimum drag to jet blast and environmental wind. Its total weight is not to exceed 45 kg .

11. The housing, optical frame, cover, breakable coupling, and flange are to be protected by a stove baked polyester paint deposited by an electrostatic process. The optical frame is to be in black; the housing, cover, breakable coupling, and flange are to be in aviation yellow.

12. The use of special instrument or bench for resetting the beam after servicing the unit is not acceptable.

13. The unit shall have minimum ingress protection of IP-54.

14. Special Drainage holes are to be provided for the evacuation of eventual condensation water.

D. Halogen components shall comply with the requirements listed in Article "HALOGEN FIXTURES GENERAL REQUIREMENTS" of this Specification Section.

2.10 AIRFIELD GUIDANCE SIGNAGE

A. The airfield guidance signage shall be non-illuminated and fully comply with ICAO Annex 14, Chapter 5.

B. The sign shall consist of rigid, self-carrying and low mass aluminum housing with a poly-carbonate front panel (minimum 4mm thick). The legend shall be applied inside and no paint shall be used in order to limit damage and aging to a minimum.

C. The frangibility shall be in full compliancy with ICAO Design Manual Part 6 and must withstand exposure to wind and/or jet blast velocities as follows:
1. Signs located on the runway, and on exit/rapid exit taxiways up to and including the signs located at the nearest runway holding position from runway centerline shall withstand exposure to wind and/or jet blast velocities of up to 480km/h.
2. Wind load and frangibility test of these signs shall ensure that:
3. The signs must withstand an applied static load of 13.8kPa without breaking nor suffering permanent distortion.
4. The frangible points of these signs must break before an applied static load of 19.3kPa.
5. Signs located elsewhere on the airfield shall withstand exposure to wind and/or jet blast velocities of up to 322km/h. Wind load and frangibility test of these signs shall ensure that:
6. The signs must withstand an applied static load of 6.21kPa without breaking nor suffering permanent distortion.
7. The frangible points of these signs must break before an applied static load of 8.96kPa.

D. Mounting legs shall have frangible point (breakaway or yield point) located not more that 50mm above the concrete pad. Frangible mechanisms shall be suitable for the size of the signs. Frangible points shall withstand the specified wind/jet blast loading but should break before reaching an applied static load distributed over the legend panel surface of 19.3kPa (2.8psi). Number and arrangement of mounting legs shall be as suitable to withstand the required wind/jet blast loading.

1. Legend panels and panel supports shall withstand, as a minimum, the pressure at which the frangible points break.

2. Legend panels shall not be sourced locally, but shall be part of the complete procured sign product.

3. Stainless steel tethers (minimum two per sign) shall be provided with the sign to prevent the sign from being blown onto neighboring taxiways or runways incase the column breaks.

4. The overall weight of the signs shall not exceed 24.5kg/m length.

5. The signs shall have an ingress protection of minimum IP54 or higher.

E. The signage sizes and color schemes shall conform to the following:

Type of Signs	Leg-end Height mm	Face (min.) Height mm	In-stalled (max.) Height mm	Background and Inscriptions
Mandatory Instruction Signs	400	600	1100	White inscription on red background.
Runway Exit Signs	400	600	1100	Black inscription on yellow background.
Location Signs	300	450	900	Yellow inscription on black background and where it is a stand-alone sign, it shall have a yellow border.
Information Signs other than Location Signs	300	450	900	Black inscription on yellow background.

F. The form and dimensions of signage inscriptions shall be as follows:

1. The form of characters, i.e. letters, numbers, arrows and symbols, shall conform to those shown in Figure A4-2 of ICAO Annex 14, Appendix 4.

2. The width of characters and the space between individual characters shall be determined as indicated in Table A4.1 of ICAO Annex 14, Appendix 4.

3. The face height of signs shall be as per above.

4. The face width of signs shall be determined using Figure A4.3 in ICAO Annex 14, Appendix 4, except that:
   a. Where a mandatory instruction sign is provided on one side of a taxiway only, the face width shall not be less than 1.94m.
   b. The total length of a sign should not exceed 3m.

5. Arrow dimensions shall be as follows:

Legend Height	Stroke
300 mm	48 mm
400 mm	64 mm

6. Stroke width for single letter shall be as follows:

Legend Height	Stroke
300 mm	48 mm
400 mm	64 mm

7. Signage Borders:
   a. The black vertical delineator between adjacent direction signs should have a width of approximately 0.7 of the stroke width.
   b. The yellow border on a stand-alone location sign should be approximately 0.5 stroke width.

G. The colors of signage shall be in accordance with the appropriate specification in ICAO, Annex 14, Appendix 1.

2.11 ADHESIVE COMPOUNDS, TWO-COMPONENT FOR SEALING WIRE AND BASES IN PAVEMENT (sealing of wire is only allowed for temporary installations and subject to Employer review and approval)

A. Description: This specification covers a liquid suitable for sealing electrical cable in saw cuts in pavement and for sealing shallow bases in pavement. The material is a two-component filled formula with the characteristics specified in paragraph 2.36.D. Materials supplied for use with bituminous concrete pavements must be formulated so they are compatible with the bituminous concrete to avoid cracking and separation of the cured material.

B. Curing. When pre-warmed to 77º F (25º C), mixed and placed in accordance with manufacturer's directions, the materials shall cure at temperatures of 45º F (7º C) or above without the application of external heat.

C. Caution. Installation and use shall be in accordance with the manufacturer's recommended procedures.

D. Characteristics. When mixed and cured in accordance with the manufacturer's directions, the materials shall have the following properties shown in Table 1.

E. Tensile Properties. Tests for tensile strength and elongation shall be conducted in accordance with ASTM D638.

F. Expansion. Tests for coefficients of linear and cubical expansion shall be conducted in accordance with ASTM D1168, Method B, except that mercury shall be used instead of glycerin. The test specimen shall be mixed in the proportions specified by the manufacturer, and cured in a glass tub approximately 2 inches (50mm) long by 3/8 inch (9mm) in diameter. The interior of the tube shall be precoated with a silicone mold release agent. The hardened sample shall be removed from the tube and aged at room temperature for 1 week before conducting the test. The test temperature range shall be from 35º F (5º C) to 140º F (60º C).

G. Test for Dielectric Strength: Test for dielectric strength shall be conducted in accordance with ASTM D149 for sealing compounds to be furnished for sealing electrical wires in pavement.

Physical or Electrical Property	**Minimum**	**Maximum**	**ASTM Method**
Tensile			
Portland Cement Concrete	1, 000 psi (70 Kg/cm²)	-	D638
Bituminous Concrete	500 psi (35 Kg/cm²)	-	-
Elongation			
Portland Cement Concrete		-	D638
Bituminous Concrete	50%	-	D638
Coefficient of cub. exp. (cu.cm/cu.cm/°C)	0.00090	0.00120	D1168
Coefficient of lin. exp. (cm/cm/°C)	0.000030	0.000040	D1168
Dielectric strength, short time test	350 volts/mil.	-	D149
Arc resistance	125 secs.	-	-
Adhesion to steel	1,000 psi (70 Kg/cm²	-	-
Adhesion to Portland Cement Concrete	200 psi (14 Kg/cm²	-	-
Adhesion to Aluminum	250psi 17.5 Kg/cm²	-	-

Table 1. Property Requirements

H. Test for Arc Resistance. Test for arc resistance shall be conducted for sealing compounds to be furnished for sealing electrical wires in pavement.

I. Test for Adhesion to Steel. The ends of two smooth, clean, steel specimens of convenient size (1 inch by 1 inch by 6 inches) (25 by 25 by 150 mm) would be satisfactory are bonded together with adhesive mixtures and allowed to cure at room temperature for a period of time to meet formulation requirements and then tested to failure on a Riehle (or similar) tensile tester. The thickness of adhesive to be tested shall be ¼ inch (6mm).

J. Adhesion to Portland Cement Concrete

1. Concrete Test Block Preparation. The aggregate grading shall be as shown in Table 2.The coarse aggregate shall consist of crushed rock having a minimum of 75% of the particles with at least one fractured face and having water absorption of not more than 1.5%. The fine aggregate shall consist of crushed and manufactured from the same parent rock as the coarse aggregate. The concrete shall have a water-cement ratio of 5.5 gallons (21 liters) of water per bag of cement, a cement factor of 6, plus or minus 0.5, bags of cement per cubic yard (0.76 cubic meter) of concrete, and a slump of 2-1/2 inches, plus or minus ½ inch (60 mm plus or minus 12 mm). The ratio of fine aggregate to total aggregate shall be approximately 40% by solid volume. The air content shall be 5.0%, plus or minus 0.5%, and it shall be obtained by the addition to the batch of an air-entraining admixture such as Vinsol brand resin. The mold shall be of metal and shall be provided with a metal base plate. Means shall be provided for securing the base plate to the mold. The assembled mold and base plate shall be watertight and shall be oiled with mineral oil before use. The inside measurement of the mold shall be such that several 1-inch by 2-inch by 3-inch (25 by 50 by 75 mm) test blocks can be cut from the specimen with a concrete saw having a diamond blade. The concrete shall be prepared and cured in accordance with ASTM C192.

Type	Sieve Size	Percent Passing
Coarse Aggregate	3/4 inch (19.0mm)	97 to 100
	1/2 inch (12.5mm)	63 to 69
	3/8 inch (9.5mm)	30 to 36
	No.4 (4.75mm)	0 to 3
Fine Aggregate	No.4 (4.75mm)	100
	No.8 (2.36mm)	82 to 88
	No.16 (1.18mm)	60 to 70
	No.30 (600 micro-m)	40 to 50
	No.50 (300 micro-m)	16 to 26
	No.100 (150 micro-m)	5 to 9

Table 2. Aggregate For Bond Test Blocks

2. Bond Test. Prior to use, oven-dry the test blocks to constant weight at a temperature of 220 to 230°F (104 to 110 °C), cool to room temperature, 73.4 plus or minus 3 °F (23 plus or minus 1.6 °C), in a desiccator, and clean the surface of the blocks of film or powder by vigorous brushing with a stiff-bristled fiber brush. Two test blocks shall be bonded together on the 1-inch by 3-inch (25 by 75mm) sawed face with the adhesive mixture and allowed to cure at room temperature for a period of time to meet formulation requirements and then tested to failure in a Riehle (or similar) tensile tester. The thickness of the adhesive to be tested shall be ¼ inch (6mm).

K. Compatibility with Asphalt Concrete. Test for compatibility with asphalt in accordance with ASTM D3529.

L. Adhesive Compounds - Contractor's Responsibility. The Contractor shall furnish the vendor's certified test reports for each batch of material delivered to the project. The report shall certify that the material meets specification requirements and is suitable for use with Portland cement concrete and/or bituminous concrete pavements. The report shall be delivered to the Engineer before permission is granted for use of the material. In addition the contractor shall obtain a statement from the supplier or manufacturer which guarantees the material for one year. The supplier or manufacturer shall furnish evidence that the material has performed satisfactorily on other projects.

M. Application. Adhesive shall be applied on a dry, clean surface, free of grease, dust and other loose particles. The method of mixing and application shall be in strict accordance with the manufacturer's recommendations.

N. The material manufacturer's representative shall be present during the initial installation of the material to ensure the installation procedures are in accordance with the manufacturer's recommendations.

O. Related Standards:
1. ASTM C192 Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
2. ASTM D149 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
3. ASTM D638 Standard Test Method for Tensile Properties of Plastics
4. ASTM D1168 Standard Test Method for Hydrocarbon Waxes Used for Electrical Insulation
5. ASTM D5329 Standard Test Methods for Sealants and Fillers, Hot-applied, for Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements

2.12 EPOXY MORTAR FOR FILLING CABLE SAW-CUTS IN PORTLAND CEMENT CONCRETE PAVEMENT (only allowed for temporary installations and subject to Employer review and approval)

A. Description: This specification covers the Epoxy Mortar used for filling cable saw-cuts in Portland Cement Concrete Pavement that are wider than 30mm. This shall be a solvent-free, 3-component mortar based on a combination of epoxy resins and selected high strength aggregates. Supplied epoxy mortars shall have high abrasion and impact resistance and shrinkage-free hardening properties

B. Material Properties:

1. Density: The density of the epoxy mortar after mixing all components shall be greater or equal to 2.1 kg/l when measured at 20°C

2. Mechanical Strength: Compressive, flexural and adhesive tensile strengths of the epoxy mortar shall comply with Table 3.

In N/mm^2	1 day	3 days	7 days	14 days
Compressive at +5°C	4.0	90	100.0	110.0
Strength at +20°C	100.0	100.0	110.0	110.0
Flexural at +5°C	2.0	20.0	23.0	25.0
Strength at +20°C	20.0	22.0	25.0	25.0

Table 3. Epoxy Mortal Characteristics

3. Adhesive tensile strength:
   a. On concrete with primer ≥ 4 N/mm^2.

b. On steel with primer ≥ 20 N/mm^2.

4. Modulus of Elasticity: The static modulus of elasticity of the epoxy mortar shall be greater or equal to 26,000 N/mm^2.

5. Coefficient of Thermal Expansion: The epoxy mortar shall have a coefficient of thermal expansion 'α' in the range of $12x10^{-6}$ K^{-1}.

6. Colour: The epoxy mortar shall have a gray color close to that of the concrete.

7. Mix Ratio: The mix ratio of the various component of the epoxy mortar shall be in accordance with the manufacturer's instructions given in the Technical Data Sheet relevant to the supplied product.

8. Pot Life: The pot life of the fresh mortar shall meet the following minimum periods:

Temperature	Time
30°C	20 min.
20°C	40 min.
10°C	75 min.
5°C	90 min.

9. Storage: Products for preparing epoxy mortar shall be stored at temperatures between +5°C and 30°C.

10. Approved manufacturers: Approved Manufacturers are: Sika, Fosroc, BASF and others who can provide products of similar quality and experience record.

C. Application

1. Storage: Products for preparing epoxy mortar shall be stored at temperatures between +5°C and 30°C.

2. Surface Preparation: All surfaces must be clean, free from oil, grease, old coatings, laitance, standing water and all loosely adhering particles. Whenever deemed necessary, sandblasting, grinding and final cleaning operations shall be performed prior to laying any cables in the saw-cut.

3. Priming: Follow manufacturer's instruction for application of compatible priming material and the required dosage.

4. Mixing: Pour all components in one container following the correct sequence and dosages specified by the manufacturer. Mix thoroughly with low speed electrical drill using special mixing disk until initially turbid liquid becomes clear. Avoid entraining air. Mix continuously for at least 3 minutes i.e. until the mix reaches even consistency.

5. Application of Mix: Whilst the primer is still tacky, spread the mixed epoxy mortar and then trowel firmly into place.

6. Cleaning: All tools and equipment shall be cleaned immediately after use in order to keep them serviceable for future use.

7. Maximum Thickness per Layer: The maximum thickness per layer of mortar used for filling shall be in the range of 5-6cm.

8. Application and Substrate Temperatures: The minimum allowable application and substrate temperature is +5°C and the maximum allowable application and substrate temperature is +30°C.

D. Caution. Installation and use shall be in accordance with the manufacturer's recommended procedures.

2.13 AIRFIELD LIGHTING CABLES AND CONNECTORS

A. Airfield Lighting (AGL) Cables and their installation are to comply with ICAO Aerodrome Design Manual, Part 5 and the FAA specifications for L-824 (AC 150/5345-7) except if otherwise stated herein. Two types of AGL Cables shall be included, Primary Cables, compliant to FAA L-824 Type C, and Secondary Cables.

B. AGL Plugs, Receptacles and Cable Connectors and their installation are to comply with ICAO Aerodrome Design Manual, Part 5 and the FAA specifications for L-823 (AC 150/5345-26) except if otherwise stated herein.

C. Airfield Lighting Primary Cables

1. AGL primary cable is used to connect the Constant Current Regulator (CCR) to the primary windings of the isolating transformers. AGL primary cable shall be a single core, screened 5kV insulated cable and its construction shall be as follows:

   a. Conductor: stranded 7 wires tinned copper conductor, minimum cross section: 6mm².

   b. Extruded semi-conductive layer

   c. Cross-linked polyethylene (XLPE) insulation with minimum thickness of 2.16mm.

   d. Semi-conductive tape

   e. Tinned copper wire braid, copper tape or brass tape screen

   f. Nonmetallic separation tape

   g. Black polyethylene (PE) or polyvinyl chloride (PVC) sheath, abrasion/oil/UV/Deicer resistant with termite repellant, minimum 1.4mm thickness

   h. Supplied on non-returnable wooden drums in length of approx. 1000 meters.

2. Connection of the primary cables to the isolating transformer primary leads are to be done using Type I (rated 25A, 5kV), Class B field attached, connector kit in accordance with FAA specification L-823 comprising:
   a. One plug Style 3 as per figure 3(a-c) of AC150/5345-26.
   b. One receptacle Style 10 as per figure 3(b-d) of AC150/5345-26.

3. The primary cable connector kit is designed to fulfill the following:

   a. To ensure the electrical continuity of the screen.

   b. To earth the screen.

   c. To ensure the continuity of the primary cable conductors.

   d. To ensure a watertight post installation connection.

4. The construction of primary cable connector kit is to consist of:

   a. One pin (male connector) and one socket (female connector), made of tin plated copper or brass, with crimping section fully annealed. The socket must be spring loaded to ensure good electrical contact.

   b. One plug connector housing and one receptacle connector housing, made of the same thermoplastic elastomer (TPE) material as the opposite connector of the isolating transformers. Each plug and receptacle housing shall have a metal insert molded into the rubber, which shall mate with a corresponding part of the appropriate pin or socket, to provide a permanent metal to metal connection between the housing and the pin or socket. Cable entry sleeve within the housing shall be suitable for the overall outer diameter of the primary cable.

   c. Connection accessories for the cable screen including:
      1) Two screen continuity insulated connectors, made of the same material of the primary cable screen, and of cross section suitable to ensure continuity of screen.
      2) One terminal block for interconnection of the screen continuity connectors.

   d. Resin compound ensuring the electrical insulation of the conductor and screen and the water tightness of the connector. As the filling compound has a limited shelf life, the supplier is to take care of supplying compound capable of being used until the expected installation date.

   e. Pull over sleeve, to be pulled over at the interface end of completed plug/receptacle connections, thus providing a full seal against dirt, and a second seal against water entry. The sleeve shall be reusable for the life of the connectors.

   f. Hardware, accessories and instructions to perform a correct assembly of the connector.

5. The primary cable connector kit shall fulfill the following test requirements:

   a. After assembly, the connection between the connector housings (plug or receptacle) and the primary cable must be capable of withstanding a static longitudinal pull test of 50 kg.

   b. This shall be confirmed by a pull test in which the connector housings shall be held (or pulled) in such a manner as not to impart a crimping or clamping action to the connector or cable (that would affect the pull test), and the cable shall be pulled (or held) from the conductor only (to prevent separation of the cable sheath from the remainder of the cable assembly). A force of at least 50 kg shall be applied and then released.

   c. A change in position between a connector housing and cable sheath of more than 10mm shall be cause for rejection.

D. Airfield Lighting Secondary Cables

1. AGL Secondary cable is used to connect the airfield lighting fixture (or guidance signs, traffic signals…) to the secondary windings of series isolating transformers or to the ILCM unit connecting to the transformer. Secondary cable shall be two cores cable of 1000 V nominal voltage, and its construction shall be as follows:

   a. Conductor: stranded 7 wires copper conductor, minimum cross section: 4mm^2.

   b. Insulation (with minimum thickness of 1.016 mm):
      1) Cross-linked polyethylene (XLPE), or

2) Ethylene Propylene Rubber (EPR).

c. Outer sheath of one of the following:
1) Heavy Duty Neoprene
2) Heavy Duty Chlorosulfonated Polyethylene
3) Polyvinyl Chloride
4) Polyethylene
5) Chlorinated Polyethylene, Thermoplastic
6) Chlorinated Polyethylene, Cross Linked, Heavy Duty

d. Supplied on non-returnable wooden drums in length of approx. 600 meters.

e. The connector kit for secondary cable to be supplied separately, and to be complied with the ICAO requirements and FAA specifications.

2. The secondary cables shall be connected using Type II (rated 20A, 0.6kV), Class B field attached, connector kits in accordance with FAA specification L-823 comprising:

1) One plug Style 5 as per figure 7(a-b-c) of AC150/5345-26.

2) One receptacle Style 12 as per figure 6(a-b-c) of AC150/5345-26.

3. The secondary cable connector kit is designed to fulfill the following:

a. To ensure the continuity of the secondary cable conductors.

b. To ensure a watertight post installation connection.

4. The construction of secondary cable connector kit is to consist of:

a. One “insert assembly” with two pins or sockets. The pins and sockets shall be made of tin plated copper or brass, with the crimping section fully annealed. The socket must be spring loaded to ensure good electrical contact.

b. One plug/receptacle connector housing made from the same thermoplastic elastomer (TPE) material as the opposite connector of the light fixtures, isolating transformers or ILCM units.

c. Hardware, accessories and instructions to perform a correct assembly of the connector.

5. Secondary cable joints in secondary cables, other than those at the interfaces between light fixtures, isolating transformers and/or ILCM units, shall not be permitted.

2.14 SERIES ISOLATING TRANSFORMERS

A. Series Isolating Transformers are to be manufactured in accordance with FAA type L-831 (AC 150/5345-47), IEC-61823 and ICAO Aerodrome Design Manual Part 5 and to the requirements specified herein below.

B. The isolating transformer should consist of a primary and a secondary coil wound on a magnetic core in a weatherproof case with primary and secondary leads for connecting the primary series circuit to the light fixture.

C. The primary and secondary circuits should be isolated electrically, but linked by the magnetic core. This latter should remain unsaturated in normal operating conditions, but would become saturated if the secondary circuit is open-circuited. This will maintain the integrity of the primary circuit.

D. Transformer Operation: The transformers shall be designed to operate continuously under rated load, short circuit, or open circuit conditions in the secondary side, with rated current and rated frequency in the primary side, without damage or deterioration on the transformer. The transformer shall have sufficient rated capacity to allow for LED module/driver, secondary cables losses, ILCM units consumptions and contact losses.

E. Isolating Transformers are to be completely molded or encapsulated in a thermoplastic elastomer (TPE). The winding should be tightly wound and secured prior to molding to reduce the possibility of turns becoming loose. The isolating transformers housing shall be suitable for installing by direct burial, underwater, in underground enclosures or exposed to the weather and projects environmental conditions. It shall protect the transformer from damage in case it was dropped, carried from any of the leads, or completely immersed in water.

F. The isolating transformer shall be equipped with the following:

1. At the primary side, two number single core 6mm² primary cable leads, 19 strands, 0.6m long each, equipped respectively with:

   a. One L-823 Plug, Type I (rated 25A, 5kV), Class A Factory Molded, Style 2 as per figure 2(a) of AC150/5345-26.

   b. One L-823 Receptacle, Type I (rated 25A, 5kV), Class A Factory Molded, Style 9 as per figure 2(b) of AC150/5345-26.

2. At the secondary side, one number two core 4mm² secondary cable lead, 1.2m long, equipped with one L-823 Receptacle, Type II (rated 20A, 0.6kV), Class A Factory Molded, Style 8 as per figure 1(c), or Style 7 as per figure 1(b) of AC150/5345-26.

3. One external earth connection terminal (connected internally to one side of the secondary circuit).

G. The following operating conditions shall apply to the isolating transformers:

Insulation	Primary 5000 V, Secondary 1000V
Rated Frequency	50 Hz
Rated Current	6.6/6.6 A
Rated Wattage	500W, 300W, 200W, 150W, 100W, 65W, 30/45W, 20/25W or 10/15W as per the Drawings and as suitable to the connected equipment load.
Operating Temperature	-55 to +65 degrees Celsius
Minimum Power Factor	0.95
Minimum Efficiency	10/15W and 20/25W: 70% 30/45W and 65W: 80% 100W and 200W: 85% 200W, 300W and 500W: 90%

H. The transformers are to be in continuous service and be used for outdoor application, inside draw pits/manholes and may be exposed to and therefore protected against the effects of the following substances:

1. residues of de-icing or cleaning chemicals
2. salt water
3. aircraft fuels
4. ozone gas

5. carbon dioxide
6. mineral oil

2.15 CONSTANT CURRENT REGULATORS

A. The Constant Current Regulator's (CCR) construction and performance shall comply to the following:

1. ICAO, Aerodrome Design Manual Part 5 Paragraphs 3.2.1.4 to 3.2.1.6.

2. FAA Type L-829, Class 1 to AC 150/5345-10.

3. IEC – 61822.

B. CCR Architecture

1. CCRs are to be of the Pulse Width Modulation (PWM) type, solid state, microprocessor controlled, using Insulated Gate Bipolar Transistors (IGBT's) H-bridge with the output transformer for automatic step less current correction against load switching and mains variations.

2. CCRs are to be air-cooled and naturally ventilated. Use of forced air ventilation is not permitted.

3.

4. CCRs shall have proper EMI shielding and shall not generate any kind of Electro-Magnetic Interference causing disturbance to the equipment that may be located on or near the airport.

5. Taps shall be provided on the output winding of the CCR transformer to allow for matching the output capacity to the actual output circuit lighting load.

6. The CCRs shall be equipped with a built in Series Circuit Cut-Out easily accessible from behind the front panel. The cutout shall provide the following:

a. Isolate the series circuit (AGL primary circuit) from the CCR output.

b. Grounding facilities for the series circuit

c. A measuring point for the series circuit insulation resistance.

C. CCR Rating Characteristics

1. Constant current regulators are to operate continuously at full load and full intensity/brightness level under the following environmental conditions:

Temperature Range:	-40 to + 55 degrees C
Relative Humidity:	10% to 100%
Maximum Altitude	2000m

2. The input and output power characteristics of the CCR shall be as follows:

Input Voltage:	230V phase to neutral or 400V phase to phase. Input voltage tolerance from -10% to +10%.

	CCR must withstand momentary under-voltage of down to 80% or over-voltage of up to 120 % of rated voltage not longer than 50ms duration and occurring not more than once per minute. CCR shall shutdown when voltage is below 0.8 of nominal voltage and automatic restart when voltage reaches again 0.9 of nominal voltage.
Input Frequency:	50 Hz ± 7.5%
Standard Rating:	2.5, 5, 7.5, 10, 15, 20, 25 or 30kW as shown on the Drawings while maintaining minimum 25% spare capacity for future use.
Output Current:	6.6A (at full intensity/brightness level) ± 2 % (at any intensity/brightness level), for any load from half load to full load, within specified input voltage & frequency ranges, within specified environmental conditions, with up to 30% of isolating transformers secondary windings open circuited.
Minimum Power Factor:	0.90 for ratings lower or equal to 10kW 0.95 for ratings above 10kW at maximum intensity setting, nominal input voltage and full load of unity power factor
Minimum Overall Efficiency:	90% at nominal input voltage and full load of unity power factor

D. CCR Construction Requirements

1. CCRs are to be of the indoor floor standing type. CCR enclosure is to be a self-contained, metal clad, IP-20 or higher, with lifting lugs, and two cross pieces for floor mounting and with lockable doors.

2. All monitoring and control functions are to be front mounted

3. Cable terminal boxes shall be equipped with compression glands.

4. All terminal blocks are to be legibly marked and conveniently arranged, ready for exterior wiring.

5. Finish is to consist of phosphatizing and baked polyester electrostatic paint coating.

6. CCR access panel shall be equipped with safety switch with action user configurable.

7. The CCR shall be properly identified with engraved labels (in addition to the identification digitally displayed on in the display unit).

8. For ease of maintenance, all modules within the CCR shall be easily accessible for servicing or replacement without the use of special tools.

9. CCR shall include of the following components/parts:
   a. Mounted on the CCR front panel:
      1) Alpha numeric LCD display within operator control buttons.
      2) Back indication LED's for mode of operation and faults.
      3) Reset button.

4) Selector switch for “Remote”, “Off”, “Brightness Steps”.

b. Internally mounted within the CCR enclosure:

1) Main circuit breaker or fused switch.

2) Input and output power cables terminals.

3) Power transformer.

4) IGBT modules.

5) Output lightning surge arrestors.

6) Circuit cut-out.

7) Single lamp control and monitoring module (optional).

8) Control, protection and monitoring modules/boards, including:

a) Measurement modules.

b) Open circuit protection device.

c) Over current protection device.

d) Earth leakage fault detection / insulation resistance monitoring module.

e) Lamp fault detection module.

9) Communication modules/boards.

10) Connectors for remote control and monitoring signals.

11) Diagnostic connector.

12) Earth terminal.

13) Output tapping terminals.

14) Auxiliary fuses.

E. CCR Performance Requirements

1. The CCR shall electrically isolate the input power circuit from the output lighting circuit.

2. The CCR shall be able to respond to circuit changes within 15 cycles.

3. The CCR shall stabilize the output current at any selected current step within 500ms. In the event of an input power loss for uo to 60s, the CCR shall resume operation on the selected current setting within 500ms after the restoration of input power.

4. The CCR shall provide pure sinusoidal and low harmonic output.

5. The CCR shall be rated to handle starting of LED fixtures and shall cater for their load requirements at start-up.

6. The CCR shall be suitable for operation with Single Lamp Addressable Control & Monitoring System without having to replace or modify any parts of its hardware.

7. The CCR shall be able to handle non-linear load with no restrictions on its performance or on the Single Lamp Addressable Control & Monitoring System signals being transmitted over the CCR output circuit.

8. Provision is to be made to indicate a ground fault on the circuit while permitting the circuit to operate normally when only a single ground fault prevails.

9. Open circuit output voltage is not to exceed 120% of nominal voltage.

10. Intensity Settings (Brightness Steps):

    a. The regulators are to be provided with user configurable 3-step or 5-step of intensity/brightness steps with default values set as per ICAO Design Manual Part 4 requirements.

    b. The output current shall be digitally adjustable for all intensity steps over full current range from 1.8A (RMS) to 6.6A (RMS) with the 1.8A being a non-illuminating step.

    c. The intensity settings should be changed without de-energizing the regulator.

    d. The CCR shall have selectable internal latch function for latest intensity step.

11. In case of input power supply failure, the CCR shall resume operation at the last selected brightness setting or from a pre-defined step (user configurable) after the restoration of input power. This shall be an in-built feature within the CCR (not from the airfield lighting control and monitoring system).

12. The CCR LCD display shall allow to indicate the following:

    a. Series circuit identification.

    b. Input voltage [RMS]

    c. Input current [RMS]

    d. Input power factor.

    e. Output current [RMS]

    f. Output voltage [RMS]

    g. Output load [kVA]

    h. Efficiency

    i. IGBT temperature (Alarm/Warning)

    j. Insulation resistance value

    k. Intensity/brightness step

    l. Number of failed lamps

    m. Warnings and alarms.

    n. Hours run counter [total and at individual steps]

    o. User configurable thresholds and settings

13. The CCR back indication LEDs shall be for the following:

    a. CCR on status.

    b. CCR in local mode.

    c. Earth leakage fault.

    d. Over-current fault.

    e. Open-circuit fault.

    f. Lamp fault.

F. CCR Protection Devices

1. Open-Circuit Protection: The CCR shall include an open - circuit protective device to protect it if an open circuit occurs in the output lighting circuit of the CCR:

a. The open-circuit protective device shall interrupt the input power circuit prior to the current regulating/transformer circuits of the CCR within 2 seconds after an open circuit has occurred in the output lighting circuit.

b. The device shall be reset within 2 seconds after the CCR is turned off and re-energized, and shall not be tripped by switching of load circuits or other transients.

c. The CCR shall have selectable remote reset for open-circuit trip.

2. Over-Current Protection: The CCR shall include an over-current protective device to protect it when the output current in the output lighting circuit of the CCR exceeds 100 percent:

a. The over-current protective device shall interrupt the input power circuit prior to the current regulating/transformer circuits of the CCR, or alternatively reduce the output current of the CCR, in case the output current exceeds the 6.6A current by 5%.

b. The device shall operate within 5 seconds after an over-current of 5% and within 1 second after an overcurrent of 25%.

c. The device shall reset within 2 seconds after the CCR is turned off and re-energized.

d. The over-current protection shall not be activated by a momentary (0.25 second) over-current caused by switching of lighting circuits or other transients on the output lighting circuit of the CCR.

e. The CCR shall have selectable remote reset for over-current trip.

3. Lightning Protection: The CCR shall be protected by lightning surge arrestors fitted to the output circuit of the CCR.

G. CCR Control and Monitoring

1. A built-in microprocessor shall allow for comprehensive local control, monitoring and diagnosis of the CCR, and adaptation of user defined optional parameters. In this respect:

a. Local monitoring within the CCR shall function when the regulator is in the remote or local control mode.

b. All control, monitoring and regulation circuits are to be contained in plug-in printed circuit boards.

2. The CCR shall also allow for remote control and monitoring via two redundant serial field bus communication interfaces [J-Bus, Modbus, Profibus or other] over Ethernet. In this respect:

a. The CCR manufacturer shall provide all communication message descriptions to allow full integration with the Airfield Lighting Control & Monitoring System.

b. The CCR shall be able to communicate over the Ethernet without any need of external interface devices.

c. All available CCR parameters, local controls, monitored parameters, warnings and alarms shall be transmitted to the Airfield Lighting Control & Monitoring System.

d. The CCR is to include all the necessary interface modules for the ILCM units.

e. The CCR’s control and monitoring procedures and functions shall be available on an open industry standard protocol.

f. Resetting of CCR's should be possible by remote control from the Air Traffic Control Tower workstation by a sequence ON/OFF/ON operation.

3. The CCR's operational parameters are to be adaptable and modifiable, locally through the operator panel, or remotely from the Airfield Lighting Control & Monitoring System workstations. In this respect:

   a. The access to the settings of the CCR parameters (whether locally or remotely) shall be password protected.

   b. The latest configuration of the CCR parameters shall be stored within the CCR on a replaceable card/memory and transmitted/stored in the Airfield Lighting Control & monitoring System.

   c. The configuration of the CCR shall also be possible also through the ALCMS Ethernet network.

4. Earth Fault Monitoring and Detection: The CCR is to be provided with built in series circuit insulation monitoring, which will measure the insulation resistance of the series circuit versus ground with both the regulator on and off.

   a. The measurement shall be by applying a stabilized DC voltage between the series circuit and the ground, and measuring the resulting leakage current.

   b. The measurement range for the insulation resistance module shall be from 0 to 500 Mega-Ohm.

   c. It shall be possible to set two threshold values for the generation of earth fault warning or alarm.

   d. It shall be possible to set the delay time between the detection and the generation of the fault to alarm.

5. The CCR local and remote control and monitoring shall minimum cover the following:

   a. Input power parameters monitoring and warning/alarm generation:
      1) Voltage [RMS]
      2) Current [RMS]
      3) Frequency.
      4) Power factor.

   b. Output power parameters monitoring and warning/alarm generation:
      1) Current [RMS]
      2) Voltage [RMS]
      3) Load [kVA]
      4) Power factor.
      5) Efficiency

   c. Intensity/brightness step control and monitoring.

   d. Earth fault monitoring and detection.

   e. Open-circuit monitoring and detection.

   f. Over-current monitoring and detection

   g. IGBT H-bridge temperature (Alarm/Warning)

   h. Hours run counter [total and at individual steps]

   i. CCR operating mode control and monitoring.

   j. Setting of the CCR operational parameters.

6. The following fault conditions shall be detected and reported on the local CCR display and over the remote control communication:

a. Loss of input power to the regulator.

b. Supply power parameters variations outside user defined limits.

c. Output power parameters variations outside user defined limits.

d. Shut down of the regulator due to operation of any of the protective devices (open-circuit or over-current).

e. Failure of the regulator to deliver the output current corresponding to the brightness step selected.

f. Failure of AGL lights in the series circuit exceeding the user-defined thresholds.

g. Earth fault in the series circuit exceeding the user-defined thresholds.

7. A local visual indication shall be provided on the CCR display or/and back indication LEDs to indicate which monitoring parameter caused the fault indication.

8. The CCR Manufacturer shall provide the software and the necessary tools required for set up and maintenance procedures, to be handed over to the Client.

9. The CCR local and remote control and monitoring systems shall operate in a failsafe manner that ensures that the CCR will never become inoperable or delivers incorrect output current to the series circuit.

H. Series Circuit Cut-Out

1. The series circuit cut-out is used to isolate safely the series circuit from the Constant Current Regulator during maintenance or testing operations; and also to allow periodical isolation resistance measurement of series circuit to ground without disconnecting the series primary cable. It shall short the output of the CCR and the input to the series ciruit and ground the series circuit.

2. The circuit cut-out shall comply with ICAO recommendations and FAA Regulations (AC150/5340-30), and to be compatible with all types and ratings of the CCRs.

3. The series circuit cut-out shall be rated 25A, 5kV.

I.

2.16 LIGHT BASES

A. Light bases shall be of the shallow type. Shallow bases are to be constructed to meet the following standards:

1. Class 1 for direct-mounted inset fixtures as per FAA AC150/5345-46

2. Requirements of FAA AC/5340-30 for direct mounted inset fixtures.

3. Bases type L-868 to FAA AC150/5345-42, as far as their construction qualities and testing are concerned.

4. ICAO Aerodrome Design Manual Part 5.

5. The requirements specified here-under.

B. Shallow bases shall comply with the following requirements:

1. Shallow bases shall be made of tempered aluminum alloy casting, anodized for corrosion resistance (preferable the same alloy as the inset lights being installed on them)

2. Shallow bases shall be designed to maximize adhesion via the securing compound and to resist rotation and uplift.

3. Shallow bases shall either 8inch (203mm) or 12inch (305mm) as specified for each light fixture type.

4. Shallow bases dimensions, number/position/size of threads, anti-rotation pins and gaskets shall ensure proper mating between the base and the inset light fixture. Flat gaskets shall not be used at the interface between the shallow base and the inset light fixture.

5. The minimum depth of shallow bases shall be 100mm, and shall be suitable for the installed inset lights and the secondary cables/connectors.

6. Shallow bases shall be equipped with below duct entry for mounting in new pavements or with side cable entry for mounting in existing pavements, with appropriate compression glands and accessories to ensure water tightness. Any cable entrances to the base, whether used or not used, are to be provided with water-tight seals or plugs.

7. Shallow bases shall be equipped with high torque and pull out resistance threads.

8. Shallow bases shall be furnished with a built–in earthing terminal to be connected to the counterpoise earthing system.

C. Mounting system of the shallow bases is to provide a sealed installation in recess cored out into the pavement. Sealing shall be with suitable adhesive compound as specified in this specification section.

D. Installation of shallow bases shall follow the instructions set by manufacturer of the bases.

E. Dummy covers of shallow bases shall be made of the same material with dimension and thickness that suit the shallow base, ensure water tightness and meet the loading requirements for the intended application.

F. Stainless steel fully threaded bolts/nuts for mounting the light fixture shall be procured with the shallow bases.

PART 3 - EXECUTION

3.1 CONSTRUCTION REQUIREMENTS

A. All installation works shall be done in accordance with relevant ICAO & FAA standards and manufacturers' instructions. In case of conflicts, ICAO requirements shall take precedence.

B. The Contractor shall examine areas and conditions for compliance with requirements for clearances, installation tolerances and other conditions affecting performance of the Works.

C. All components shall be examined before installation. Any components that are wet, moisture damaged, mould damaged, dust contaminated or in any way deteriorated shall be replaced prior to installation.

D. Visual inspection is to include inspection of condition of each piece of equipment, quality of workmanship, alignment, perpendicularity, labeling and the like, all in conformance with the Specification.

E. Operational and other performance tests are to be carried out after 100 hours normal operation, and are to include measurement of lighting levels and uniformities on required illuminated surfaces.

F. Other tests are to be carried out as required by the Engineer to verify conformity with the specification.

G. Earthing resistance tests are to include measurement of earth electrode resistance and continuity of protective conductors.

H. Results of tests are to be recorded on site and signed by witnessing parties.

I. Test equipment and labor: provide equipment and labor including instruments and complete provisions for carrying out tests.

3.2 Testing

1. The Contractor is to supply all necessary equipment, tools and appliances for a complete testing and commissioning of the airfield lighting installations. Any special software and hardware tools used for this purpose shall be the property of the owner after testing and commissioning. The Contractor is to test and demonstrate to the satisfaction of the Engineer the following:

    a. All the lighting levels and information achieved are in accordance with ICAO regulations. All equipment for testing are to be ensured by Contractor on site for proper testing. The testing and results shall not be considered final and accepted unless the acceptance and testing sheets are signed approved by the Engineer.

    b. The CCR’s shall be tested after the completion of the installation to the designed ambient condition and full load rating.

    c. All lighting power and control circuits are continuous and free from short circuits.

    d. All circuits are free from unspecified earths.

    e. The insulation resistance to earth of all series circuits shall be as required by ICAO Design Manual Part 5, FAA AC150/5370-10 and AC 150/5340-26.

    f. All circuits are properly connected in accordance with applicable wiring diagrams.

    g. All circuits are operable. Tests are to be conducted that include operating each control not less than 10 times and the continuous operation of each lighting and power circuit for not less than 1/2 hour.

    h. Electrical tests on a sample transformer, measuring power factor, efficiency, secondary current at full load and under short circuit, and the secondary voltage with opened circuit. The measured values are to be within the limits given by Table 2 of FAA AC150/5345-47.

    i. All isolating transformers are to be tested by measuring the transformation ratio and high voltage dielectric test. Mechanical tests on a transformer sample by subjecting it to dropping from a 2 m height on a strong surface. No damages are to be observed in the transformer and the performance parameters reached after the test are not to deviate by more than 1% of the measured values before the test. Those tests will be

realized according to the procedures described in the FAA document AC150/5345-47, paragraph 4.

j. On selected samples of the isolating transformers, the following functional tests shall be performed.

1) Power factor, efficiency and secondary current at full capacity and with short circuit.
2) Secondary open circuit voltage.
3) Transformation ratio, dielectric test

k. A complete functional test of the photometric performance parameters of the fixture shall be made on each series of lights. This functional test shall involve:

1) The plotting of luminous intensities in horizontal & vertical axis.
2) The computing & drawings of the average intensity in the specified beam coverage.
3) The plot of isocandela curves corresponding to ICAO- Annex 14 Volume-I, Appendix 2 requirements.
4) The photometric measures shall be carried out on the complete fixture equipped with their closing glasses, filters and other accessories necessary for the normal service.
5) The light shall be powered at its full intensity and the measures shall be made at the operating temperature of the different components especially for the colored filters.
6) For the considered beam coverage functions, it shall take into account the tolerances of the light positioning & orientation. When colored filters are used, the color point shall be at the operating temperature of the filter. This color point shall comply with the ICAO requirements indicated in the appendix 1 to Annex 14.
7) For all the lights the main functions and dimensions shall be controlled in order to establish the conformity according to the requirements.

3.3 INSTALLATION

A. Installation of airfield lighting materials and equipment shall conform to ICAO requirements, the manufacturer's instructions, and applicable codes. In the event of any conflicts, ICAO requirements shall take precedence.

B. Installation of Wire and Cable

1. Before installation of wires and cables, a suitable wire brush and swab is to be pulled through the duct to remove extraneous matter and to verify that the duct system is free of obstructions. Ducts are to be dry before installation of wires and cables. Water is to be removed from manholes, handholes and light bases before installing cables.

2. When more than a single cable is pulled, all cables are to be pulled directly into the duct from the coils or reels on which they are received. They are not to be pulled off and laid on the ground prior to installation. All pulls are to be made in one direction.

3. No wire or cable is to be left neither under tension nor against bushings or fittings. Where pulling grips are used, damaged ends are to be removed as soon as wire and cable have been installed. Cable and conductor pulling tensions recommended by the manufacturer are not to be exceeded.

4. Lubricants for pulling wires and cables are to be Ideal Industries Inc., Sycamore, I11 type Yellow 77 or No. 100 Mineralac or approved equal. Nylon rope is not to be used to pull cable into ducts.

5. Ends of all wires and cables are to be marked for identification. Terminal ends at equipment and at all terminals between are to be identified by permanent, non-metallic tags, vinyl tape or sleeves. Groups of wires or cables with the same circuit number are to be identified by a common tag, tape or sleeve with the circuit number, machine printed.

6. Where wires and cables are terminated or jointed at locations such as control boards, switchgears, etc., pressure type terminal lugs or connectors are to be used. Terminations are to be in accordance with manufacturer's recommendations.

7. Shielded cables are to be stripped back to a safe distance according to the circuit voltage, and at such points, the terminators, stress cones or similar devices are to be installed for stress reduction.

8. Splices or terminations are to be watertight and protected from mechanical injury and sealed to prevent entrance of moisture. The Contractor is to take the utmost care to prevent the entrance of water into the cable prior to and during installation. The Contractor is to check to determine if any water has entered the cable; if not, the cable ends are to be sealed unless they are to be immediately spliced. If water has entered, the cables are to be cut back until no water is present, and sealed. All metallic shielding components are to be grounded.

9. Cables are to be neatly trained and racked in trenches and or ducts as applicable.

10. Cable are to be identified with anti-corrosion and saline-proof flexible metallic labels which are to be engraved with cable reference as instructed by the Employer.

C. Shallow base installation

1. The shallow bases shall be accurately installed and aligned so as to ensure the light output from the inset light fittings shall be at the specified azimuth and elevation.
2. The shallow bases installation shall ensure all bases are resistant to the turning forces imposed by taxiing and turning aircraft.
3. Shallow bases shall be installed according to manufacturer's tolerances and by using the manufacturer's installation and alignment tools. During grouting shallow bases shall be temporarily fixed in position to prevent any movement. During installation shallow base shall be firmly supported by use of the manufacturers' adjustable jig supported on levelling screws on the adjacent pavement until the mortar has set.
4. The shallow bases shall be installed that the rim of the shallow base is flush with the finished surface of the pavement and the shallow base is level to true horizontal in all directions.
5. Where the light fittings shall be installed in a straight line each shallow base shall be aligned in azimuth along the line of shallow bases in which it is located.
6. On bends alignment shall be related to the centre of curvature of the bend or to the light fitting positions before or after a curve. Special equipment shall be used to enable the accurate setting out of shallow bases.
7. The shallow bases shall be bedded with an approved polyester resin adhesive bedding mortar.
8. For filling around the AGL base units with an annular gap up to 12mm the material shall be an approved pourable fine grade fast setting high strength polyester resin adhesive mortar. The mortar shall have high speed setting and rapid strength gain characteristics which will attain a compressive strength to FAA AC 150/5370-10, Item P-606 Table 1. In addition, the Constructor shall demonstrate that the mortar adheres firmly to the prepared concrete/asphalt or metal surfaces as required. Such adhesion shall generally be shown as specified in FAA AC 150/5370-10, Item P-606. The cured product shall not exhibit any noticeable shrinkage.
9. For annular gaps greater than 12mm the filling mortar shall be bulked out with coarse aggregate in accordance with the manufacturer's instructions.

D.

3.4 DOCUMENTATION

A. As built documents and drawings to be prepared and handed over.

B. The AGL schedule shall be updated and included in the as built documentation.

C. An Airfield Ground Lighting System Manhole Schedule shall be prepared for the AGL installation. The schedule shall provide details on the following:
1. .
2. Lighting Fixtures: Light Tag Number, Fixture Wattage, Drawing No.
3. Isolating Transformer Rating.
4. Remarks.

3.5 SPARE PARTS

A. The Contractor shall provide spares to be used during the DLP period.

B. The Contractor shall provide contractual spares that shall min. 10% of the total material quantity of the material.

C. Contractor shall provide spare parts that are required for the commissioning and start-up of the equipment.

D. Contractor shall provide a quotation covering recommended on-hand spare parts for two years of continuous operation and a complete parts list with an illustrated parts breakdown or a cross-sectional drawing. Information required with the recommended spare parts includes the following:
1. Part description, serial or part number, and price
2. Reference to assembly drawing
3. Total number of identical parts in the equipment
4. Number of on-hand parts recommended.
5. Location and seller of stocked spare parts.

3.6 SITE TESTING

A. Test airfield lighting system in accordance with the applicable ICAO recommendations and the manufacturer's written instructions, and applicable Electrical sections.

B. Contractor shall test, through appropriate test equipment, each completed primary circuit.

C. Photometric testing equipment, material, planning and procedures shall be coordinated with the Employer, taking into consideration the current practices and procedures in the Airport.

D. Photometric performance and candela levels measurement of inset lights as per ICAO regulations.

E. Carry out flight check(s) to confirm the setting (including checking of failures and alignment) of threshold lights, runway end lights, and PAPI. The flight check shall be carried out by a competent third party in accordance with ICAO recommendations, including those mentioned in Aerodrome Design Manual, Part 4, Chapter 8, Paragraph 8.3.16 and ICAO Airport Operational Services Manual – Part 8 Chapter 5.

F. Carry out the performance testing of the equipment / System in accordance with the relevant clauses of the specification.

END OF SECTION 344314