

## **8.0 ROAD PAVEMENT**

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## **8.0 Pavements**

### **8.0.1 Description**

1. Pavements are composed of Subgrade preparation, Sub-base course, Base course, Binder course and Surface course.
2. Subgrade refers to the soils about 1 (one) meter under the pavement and it is the part at the depth of about 1 (one) meter below the finished surface of the embankment or cuts.

## **8.1 Materials**

### **8.1.1 Prior Approval by the Engineer**

3. The Contractor shall get approval in writing from the Engineer for all kind of materials to be used in pavement works 30 days prior to use of them.
4. The application letter shall be attached testing result sheet by the manufacturer or the Contractor, and the Engineer may visit the factory, quarry or laboratory for the inspection of testing itself or testing facilities.

### **8.1.2 Bitumen**

5. Bitumen to be used as a binder of bituminous mixtures shall be petroleum derivative Penetration grade 60 - 70 conforming to the requirements of AASHTO M20.

### **8.1.3 Rubberized Asphalt and Thermoplastic Asphalt**

6. Rubberized asphalt and thermoplastic asphalt are used to improve durability of bitumen for the mixtures on steel deck. They are bitumen to which polymeric materials, such as rubber and thermoplastic resin are added, in an attempt to improve viscosity at 60 degrees, toughness, tenacity and temperature susceptibility.
7. The properties of rubberized asphalt and thermoplastic asphalt shall be as shown in the Table below or equivalent. Here, Type I is with rubber type polymeric materials and Type II is with both thermoplastic resin and rubber.

**Table 8-1 Properties of rubberized asphalt and thermoplastic asphalt**

| Item   | Type I(50-70) | Type I(50-70) | Type II(70-90) |
|--|---------------|---------------|----------------|
| Penetration (at 25 degree). 1/10 mm                  | 50-70         | 70-90         | Min 40         |
| Softening Point, degree                              | 50.0 - 60.0   | 48.0 - 58.0   | 56.0 - 70.0    |
| Ductility (7 degree), cm, Min                        | 20            | 40            | -              |
| Ductility (15 degree), cm, Min                       | -             | -             | 30             |
| Flash Point, degree, Min                             | 260           | 260           | 280            |
| Weight change in thin film oven test,<br>%,Max.      | 0.6           | 0.6           | 0.6            |
| Penetration change in thin film oven<br>test, %, Max | 55            | 55            | 65             |
| Toughness, kgf-cm, Min.                              | 60            | 50            | 80             |
| Tenacity, kg-cm, Min.                                | 30            | 25            | 40             |

#### 8.1.4 Emulsified Bitumen for Prime Coat & Tack Coat

8. Emulsions shall be in accordance with AASHTO M140 or M208.

#### 8.1.5 Cut back bitumen for Prime Coat & Tack Coat

9. Cut-backs shall be in accordance with either AASHTO M81 or M82 depending on the curing rate.

10. Prime Coats shall be low viscosity, medium curing material such as MC-70.

11. Tack Coats shall be high viscosity, rapid curing material such as RC-250.

12. Prime coat on the steel deck shall be rubberized one with approval of the Engineer.

#### 8.1.6 Aggregate

13. Aggregate means crushed stone, crushed gravel and gravel composed of hard rock and shall have good adhesion to bituminous materials and durability for heating for the materials of hot mixture, such as basalt, andesite, rhyolite, sandstone, lime stone, etc.

14. Crushed stone shall have sufficient uniformity, cleanliness, strength and durably, and be free of deleterious quantity of flat or elongated particles, dirt, mud, organic matters and other deleterious substances as shown in the Table 8.2 or as approved by the Engineer.

**Table 8.2 Properties of Crushed Aggregate**

| Property                                       | Surface/ Binder course | Base course  |
|--|------------------------|--------------|
| Bulk specific gravity in saturated surface-dry | 2.45 or more           | -            |
| Water absorption                               | 3.0 % or less          | -            |
| Abrasion loss(AASHTO-96)                       | 30 % or less           | 50 % or less |
| Sodium or Magnesium Soundness (AASHTO T104)    | 12 % or less           | 20 % or less |

15. **Crushed gravel** shall have one or more fractured faces accounting for at least 40% by weight, of the total particle retained on a 4.75 mm sieve. Without any further processing , this product of crushed gravel is called “**crusher-run**”. The specification of crushed stone shall be applied for the qualities of crushed gravel.
16. **Gravel** shall be approved by the Engineer , if the aggregate be used for the pavement works. The specification of quality shall be same as crushed stone.
17. The Grading of Aggregate materials shall meet with following Table 8.3.

Here, S means single sized crushed stones, M means mechanical stabilized crushed stones and C means crusher-run.

**Table 8.3 Grading of Aggregate**

| Type | Sieve | mm  | 53     | 37.5   | 31.5   | 26.5   | 19     | 13.2  | 4.75  | 2.36 | 1.18  | 0.425 | 0.075 |
|------|-------|-----|--------|--------|--------|--------|--------|-------|-------|------|-------|-------|-------|
| S-40 | 40-30 | 100 | 85-100 | 0-15   |        |        |        |       |       |      |       |       |       |
| S-30 | 30-20 |     | 100    | 85-100 |        | 0-15   |        |       |       |      |       |       |       |
| S-20 | 20-13 |     |        |        | 100    | 85-100 | 0-15   |       |       |      |       |       |       |
| S-13 | 13-5  |     |        |        |        | 100    | 85-100 | 0-15  |       |      |       |       |       |
| S-5  | 5-2.5 |     |        |        |        | 100    | 85-100 | 0-25  | 0-5   |      |       |       |       |
| M-40 | 40-0  | 100 | 95-100 |        |        | 60-90  |        | 30-65 | 20-50 |      | 10-30 | 2-10  |       |
| M-30 | 30-0  |     | 100    | 95-100 |        | 60-90  |        | 30-65 | 20-50 |      | 10-30 | 2-10  |       |
| M-25 | 25-0  |     |        | 100    | 95-100 |        | 55-85  | 30-65 | 20-50 |      | 10-30 | 2-10  |       |
| C-40 | 40-0  | 100 | 95-100 |        |        | 50-80  |        | 15-40 | 5-25  |      |       |       |       |
| C-30 | 30-0  |     | 100    | 95-100 |        | 55-85  |        | 15-45 | 5-30  |      |       |       |       |
| C-25 | 25-0  |     |        |        | 100    | 95-100 | 60-90  | 20-50 | 10-35 |      |       |       |       |

**8.1.7 Sand**

18. Fine aggregate shall consist of that portion of the total aggregate that passes the 4.75 mm sieve. At least 85 % of material produced by crushing gravel retained on a 2.36 mm sieve shall consist of fragments having at least one mechanically fractured face. Natural uncrushed material in a mixture with crushed fine aggregates shall be no more than 25 % of the total mass.

**8.1.8 Filler**

19. Mineral filler shall consist of lime stone powder, crusher run rock dust or Portland cement. It shall be sufficiently dry to flow freely and be free from agglomerations. Filler material shall conform to the requirements of AASHTO M17 and have grading limits as given in Table 8.4.

**Table 8.4: Grading for Mineral Filler**

| AASHTO sieve      | % passing (by mass) |
|-------------------|---------------------|
| 600 $\mu\text{m}$ | 100                 |
| 300 $\mu\text{m}$ | 90 - 100            |
| 75 $\mu\text{m}$  | 70 - 100            |

## **8.2 Construction**

### **8.2.1 Mixing plant and Crushers**

20. Stationary mixing plant may be used prior approval of the Engineer for the plant and the materials.
21. Prepared aggregates shall be stored so as to prevent contamination and deterioration. They shall be stockpiled on hard, clean, smooth surfaces and, if required by the Engineer, placed under cover. Stored materials shall be located to facilitate inspection and handling. The center of the storage area shall be elevated and sloped to the sides to provide drainage.

### **8.2.2 Subgrade Preparation**

#### **8.2.2.1 Description**

1. The work shall consist of preparing the subgrade to receive pavement, shoulders, gutters or curbs, and shall include shaping and compacting the subgrade surface to elevations and profiles as shown on the Drawings or as instructed by the Engineer.

#### **8.2.2.2 Construction Requirements**

##### *Subgrade in Cut*

2. Soil below subgrade level to a depth of 20 cm in cut shall be scarified, broken up, adjusted to an optimum moisture content and re-compacted to the required density. If quality control tests show the required compacting cannot be achieved, the layer shall be replaced with suitable excavated material.
3. Subgrade in cut classified by the Engineer as rock shall be neatly trimmed to the required level and profile as shown on the Drawings. Loose blocks and pieces shall be removed and the remaining pockets and voids filled with compacted suitable material. If necessary the whole subgrade surface shall have a blinding layer applied as instructed by the Engineer.
4. Subgrade in cut shall have a minimum CBR value of 25 % measured in accordance with AASHTO T193 at the in-place density and moisture content.

*Subgrade on Embankment*

5. When the subgrade is formed on embankment, it shall be the full width of the top of the embankment unless otherwise shown on the Drawings.
6. Material placed in the top 30 cm of embankments shall have a minimum subgrade CBR value of 25 % measured in accordance with AASHTO T193 at the in-place density and moisture content.

*Subgrade over Existing Road Surfaces*

7. When the width of subgrade of the road under construction is greater than the surface width of the existing roadway, subgrade which falls outside the limits of the existing road surface shall be constructed as for new construction.

**8.2.2.3 Tolerance**

8. Variation of any point of the constructed subgrade surface from the levels determined from the Drawings shall be within +2 cm and -3 cm, and more than - 5 cm in width. Where in particular rock formations, it is not possible to achieve these tolerances due to the nature of the cut rock, the requirements shall be as instructed by the Engineer.
9. Traffic on the finished subgrade shall be kept to a minimum and if the next layer is not placed within 10 days of approval of the subgrade, the subgrade shall be submitted for re-approval.

**8.2.2.4 Measurement and Payment**

10. No separate measurement or payment will be made for subgrade preparation, and shall be considered incidental work to all other items of the Bill of Quantities such as 'Earth Works' and 'Subbase and Base courses' etc.

**8.2.3 Subbase and Base course**

**8.2.3.1 General**

1. This work shall consist of supplying, placing and compacting one or more courses of specified material onto a prepared subgrade surface and a finished subbase course.

#### **8.2.3.2 Material**

2. Materials for subbase course shall be crushed stone as shown in Table 8.3 or equivalent as approved by the Engineer. The modified CBR shall be more than 20 and the plastic index (PI) for the materials passing sieve 0.075 shall be less than 6.
3. Materials for base course shall be crushed stone as shown in Table 8.3 or equivalent as approved by the Engineer. The modified CBR shall be more than 80 and the plastic index (PI) for the materials passing sieve 0.075 shall be less than 4.

#### **8.2.3.3 Construction Requirements**

##### *Spreading*

4. Subbase and Base course materials as specified on the Drawing shall be spread on approved subgrade in layers not exceeding 150 mm compacted depth. Spreading shall be done by mechanical spreaders, distributing material to the required width and loose thickness. Where the required thickness is greater than 150 mm material shall be placed in layers of equal thickness, but in no case shall a layer be less than 75 mm thick. Each layer shall be approved before the next is placed and spread.
5. Material shall be handled so as to prevent segregation. If segregation does occur the material shall be removed and re-mixed. No hauling or placement of subbase material will be permitted when, in the opinion of the Engineer, plant, method or conditions are such that the operation will cause damage to the subgrade or contamination of the subbase material.

##### *Compacting*

6. The moisture content of the material shall be adjusted if necessary to obtain the specified compacted density either by watering with sprinkler trucks or by drying out.
7. The subbase and base course shall be compacted by compacting equipment progressing gradually from the shoulder towards the centerline, with each succeeding pass uniformly overlapping the previous one. Rolling shall continue until the entire thickness of each layer is uniformly compacted to the specified density. Rolling shall



be accompanied by blading to produce a smooth surface to the specified profile tolerances. Areas inaccessible to normal compacting plant shall be compacted by pedestrian rollers, mechanical rammers or other appropriate equipment.

#### Compacting Trials

8. If instructed by the Engineer, prior to commencement of subbase construction the Contractor shall lay full width trial lengths, not exceeding 500 m. Materials used in the trials shall be those proposed for the Works, and the equipment used shall be according to the Contractor's approved detailed Programme of Work.
9. The objective of the trials is to determine the adequacy of the Contractor's equipment, methods and the relationship between the number of compaction passes and the resulting density of subbase.

#### 8.2.3.4 Quality Control Testing

10. Samples for testing shall be taken by the Contractor, in the presence of the Engineer. Duplicate samples shall be submitted to the Engineer for future reference, if instructed. Sampling shall be in accordance with AASHTO T2. The Contractor shall conduct the tests in the Site Laboratory, or may have the tests carried out at an approved external laboratory.
11. The minimum frequency of sub-base and base course testing shall be 1 set of 3 density tests for each 1,500 m<sup>2</sup> placed and compacted, and 1 sampling with tests for each 500 m<sup>3</sup> of produced material in stockpile.
12. The thickness of the finished subbase will be checked at 25 m intervals parallel to the road center line. Humps, depressions and thickness deficiencies exceeding the specified tolerances shall be corrected by removing defective work or by adding new material as instructed by the Engineer.

#### *Tolerances*

14. Subbase and base course shall be compacted to 96.5 % of the maximum dry density determined according to AASHTO T 180D. The moisture content shall be the optimum value  $\pm 2$  %. The specified CBR value shall be measured at the in-place density and moisture content.

15. Finished subbase and base course shall not vary from the values shown on the Drawings and Sections by more than the following:

**Table 8.5 Tolerance of Finished Grade**

|                  |                  |
|------------------|------------------|
| Subbase Course   |                  |
| Surface Levels:  | +20 mm to -20 mm |
| Layer Thickness: | more than -10 mm |
| Width            | more than - 5 cm |
| Base Course      |                  |
| Layer Thickness: | more than -10 mm |
| Width            | more than - 5 cm |

**8.2.3.5 Method of Measurement**

16. The approved work shall be measured by the square meter as placed and compacted according to the dimensions of the subbase and base course shown on the Drawings.

**8.2.3.6 Basis of Payment**

17. The amount of completed and accepted work, measured as provided for above, will be paid for at the unit rate for 'Subbase course' and 'Base course' in the Bill of Quantities, which rate shall include for all preparation, supply, placing, for the trial Sections, mixing of materials, spreading, compacting and finishing, including materials, labor, equipment, tools and other items necessary for the proper completion of the work.

**8.2.3.7 Items in the Bill of Quantities**

- Item No. 8.1.1 "Subbase Course" (square meters)  
Item No. 8.1.2 "Granular Base Course" (square meters)

**8.2.4 Bituminous Prime Coat and Tack Coat**

**8.2.4.1 Description**

1. This work shall consist of applying a bitumen-based surface coat by spray onto previously constructed base course, binder course, concrete bridge deck or steel bridge deck.

### 8.2.4.3 Construction Requirements

#### *Preparation of Surfaces*

2. Prior to the application of the spray coat, loose material shall be removed from the surface and the surface shall be cleaned by mechanical sweepers, blowers and hand brooms until it is free from dust. On a soil surface or granular subbase, the cleaned surface shall be given a light application of water and allowed to dry to a surface-dry condition before bituminous material is applied. No traffic shall be permitted on the surface after it has been prepared to receive the spray coat.
3. Bridge deck surfaces shall be cleaned of loose material by mechanical sweepers and hand brooms, followed by air blowers. Expansion joints shall be cleaned and filled with bituminous material or otherwise protected to the approval of the Engineer.

#### *Application of the Spray Coat*

4. Unless shown on the Drawings or otherwise specified, the Contractor shall submit details of the material selected for the tack or prime coat application for approval before commencing the treatment. The Engineer may require trials to confirm the product's suitability.
5. Bitumen heating shall be by methods that do not introduce free steam or moisture into the material.
6. The rate of application shall be within the limits shown in Table 8.6.

**Table 8.6: Rate of Application of Spray Coat**

| Type of Surface | Application Rates<br>(kg/m <sup>2</sup> ) |         |
|-----------------|---|---------|
|                 | Minimum                                   | Maximum |
| Prime Coat:     | 0.8                                       | 1.2     |
| Tack Coat:      | 0.2                                       | 0.4     |

7. The Engineer may require test sections or testing board to determine the optimum rate of application, or to alter previously established rates if necessary.
8. The cut-back bitumen shall be applied by pressure distributors. Spray nozzles and the spray bar shall be adjusted and frequently checked so that uniform distribution is

obtained. Spraying shall cease immediately upon clogging or interference of any nozzle and corrective measures taken before spraying is resumed. Hand sprays shall be used only for priming small patches or inaccessible areas that cannot be covered by normal operation of the distributor. Any excess at the junction of spread shall be scraped from the surface. Deficient areas shall be corrected by means of hand sprays.

9. Spray coat shall not be applied during rainfall and if the surface temperature is less than 10 °C.
10. When bituminous spray is being applied, nearby structures, safety barriers, curbs, gutters, and other fixed items shall be protected from over-spray in a manner approved by the Engineer.
11. If 48 hours after the spray coat has been applied it has not cured sufficiently and the road must be used by public traffic, the Engineer may instruct a blinding (blotting) material to be applied. This shall be clean fine, sharp sand or crushed rock with no more than 15 % by weight retained on a 6.7 mm sieve. Blinding shall be applied sparingly only on areas that have not cured.
12. The Contractor shall provide traffic diversions as necessary whilst spray coating is being done. Where no convenient diversion can be provided, the operation shall be confined to one-half of the roadway with traffic control.

#### **8.2.4.5 Basis of Payment**

13. The amount of completed and accepted work will not be paid as 'Bituminous Prime Coat' and 'Bituminous Tack Coat', and the cost shall be included in the cost for binder course or surface course, including providing all materials, blinding material, placing, curing, labor, equipment, tools and other items necessary for the proper completion of the Work.

#### **8.2.5 Bituminous Binder course and Surface course**

##### **8.2.5.1 Description**

1. Binder course means the layer between Base course and Surface course. Surface course means top layer of the pavement. Wearing course will be placed on the surface course

where the excessive abrasion of the surface course by the traffic may be expected. Wearing course shall not be taken into account of structural design of the pavement.

2. These works shall consist of mixed graded aggregate with single sized crushed stone, sand and filler, and bitumen binder in a central plant, spreading and compacting the mixture (asphalt) on an approved base course, binder course, concrete deck or steel deck.

#### 8.2.5.2 Type of Asphalt Mixtures

##### Bituminous binder course

3. Course graded asphalt mixtures (CG12) given in Table 8.7 or as shown in the Drawing be used onto the embankment section or aggregate base course.
4. Dense graded mixture (DG20) or ( DF20) given in Table 8.7 or as shown in the Drawing be used onto the concrete deck section.
5. Dense and gap graded mixture (DPG13) or ( DF20) given in Table 8.7 or as shown in the Drawing be used onto the steel deck section with the binder of rubberized and thermoplastic bitumen.

##### Bituminous surface course

6. Graded asphalt mixtures (CG12) given in Table 8.7 or as shown in the Drawing be used onto the embankment section or aggregate base course.
7. The dense graded mixture (DG20) or ( DF20) given in Table 8.7 or as shown in the Drawing shall be used on the concrete deck section.
8. The dense and gap graded mixture (DPG13) or ( DF20) given in Table 8.7 be used onto the steel deck section with the binder of rubberized and thermoplastic bitumen.

**Table 8.7: Overall Grading of Aggregate for Asphalt Mixtures**

| Type                  |      | Sieve by mm |        |       |       |       |       |       |      |       |
|-----------------------|------|-------------|--------|-------|-------|-------|-------|-------|------|-------|
|                       |      | 26.5        | 19     | 13.2  | 4.75  | 2.36  | 0.6   | 0.3   | 0.15 | 0.075 |
| Course graded mixture | CG20 | 100         | 95-100 | 70-95 | 35-55 | 20-35 | 11-23 | 5-16  | 4-12 | 2-7   |
| Dense graded mixture  | DG20 | 100         | 95-100 | 70-95 | 45-65 | 35-50 | 18-30 | 10-21 | 6-16 | 4-8   |

|                            |       |     |        |       |       |       |       |       |      |
|----------------------------|-------|-----|--------|-------|-------|-------|-------|-------|------|
| ditto                      | DG13  | 100 | 95-100 | 55-70 | 35-50 | 18-30 | 10-21 | 6-16  | 4-8  |
| Fine graded mixture        | FG13  | 100 | 95-100 | 65-80 | 50-65 | 25-40 | 12-27 | 8-20  | 4-10 |
| Dense & gap graded mixture | DGP13 | 100 | 95-100 | 35-55 | 30-45 | 20-40 | 15-30 | 5-15  | 4-10 |
| Dense graded mixture       | DF20  | 100 | 95-100 | 75-95 | 52-70 | 40-60 | 25-45 | 16-33 | 8-21 |
| ditto                      | DF13  | 100 | 95-100 | 52-70 | 40-60 | 25-45 | 16-33 | 8-21  | 6-11 |
| Fine & gap graded mixture  | FPF13 | 100 | 95-100 | 60-80 | 45-65 | 40-60 | 20-45 | 10-25 | 8-13 |
| Fine graded mixture        | FF13  | 100 | 95-100 | 75-90 | 65-80 | 40-65 | 20-45 | 15-30 | 8-15 |
| Dense & gap graded mixture | DPF13 | 100 | 95-100 | 45-60 | 30-45 | 25-40 | 20-40 | 10-25 | 8-12 |
| Open graded mixture        | OF13  | 100 | 95-100 | 23-45 | 15-30 | 8-20  | 4-15  | 4-10  | 2-7  |

*Job-Mix Formula*

9. At least 30 days before beginning production of bituminous binder and surface course and having received approval of the aggregates from the Engineer and delivery to site of the bitumen, the Contractor shall make written proposals to the Engineer for the Job-Mix Formula for the type of Binder and Surface course specified. These shall be based on Trial Mixes prepared by the Contractor in the Site Laboratory in the presence of the Engineer.
10. The Marshall design procedure shall be used to determine the optimum percentage of bitumen to be incorporated into the mixture. The number of blows in preparing the test briquettes shall be 75 at each end of the mold. The number of blows may be reduced to 50 with the approval of the Engineer.
11. The Job-Mix formula shall combine aggregates of the type required in Table 8.7 and bitumen to produce an mixture having a binder content as given in Table 8.8. When tested according to AASHTO T245 the mixture shall have the properties given in Table 8.8.

**Table 8.8: Physical Properties of Mixtures**

|                       |      | Bitumen Contents |          | Marshall                     | Test      |            |
|-----------------------|------|------------------|----------|------------------------------|-----------|------------|
|                       |      | %                | Air void | Voids filled<br>with bitumen | Stability | Flow value |
| Coarse graded mixture | CG20 | 4.5-6            | 3-7      | 65-85                        | >500      | 20-40      |
| Dense graded mixture  | DG20 | 5-7              | 3-6      | 70-85                        | >500      | 20-40      |

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|                            |       |         |     |       |      |       |
|----------------------------|-------|---------|-----|-------|------|-------|
| ditto                      | DG13  | 5-7     | 3-6 | 70-85 | >500 | 20-40 |
| Fine graded mixture        | FG13  | 6-8     | 3-6 | 70-85 | >500 | 20-40 |
| Dense & gap graded mixture | DGP13 | 4.5-6.5 | 3-7 | 65-85 | >500 | 20-40 |
| Dense graded mixture       | DF20  | 6-8     | 3-5 | 70-85 | >500 | 20-40 |
| ditto                      | DF13  | 6-8     | 3-5 | 70-85 | >500 | 20-40 |
| Fine & gap graded mixture  | FPF13 | 6-8     | 3-5 | 70-85 | >500 | 20-40 |
| Fine graded mixture        | FF13  | 7.5-9.5 | 2-5 | 75-90 | >350 | 20-80 |
| Dense & gap graded mixture | DPF13 | 5.5-7.5 | 3-5 | 70-85 | >500 | 20-40 |
| Open graded mixture        | OF13  | 3.5-5.5 | -   | -     | >350 | 20-40 |

13. The asphalt plant production shall be tested at the intervals instructed by the Engineer and the Contractor shall control the plant to maintain conformity with the Job-Mix Formula. If, during production, the binder or the aggregate source is changed, the mix shall be redesigned and a new Job-Mix Formula approved.
14. The assistance of the Engineer in the preparation of the Job-Mix Formula does not relieve the Contractor of the responsibility of producing a bituminous binder and surface course meeting the requirements of the Specification.

**8.2.5.3 Construction Requirements for hot type mixture**

*Asphalt Production*

15. Bitumen shall be heated within a temperature range of 135 °C to 170 °C at the time of mixing. Bitumen received directly from the refinery at temperatures in excess of 170 °C, but not exceeding 190 °C, may be used.
16. Aggregates shall be dried in hot bins at temperatures not exceeding 170 °C. If the aggregates contain sufficient moisture to cause foaming in the mixture or their temperature is in excess of 170 °C, they shall be removed from the bins and returned to the stockpiles.
17. Mixing time shall be the shortest that will produce a satisfactory mixture and shall be set to achieve 95 % of coated particles as determined according to AASHTO T195. Batch plant dry mixing time shall not exceed 10 seconds; wet mixing time shall not exceed 50 seconds. Timing shall begin at the start of the bitumen introduction into the pugmill.

18. The temperature of the binder, shall not be less than 14 °C below the temperature of the aggregate at the time the two materials enter the mixer.

*Placing of the Binder course Asphalt*

19. The hot mixture shall be spread and finished by an automatically controlled asphalt paver. Hot mixtures may be spread and finished by hand methods only where machine methods are impractical as agreed with the Engineer. The paver shall be operated at a speed which co-ordinates satisfactorily with the rate of delivery of hot mix so as to provide a constant uninterrupted rate of placement.
20. Hot mixture shall be delivered to the paver in time to permit completion of spreading, finishing and compaction of the mixture during daylight hours. Delivery temperatures shall be between 140 °C and 165 °C.
21. Trucks used for hauling hot mixture shall have tight, clean, smooth metal beds which have been thinly coated with a minimum amount of paraffin oil, lime solution or other approved material to prevent the hot mixture from adhering to the metal. Each vehicle shall be fitted with a canvas or similar cover to protect and maintain the temperature of the mixture.

*Compaction*

22. The degree of compaction of the mixture in the road shall be determined in accordance with AASHTO T230, and bulk density (Specific Gravity) in accordance with AASHTO T166 by a pre-trial paving.
23. Rolling shall begin as soon as the mixture will bear the roller without undue displacement. Initial or breakdown rolling and final surface rolling shall be done by either a tandem steel roller or a three wheel steel roller. Compaction shall follow the initial rolling by means of multi-wheeled pneumatic tired rollers, vibratory rollers, or a combination of these. The number and mass of rollers shall be sufficient to compact the mixture to the required density while it is still in a workable condition.
24. Rolling shall proceed longitudinally, beginning at the low side and progressing towards the high side, overlapping on successive passes by at least half the width of the rear roll or in the case of a pneumatic tired roller, at least the nominal width of one tier. Alternate passes of the roller shall be of slightly different lengths.



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- 25. Vibratory rollers shall not be used on bridge decks in vibrating mode.
- 26. The Contractor shall protect the newly compacted mixture from traffic until it has cured properly. It shall be kept clean and uncontaminated. The only traffic permitted to run on bituminous material which is to be overlaid shall be that engaged in spreading and compacting the next layer.

*Joints*

- 27. Joints in successive layers shall be offset by at least 30 cm and in a layout agreed with the Engineer. Longitudinal joints in the top layer shall coincide with a lane line wherever possible. Unless otherwise agreed with the Engineer, where successive layers are to be placed, the surface of the existing layer shall be swept clean with a power broom and a tack coat applied.
- 28. Joints between old and new pavements or between successive days' work shall be made so as to provide thorough and continuous bond between old and new mixtures. Transverse construction joints in previously laid material shall be constructed by cutting material back vertically for its full depth so as to expose a fresh surface.
- 29. Before placing fresh mixture against a cut joint or against old pavement, the contact surface shall be sprayed or painted with a thin uniform coat of RC-250 cut-back bitumen or SS-1 bitumen emulsion.
- 30. Contacting surfaces of curbs, gutters, manholes and similar structures shall be painted with a thin uniform coating of hot bitumen or cut back asphalt.

*Quality Control*

- 31. The quality control shall be carried out by the Contractor as approved by the Engineer for the items shown in the Table below.

|        | Item        | Frequency | Tolerances           | Remarks                       |
|--------|-------------|-----------|----------------------|-------------------------------|
| Binder | property    | any time  | within specification | Penetration & Softening Point |
|        | Temperature | any time  | 135 to 170 °C        |                               |

|                      |                  |                                    |                      |
|----------------------|------------------|------------------------------------|----------------------|
| Cold Aggregate       | Appearance       | any time                           |                      |
|                      | Grading          | any time                           | within specification |
| Aggregate in Hot Bin | Temperature      | always                             | less than 170 °C     |
|                      | Grading          | any time                           |                      |
| in Mixer             | Mixed grading    | any time                           | within specification |
|                      | Temperature      | any time                           | 140 °C and 165 °C    |
| at Mixing            | Appearance       | any time                           |                      |
|                      | Grading          | 2 times per day                    | within specification |
| on Track             | Bitumen Contents | 2 times per day                    | within specification |
|                      | Temperature      | every track                        | 140 to 165 °C        |
| arriving on Site     | Bitumen contents | 2 times per day                    | ± 0.5 %              |
|                      | Thickness        | any time                           |                      |
| on paving            | Appearance       | always                             | hair cracks          |
|                      | Temperature      | any time                           |                      |
| on compacting        | Appearance       | always                             |                      |
|                      | Width            | every 50 m                         | ± 3 cm               |
| after completion     | Length           | every day                          |                      |
|                      | Flatness         | whole length for each traffic lane | < 2 mm               |
|                      | Thickness        | 1 set per 1000m <sup>2</sup>       | ± 3 mm               |
| After taking sample  | Density          | 1 set per 1000m <sup>2</sup>       | >96%                 |

32. The sampling equipment from the finished pavement shall be capable of coring or cutting the asphalt without shattering the edges of or otherwise disturbing the specimen. Sawn samples shall be 100 mm square and cored samples shall be 100 mm in diameter.

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33. 1 set of sample shall be 3 specimens per layer per 1000 square meters or a minimum per day.
34. The first sampling operation shall be taken when a binder course layer is laid. The second sampling shall be done through the last layer adjacent to the location where the first was taken except on steel deck section.
35. The holes from which samples have been cut shall be thoroughly dried, painted with hot binder and filled with same mixture or surface course mixtures well rammed in layers not exceeding 50 mm in thickness.
36. The density shall be at least 96 % of the Job-Mix Formula value.
37. Surface irregularity shall be checked with a 3 m straight edge, parallel to the center line at 10 m intervals for each traffic lane or as required by the Engineer. The tolerances for surface irregularity shall be given by the Engineer, if another method was requested .

**Remedial works for the finished binder and surface course.**

38. If tolerances are exceeded, the full extent of the area which does not comply with the Specification shall be determined by further sampling and testing and then made good.
39. Unacceptable areas shall have the full depth of layer removed and replaced with fresh material. The area rectified shall be the full width of the paving laid in one operation and at least 15 m long for the top layer, and 5 m long for lower layers. Areas to be removed shall have their edges saw cut. Cut faces shall be coated with hot bitumen immediately before laying the new material.

**Table 8.10: Construction Tolerances for Binder course**

| Property                                    | Limit   | Action                                |
|---|---|---------------------------------------|
| Thickness of layer                          | 3 mm deficiency                                 | Full payment                          |
|   | 3 - 10 mm deficiency                            | 85 % payment                          |
|   | >10 mm deficiency (or 15 % of design thickness) | Replace                               |
| Surface irregularity<br>(3 m straight edge) | >5 mm   | Replace (minimum 15 m length of road) |
| Surface level                               | >6 mm   | Replace (minimum 5 m length of road)  |

|         |                  |                                       |
|---------|------------------|---------------------------------------|
| Density | <96 % of maximum | Replace (minimum 15 m length of road) |
|---------|------------------|---------------------------------------|

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40. In lieu of making the rate adjustment given in Table 8.10 or requiring the Contractor to remove deficient bituminous binder course, the Engineer may permit the Contractor to make up the thickness deficiency with additional bituminous Surface course at the Contractor's expense. If such remedial action is implemented, thickness determinations shall be made by measurements of new samples taken after the surface course has been completed.
41. If binder course deficiencies are corrected by adding surface course, full payment for the bituminous binder course will be made to the Contractor but no payment will be made for the increase in thickness of the surface course.

#### **8.2.5-4 Method of Measurement**

42. The approved work shall be measured in square meters according to the dimensions shown on the Drawings. No measurement will be made of unauthorized areas or for extra thickness.

#### **8.2.5-5 Basis of Payment**

43. The amount of completed and accepted work measured as provided for, above will be paid for at the unit rate for 'Bituminous Binder course' and 'Bituminous Surface Course' in the Bill of Quantities, which rate shall include for drying and screening aggregate, mixing, placing, finishing and the equipment, materials, tools and other items necessary to complete the Work.
44. The tendered rate for 'Bituminous Binder course' and 'Bituminous Surface Course' shall be based on a nominal bitumen content range as shown in Table 12-18. An addition or deduction exceeding the range shall be made based on the bitumen content agreed for the Job-Mix Formula at the unit rate for 'Increase or decrease in bitumen content from nominal rate' in the Bill of Quantities.

#### **8.2.5.6 Items in the Bill of Quantities**

- Item No.8.2.1 Bituminous binder course 5 cm on Main Bridge (sq. m)
- Item No.8.2.2 Bituminous binder course 4 cm on App. Bridge (sq. m)
- Item No.8.2.3 Bituminous binder course 5 cm on App. Bridge (sq. m)

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Item No.8.2.4 Bituminous surface course 3 cm on Main Bridge (sq. m)

Item No.8.2.5 Bituminous surface course 3 cm on App. Bridge (sq. m)

Item No.8.2.6 Bituminous surface course 5 cm on App. Roads (sq. m)

Item No.8.2.7 Bituminous surface course 4 cm on Maintenance Roads (sq. m)

Item No.8.2.8 Increase or decrease in bitumen content from nominal rate.

### **8.3 Concrete Pavement**

#### **8.3.1 Description**

1. This Work shall consist of mixing, placing, compacting, and finishing of road pavement composed of Portland cement concrete, with or without reinforcement, on a prepared subgrade, subbase or base course surface. Plain and reinforced concrete pavement shall include deformed bars for contraction joints and dowel bars for expansion joints.

#### **8.3.2 Materials**

##### *Concrete*

2. Cement, aggregate, water and concrete mixes shall conform to the requirements of *Clauses* 501 and 502. Reinforcing steel shall conform to the requirements of *Clause* 509.

##### *Dowel bars*

3. Dowel bars shall be Grade 250 steel complying with BS 4449 and shall be free from oil, dirt, loose rust or scale. They shall be straight, free of irregularities with the sliding end sawn.
4. Dowel bars shall be covered by a thin plastic sheath as shown on the Drawings. The sheath shall be tough, durable and of average thickness not greater than 1.25 mm. The sheathed bar shall comply with the following pull-out test:
  - (i) 4 bars shall be taken at random from stock and without any special preparation shall be covered by sheaths. The halves of the dowel bars which have been sheathed shall be cast centrally into concrete specimens 150x150x450mm made of the same mix proportions as the pavement, but with a maximum nominal aggregate size of 20 mm, and cured in accordance with BS 1881. At 7 days a tensile load shall be applied to achieve a movement of the bar of at least 0.25 mm. The average bond stress to achieve this movement shall be not greater than 0.14N/mm<sup>2</sup>.
5. For expansion joints, a closely fitting cap 100 mm long consisting of waterproofed cardboard or an approved synthetic material shall be placed over the sheathed end of

each dowel bar. An expansion space equal in length to the thickness of the joint filler shall be formed between the end of the cap and the end of the dowel bar.

*Tie bars*

6. Tie bars shall be Grade 460 type 2 deformed steel bars to BS 4449. Tie bars shall be free from oil, dirt, loose rust and scale.
7. Tie bars shall be protected from corrosion for 75 mm each side of the joint by a suitable close fitting, flexible, plastic sleeve with a wall thickness not greater than 3 mm.

*Joint Seals and Filler Board*

8. Joint seals and filler board shall comply with Clause 1103.

**8.3.3 Construction Requirements**

*Pavement Foundation*

9. The surface upon which concrete pavement is laid shall have been constructed in compliance with the Specification to the levels and cross-Sections shown on the Drawings. It shall be maintained throughout the placing of concrete pavement.
10. The prepared surface shall be moistened and covered with 125µm thick plastic sheeting laid flat without creases. Where an overlap of plastic sheets is necessary this shall be at least 300 mm. Water shall not be allowed to pond on or under this membrane when concrete is being placed on it.
11. To give correct layer thickness and cross Section, a template resting on accurately set side forms shall be moved over the foundation surface immediately before placing concrete. High spots shall be planed down and the Contractor shall have the option of either filling low spots to proper elevation with approved compacted material or of placing additional concrete.

*Placing Forms*

12. Forms shall comply with *Clause 5.1.5*.
13. Forms shall bear fully upon the foundation throughout their length and shall be placed to the required elevation and alignment of the edge of finished pavement. They shall

be supported during the operation of placing, compacting and finishing the pavement layer and not deviate more than 3 mm from the correct elevation.

14. Forms shall not be removed for at least 12 hours after concrete has been placed. They shall be carefully removed to avoid damage to the concrete. Crowbars between forms and pavement shall not be used. Pavement which is damaged shall be repaired as instructed by the Engineer.
15. When concrete pavement is placed adjoining existing pavement upon which the finishing machine will travel, any irregularities in the old pavement shall be ground down to a level, uniform surface to accommodate the wheels of the finishing machine.

#### *Placing Reinforcement*

16. The marginal bars, dowel bars, and tie bars shown on the Drawings shall be held in position by a sufficient number of metal bar supports or pins. If the center joint is to be sawn in lieu of placing metal center strip, ties may be installed mechanically. The Engineer may require, when satisfactory placement is not obtained by mechanical means, that tie bars be installed ahead of placing concrete and that they be securely staked and ties. Use of removable devices supporting bars from the forms will not be permitted.
17. Placed concrete shall be struck-off to conform to the cross-section shown on the Drawings and to a level such that when compacted and finished, the surface of the pavement will be at the elevation shown on the Drawings.
18. The entire width of the bottom layer of a 2-layer pavement shall be struck-off to a length and thickness so that sheet fabric or bar mat may be laid full length on the concrete in its final position without further manipulation. Any part of the bottom layer concrete which has been placed more than 15 minutes without being covered with top layer shall be removed and replaced with freshly mixed concrete at the Contractor's expense. Only plain concrete and concrete with two layers of reinforcement may be placed in one layer.
19. Where 2 layers of mesh reinforcement are required the bottom mesh shall be supported in the required position with bar chairs. Separators shall be used for the top mesh if strike-off cannot be used for the operation. Laps in adjacent sheets of reinforcement shall be as shown on the Drawings. Laps parallel to centerline of pavement will not be



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permitted except for unusual widths of pavement lanes or for irregular areas. Adjacent sheets shall be fastened or tied together to hold all parts in the same plane.

20. If removal of part of an existing pavement is required to connect with new pavement concrete, and the edge is not an existing joint, a new joint shall be made by sawing the existing pavement not less than 50 mm deep before removal.

### *Placing Concrete*

21. Concrete shall be placed on the foundation surface in successive batches for the full width between forms. Spreading shall be done by an approved mechanical spreader in a manner that will prevent segregation and separation of materials. Secondary hand spreading shall be done with shovels, not rakes. The volume of concrete placed shall be in excess of that required to form the pavement after compaction.
22. Concrete shall be placed as near to expansion and contraction joints as possible without disturbing them, but shall not be discharged directly onto a joint assembly unless the hopper is well centered on the joint assembly. Damage to joint assemblies caused by placing concrete shall be repaired immediately as instructed by the Engineer.
23. Placement of concrete ahead of the initial spreader strike-off shall not be more than 15 minutes before final spreader strike-off. If concrete is placed in a single layer it shall not be more than 20 minutes ahead of spreader strike-off.

### *Finishing*

24. After being spread and struck-off the concrete shall be compacted by vibrating finishing beams. In addition, internal poker vibration shall be used for slabs thicker than 200mm, and may be used for lesser thickness. Where used, pokers shall be at points not more than 500 mm apart of the whole area of the slab, and adjacent to the side forms or the edge of a previously constructed slab. Vibrators shall not come in contact with a joint assembly or side form. A vibrator shall not be operated longer than 15 seconds in any one place.
25. The surface shall be regulated and finished to the level of the top of the forms or adjacent slab or pavement layer by using twin vibrating finishing beams. The beams shall be moved forward at a steady speed of 0.5m to 1m per minute while vibrating over the compacted surface, to produce a smooth finish.

26. The addition of water to the concrete surface to assist in finishing operation will not be permitted.
27. After final regulation of the surface of the slab and before the application of the curing membrane, the surface shall be textured with a broom in a direction at right angles to the longitudinal axis of the carriage-way.
28. The broomed surface texture shall be applied evenly across the slab in one direction by the use of a brush. Grooves so formed shall be about 2 mm in depth.
29. The edges of the concrete at expansion joints shall be finished with an edger to the radius shown on the Drawings. The exposed edge of the pavement shall be finished with an edger to a radius of 6 mm. Tool marks appearing on the slab adjacent to joints or edge of slab shall be removed by dragging the surface.

#### *Curing*

30. Curing shall be carried out to the requirements of Clause 5.0.3. and also to comply with the additional sub-Clauses that follow.
31. Before the surface of concrete has set, a liquid curing membrane to AASHTO M148 (Type 2) shall be applied evenly at a rate of not less than  $0.31/m^2$  using mechanical pressure distributors (spray bars).
32. Irregular areas unsuitable for spray bar distribution may be covered with hand sprays. When hand sprays are used the liquid shall be applied twice, each at a rate of not less than  $0.21/m^2$ . The path of spray on the second application shall be at right angles to the first.
33. Immediately following application of the curing membrane, a shade-canvas shall be placed approximately 300 mm above the pavement surface so that no part of the shade-canvas comes in contact with the concrete. New concrete pavement shall not be exposed to direct rays of the sun for more than 1 hour before being shaded.
34. When the forms are removed, and following the sawn joint operation, the edges of the concrete shall receive curing membrane at the rate of coverage specified for pavement surface. The liquid shall be applied with hand sprays or by nozzles attached to the mechanical distributor, at the rate specified within 30 minutes of concrete exposure. Cleaning and sealing of joints shall be performed immediately following removal of the

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shade-canvas at the end of initial curing period and prior to application of polyethylene sheeting.

### *Final Curing*

35. At the end of the 24 hour initial curing period and after the jointing operation is completed, the pavement shall be covered with White Opaque Polyethylene Film as specified in AASHTO M171. Adjoining sheets shall be lapped a minimum of 450 mm. Sheeting shall be held in place in a manner approved by the Engineer.
36. Final curing shall be continued until concrete reaches an age of 14 days, unless high early strength concrete mixes are used, in which case the minimum total curing period shall be 7 days. During this period the curing membrane and polyethylene film shall be protected. No traffic, including workmen and pedestrians, shall be allowed on the pavement surface within the final curing period.

### *Expansion Joints*

37. The joint assembly shall be of a type shown on the Drawings and shall be installed with its centerline perpendicular to the pavement slab centerline and the dowels parallel to the slab centerline. Finished joints shall not deviate more than 6 mm in horizontal alignment from a straight line.
38. Joints for a pavement designed for 1 or 2 lanes of traffic shall either be assembled and installed in one continuous piece or the connections between Sections shall be made rigid and tight to prevent offsets in Sections of joints. The length of individual pieces of expansion joint filler shall be not less than the width of one traffic lane.
39. The finishing machine shall be operated in a manner that will avoid displacement of the joint. If it is necessary to straighten a joint, any depressions caused by this operation shall immediately be filled with fresh concrete, and re-spaded in advance of the longitudinal finishers.

### *Contraction Joints*

40. Sawn contraction joints shall not be cut until the concrete has hardened to the extent that tearing and raveling will not occur. The cut shall be between 25% and 33% of the depth of slab and not less than 3 mm wide.

41. Dust resulting from sawing shall be completely removed from the joint and adjacent areas by an air jet or a combination of air and water applied under pressure immediately after the joint has been cut and before filling with joint compound.
42. Joint dowels shall be treated, and the entire joint assembly shall be installed as for Expansion Joints described in Section of Expansion Joint

#### *Construction Joints*

43. Construction joints made at the end of each day's work shall be expansion joints or contraction joints.
44. Emergency transverse construction joints shall be made when concrete placing is stopped for more than 30 minutes. No emergency joint shall be made within 3m of another transverse joint. If this is not possible then the concrete shall be cut back to the previous transverse joint.
45. The stop end formwork for emergency joints in reinforced concrete slabs shall be sufficiently rigid to hold dowel bars, tie bars or reinforcement accurately in position, and placed so that the longitudinal reinforcement projects through the joint at least 750 mm.

#### *Joint Sealing*

46. After concrete curing the protective covering shall be removed and the joint cleaned with a compressed air jet, air and water under pressure, or wire brushes.
47. Hot or cold-applied sealant shall be used to seal the joints as shown on the Drawings and in accordance with the manufacturer's instructions.

#### *Quality Control and Tolerances*

48. As soon as the concrete has hardened sufficiently, the pavement surface shall be tested with a 3m straight-edge for riding surface quality.
49. The thickness of the pavement shall be determined by measurement of cores taken in each 300m unit length of traffic lane. If the thickness is deficient by 5 mm to 25 mm from the thickness shown on the Drawings, two additional cores at intervals of not less

100m shall be taken and the three thickness used in determining the average for that unit.

50. Areas such as intersections, entrances, cross-overs, and ramps will be considered as one unit. Small irregular unit areas may be included as part of another unit. One core shall be taken for each 750m<sup>2</sup> of pavement in the unit. Two additional cores shall be taken from the area represented and the average of the 3 cores determined.
51. There will be action taken either to replace concrete pavement deficient in riding quality or layer thickness or to reduce the payment due to the Contractor. The tolerances and the required action are given in Table 8.30. The rate reduction schedule is given in Table 5.11.

**Table 8.30: Concrete Pavement Tolerances**

| Property                | Allowable Limits (mm)    | Action   |
|-------------------------|--------------------------|--|
| Riding surface flatness | ±3<br>± 3 to ±12<br>> 12 | None<br>Grind to within ± 3 mm<br>Remove layer and replace |
| Layer thickness         | ±5<br>± 5 to ±25<br>> 25 | None<br>Payment reduction<br>Remove layer and replace      |

52. Any area or Section removed shall not be less than 3m in length nor less than full width of the lane involved. When it is necessary to remove and replace a Section of pavement any remaining portion of slab adjacent to a joint that is less than 3m in length shall also be replaced.

#### **8.3.4 Method of Measurement**

53. The approved work measured will be by the square meter. The width for measurement will be the width of pavement shown on the typical cross-Sections or as otherwise instructed by the Engineer. The length will be measured horizontally along the centerline of each traffic lane.

#### **8.3.5 Basis of Payment**

54. The amount of completed and accepted work, measured as provided for above, will be paid for at the unit rates for 'Concrete Pavement' in the Bill of Quantities which rate(s) shall include for delivering and placing all materials including reinforcing steel, joint assemblies, joint sealant, curing, and for labor, equipment, tools and other items necessary for the proper completion of the work, except that when the average thickness of the concrete pavement is deficient an adjusted unit rate will be paid.

### **8.3.6 Rate Adjustment**

55. Where the average thickness of concrete pavement is deficient by more than 5 mm, but not more than 25 mm, payment will be made at an adjusted rate as given in Table 8.31.

**Table 8.31: Concrete Pavement Payment Schedule**

| Deficiency in thickness (mm) | Percentage of price paid |
|------------------------------|--------------------------|
| 0.0 to 5.0                   | 100                      |
| 5.1 to 8.0                   | 80                       |
| 8.1 to 10.0                  | 72                       |
| 10.1 to 13.0                 | 68                       |
| 13.1 to 19.0                 | 57                       |
| 19.1 to 25.0                 | 50                       |

### **8.3.7 Items in the Bill of Quantities**

Item No. 8.3.1 Un-reinforced concrete pavement (class)(thickness)

Item No. 8.3.2 Reinforced concrete pavement (class)(thickness)

## 9.0 SAFETY FACILITIES

|     |  |    |
|-----|--|----|
| 9.1 | Safety Barrier by Corrugated Steel Beam -----  | 1  |
| 9.2 | Safety Barrier by Concrete-----                | 4  |
| 9.3 | Reflectorised Markers for Safety Barriers----- | 5  |
| 9.4 | Delineators -----                              | 6  |
| 9.5 | Traffic Signs-----                             | 7  |
| 9.6 | Road Markings -----                            | 10 |
| 9.7 | Chain-Link Fences-----                         | 13 |
| 9.8 | Concrete Curbs-----                            | 16 |
| 9.9 | Sidewalks and Paved Areas-----                 | 18 |

## **9.0 SAFETY FACILITIES**

### **9.0.1 Reference Standards**

1. The following standards shall be referred to in this part:

|              |  |
|--------------|--|
| BS 873:1970  | The Construction of Road Traffic Signs and Internally Illuminated Bollards.              |
| BS 1088      | Marine Plywood Manufactured from Selected Untreated Tropical Hardwoods.                  |
| BS 1186      | Quality of Timber and Workmanship in Joinery   |
| ISO 216:1975 | Writing Paper and Certain Classes of Printed Matter<br>- Trimmed Sizes - A and B Series. |

### **9.1 Guard Rail on Steel Bridge**

#### **9.1.1 Description**

1. This Work shall consist of the fabrication, supply and installation of corrugated steel beams, posts, anchorage and connections.

#### **9.1.2 Materials**

2. Beams, washers and bolts shall conform to the requirements of AASHTO M 180. Beams shall be type 1 Class B.
3. The beams shall be completely formed, punched with holes for mounting and splicing, and ready for assembly when delivered. They shall be of uniform corrugated section, straight or curved as required. Beams to be erected on a radius of 45 m or less shall be shop-curved as indicated on the Drawings.
4. Posts and other fittings shall be steel as specified in Clause of Steel Works and of the dimensions and mass shown on the Drawings.
5. Galvanizing shall be carried out after fabrication and each element and end sections shall be marked at the point of fabrication with the manufacturer's name or trademark, gauge and heat number, and with the coating lot reference.



6. The Contractor shall submit to the Engineer the manufacturer's Certificates of Guarantee stating that the materials supplied conform to the Specification.
7. Concrete for footings and anchorages shall be grade 24 in accordance with Clauses of Concrete works.

#### **9.1.3 Construction Requirements**

8. Steel safety barriers shall be installed at the locations shown on the Drawings. Posts shall be set plumb and to the indicated lines and levels.
9. Beams and posts shall not be punched, reamed, or drilled on site. Special closure pieces, where required, shall be fabricated at the manufacturer's works, unless otherwise agreed by the Engineer.
10. Beams shall be spliced by lapping with the edge facing away from the nearside direction of traffic.
11. Unless otherwise shown on the Drawings the Contractor may use driven posts or posts set in concrete foundations.
12. Safety Barriers shall be erected to present a flowing alignment to the following tolerances:
  - (i) The alignment on plan shall not depart from the prescribed alignment by more than  $\pm 30$  mm, nor deviate in any 10 m length from the prescribed alignment by more than  $\pm 15$  mm.
  - (ii) The height of the beam shall not depart from the prescribed height by more than  $\pm 30$  mm, nor deviate in any 10 m length from the prescribed height by more than  $\pm 10$  mm.

#### **9.1.4 Method of Measurement**

13. The approved work shall be measured **by the linear metre** erected in place calculated by the length of beam from center of end post to center of end post.
15. No separate measurement shall be made for safety barrier post, fittings, spacers, excavation, footings and backfill.

14. 'End Anchorages' shall not be measured separately and shall be included to the cost of above.

#### **9.1.5 Basis of Payment**

16. The amount of completed and accepted work measured as provided for above will be paid for at the unit rate for 'Safety Barrier by Corrugated Steel Beam' in the Bill of Quantities which rate will include for supplying all materials for excavation, backfilling, installing, concrete, driving, fitting, finishing and for labour, equipment tools, supplies and other items necessary for the proper completion of the Work.

#### **9.1.6 Items in the Bill of Quantities**

|                |   |
|----------------|---|
| Item No. 9.1.1 | Guard Rail on Steel Bridge (linear meter)             |
| Item No. 9.1.2 | Guard Rail on Embankment road (linear meter)          |
| Item No. 9.1.3 | Guard Chain Link Fence on Steel Bridge (linear meter) |

## **9.2 Safety Barrier by Concrete**

### **9.2.1 Description**

1. This work shall consist of the construction of concrete safety barriers.

### **9.2.2 Materials**

2. Materials for concrete safety barriers shall conform to the requirements of Clauses of Concrete.

### **9.2.3 Construction Requirements**

3. Concrete safety barriers shall be constructed to the requirements of Clauses of Concrete.

### **9.2.4 Measurement**

4. The approved work shall be measured **by the linear metre** along the front face of installed safety barrier at finished ground level. Barrier base, dowel bars, excavation and reinforcement for the barrier shall not be measured separately.

### **9.2.5 Basis of Payment**

5. The amount of completed and accepted work measured as provided for above will be paid for at the unit rate for 'Concrete Safety Barrier' in the Bill of Quantities which rate will include for supplying all materials for excavation, backfilling, installing, fitting, finishing and for labour, equipment tools, supplies and other items necessary for the proper completion of the Work.

### **9.2.6 Items in the Bill of Quantities**

Item No. 9.2 Safety barrier by Concrete

### **9.3 Reflectorised Markers for Safety Barriers**

#### **9.3.1 Description**

1. This Work shall consist of the fabrication, supply and fixing of reflectorised markers to safety barriers and other roadside obstructions.

#### **9.3.2 Materials**

2. Reflectorised markers shall consist of two retro reflective faces of minimum area 4,000 mm<sup>2</sup> on a weatherproof, durable backing capable of being fixed to safety barrier. Metal fittings shall be galvanized or stainless steel of approved manufacture.
3. Reflectorised faces shall consist of a minimum of 210 glass beads set in a 3 mm thick tough durable plastic backing. Both faces shall be red, unless otherwise shown on the Drawings.

#### **9.3.3 Construction Requirements**

4. Reflectors shall be fixed to safety barriers and other structures where shown on the Drawings.
5. Stainless steel fixings complying with BS 6105, Grade A4 shall be used to attach markers to concrete. Plastic isolation washers shall be used if the marker is galvanized.

#### **9.3.4 Method of Measurement**

6. The approved work shall not be measured separately.

#### **9.3.5 Basis of Payment**

7. The amount of completed and accepted work will be paid in the unit rate for 'Safety Barriers by Steel Beam' or 'Safety Barriers by Concrete' in the Bill of Quantities which rate will include for supplying all materials, fixing, and for labour, equipment tools, and other items necessary for the proper completion of the Work.

#### **9.3.6 Items in the Bill of Quantities**

Item No. 9.3 Reflection Markers ( Not applied)

## **9.4 Delineators**

### **9.4.1 Description**

1. This work shall consist of the supply and installation of roadside delineator posts.

### **9.4.2 Materials**

2. Delineators shall be fabricated from approved, durable, **flexible**, molded plastic. They shall be self-colored posts as specified in the AASHTO 'Manual for Signing and Pavement Marking of the National System of Interstate and Defense Highways', and of the lengths shown on the Drawings. A red reflectorised area of minimum size 10,000 mm<sup>2</sup> shall be fixed to the post as shown on the Drawings, and shall consist of at least 500 glass beads set in a 3 mm thick tough, durable plastic backing.

### **9.4.3 Construction Requirements**

4. Delineators shall be installed at the locations and at the spacing shown on the Drawings.
5. Delineators shall be set plumb, to the correct line, in concrete of *Class 16* according to Clause of Concrete placed in a hole excavated to a depth of 1.5 times the delineator post length.

### **9.4.4 Method of Measurement**

7. The approved work shall be measured by the number of delineator posts installed.

### **9.4.5 Basis of Payment**

8. The amount of completed and accepted work measured as provided for above will be paid for at the unit rates in the Bill of Quantities which rate will include for supplying all materials, installing, and for labour, equipment tools and other items necessary for the proper completion of the Work.

### **9.4.6 Items in the Bill of Quantities**

Item No. 9.4 Delineators

## **9.5 Traffic Signs**

### **9.5.1 Description**

1. This work shall consist of supplying and erecting posts, gantries and signs.

### **9.5.2 Materials**

#### *Supports*

2. Foundation concrete shall be Class 24 in accordance with Clauses of Concrete. Reinforcement shall conform to the requirements of Clause of Reinforcement.
3. Steel for sign support posts and gantries shall conform to the requirements of Clause of Steel works.
4. Steel posts shall be galvanized in accordance with AASHTO M 111. Steel bolts, nuts and washers shall be galvanized in accordance with AASHTO M 232 or stainless steel.
5. Paint for sign supports shall conform with the requirements of Clause of Paint.

#### *Sign Panels*

6. Aluminum alloy sheets shall conform to ASTM B 209, 6061-T6, degreased and alodine-treated, and shall be a minimum 3 mm thick. Stiffening sections shall be aluminium.
7. Bolts, washers, self-locking nuts and other fittings used to construct the sign panels or hold the sign to the supports shall be stainless steel conforming to ASTM A 276, Chromium-Nickel Grade. Minimum yield 210 N/mm<sup>2</sup>.
8. Retro reflective sheeting shall comply with AASHTO M 268 Type IV.
9. Extruded aluminum channels when assembled shall form a continuous sign face, of either self-locating or bolted connection type.

### **9.5.3 Construction Requirements**

#### *General*

10. The work shall comply with BS 873.

*Sign Faces*

11. The type, color, layout and size of sign faces shall, except where otherwise shown on the Drawings.
12. The Contractor shall submit to the Engineer for approval 2 copies of detailed shop drawings of sign faces required in the Works, including the arrangement and spacing of both Arabic and English wording.
13. The Arabic and English spelling of the names of towns, districts, roads and streets will be as supplied or confirmed by the Engineer. Arabic shall be in '**Advertisers Naskh Medium**' characters. English shall be in '**Transport Heavy**' for black letters and '**Transport Medium**' for white letters.
14. The reverse face of all signs shall be painted with 2 coats of primer and 2 coats of dull grey aluminum paint.
15. Rivets and other devices used for fixing sheet sign plates to their stiffeners or framework shall be compatible with the materials being joined. Hollow rivets shall be blocked. They shall be self-colored or fitted with plastic caps to match the color of the front of the sign face where they are located.
16. Signs shall be located as instructed by the Engineer and, unless otherwise shown on the Drawings, erected so that the face is vertical and at an angle of 92° to the road centerline. Where lanes divide or are on small radius curves, the Contractor shall orientate sign faces to avoid specular reflection and glare.

*Sign Supports*

17. Sign supports shall be vertical. Signs shall be centrally placed on single post supports unless otherwise shown on the Drawings.
18. Excavation for post footings shall be to the dimensions shown on the Drawings. Concrete shall be placed against the excavated faces. Where footings are to be exposed, exposed surfaces and 150 mm below finished ground level shall be formed. The concrete shall be thoroughly compacted. Tops of footings, unless over 150 mm below finished ground level shall receive a U2 finish. Backfill shall be compacted by mechanical tampers up to the finished ground level.

19. The Contractor shall determine the post length to provide the vertical clearance shown on the Drawings. Posts in side walks shall be painted with black and white stripes as shown on the Drawings.
20. If steel is mixed with aluminum in a sign, approved nylon or neoprene insulation shall be installed where the dissimilar metals would come into contact.
21. Fabricating, erecting and finishing of sign gantry structures shall conform to the relevant requirements of Clauses of Steel works.

#### **9.5.4 Method of Measurement**

22. **The approved work shall not be measured separately.**

#### **9.5.5 Basis of Payment**

23. The amount of completed and accepted work measured as provided for above will be paid as a **Lump Sum** for 'Highway Signs' in the Bill of Quantities, which rate shall include for supplying all materials, fabrication, erection, painting, fixing, excavation, backfilling and for materials labour, equipment, tools, and other items necessary for the proper completion of the work.

#### **9.5.6 Items in the Bill of Quantities**

Item No. 9.5 Traffic Signs (lump Sum)



## **9.6 Road Markings**

### **9.6.1 Description**

1. This work shall consist of the painting on road pavements white or yellow lines, chevron striping, arrows lettering, painting on curbs, and supplying and installing road studs.

### **9.6.2 Materials**

2. Thermoplastic material for road markings shall comply with BS 3262 Class A.
3. Road markings shall be white or they shall be yellow complying with BS 381C No. 355 as shown on the Drawings.
4. Chlorinated rubber paint for painting curbs shall be elasticized and drying shall be by solvent evaporation alone. It shall have the properties given in Table 14.1.
5. Epoxy resin adhesive shall comply with AASHTO M 237.

**Table 14.1: Paint for Curbs**

| Property                   | Allowable Limits                     |
|----------------------------|--------------------------------------|
| Relative Density           | 1.48 minimum                         |
| Viscosity at 21°C          | 65 to 70 KU                          |
| Drying Time                | Approx. 10 - 15 mins                 |
| Coverage                   | 3 m <sup>2</sup> per litter maximum  |
| Brightness                 | 80 minimum                           |
| Flexibility                | Passes around 12 mm diameter mandrel |
| Chlorinated Rubber Content | 9.0 %                                |

6. Reflecting and Non-reflecting Road Studs shall comply with BS 873: Part 4. They shall be aluminum and incorporate an integral plug at least 60 mm deep. Samples of studs proposed for use in the Works shall be submitted for the Engineer's approval. The color of the reflectors shall be as shown on the Drawings.

### **9.6.3 Construction Requirements**

#### *General*

8. Traffic shall be kept off markings, studs and buttons until the installation has fully cured.

*Road Markings*

9. Spraying equipment shall consist of a motor powered self propelled machine with compressor. A minimum line width of 100 mm shall be sprayed in one pass. The bead gun shall be synchronized to spray glass spheres immediately onto the hot thermoplastic. An automatic skip mechanism shall be fitted to produce broken and dotted lines as shown on the Drawings, without pre-measurement.
10. If hand methods are used the Contractor shall provide, stencils, specialized labour and anything necessary so that the results obtained match in quality and finish the mechanically sprayed work, to the satisfaction of the Engineer.
11. Lines, chevron striping, arrows and lettering shall be provided to the size and in the location shown on the Drawings and in accordance with the 'Egypt Highway Design Standards'.
12. Where indicated on the Drawings curbs shall be painted alternately black and yellow to cover the entire exposed surface. Changes in colours shall be made at joints between curbs.
13. Obsolete or existing marking to be replaced shall be removed by a line removal machine. Hand operated machines may be used for removal of small areas of marking.
14. The surface to be painted shall be clean and dry. Premarking for painting shall be done manually on straight lines and curves using a 100 m long string. On straight the premarking shall consist of 1 dot mark every 3 m, and on curves every 1 m. The pre-marking dot shall be a circle of 40 mm diameter cut into 2 equal parts by a gap of 10 mm. Longitudinal changes in line types shall be within 300 mm of the location specified on the Drawings.
15. Paint shall be applied 1.5 mm thick for broken, dotted and continuous lines. Striping, pedestrian crossings, stop lines, special letters, arrows and symbols shall be 3 mm thick. In addition to the balloting premixed in the material, a further quantity shall be sprayed onto the hot spray plastic markings at a rate of application of 400-500 g/m<sup>2</sup>.

*Road Studs*

16. Road studs shall be fixed so that the displacement to the left or right of the correct line does not exceed 10 mm. The angular displacement of road studs shall not exceed 15°.
17. Studs shall be installed after completion of the surface course and the installation shall be carried out in accordance with the manufacturer's instructions and as agreed by the Engineer.
18. Studs shall be applied on clean, sound, dry asphalt or concrete surfaces. The air temperature shall be greater than 5 °C at the time of installation and it shall be anticipated that it will remain above 5 °C for the following 24 hours.

#### **9.6.4 Method of Measurement**

19. The approved work will not be measured separately .

#### **9.6.5 Basis of Payment**

20. The amount of completed and accepted work will be paid as a lump sum for 'Road Marking' in the Bill of Quantities which rate shall include for supplying all materials, fixing, applying, surface preparation, labour, equipment, tools and other items necessary for the proper completion of the work. The variations of area of the Road Marking up to 20 % of the original volumes shall not be taken into account for the adjusting of the cost as the increase or decrease of the works by the order of the Engineer.

#### **9.6.6 Items in the Bill of Quantities**

Item No. 9.6 Road Marking (Lump Sum)

## 9.7 Chain-Link Fences

### 9.7.1 Description

1. This work shall consist of the supply and installation of steel chain-link fencing, posts and gates.

### 9.7.2 Materials

2. Fence material shall comply with AASHTO M 181 Type IV. Where shown on the Drawings it shall be **plastic coated** with Class B bonded dark green PVC coating.
3. The nominal size of mesh shall be 50 mm. The wire shall be galvanized gauge 6 (4.9 mm diameter). The height of fabric shall be 1.5 metres, or as shown on the Drawings.
4. Posts and gate frame pipe shall be galvanized grade steel, PVC coated. The diameter and wall thickness for each purpose shall be as given in Table 11.1.
5. Other fittings and hardware shall be galvanized, with PVC coating where required.
6. Post tops shall be of pressed steel or malleable iron designed as a weathertight closure cap for the posts. Where shown on the Drawings, sleeve-type tops shall be provided to permit the passage of tension cable over the post.

**Table 11.1: Post and Frame Dimensions**

| Use of Pipe | Dimension         | Size (mm) |
|-------------|-------------------|-----------|
| End Post    | Internal Diameter | 65        |
| Corner Post |                   |           |
| Pull Post   | Wall Thickness    | 5         |
| Gate Post   |                   |           |
| Line Post   | Internal Diameter | 50        |
|             | Wall Thickness    | 4         |
| Gate Frame  | Internal Diameter | 40        |
|             | Wall Thickness    | 3         |

7. Post footings shall be of Class 16 concrete conforming to the requirements of Clauses of Concrete.

### **9.7.3 Construction Requirements**

#### *Installation of Posts*

8. Fencing shall be installed on the previously prepared surface to correct line and level, and in accordance with the manufacturer's instructions.
9. Post holes for concrete footings shall be cleared of loose material and the posts shall be set plumb and in proper alignment. Posts in soil shall be set in concrete; posts in rock shall be set by cement mortar. Posts in concrete structures shall be set in pipe sleeves and then grouted by cement mortar.
10. Concrete footings shall be thoroughly compacted by rodding and hand tamping, and finished with a convex surface. The concrete and mortar shall be cured for a minimum of 72 hours before any further work is done involving the posts.

#### *Mesh Installation*

11. Top and bottom tension cables shall be fitted and tensioned, prior to installation of the mesh fabric. Straight runs between braced posts shall not exceed 100 m and cable ends shall be secured to posts with wire rope clamps. The bottom tension cable shall be securely tied to all posts.
12. The fabric shall be pulled taut and secured with tie wire to the top and bottom cables, at intervals of not more than 600 mm, and to the intermediate posts at intervals of not more than 300 mm. Stretcher bars shall be attached to the posts by tension bands at a maximum spacing of 300 mm.
13. Double and single leaf gate frames shall have fully welded joints and shall be installed where shown on the Drawings. Pipe frames shall be fitted with chain-link fabric as for the fencing and provided with zinc coated hinges, stops and latch and brass padlocks.

### **9.7.4 Method of Measurement**

14. The approved work shall be measured by the linear metre of fence including posts and gates calculated from the length of mesh face between end posts.

### **9.7.5 Basis of Payment**

15. The amount of completed and accepted work measured as provided for above will be paid for at the unit rate for 'Chain-Link Fences' in the Bill of Quantities which rate will include for supplying all materials, excavation, backfilling, concrete, installing, fitting, finishing and for labour, equipment, tools, supplies and other items necessary for the proper completion of the Work.

**9.7.6 Items in the Bill of Quantities**

Item No. 9.1.3      Chain Link Fence on Steel Bridge ( per linear meter)

## **9.8 Concrete Curbs**

### **9.8.1 Description**

1. This work shall consist of installing precast curbs on foundation concrete placed on previously prepared steel deck, concrete deck or aggregate base course.

### **9.8.2 Materials**

2. Concrete shall be in accordance with Clauses of Concrete.
3. Concrete curbs shall be precast and comply with BS 7263.
4. Concrete curb foundation and backing concrete shall be **Class 20**.

### **9.8.3 Construction Requirements**

#### *Precast concrete curbs*

6. Curbs shall be butted up close together without mortared joints unless otherwise shown on the Drawings.
7. Where curbs are laid with concrete pavement, joints shall be provided in the curb, foundation and backing in the same locations as in the pavement, and constructed and sealed to similar details using the same materials.
8. The foundation concrete shall be compacted with an internal vibrator.
9. The backfill to curbs shall be compacted to a density equal to or greater than the adjacent ground.
10. For curves of 12 m radius or less, curbs of appropriate radius or length shall be used.
11. Curb units shall not deviate by more than 3 mm in 3 m from line and level.

### **9.8.4 Method of Measurement**

14. The approved work shall be measured by the linear metre laid calculated by the length along the front face of each section. Concrete foundation and backing shall not be separately measured.

### **9.8.5 Basis of Payment**

15. The amount of completed and accepted work, measured as provided for above, will be paid for at the unit rate for 'Concrete Curbs' in the Bill of Quantities which rate shall be full compensation for excavation, placing, jointing, and backfilling, and for materials,

labour, equipment, tools and other items necessary for the proper completion of the work.

**9.8.6 Items in the Bill of Quantities**

Item No. 9.8.1 Curb on Concrete of App. Bridge ( per linear meters)

Item No. 9.8.2 Curb on App. Roads ( per linear meters)



## **9.9 Sidewalks and Medians**

### **9.9.1 Description**

1. This work shall consist of installing **precast paving** blocks on a previously prepared subgrade.

### **9.9.2 Materials**

2. Concrete materials shall be as specified in Clauses 501 and 502.
3. Granular bedding for paving shall comply with OS 2 grading zone 4.
4. Cement paving tiles shall comply with OS 3.
5. Paving slabs shall be to BS 7263 of pressure-cast high strength concrete of approved commercial manufacture.
6. Precast concrete paving blocks shall comply with BS 6717, and be of the color and shape shown on the Drawings.
7. Grouting and bedding mortar shall be as specified in Clause 508.
8. Asphalt shall be Class B to Clause 405.

### **9.9.3 Construction Requirements**

9. Prior to commencing laying paving slabs, paving blocks, cement paving tiles and asphalt, the prepared subgrade surface shall be cleared of loose and waste material and prepared to receive subbase to **Clause 2.0.5**.
10. Granular subbase material shall be placed on the subgrade and compacted to the thickness shown on the Drawings. Where shown on the Drawings aggregate base course shall be placed and compacted and prime coat applied.
11. After the supporting layers have been approved by the Engineer, the finished surface shall be placed, complete with any bedding sand or mortar, to the thickness, level and profile shown on the Drawings.

12. Paving slabs and cement tiles shall be laid in mortar to the pattern shown on the Drawings. Prescribed slopes shall be set to drain the surface to the specified outlets. Slabs and Tiles shall be laid by hand.
13. Precast concrete paving blocks shall be laid to the recommendations of BS 6717: Part 3.
14. The layout of blocks and tiles and details at edges, gullies manholes and other openings shall be agreed with the Engineer prior to laying.

#### **9.9.4 Method of Measurement**

15. The approved work of excavation, subbase, aggregate base course, prime coat, curbs, cement tiling and asphalt shall be measured in accordance with the relevant Sections of this Specification.
16. Precast slabs and precast blocks shall be measured by the theoretical area in square metres laid according to the dimensions on the Drawings. Bedding mortar and sand shall not be measured separately.

#### **9.9.5 Basis of Payment**

17. The amount of completed and accepted Work measured as provided for above, will be paid for at the unit Rate for 'Paving' in the Bill of Quantities, which rate shall be full compensation for supplying, manufacturing and laying, and for labour, equipment, tools, supplies and other items necessary for the proper completion of the Work .

#### **9.9.6 Items in the Bill of Quantities**

|                |   |
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| Item no. 9.9.2 | Sidewalk on Approach Bridge (per square meters) |
| Item no. 9.9.3 | Median on Main Bridge (per linear meters)       |
| Item no. 9.9.4 | Median on Approach Bridge (per linear meters)   |
| Item no. 9.9.5 | Median on Approach Road (per linear meters)     |

## **10 Electrical and Telephone Works**

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## SECTION - 1

### GENERAL

#### 1.1. SCOPE OF WORK

- 1.1.1 The work shall include but not be limited to furnishing labor , supervision , required equipment and materials, services , transportation , as necessary to complete the electrical works specified , and including all kinds of cables , conduits , raceways and related supports and fixation.

#### 1.2. PROJECT RELATED INFORMATION

The Contractor should take into consideration the following information :

- 1.2.1 Location of existing underground lines and obstructions if any.
- 1.2.2 Type, voltage and frequency of primary and secondary power supply.
- 1.2.3 Location of the point of connection to the Electric Distribution Company.
- 1.2.4 Type and location of all electrical equipment.

#### 1.3. QUALITY ASSURANCE

##### 1.3.1 QUALIFICATIONS OF INSTALLERS:

It is not intended that the drawings shall show every conduit outlet and all wiring. The contractor shall furnish and install all such parts as may be necessary to complete the systems in accordance with the best trade practice and to the satisfaction of the Employer.

##### 1.3.2 CODES AND STANDARDS

- 1.3.2.1 The electrical works shall comply with the requirements of the Egyptian Standards and the Egyptian Electrical Company Regulations.

1.3.2.2 The electrical installations and systems delivered and installed by the Contractor shall comply with one of the requirements of the following governing standards and code of practice. The most recent approved edition shall apply.

1.3.2.2.1 IEC-Publications (International Electrical Commission)

1.3.2.2.2 AMERICAN STANDARDS

IEC - International Electrical Commission

UL - Underwriters Laboratories, Inc.

FCC - Federal Communications Commission

EIA - Electronic Industries Association

ANSI - American National Standard

B.S. - British Standard.

1.3.2.2.3 CODE OF PRACTICE (CP)

1.3.2.2.4 IES (illuminating Engineering Society)

1.3.2.2.5 ISO (INTERNATIONAL STANDARD ORGANIZATION)

1.3.2.3 PROTECTION CODES

Protection codes shall be in accordance with IEC 536.

1.3.2.4 Equipment, materials and installations conforming with other than the stated standards or codes may be used only with previous approval of the Engineer. The contractor shall make a written application for permission to substituted equipment , materials and installation by another standard or code.

- 1.3.2.5. The contractor shall follow the chosen standard or code exclusively in all of its sections which are relevant to the equipment, materials and installations.
- 1.3.2.6. In case where the chosen standard or code does not cover a certain situation, the Contractor shall propose an applicable section of an alternative standard or code.
- 1.3.2.7. This proposal shall be submitted in writing for approval by the Engineer before ordering is commenced. In case of conflict between the chosen standard or code and the requirement of this specification, the requirements of this specification shall prevail.

#### 1.4 SUBMITTALS

- 1.4.1 The contractor should submit within sixty days before the commencement of electrical works , samples of all items to the Engineer, for approval.
- 1.4.2. Materials installed or work performed without approval of materials shall be done at the risk of the Contractor and the cost of removal of such material or work which is judged unsatisfactory for any reason shall be at the expense of the Contractor.
- 1.4.3. The contractor should prepare and submit detailed shop drawings for conduit and other distribution services described herein, including locations and sizes of all openings in walls and floors , before the execution of works by at least two months.
- 1.4.4. The contractor shall submit manufacturers specifications and catalogues as required to demonstrate compliance with the specified requirements.
- 1.4.5. The contractor shall submit prior to the commissioning of all electrical materials and equipment by 3 months a complete testing procedures according to the international standards and manufacturers instructions for the Engineer approval.
- 1.4.6. (Deleted)
- 1.4.7. DRAWINGS :

1.4.7.1. As soon as the electrical installations are completed and all tests have been satisfactorily carried out, the Contractor shall hand over to the Engineer the as-built drawings showing the work as finally installed. They should show the general arrangements of all installations low-tension switchgear, distribution boards, lighting and power points, fittings, switches, etc. together with the schedule of circuits and all other information relevant to the electrical work.

#### 1.4.8 MANUAL

The contractor shall also hand over to the Engineer at the same time six sets of technical catalogues, instruction manuals, maintenance manuals, tools and spare parts lists of each type of equipment installed by the Contractor and according to the manufacturer's recommendations and instructions..

### 1.5. PRODUCT HANDLING

#### 1.5.1. PROTECTION

1.5.1.1. The Contractor is responsible for work and equipment provided under this section until finally inspected, tested and accepted. Materials and equipment shall be carefully stored unless they are immediately installed after delivery to site. Close the exposed parts of the work with temporary covers or plugs during construction to prevent entry of moisture or obstructing materials.

#### 1.5.2 REPLACEMENTS :

In the event of damage, the Contractor shall immediately make all repairs and replacements necessary to the approval of the Engineer and at no additional cost to the Employer.

#### 1.5.3 GUARANTEE :

The Contractor shall submit a written guarantee stating that all portions of the work are in accordance with the contract requirements. Guarantee all work against faulty and improper material and workmanship for a period of one year

from date of provisional acceptance by the Employer, at no additional cost to owner, within 24 hours after notification to correct any deficiencies which occur during the guarantee period, all to the satisfaction of the Engineer.

**END OF SECTION 1**



## **SECTION 2**

### **DISTRIBUTION SYSTEM**

#### **2.1 Scope of work**

The scope of work under this section is to provide , install , put into operation and test the electrical feeding system for the project which should comprise the following:-

- The medium voltage package unit.
- The medium voltage cables.
- The distribution boards.
- The low voltage cables.

#### **2.2 Medium voltage package unit.**

##### **2.2.1 General**

The medium voltage package unit consists of the ring main unit , the oil filled power transformer and main low voltage distribution board.

##### **2.2.2 Ring Main Unit**

The ring main unit consists of two isolating switches for the incoming and outgoing feeders, and one fused isolating switch for the power transformer.

The equipment shall be suitable for operation on 11000 volt 3 phase, 50 Hz, 3-conductor delta connected system as well as 3-phase, 3-conductor grounded neutral system.

The switchgear shall be of the indoor dust proof and vermin proof unit type.

Each unit shall contain the main Isolating switch or circuit breaker , bus bars, disconnection devices, instrument transformers, bays wiring and other necessary components, bolted together to form a rigid self supporting assembly.

Each cubicle shall have front hinged panel doors with lock. The rear plates will be removable.

**2.2.2.1 Ratings:**

The switchgear shall have the following ratings :

|                                   |                              |
|-----------------------------------|------------------------------|
| Nominal voltage                   | 11 KV                        |
| Max. operating voltage            | 18 KV                        |
| Nominal current                   | 400 A                        |
| Breaking capacity MVA             | 500 MVA Symmetrical          |
| Breaking capacity AMP             | 30 AMP. RMS at 11 KV         |
| Duration of maximum fault current | 1 Second                     |
| Power frequency test Voltage      | 50 KV for 1 minute           |
| Current transformers              | 50/5/5 A                     |
| Voltage transformer               | $1100\sqrt{3}/100\sqrt{3}$ V |

**2.2.2.2 Fabrication requirements:**

The protected type switchgear shall be designed so that the operating, safety and maintenance functions will be as simple as possible.

The switchgear shall not be fitted with control components other than equipment control levers. In particular auxiliary levers for manual locking are forbidden.

Operation of equipment shall be carried out in one complete action. All the devices permitting the carry out of the operations are to be mounted on front of the switchgear panel. The locking devices shall be designed so that when carrying out normal operations, it is not possible to block the controls, doors and access panels by unwarranted action.

Releasing the locking devices at the end of travel, controls shall only take place when the operation has been completed taking into account the normal construction tolerances of mass production.

**2.2.2.3 Composition of switchgear panels**

The switchgear panels shall be fabricated from rolled sheet steel and composed of

interchangeable units having standardized dimensions and easily joined together forming a self supporting structures.

The steel sheet used in the construction of panels shall be perfectly planned and not less than 2.5 mm thick. The cubicles and their compartment shall be dust and vermin proof.

Each Isolating switch and circuit breaker shall be provided with fixed silver-plated primary and secondary contacts, and a mechanism for racking the removable element into and out of the connected position. The mechanism shall be designed to eliminate misalignment problems.

Automatic shutters shall be provided to close all openings to power circuits when the removable element is in the test, disconnected or removed position. The stored energy springs shall be automatically discharged as the removable element enters or exits the compartment.

#### 2.2.2.4 Load Breakers.

All power circuit breaker shall be withdrawable SF 6 or vacuum type, 3 pole single throw with voltage, current and interrupting ratings as specified before .

They shall be electrically operated, mechanically and electrically trip free, with stored energy closing mechanism, and with provision for manual spring closing. Provision shall be made for remote control of the circuit breakers from the control desk as well as locally from the switchboard. They shall be equipped with self-aligning silverplated primary and secondary disconnecting devices, grounding contacts, operation counter, opposition indicator and auxiliary switches wired to terminal blocks.

Terminal blocks of each section shall have not less than ten (10) percent spares. Two (2) spare normally closed auxiliary contacts shall be furnished which can be reversed to normally open. Circuit breakers of identical continuous current and voltage ratings shall be interchangeable.

#### **2.2.2.5 Insulation**

Insulation used in the switchgear, shall be selected to assure continuity of service under normal operating conditions. Insulation shall maintain dielectric strength under conditions of high humidity, temperature and aging, and shall maintain high resistance to tracking. It shall have high flame retardance, low moisture absorption, high mechanical strength and dimensional stability. Porcelain insulation shall be used wherever practicable, but consideration will be given to glass polyester and epoxy compounds having proven characteristics. Design shall minimize the use of insulating tapes at factory or field joints.

#### **2.2.2.6 Main Bus**

The main bus shall be manufactured of high conductivity copper designed and sized for the rated continuous and momentary current at 45 degree C with a maximum of 15 degree C temperature rise. Bolted joints and points of connection shall be non-magnetic corrosion resistance material. The entire bus and structure shall be constructed and braced to withstand short circuit stresses. A safety shutter shall cover all high voltage primary connections. Primary bus conductors and connections shall be covered with insulation material. Insulating barriers shall be provided where primary buses pass from one compartment to another.

#### **2.2.2.7 Ground Bus**

A high conductivity copper ground bus extending the entire length of each switchgear shall be provided with a momentary current rating equal to any circuit breaker through which the bus extends, shall be securely bonded both mechanically and electrically to each unit. A suitable pressure type connector with locking device to prevent loosening of ground connections.

#### **2.2.2.8 Miscellaneous accessory equipment**

Miscellaneous accessory equipment such as auxiliary relays, resistors, switches, fuses, capacitors, etc. required for proper operation of the Isolating switches, or by the intent of the drawings, shall be furnished mounted on the inside of the appropriate panel or cubicle with necessary brackets, mountings, wiring, and

contacts, etc..

#### 2.2.2.9 M.V. Primary connections

Primary cable shall be large enough to accommodate cable stress cones and shall include cable connector and solidly mounted cable supports. The incoming and outgoing cables shall be accommodated at the bottom rear of each cubicle and shall be equipped with portable grounding test device. The number and sizes of cables are shown on the attached drawings and Bill of Quantities.

#### 2.2.2.10 Potential transformer

Potential transformers shall be provided in separate compartments having draw-out carriages and devices for disconnecting and automatically grounding the transformers when they are withdrawn. They shall be molded dry type and provided with high interrupting capacity primary fuses. Potential transformers shall have sufficient iron to prevent saturation when phase-to-phase voltage is applied, and shall have adequate secondary loading resistance for operation on an 11 KV underground system, connected delta on H.T. side and one of the two secondaries open delta.

Accuracy class shall be 0.5 thermal + 55 degree C ambient.

#### 2.2.2.11 Current transformers

Current transformers shall be able to withstand without injury, the momentary and short circuit stresses specified for the circuit breakers. They shall have two secondary windings, one for protection and the other for metering, with output to cater the connected burden.

The accuracy class and accuracy limit factor will be in accordance with IEC publication No. 185.

The accuracy limit factor shall be associated with the relevant equivalent fault MVA of the system.

The current transformer shall be capable of providing the necessary power output to operate correctly the co-related protection devices /instruments .

The current transformers shall not saturate under system fault conditions up to 15 times the rated full load current.

When operating balanced or earth fault protection, they shall maintain stability on through faults outside the protected zone up to 15 times the full load current.

Current transformers for instruments shall have ratio and phase angle errors not exceeding the following :-

- (a) From 12 to 20 of rated current ratio error  $\pm 1$  . phase angle error  $\pm 90$  minutes.
- (b) From 20 to 100 of rated current ratio error  $\pm 1.5$  . Phase angle error  $\pm 120$  minutes.

#### 2.2.2.12 Instruments and meters

All instruments and meters shall be of the flush rectangular switchboard type having a dull black finish and shall be dust proof with anti-glare glass. (Indicating instruments shall have black markings on white dial anti-paralex scales approximately 250 degrees and 7 inches long accuracy within  $\pm 1$  of full scale and with external zero adjustment.

Unless otherwise specified, instruments and meters shall be suitable for operation from instrument transformers with normal 5 amperes and 110 volt secondaries. Scale ranges and dial constants shall be provided to match the primary voltage ratings.

#### 2.2.3 Power transformer

Three phase, oil immersed , natural cooling core type power distribution transformer.

The transformer shall be dispatched filled with oil.

#### **2.2.3.1 Construction Details:**

The overall construction and assembly of the transformers shall be robust and shall be rendered suitable for the arduous and local condition under which these transformers will operate.

The iron core shall be made of cold rolled silicon steel sheets . The losses in core shall be low.

The winding shall be built of insulated copper conductors arranged in the tank.

The transformer tank shall be made of corrugated steel and provided with an additional steel reservoir for oil expansion . Silicagel apparatus shall be fixed.

M.V. and L.V. terminals shall be brought out through porcelain bushings according to the rated voltage.

#### **2.2.3.2 Transformer oil**

Transformers shall be filled with special oil (Diala (B) or equal) of high insulating grade according to IEC specifications.

The contractor's attention is particularly drawn to the following requirements:

- a) The coil's bracing and tightening shall be such that the hum and vibration is kept to minimum and shall be sufficiently strong to withstand the short circuit forces.
- b) There shall be complete interleaving of lamination in joints between cores and yokes.
- c) Adequate insulation shall be provided at the end of the windings.
- d) The transformer coils shall be vertically mounted.

- e) The noise levels measured at one meter from the transformer shall be in accordance with the specified value in the relevant NEMA standards.
- f) The overall dimension of the transformer shall suit the space provided in the transformer room, after due allowance to the space to be provided all round the transformer.

#### **2.2.3.3 Normal Rating:**

The normal rating shall be the maximum continuous rating under tropical conditions.

The contractor shall state in the schedule, the equivalent British Standard specification or International electro-technical commission rating for the transformers offered.

#### **2.2.3.4 Voltage Ratio**

The normal voltage ratio of the transformers on normal tapping and no load shall be as stated in the schedule.

#### **2.2.3.5 Duty Under Fault Conditions:**

The transformer shall be capable of sustaining a three phase symmetrical short circuit current on the L.V. side, with the fault power being maintained on the M.V. side and without damage to the transformers for three seconds.

#### **2.2.3.6 Voltage Impedance**

The voltage impedance at normal rating and voltage at 75 deg. C. shall be as stated in the schedules.

#### **2.2.3.7 Temperature Rise**

The transformers shall be capable of carrying its full normal rated current continuously at any tapping, without the temperature rise of the winding



exceeding 50 deg. C. as measured by resistance.

**2.2.3.8 Rating and Terminal Marking Plate:**

Stainless steel diagram and rating plate in accordance with International electro-technical commission no. 76 shall be fixed to the transformer giving full detailed information as follows:

Type of cooling:

Volts at no-load and normal tapping M.V. side

Volts at L.V. side

Short circuit current/duration                      K Amps/sec.

Impedance voltage percent (%)

Current at rated load and normal, Tapping M.V. side

Number of phases

Diagram of connection

Position of tapping switch corresponding to different voltages

Manufacturer's name and transformer serial number

Frequency

Vector group reference and diagram

Weight of core and winding in kgs.

Weight of oil in kgs.

Total weight in Kgs.

Year of manufacture

The plate shall be of adequate thickness and the markings shall be engraved therein to a depth of not less than 1 mm, the background being filled in black.

**2.2.3.9 Nuts and Bolts:**

All nuts and bolts shall be locked in position in an approved manner.

Where possible it shall be arranged that in the event of nut working loose and falling off, the bolts shall remain in position.

Where bolts and studs are so placed to be inaccessible by means of ordinary spanners, the Contractor shall provide such tools as are necessary.

#### **2.2.3.10 Cable-End Boxes:**

The transformers shall be provided with suitable arrangement for terminating stranded copper conductor XLPE insulated steel wire armoured cable on the M.V. side and busway connection on the L.V. side.

The boxes shall provide sufficient space for segregating the cores and maintaining the minimum insulation clearance and creepage distance applicable.

The neutral of the star connected winding shall be separately connected to earth. The insulated neutral connection shall be brought out via a separate neutral chamber having provision for housing the necessary current transformers for earth fault protection.

Auxiliary wiring from current transformers, Buchholz relay, and oil temperature monitoring.....etc., shall be marshalled to a separate termination chamber with separate access cover.

#### **2.2.3.11 Tests:**

The contractor shall produce certificates for the type of tests carried out by the manufacturer for similar transformers to an acknowledged international testing authority.

However, he shall get all the routine tests performed on all the transformers to relevant British Standard specifications in the presence of the client's representative if he so desires, at the manufacturer's works.

All the test results shall be tabulated and submitted to the Engineer for his records.

#### **2.2.3.12 Schedule of Transformer:**

Rating : 100 and 160 KVA.  
Voltage Ratio at normal taps : 10500 V/380 V  
Frequency : 50 Hz

|                             |   |
|-----------------------------|---|
| I.E.C. Vector group ref.    | : Dyn 11  |
| Impedance voltage           | : 4%  |
| Phase connections           | : M.V. winding delta, L.V. winding star grounded      |
| Basic impulse level voltage | : 125 KV  |
| Tap change                  | : Off load tap changing gear $\pm$ 5% in steps of 2_% |
| MV side cable box           | : As specified earlier                                |
| LV side termination         | : As specified earlier                                |

#### **2.2.3.13 Instruments And Protection:**

The transformer shall be equipped with temperature indicator and monitoring system to protect the transformer against overheating due to increased ambient temp. or overload.

The unit shall be connected to 220 V supply to give alarm at 1st preset temp. and to trip the transformer circuit breaker at 2nd presetted temp. The alarm horn shall be installed on the transformer M.V. panel.

Gas relay (Buchholz relay) shall be fitted in the pipeline between transformer and conservator tank . The relay shall operate the warning circuit when gases gather around upper float. In case of severe fault, the lower float shall trip the transformer circuit breaker.

#### **2.2.3.14 Accessories:**

The list of accessories is shown below and shall not necessarily be limited to the following only:

- Rating and vector diagram plate
- Dial type thermometers for winding
- Dehydrating breather .
- Buchholz relay .
- Oil drain cock.
- Neutral bushing
- Earthing terminals
- Jacking lugs

Lifting eye bolts  
Bi-directional wheels

14/04/13

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### **2.3 Main distribution board**

The distribution board shall be of the totally enclosed, indoor type of size, rating and arrangement as indicated in the drawings, and shall consist of the required number of formed and welded sheet steel enclosures required to mount circuit breakers and other specified equipment. Distribution board shall be completely enclosed on front sides, top and rear with removable steel covers.

The doors and the mounting plates are of sheet steel fitted with strengthening strips to give the necessary rigidity. The material thickness should be selected with regard to the mechanical stresses to which the different components are subjected, however, not less than 2 mm thick, and shall be of minimum depth required to accommodate the electrical equipment shown in the drawings.

The structure shall have full height lateral strips, with front panels to prevent accidental contact with live parts. The arrangement shall permit all cable laying, connections and maintenance with a free vertical cable raceway furnished with the necessary cable supports and cable terminating facilities for cables of large cross sections.

Distribution board shall be in dust, vermin and rodent proof enclosure in accordance with IP 54 of IEC-529 and all compartments shall be suitably ventilated, the spare positions shall be fully equipped with circuit breakers whose ratings appear on the drawings.

Cable glands and gland plates of the suitable sizes shall be provided.

A ground bus shall be provided.

Distribution board shall be suitable for operation at the ambient temperature of 45 deg. C.

### **2.4 Medium voltage cables.**

#### **2.4.1 General**

These specifications apply to materials and constructions of cross-linked

thermosetting polyethylene (X.L.P.E.) insulated wires and cables for rated voltages from 600 V. up to and including 66,000V. which are used for the transmission and distribution of electrical energy for normal conditions of installation and service, either indoors, aerial, underground or submarine.

#### **2.4.2 Conductor**

The conductor shall be formed from plain annealed copper complying with ASTM B3, B8 and B231.

The conductor shall be circular stranded or compact stranded.

#### **2.4.3 Conductor shielding**

The conductor shielding shall be used on solid and stranded conductors of power cables having rated voltage above 2000V for ICEA S-66-524, above 1.8/3.0 KV for IEC 502, or above 6.6 KV for KSC 3131. Conductor shielding is a semi-conducting material applied over the surface of the conductor.

Conductor shielding shall be non-metallic and shall consist of either semiconducting tape or a layer of extruded semi-conducting compound, or a combination of the two.

#### **2.4.4 Insulation**

The insulation shall be a filled or unfilled cross-linked thermosetting polyethylene meeting the dimensional, electrical and physical requirements specified in paragraph 1 and with insulation level not less than 18 KV

The insulation is suitable for use on power cables in wet or dry locations at conductor temperatures not exceeding 90 degree C (194 degree F) for normal operation, 130 degree C (266 degree F) for emergency overload conditions, and 250 degree C (482 degree F) for short-circuit conditions.

#### **2.4.5 Insulation shielding**

The insulation shielding shall consist of a non-metallic semi-conducting part in

combination with a metallic part:

The non-metallic part shall be applied directly upon the insulation of each core and shall consist of either a semi-conducting tape or a layer of extruded semi-conducting compound or a combination of these materials or either material in combination with a semi-conducting coating.

**2.4.6 Metallic shielding**

The metallic shielding shall consist of either one or more tapes, or a concentric layer of wires. All metallic shielding materials shall be of copper.

**2.4.7 Identification of cores**

The cores of all cables shall be identified by color, color line(s) printed on the surface of binder tape on the metallic shielding in accordance with the following sequence or other sequence.

| <b>Type</b>   | <b>Colours</b>          |
|---------------|-------------------------|
| Single - Core | White (natural)         |
| Twin - Core   | White, Red              |
| Three - Core  | White, Red, Black       |
| Four - Core   | White, Red, Black, Blue |

**2.4.8 Cabling and filling**

The multicores shall be laid up together with suitable fillers to give the completed cable a substantially circular cross-section and bound with a suitable binder tape.

**2.4.9 Sheath**

The sheath consists of a thermoplastic compound (PVC, polyethylene, etc.) for use as the covering or jacket on insulated wires or cables.

**2.4.10 Installation of cables.**

All cables shall be marked with cable marking strips. Strips shall consist of

plastic, approximately 20 mm wide, and approximately 0.5 mm thick, with perforated letters, letter size shall be approx. 8 mm. Lettering shall include type of cable, cross section and cable number in accordance with the design and as-built drawing.

Underground cables shall be marked every 10 m. at the point of termination and at wall penetrations.

Above-ground cables shall be marked at the point of termination and at wall penetrations.

The cables may only be installed between main equipment and no junction or connection boxes are permitted for tying cables together. Only suitable cable splices are permitted for cable runs of more than 250 m. Splices must be approved for the cable type.

Before installation, all lengths of cables and wires shall be checked for their type, quality, section and insulation rating. In vertical ducts, the cables shall be fastened to the raceway walls by approved cable holders; in horizontal cableways, cables shall be properly laid in an orderly manner without unnecessary crossings. The attention of the Contractor is drawn to the fact that cable insulation shall not be damaged when cables are pulled; normally the thicker cables shall be pulled first and laid at the bottom, then covered by the thinner ones.

Cables running in concrete trenches shall be placed in successive layers, and layers shall be separated by metal spacers, to permit air circulation to cool the cables.

Direct buried cable installation is preferred. Underneath paved areas or underneath road crossings cables shall be installed in heavy-gauge PVC conduits, or in rigid steel conduits if properly protected against corrosion.

Cable routes shall be surveyed and marked according to the project Documents, prior to the start of excavation, the Contractor shall inform himself if existing lines or other obstructions are located on the cable routes.



Cable trenches shall be excavated as indicated on the project Documents. During excavation, the material suitable for backfilling shall be stored aside at a sufficient distance from the trench bordering. Excavated material not required or not usable for backfilling shall be hauled off to an authorized dump, or to a place determined by the Engineer.

Before cable installation, a 100 mm thick sand layer shall be laid in the bottom of the trench after the cables are laid out, another sand layer of 100 mm thickness shall be laid on top of the cables. A layer of concrete tiles 50 mm thick shall be laid on this sand layer all along the cable run. The trench shall be backfilled and compacted and a yellow cable.

Warning tape shall be installed 300 mm below finished floor level. The following distance shall be maintained, if more than one cable is installed in one trench:

LV cable next to MV cable and MV cable next to HV cable : 150 mm, separation by upside placed bricks.

The cables shall be installed at least 1 m below finish ground level if cable installation is necessary in more than one layer or at cable crossings, the various layers shall be separated by a 100 mm thick sand layer.

Unarmoured cables shall be installed with a bending radius of not less than 8 to 10 times the cable diameter and armoured cables shall be installed with a bending radius of not less than 10 to 12 times the cable diameter.

The installation requirements of the cable manufacturer must be maintained.

## **2.5 Distribution boards.**

### **2.5.1 General:**

The scope of this work includes the supply, installation and hooking up of cables to the distribution boards in the locations indicated on the drawings or as directed by the consulting Engineer.

Work as installed shall be complete with all components and materials required

for installation and fixation and other miscellaneous equipment necessary to provide a fully operational and complete system.

All necessary civil work associated with the installation shall be included within the scope of this work

The distribution boards shall be designed to give maximum reliability in services having relation with the need for speed of operation and ease of inspection and maintenance.

#### **2.5.2 Engineering Drawings:**

Prior to commencement of the work, all shop drawings indicating the full dimensions of distribution boards, base dimensions, method of installation shall be submitted to the consulting Engineer for approval.

#### **2.5.3 Composition**

Distribution boards shall be out-door type IP-54 and totally enclosed, with molded case or miniature circuit breakers bolted to the bars in a systematic arrangement. Branch circuit references are accordingly indicated on the drawings.

Distribution boards shall comprise photocell and timer control circuits.

Distribution boards interiors shall not be installed in cabinets until all conduit connections to the cabinet have been completed. All unused openings in panel board cabinets shall be properly closed. Connecting conduits shall not be used to support the distribution boards. Concealed surfaces of cabinets shall be given a heavy filled application of emulsified asphalt prior to installation.

Distribution boards shall be pre-assembled and consisting of a sub base assembly and circuit breakers of the ratings indicated on the drawings, all enclosed in an approved enclosure. Sub base assembly and circuit breakers shall be manufactured by the same manufacturers

Distribution board cabinet shall be for floor mounting on concrete base (outdoor type), and flush mounting in-door type as indicated on the drawings.

Cabinet shall be fabricated from folded and welded hot dipped galvanized sheet steel. In no case, shall the materials be less than 1.5 mm thick.

Joints shall be welded, galvanized and reinforced where necessary and galvanized after fabrication.

Cabinet shall be of sufficient size so that gutter spaces shall conform to the provisions of the I.E.C and B.S.S. standards , and in no instance shall they be less than 100 mm (four inches) on all sides.

Box shall be provided with at least 4 studs supports to fasten the interior of the panel board.

Panel boards cabinet shall be supplied with a hinged gasket and lockable door. All panel boards shall be keyed alike. The metal sheet shall be finished with two stove enamel primer finishing coats.

Directories on the backside of the front door shall be provided. Directories shall be typed to identify panel boards and to clearly indicate circuit number and description of the associated lines for each circuit on power panel-boards.

Outside of surface mounted box shall be given a coat of zinc chromate primer and finished with electro- static epoxy paint .

Directories under glassine shall be provided on the doors. Directories shall be typed to identify panel board and indicate clearly circuit number and description of the associated branch circuit and shall have at least 3 lines for each circuit on power and lighting distribution panel board. If trim without doors is requested, nameplates shall be mounted as directed later by the Engineer.

Trim shall be so constructed as to cover and overlap dead front shield which covers all terminals and bus compartment to form a dead front panel.

Trim shall be provided with rotating trim quarter turn clamps which engage the flange of the box for fastening. Use of screws engaging holes in the flange of the

box for fastening trim will not be acceptable. Trim shall be given a coat of zinc chromate primer and one coat of grey enamel.

Interior of panel board shall consist of branch breakers mounted on buses insulated and fixed to demountable frames, assembled as a complete unit to fit the cabinet.

Buses shall be 98% pure electrolytic copper and be based on a total temperature rise of 30 degrees C and a maximum current of 1.6 A per square millimeter of cross-sectional area, clamped contact surface of not more than 0.25 A per square millimeter.

Buses shall be rigidly supported on molded insulators and shall be so designed that branch circuit devices can be removed without disturbing adjacent units or additional machining, drilling or tapping. Phase bussing shall be full-height of design space.

Necessary bussing, drilling and blank plates shall be provided for installation of future circuit devices where so indicated on the drawings.

Buses shall have sufficient capacity to carry the maximum short-circuit duty of the main protective device which is at least the maximum short circuit rating at the point of application without showing any signs of deterioration and shall have a normal current rating equal to at least the frame size rating of the main breaker or twice the maximum connected load in case no protective device is indicated.

All screws and bolts used for making copper connections shall be equipped with lock washers. Riveted bus connections will not be acceptable.

Mains shall be equipped with solderless pressure type connectors and have means to prevent swiveling of connectors.

Solid neutral bar shall be insulated and shall incorporate one solderless box type connector for the neutral wire of each branch circuit and one for the main incoming neutral wire. Neutral shall be fully sized and rated as phase busbars.

Aluminium shall not be used for any interior panel board parts.

Back pan or mounting frame on which buses and branches are mounted shall be of galvanized steel forming a rigid support for components and parts. Reinforcing of back pan shall be by flanging.

The operating handle of each circuit breaker shall have a 2 mm diameter hole to fasten a tag to it.

All panel boards shall be provided with a ground earthing connector or bar with a sufficient number of terminals and shall be welded to the cabinet and should have cross sectional area suitable for the panel. That cross section shall be approved by Engineer.

#### **2.5.4 Molded case circuit breakers:**

Electrical circuits less than 1000 A shall be protected by molded case circuit breakers.

All circuit breakers shall have continuous current ratings at least as shown in the drawings at ambient temperature of 45 deg. C.

Circuit breakers shall be totally enclosed in a molded case construction.

All circuit breakers shall have an interchangeable trip unit consisting of an adjustable thermal trip and an adjustable magnetic trip on each pole.

Circuit breakers shall have quick-make, quick-break switching mechanism that is trip-free from the operating handle so that the contacts cannot be held closed against excessive currents.

The minimum interrupting ratings of the circuit breakers shall be at least equal to the available short circuit capacity at the terminals, in accordance with the interrupting capacity P-2 of the IEC-157.

Contacts shall be of non welding silver alloy.

When tripped by either the thermal or magnetic trips, the operating mechanism of the circuit breaker shall assume an intermediate position clearly indicated as

'TRIPPED' between On and OFF positions.

All poles shall be constructed so as to open, close and trip simultaneously.

Non interchangeable trip breakers shall have their covers sealed and breakers with interchangeable trips shall have the trip unit sealed.

Thermal overcurrent trips shall be ambient temperature compensated to allow for an ambient temperature higher at the breaker than at the protected circuit or device.

Circuit breakers shall have suitable number of auxiliary contacts of necessary types to perform all the control, interlocking and remote indication functions required.

#### **2.5.5 Miniature circuit breakers :**

Miniature circuit breakers shall be of the narrow type and shall be for manual operation with trip-free release. Miniature circuit breakers shall be equipped with a thermal overcurrent and a magnetic short-circuit tripping element.

The interrupting capacity of miniature circuit breakers shall not be less than 6 KA eff (380 V AC) at  $\cos. \Phi = 0.5 - 0.8$ .

#### **2.5.6 Earth fault protection circuit breakers :**

They shall be enclosed in a steel or plastic enclosure with a protection code which suits the environmental conditions of the location of installation

#### **2.5.7 Bus Bars:**

Bus bars shall be of high conductivity copper braced and rigidly supported to withstand the mechanical stress of a rated short-time withstand current , and rated peak withstand current in accordance with IEC recommendation No. 439.

Main bus shall be of continuous construction. Main bus joints and all top

connections shall be silver plated and tightly bolted to insure maximum conductivity.

Bus bars shall be clearly marked with their respective phase colours, and shall be furnished for future extensions.

A full length ground copper bus shall be provided. The ground bus shall be bound to the metal enclosure of each compartment and to metering, relaying and transformer's secondary winding. Lugs shall be provided one at each end of the ground bus and one in each cubicle for the user's copper ground cables.

All earth connection joints and termination's shall be tinned or brazed.

#### **2.5.8 Secondary Wiring:**

All secondary wiring shall be copper conductor, thermoplastic insulated at least 1.5 sq. mm flexible, neatly arranged and clipped in groups. Each conductor and its termination is to be identified and marked with numbered ferrules. All live terminals are to be shrouded. Wiring for each specific outgoing shall be shown in the schematic drawings. Control wiring, interconnections... etc. shall be wired out to terminal blocks in convenient locations in all units.

#### **2.5.9 Miscellaneous:(Legend Plates , Marking & Identification Plates):**

Functional units and cubicles are to be fitted with identification plates stating the manufacturer, the identifying designation and the order number against which the equipment is supplied.

Instruction plates: Instruction plates are to be fitted to cubicles and functional units and along side control and indicating equipment to the extent necessary to give sufficient information on their function.

Terminal Designation: Terminal devices, both terminal blocks and multi-pole pin connectors, are to be divided into groups. Each group and each individual block or pin connector shall be marked with a specific identification mark which is also found in the circuit diagrams and connection documentation. Each component shall, as far as possible, be marked with specific terminal marking.

Wire Designation: Wires are to be marked with a numerical designation, individual for each function unit, placed on marking sleeves at both ends, and also on cables at selected points approved by Engineer

#### **2.5.10 Delivery Conditions:**

The switchgear is to be delivered with all the wiring within the cubicles in position.

Bolts for joining the cubicles to each other , clamps for fixing to the floor and door knobs shall be included in the delivery.

- Fixing bolts for installation of the cubicles
- Sealing grommets of fixing devices for outgoing wiring
- Cable boxes.
- Tools or tooling sets
- Touch-up paint in spray cans
- Earth connection device
- Sealing compound for cable holes
- Spare parts.

Full instructions for the installation of the switchgear shall be supplied.

#### **2.5.11 Documentation:**

The switchgear documentation which shall be supplied for the equipment shall consist mainly of:

- Specification (list of apparatus) which, amongst other things, states the data of component used.
- Assembly drawings for the main parts of the switchgear equipment.
- Wiring and cable tables
- Circuit diagrams
- List of legend plates
- Installation instructions



### **2.5.12 Method of Measurement:**

The low voltage switchgear to be paid for under this section will be per each D.B., complete with circuit breakers, A.T.S, contractors, power factor improvement, cable terminal blocks, busbars, instruments, relays, internal wiring furnished, installed and tested in accordance with the drawings and specifications and including all connections to the incoming cables and earth continuity conductors and the outgoing bus trunking system and all other works (including civil) necessary to provide a fully operative system.

## **2.6 Low voltage cables.**

### **2.6.1 General**

Unless otherwise specifically indicated on the Engineer's drawings all wires and cables for all systems described under this subdivision of the specification shall have copper conductors in accordance with IEC 228

Copper conductors shall be stranded for cross sections of 6 mm<sup>2</sup> and above. Signal and control wires shall have solid conductors. Flexible cords shall have stranded conductors.

Conductor sizes shall be metric, as shown on the drawings. Conductors with cross-sectional areas smaller than specified shall not be accepted.

The current carrying capacity of conductors have been determined in accordance with the regulations for the specified type of insulation and the expected conditions of installation unless warranted by special conditions and approved by the Engineer.

The insulation of each conductor shall be color coded or otherwise identified as required by the "Regulations". Colour coding shall be maintained throughout the entire installation.

### **2.6.2 Armoured Cables**

The armoured cables shall be sized to comply with the following :

- i. Switch rating of the load.
- ii. Allowance for 5 % voltage drop.

The contractor shall provide armoured cables wherever specified. These cables shall be designed for 600/1000 volt systems. These cables shall be either PVC/SWA/PVC as indicated on the drawings.

Any armoured cable being used at site must bear the manufacturer's name on the outer sheath and voltage rating for which it is manufactured.

PVC /SWA /PVC                      BS. 6364

All armoured cables must have British Standard and BASEC approval certificates. Those without these certificates will not be accepted.

Cables carrying 3 phase and neutral loads shall be 4 core, the neutral conductor having the same cross-sectional area of any one of the phase conductors.

The minimum internal radii of bends in cables shall not be less than that given in the appropriate table of the IEE regulations for electrical equipment of the bridge.

The arrangement of cables and the methods of laying shall be approved by the Engineer. Cables shall be laid direct in the ground with protective covers, drawn into pipes or ducts.

Cables buried underground shall be laid at a minimum depth of 600 mm from the ground level . The cables shall be laid on a cushion from the ground level. The cables shall be laid on a cushion of graded and washed builders fine sand of 200 mm thick and shall be covered with another layer of 200 mm above it.

Mechanical punners shall not be used for this work. Cable marking tape shall be installed on the top layer of sand throughout the cable route. A minimum horizontal clearance of 50 mm shall be maintained between the cables.

Where, in the opinion of the Engineer, the soil on the site is unsuitable for

backfilling, the Contractor shall arrange for the importation of suitable material. Unless otherwise approved, the minimum distance between the centers of three core power cables or three phase groups of single core power cables shall be 0.15m. On no account shall double banking of cables be allowed.

Cable and joint route markers of approved type shall be provided along the route of buried cables as instructed by the Engineer. Markers shall be installed at all duct and joint positions, all places where the route changes direction and on straight routes at distance not exceeding 100 mm. Their provision and installation shall be included in the schedule rate for excavation and reinstatement.

Where three single core cable are laid direct in the ground and from one three phase circuit, they shall, unless otherwise stated, be laid touching one another in triangular formation, the apex of the triangle being uppermost. In order to maintain a triangular formation, the three cables shall be tied together with tarred twine or by other approved means at intervals of 1.5m.

After any cable has been laid and until the whole of the cables to be laid in the trench have been covered with their protective covers, no sharp metal tools, such as spades or fencing stakes, shall be used in the trench or placed in such a position that they fall into the trench. Rollers used during the laying of cables shall have no sharp projecting parts liable to damage the cables.

Where any part of the cable is buried in the ground, the armoring shall not be used as the earth. Either a separate earth conductor shall be provided or the cable shall be increased by an extra core.

Cables crossing the roads/pathways shall be provided with PVC duct of minimum 150 mm dia., buried at a depth of 800 mm below ground level unless otherwise mentioned.

Cables laid in the concrete or block work trenches shall be supported on supports made out of 50x50x6 mm angle iron with clamps. These supports shall be provided at a distance of not more than one meter each. All cables shall be run in a neat and orderly manner and the crossing of cable within the trench shall be avoided as far as possible.

The Contractor will be responsible for removing and replacing the trench covers, free of charge, during the execution of his work as directed by the Engineer.

All cable termination shall be carried out using compression type cable glands designed to adequately secure the steel wire armoring. All armoring and all faces of armor clamps making contact with them shall be thoroughly cleaned during installation and all clamps shall be adequately tightened to ensure good electrical contact. The installation shall be such that there is no discontinuity in the return circuit via the armoring and no local spot or high resistance.

Means of earthing the armoring to the main earth electrode at the supply end shall be provided by means of a metallic bond of adequate conductance and the bonding connection shall be as short and straight as practicable. All termination are to be fitted with PVC shrouds.

All cables shall be scheduled and installed with a unique number. The contractor shall prepare cable schedules in accordance with the typical blank specification schedule. All information required to be completed on the schedules shall be prepared and recorded by the Contractor. All cables shall be of the numbering system already employed at the site. The Engineer will advise the Contractor during the contract of the details of the system and cable numbers allocated for the contract works. All cable schedules shall be to the Engineer's approval.

Each cable end shall be provided with markers for identification. The markers are to be fitted in a suitable position under cable termination. Where cables enter and leave ducts or pipes, suitable identification markers shall be fitted. The materials of the markers and the labels and fastenings shall be such as to avoid corrosion due to incompatibility of materials and to ensure permanent legibility.

Each cable is to run in one continuous length except where the run of cable exceeds normal manufacturing lengths. Other straight-through joints will not be permitted unless specifically authorized by the Engineer. Where joints cannot be avoided, the estimated weight of joints and supporting steel work together with any additional civil requirements shall be taken into consideration. Joints shall be adequately supported and the provision for such shall be included in the schedule

of rates. Each joint shall be clearly labeled in an approved manner to indicate the cable number and the joint number and single core joints shall be so marked that the phase identity of each joint may be subsequently ascertained.

Where the armor wires of plastic insulated cables constitute the earthen metallic shield, such wires shall be efficiently bonded across the joint in an approved manner. The electrical resistance of such bonds shall not exceed that of an equal length of the cable armoured wires. Suitable care shall be taken to ensure that the bond contacts do not deteriorate in service.

The exact location of earth trench shall be approved by the Engineer. Trenches shall be kept as straight as possible and each trench shall be excavated to an approved formation and dimensions shall have a vertical sides which shall be timbered where necessary so as to avoid subsidence and damage. The bottom of each trench shall be firm and of smooth contour. Where trenches pass from a footway to roadway or at other positions where a change of level is necessary, the bottom of the trench shall rise or fall gradually.

The contractor shall take reasonable precautions to prevent damage to the highway or ground surface from a slip or breaking away of sides of trench. Rate of rise or fall shall be approved before-hand.

The contractor shall deal with and dispose of water so as to prevent any damage to the cables and other materials to be laid in the trenches being affected detrimentally. He shall provide all pumps and appliances required and shall carry out the necessary pumping and bailing.

Unless otherwise agreed, provision shall be made during excavation for reasonable access of persons and vehicles to property or places adjacent to the route. This provision shall be maintained until restoration has been completed. When the excavation for trenches have been accurately executed, notice shall be given by the Contractor to the Engineer. Laying of cables or building of the structures shall not be started until the Contractor has obtained the Engineer's permission to proceed with the work.

The unit price quoted in the schedules shall include the provision of such

quantities of skeleton timbering consisting of pairs boards and struts at intervals of not less than 3m as may be required by the Contractor.

The material excavated from each trench shall be placed so as to prevent nuisance or damage. Where this is not possible, the excavated material shall be removed from the site and returned for refilling the trench on completion of laying, without cost to the client. Surplus material shall be disposed of by and at the cost of the Contractor.

Single line cable routing drawings showing main cable routes only will be provided by the Engineer, but not detailed routing or cable supporting steelworks drawings and the Contractor is to be included in the rate in the schedules for the preparation of all detailed routing and steelworks drawings necessary to enable the Engineer to give his approval of all main and subsidiary routes before installation commences. Adequate allowance is to be made in the designs for additional cabling required for future extensions plus 20%.

All cables are to be run with a particular regard to neatness of appearance. Multiple runs are to be arranged so that cables entering or leaving the run do so in a logical manner.

All supporting steel work shall be hot galvanized in accordance with BS 729. If not, all the supports shall be painted with two coats of red oxide paint and one coat of approved synthetic paint. All supporting arrangements shall be approved by the Engineer.

Included in the contract are the excavation of trenches for laying and installation of the above cables and equipment including all guarding, watching and lighting, the removal of accumulated water, the removal and disposal of all surplus excavated materials, the provision and removal of skeleton timbering and the slinging, strutting and shoring of other works within the trench, the filling of all trenches and interim restoration.

### **2.6.3 Termination**

Where cables enter boxes and equipment, the following methods of termination

shall be adopted.

- a. A universal ring type gland (URT) shall be used as standard in all situations other than those specified below and on no accession shall any other glands be used for main and sub-main cables.
- b. Where entry to the equipment or box is already tapped, the gland shall be screwed direct into the equipment utilizing, where necessary, reducing sockets. The minimum size of entry permitted shall be 20 mm ET.
- c. Where the entry to the equipment or box is a clearance hole, the gland shall be fixed with a solid locknut.

Termination shall comply with BS 6081 Part .1. The temperature classification of the seal shall be class 105 unless otherwise indicated or directed by the Engineer. Glands shall be type "Y" and PVC shroud over glands shall be provided when PVC covered cables are used. Before applying a shroud, all bare metal shall be wrapped with pressure-sensitive PVC tape.

A sealing pot only is required where cables are terminated in flush mounted accessories, e.g. switches and socket outlets having integral means of bonding. Where sealing pots incorporate an earthing tail, the conductor shall not be bonded to the metal body of the pot by means of soldering alone.

Unless otherwise detailed elsewhere in this specification, all cable ends shall be sealed with cold, screw-on pot type seals of the appropriate size and utilizing cold plastic compound. Where seals are used without a gland, the seal shall be fitted with a permanently fixed flexible earth "tail" by the manufacturer. The seals shall be drilled between the cable entry and knurling to accept the tail and then "spot crimped" to ensure electrical connection. The earth "tail" shall be connected to an earth terminal inside the accessory or apparatus. It should be noted that for certain sizes of cable, a larger size seal is required when an earth "tail" is added.

On flush lighting installations only, where special MICS clamp boxes are specified, it is not permissible to omit the flexible copper earth tail. The cable tails shall normally be of neoprene or high temperature insulation with red PTFE or

similar material, silicone rubber shall not be used without the approval of the Engineer.

Where the Contractor considers it impracticable to utilize the solid conductor for making off his final connections, he may, with the permission of the Engineer and using an equivalent cross-sectional area flexible conductor, make an extended tail utilizing the self-screw sleeve connector. This extension shall be carried out within the apparatus concerned.

#### **2.6.4 WIRES AND CABLES FOR CONTROL AND SIGNALING WIRING**

- Wires and cables for the above circuits shall be rated for 150 volt service.
- Insulation shall be moisture resistant, flame retardant, P.V.C. compound.
- Conductors shall be tinned annealed copper of minimum size 0.6 mm<sup>2</sup>
- Where run in underground ducts, control and signaling wiring shall be multicore cables, plastic insulated conductors, P.V.C. sheathed steel wire armoured, and P.V.C. sheathed overall.
- P.V.C. wires shall be in accordance with DIN 57281/VDE 0281 or equal.

#### **2.6.5 Joining Sleeves**

Joining sleeves shall be of brass with standard termination. Solder ferrules shall be used to join the conductors, the solder used shall comply with BS 219, type M Non-corrosive flux only shall be used.

#### **2.6.6 Installation**

All joints shall be made at main switches, distribution boards, switches, ceiling rose boxes, socket outlet boxes and fixed apparatus only. No joints shall be made in joint boxes or through joints made, unless the special permission of the Engineer is obtained and his approval given to the method of joint proposed.



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As indicated or as directed by the Engineer, cables shall be run neatly on the surface of the building or in roof, ceiling or floor voids, sleeved in galvanized conduits in wall cavities, run neatly or laid in floor trenches or drawn into ducts and buried in the ground through ducts.

No bend in cable shall have an inside radius of less than six times the outside diameter of the cable.

All cable routes shall be determined by the Contractor and agreed by the Engineer before work is started. Cables shall be run at least 150 mm clear of all plumbing and mechanical services. The use of conduit and/or cable trunking to enclose conductors shall be kept to a minimum.

Cables shall be terminated at apparatus or joint boxes. Conductors shall be directly connected to terminals on or within the apparatus or to each other.

Where necessary and with the approval of the Engineer, the Contractor may, in concealed situations, use straps and saddles of special design for the appropriate purpose, made of heavy gauge metal strip.

Tools required for the manipulation and termination of cables shall be a design approved by the cable makers. Corrugation of the copper sheath at bends will not be accepted.

A wood block or wooden faced tool shall be used to finally dress the cables into position.

Care shall be exercised during stripping of the sheath and fitting of the sealing pot to ensure that :

- a. The sheath is not bent inwards and burrs are not left which could reduce the design clearance between sheath and conductor (s).
- b. The sealing pot is correctly positioned relative to the cut end of the sheath.
- c. The interior of the sealing pot is free of any metal particles formed during the process of attaching the pot to the cable.
- d. The insulating sleeve is correctly placed relative to the closure of the mouth of

the pot.

- e. All air is excluded from the sealing pot by the correct introduction of the plastic filling.

Plastic filling compound shall be stored in duct-tight containers when not actually in use. It shall not be used if it is, or is suspected to be, contaminated with dirt or moisture.

The contractor shall at the request of the Engineer, subject any length of installed cable to a insulation resistance test, consisting of applying a 1000 volt megger test to the length of cable when both ends have had the seals affixed. The tests between conductors and between conductors and sheath shall be infinity before conductors are connected at any apparatus.

#### **2.6.7 Tests**

An insulation resistance test shall be performed for direct buried cables prior to backfilling of trenches prior to energization, an insulation resistance test shall be executed for each circuit without a connection between the neutral and protective earth conductors. The following shall be measured:

- Neutral against line conductors.
- Line conductors against protective earth conductor.
- Neutral conductor against protective earth conductor.
- Line conductors against line conductors.

Motor feeders shall be tested when the motor is disconnected.

#### **Pay Item**

##### **Medium voltage package unit**

10.2.1 With transformer 100 KVA                      Numbers

10.2.2 With transformer 160 KVA                      Numbers

##### **Distribution Boards:**

10.2.3 Distribution Board DB -1                      Numbers

10.2.4 Distribution Board DB -2                      Numbers

10.2.5 Distribution Board DB -3                      Numbers

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|         |                    |             |         |
|---------|--------------------|-------------|---------|
| 10.2.6  | Distribution Board | DB -4       | Numbers |
| 10.2.7  | Distribution Board | DB -5       | Numbers |
| 10.2.8  | Distribution Board | DB of Box A | Numbers |
| 10.2.9  | Distribution Board | DB of Box B | Numbers |
| 10.2.10 | Distribution Board | DB of Box C | Numbers |

**Feeding Cables:**

|         |   |               |
|---------|---|---------------|
| 10.2.11 | $(3 \times 185 + 95) + 70 \text{ mm}^2$ | Linear meters |
| 10.2.12 | $(3 \times 120 + 70) + 50 \text{ mm}^2$ | Linear meters |
| 10.2.13 | $(3 \times 25 + 16) + 10 \text{ mm}^2$  | Linear meters |
| 10.2.14 | $(4 \times 16 + 10) \text{ mm}^2$       | Linear meters |
| 10.2.15 | $(5 \times 10) \text{ mm}^2$            | Linear meters |
| 10.2.16 | $(3 \times 6) \text{ mm}^2$             | Linear meters |

**END OF SECTION 2**