3.0 Concrete Mixtures and Concrete Structures

3.0 Concrete Mixtures and Concrete Structures

3.0.1 Description

1. This section describes the Classes of Concrete Mixtures and the following sections describe Materials for Concrete, Reinforcing steel, Prestressing, Construction requirement and Concrete Structures such as Piers , Columns , Prestressed Concrete Bridge and Pylons. (Box culvert and small bridges are specified in the Section of Drainage and Service Duct.)

3.0.2 Classification of Concrete Mixtures

2. The mixes for the Classes of concrete shown in Table 3.1, when specified for use in the Works, shall be designed by the Contractor.

Table 3.1: Concrete classes

Nominal Type	Max. Water: Cement Radio	Characteristic Strength by Cylinders N/mm²	kg/cm²	by Cubes N/mm²	Max. Size of Aggregate (mm)	Min. Cement Content (kg/m³)
18	0.55	18	180	22	25	305
24		24	240	29		320
30	0.45	30	300	37	25	360
35		35	350	43		390

Reference Note : Unit conversion : $N/mm^2 \times 10.197 = kg/cm^2$

Cylinder Strength / 0.8 = Cubes Strength

3. Each type of Concrete shall be used as follows;

Table 3-2 Usage of Each Type of Concrete

Nominal Type	Usage	
18	Blinding Concrete	
24	Pile Cap, Column and other ordinary use	
30	Lower part of Pylon, Diaphragm Wall	
35	PSC Girder and Upper part of Pylon	

4. No cement content in any mix shall exceed 540 kg/m^2. The water/cement ratio shall be strictly controlled within the limits specified.

5. The workability chosen by the Contractor, indicated by the Slump value, shall be appropriate for the proposed use of the particular concrete. Concrete which is not within the approved slump limits at the time of pouring shall be rejected.

6. For each Class of concrete the characteristic strength shall be the measured compressive strength of cubes or cylinders. The Seven (7) day strengths shall not be less than 70% of the specified 28 day strengths.

7. The ultimate compressive strength of concrete shall be determined according to AASHTO T22 on cylindrical specimens obtained and prepared in accordance with AASHTO T23 or AASHTO T126 using 152 mm diameter and 305 mm length molds. Alternatively, 150 mm cubes may be used, tested in accordance with BS 1881. The characteristic strength of the cube may be taken as 1.25 times the cylinder strength.

8. If other than the standard nominal maximum size of aggregate (25 mm) in the mix is required, the minimum cement contents may be adjusted in accordance with Table 3.3, but the minimum content shall not be less than 250 kg/m^3 for reinforced concrete, or 300 kg/m^3 for prestressed concrete.

Table 3.3: Adjustment to minimum cement content

Nominal maximum aggregate size (mm)	Adjustment to cement content (kg/m^3)
10	+40
14	+20
25	0
37.5 and larger	-30

3.0.3 Materials for Concrete

3.0.3.1 Cement

1. Cement shall be Portland Cement, originating from manufacturers approved by the Engineer and shall, as shown on the Drawings, be either:

   (i) Ordinary Portland Cement to **BS 12** or AASHTO M85 Type I
   (ii) **Sulphate Resisting Portland Cement** to **BS 4027** or AASHTO M85 Type II or Type V or ES 583.

2. The equivalent sodium oxide content in either cement, determined in accordance with **BS 4550: Part 2**, shall not exceed 0.60% by mass of cement.

3. The Contractor shall obtain from each proposed manufacturer a typical sample of cement proposed for the Works which shall be independently tested in accordance with the appropriate Standards. The following information shall be supplied with the Contractor's submission for cement approval.

   (i) Manufacturer

   (ii) Cement Type

   (iii) Manufacturer's description, brand name and Standards with which product compliance is guaranteed.

   (iv) Manufacturer's Certificate of average values and corresponding maximum and minimum values in respect of the composition and properties for a continuous production period of at least 6 months ending not earlier than 3 months before submission of the data.

4 At the Construction East Section of Egyptian Portion, sea water cement shall be used for the following structure potions:

   (1) Piles

   (2) Pile caps (PE1 - PE 21)

   (3) Pier Column (PE1 - PE 21), until 7.5 m above D.L.

   The sea water cement shall be in accordance with Egyptian Standards 583/1993 " Sulphate Resident Portland Cement (Sea Water)".

Storage

4. Cement in bags shall be stored in moisture-proof storage sheds. Damp, caked, reclaimed or re-sacked cement shall not be used.

5. The Contractor shall provide details of off-site storage and loading arrangements and shall provide reasonable facilities for the Engineer to inspect these arrangements when bulk cement deliveries are proposed for the site. Consignments shall be used in the order in which they are delivered.

6. Cement remaining in bulk storage for more than 6 months prior to shipment, or cement stored in bags in local storage by the Contractor or a vendor for more than 3 months after shipment from the mill, shall be retested, recertified and re-approved before use in the Works.

3.0.3.2 Water

1. The Engineer's approval shall be obtained for the source of water proposed for the concrete. Water shall be free from deleterious matter and shall comply with AASHTO T 26 and BS 3148. If the specific conductance is less than 1500µmhos/cm the total solids content requirement may be waived. Water taken directly from the sea shall not be used.

2. Cement mortar prepared with the water submitted by the Contractor for approval, shall show no change in time of set, no indication of unsoundness or a reduction of more than 10% in mortar strength measured in accordance with AASHTO T132 when compared with mortar made with water of known satisfactory quality.

3. Water at a temperature in excess of 60°C shall not be brought into contact with cement in the concrete mix.

3.0.3.3 Admixtures

Admixtures or any other additions shall not be used exept with the written approval of the Engineer.

Admixtures if specified or permitted shall conform to the requirements of AASHTO Standards Specification M 194-74 or equivalent BS Standards.

3.0.3.4 Aggregates

Quality

8. The Contractor shall submit for approval details of the proposed sources for concrete aggregate. The submission shall contain the following information for each source:

   Location, national grid reference, type of deposit, method of extraction, processing methods, type of plant, number of processing stages, standards of maintenance and process control, producer's laboratory facilities and technical staffing, stockpiling, loading, hauling and delivery arrangements.

9. As part of the submission procedure each size of aggregate shall be sampled at the discharge points on the production plant (conveyors or hoppers) at 3 intervals during the course of each of 3 consecutive production days. These samples shall be designated 'production samples'.

10. Samples shall be taken from the produced stockpiles to represent any visible variations in physical characteristics of aggregate ready for loading. These samples shall be designated 'stockpile samples'.

11. Samples shall be taken in the presence of the Engineer and shall be tested as required in sub-Clause 12 below Representative portions of certain samples as instructed by the Engineer shall be kept for reference purposes and shall be retained on site by the Contractor.

12. Each production sample shall be tested for the following:

    (i) Percentage of natural (uncrushed) material (by mass)
    (ii) Particle size distribution
    (iii) Clay and silt content

13. Representative portions of equal weight shall be taken from each of the production samples of each size of aggregate and combined to provide composite production samples for each size of aggregate. The composite samples shall be tested as for the individual samples and as follows:

(i) Petrographic examination and description, including approximate composition according to ASTM test C295.

(ii) Potential Alkali-Silica Reaction (where instructed by the Engineer).

14. Fine and coarse aggregates for concrete shall comply with the relevant requirements of BS 882:1983 as modified by any particular requirements in this Specification.

Aggregates shall be non-reactive with alkali in the concrete and the alkali content of concrete mixes shall be limited in accordance with Table 3.5. (Here the comments in Italic may be omitted with approval of the Engineer.)

Table 3.5: Test for Concrete Aggregates

Property	Test	Limits	Frequency
1. Description and classification of materials	BS 812: Part 1:1975 Section 6	as specified in Standard	
2. Particle size distribution by sieve analysis	BS 812: Part 1:1975 Test method 7.1	as specified in Standard	Daily (More frequency at start of production)
3. Clay, fine silt and fine dust in fine or coarse aggregate	BS 812: Part 1:1975 Test method 7.2.4	3% max. for natural or crushed gravel sands, 5% max. for crushed stone sands, 1% max. for natural or crushed gravel coarse aggregates, 3% max. for crushed rock coarse aggregates	Daily
4. Organic content	ASTM C-40: (latest)	no organic material	Weekly
5. Clay lumps	ASTM C-142: 1978	3% max. for fine aggregate, 2% max. for coarse aggregate	Daily (Reducing to weekly when stable)
6. Flakiness index	BS 812: Part 1:1975 Test 7.3	25% max. for all coarse aggregate test fractions	Daily (Reducing to weekly when stable)
7. Elongation index	*BS 812: Part 1:1987 Test 7.4*	*25% max. for all coarse aggregate test fractions*	*Daily (Reducing to weekly when stable)*

Property	Test	Limits	Frequency
8. Angularity number	*BS 812: Part 1:1975 Test 7.5*	*9 or 10. To be confirmed by the Engineer*	*Daily (Reducing to weekly when stable)*
9. Determination of relative densities and water absorption	BS 812: Part 2:1975 Test 5	Water absorption 2.5% max. for all aggregates	Daily
10. Determination of bulk density and voids and bulking of aggregates	BS 812: Part 2:1975 Test 6.3	To be determined by the Engineer from test results	
11. Field settling test	*BS 812: Part 1:1975 Test 7.2.5*	*To be determined by the Engineer from test results*	*Daily*
12. 10% fines value	*BS 812: Part 3:1975*	*For concrete Class 40 and above not less than 100 kN. For other concrete not less than 50 kN*	*Weekly*
13. Soundness of aggregate	ASTM C88-76 by use of 5 cycles of magnesium sulphate tests	Mag. sulphate 15% (coarse) 10% (fine)	Weekly (Reducing to monthly when stable)
14. Aggregate shrinkage	British Building Research Station Digest No. 35 (2nd Series)	0.05%	
15. Total acid soluble sulphate (as SO_3)	Wet chemical analysis	0.4% max. of each aggregate proposed	Weekly (For natural sand - every load delivered until control ensures stability)
16. Total acid soluble chloride content (as NaCl)	BS 812: Part 4:1976	maximum contents. 0.06% for fine aggregate, 0.04% for coarse agg. 0.05 % for mixed agg.	Daily (For natural sand - every load delivered until control ensures stability)
17. Potential reactivity of aggregate	*ASTM C289-71 (chemical method)*	*To be innocuous*	*Initially for each source and as directed by the Engineer*

Property	Test	Limits	Frequency
18. Potential alkali reactivity of cement combinations	ASTM C227-71 (mortar bar method)	Expansion less than 0.10% at six months	Initially for each source and as directed by the Engineer
19. Gel-Pat test	*National Building Studies Research Paper No. 25*	*As given in NBS Research Paper No. 25*	
20. Concrete prism test (alkali silica reaction)	CAN/CSA-A23.2-M90 Method No. A23.2-14A	Criteria in Appendix B to CAN/CSA-A23.1-M90	
21. Mica content	By physical separation	1% max (muscovite) 1.5% max (biotite) 1.5% max (combined)	Weekly initially every load delivered until control ensures stability

15. Aggregates shall be used only with the prior approval of the Engineer.

16. The properties of the aggregate shall be such that the drying shrinkage of concrete prepared and tested in accordance with the United Kingdom Building Research Station Digest No. 35 (Second Series) shall not exceed 0.045%.

17. The overall grading of the aggregates shall be controlled throughout the production so that the output conforms to that used in the Job Mix described in Clause 3.0.4. Each delivery shall, if required by the Engineer, be tested and the Contractor shall also provide copies of the results of routine control tests carried out at the production site.

    All aggregate shall be thoroughly washed prior to stock piling using fresh water in a manner approved by the Engineer.

18. The Contractor shall either use non-reactive aggregates tested in accordance with sub-Clause 12 or restrict the content of equivalent sodium oxide in the mix.

19. When the coarse and fine aggregates are not accepted as wholly non-reactive the amount of equivalent sodium oxide in the concrete shall not exceed 3.0 kg/m^3 of concrete.

    The equivalent sodium oxide (Na_2O) shall be calculated from the equivalent sodium oxide ($Na_2O + 0.66k_2O$) in the cement, the chloride (Cl) ion in the

aggregate, and the amount of equivalent sodium oxide in the water and any admixtures as follows:

Equivalent Na_2O (concrete) = Equivalent acid soluble Na_2O (cement, admixtures and water) + 0.76 Cl ion (aggregates)

20. The whole maximum Chloride in reinforcing concrete contents expressed in terms of chloride ions as percentage of the aggregates weight given in Table 3.4 Item 16.

To avoid the rust of reinforcing steel, the whole concentration of diluted Chlorides ions in hardened concrete of age 28 days should not exceed the limit as below;

The reinforced concrete subject to Chlorides	0.015 % or less
Other structural components	0.030 % or less

Control to Avoid Damage by Alkali Aggregate Reactivity

21 As required above, aggregates shall be shown to be non-reactive with alkali in the concrete mix. However, to further limit the risk of damage by alkali aggregate reaction the total alkali content, expressed as equivalent sodium oxide (Na_2O), as calculated in BS 5328: Part 4: 1990 Section 3.8, of each concrete mix shall not exceed 3.0 kg/m^3.

The method to determine potential reactivity of the aggregates and the total alkali content of the concrete, and the documentation for alkali content to be supplied by the Contractor shall be as set out below.

22 Aggregates shall be initially subjected to petrographic analysis in accordance with ASTM C295 to make a preliminary assessment as to whether they are likely to be reactive. Aggregates shall also be tested by the Chemical Method to ASTM C289 and by the Mortar Bar Method to ASTM C227. The results of these tests shall be considered indicative but not conclusive of the potential for aggregate alkali reactivity.

On the basis of the results the Engineer may require further investigations to be carried out. These may include, but not necessarily be limited to, the Gel-pat test as described in the US NBS Research Paper No. 25, the Canadian test CAN/CSA-A23.2-M90 Method No. A23.2-14A and/or the Concrete Prism test to draft BS 812: Part 123.

Test shall be repeated as directed by the Engineer to confirm that aggregate supplies continue to be non-reactive.

23 The total alkali content of mixes shall be calculated in accordance with the requirements of BS 5328: Part 4: 1990 Section 3.8.2. unless otherwise stated herein.

The acid-soluble alkali content of the Portland cement shall be taken as the average of 25 daily determinations of equivalent sodium oxide, plus twice the standard deviation for the period in which the cement was manufactured. The acid-soluble alkali content of the Portland cement shall be determined in accordance with BS 4550: Part 2 or an X-ray fluorescence technique calibrated against this British Standard.

The equivalent sodium oxide (Na_2O) in the mix shall be the sum of the equivalent sodium oxide ($Na_2O + 0.66\ K_2O$) in the Portland cement component, 0.76 times the chloride ion content of the aggregate and the amount of equivalent sodium oxide in any admixtures, pigments, water and any other constituents of the concrete.

Sources of cement, which have been agreed with respect to the calculation of equivalent sodium oxide in the concrete shall not be changed without prior agreement of the Engineer. Proposals by the Contractor for any changes in the sources of materials shall be accompanied by test certificates giving the equivalent sodium oxide content and its variability for each material. This information shall relate to tests carried out in the period immediately preceding the Contractor's proposals.

Where at least 25 consecutive weekly test figures are not available, then 10 consecutive daily results relating to the period immediately preceding the proposal shall be submitted to the Engineer, and daily testing from the source shall continue for 10 days after the acceptance of the proposals. After these 10 days the results of weekly testing will be accepted for the source until further changes are notified.

The equivalent sodium oxide content of the coarse and fine aggregate shall be calculated from the quantity of chloride ion present, which shall be measured by the method in BS 812 : Part 117.

24 The Contractor shall submit to the Engineer:

(a) with his proposed concrete mix details (see Clause 3.0.4.1), and subsequently at monthly intervals:

(i) the manufacturer's test certificates giving, in terms of equivalent sodium oxide, the acid-soluble alkali content of Ordinary Portland Cementfor use in the Works calculated as required above;

(ii) test certificates for the chloride content of aggregates, admixtures, water, and any other constituent of the concrete calculated as required above.

(b) with his proposed concrete mix details (see Clause 3.0.4.1), calculations of the total weight of reactive alkali in concrete, and revised calculations whenever there is an increase in the alkali content of any of the constituents.

(c) when requested by the Engineer, the manufacturer's daily or weekly determinations of the alkali content of the Ordinary Portland Cement;

(d) immediate notice of any significant changes which may increase the alkali content of the cementitious materials by more than 0.1% above the original certified values.

3.0.4 Construction Requirement

3.0.4.1 Preparation of Concrete Production

Within 30 days of receipt of the Notice to Proceed the Contractor shall submit for the approval of the Engineer a Method Statement detailing with regard to the requirement of this Specification his proposal for the organization of concreting activities at the Site.

The Method Statement shall include the following items:

1. Plant proposed

2 Locating and Layout of concrete production facility including any precasting facilities.

3 Size and details of materials storage facilities.

4 Source of water supply and anticipated available flow rate.

5 Proposed method of organization of the concrete production facility.

6 Quality control procedures for concrete and concrete materials.

7 Staffing for control of production.

8 Maximum production capacity per hour and day and an estimate of maximum volume to be poured monthly.

9 Transport and placing of concrete

10 Maximum pour size anticipated and specific proposals for large pours including methods for control of temperature differences.

11 Curing Procedures

Job Mixes

7. The Contractor shall give notice to enable the Engineer to be present at the making of laboratory trial mixes and preliminary testing of the concrete. The Contractor shall prepare the mixes using the approved materials proposed for use in the Works Job Mixes.

8. A clean mixer shall be used and the first batch discarded. For each mix a set of 6 cylinders shall be molded from each of 3 consecutive batches. Three from each set of 6 shall be tested at an age of 28 days and 3 at an earlier age approved by the Engineer. The average strength of the 9 specimens tested at days shall exceed the specified characteristic strength by the 'current margin' minus 2.8N/mm^2.

Target Meam Strength

9. The 'current margin' for concrete from a mix plant shall be taken as the lesser figure from either calculation from:

(i) 1.64 times the standard deviation of tests on at least 100 separate batches of concrete of similar proportion of similar materials and produced within a 12 month period by the same plant under similar supervision, but not less than 2N/mm^2 for concrete class 12, or 3N/mm^2 for concrete class 16 and over.

(ii) 1.64 times the standard deviation of tests on at least 40 separate batches of concrete of similar proportion of similar materials and produced over a period

exceeding 5 days but not exceeding 6 months under similar supervision, but not less than $4N/mm^2$ for concrete class 12, or $6N/mm^2$ for concrete class 16 and over.

10. Where there are insufficient data to satisfy (i) or (ii) of sub-Clause. 9, the current margin shall be taken as $8N/mm^2$ for class 12 concrete, and $12N/mm^2$ for class 16 and over. Subject to the approval of the Engineer this margin may be reduced to $6N/mm^2$ for concrete class 30 and 35.

11. Where cubes are being used for testing, the margins described in sub-Clauses. 9 and 10 shall be increased by a factor of 1.25.

12. During production, if substantial changes are made in the materials or in the proportions of the materials to be used in the mix, the Contractor shall repeat the Trial Mix procedure and obtain approval for the new Job Mix.

Mixes not Approved

26 Approval of a mix may be withheld or withdrawn if, inter alia,

- the grading of the aggregate changes such that the fraction of aggregate retained on any sieve differs from the corresponding fraction of aggregate in the approved mix by more than 2% of the total quantity of fine and coarse aggregate.

- the source of supply of aggregate or cement is changed.

27 In the event that approval of a mix for any class of concrete is withdrawn for any reason the Contractor shall carry out such further trials as the circumstances require in order to achieve a satisfactory mix for that Class of concrete.

3.0.4.2 Falsework

Falsework

5. The Contractor shall submit to the Engineer for approval at least 1 month before commencing work, details of the proposed system of falsework, with drawings and calculations. Falsework shall be capable of withstanding temperature changes without causing damage to the concrete. The Engineer will refuse permission to proceed with the Permanent Work if he deems the falsework unsafe or inadequate to support the loads to which it will be subjected.

6. Approval of falsework design by the Engineer, shall not relieve the Contractor of responsibility for the adequacy and safety of its design, manufacture and assembly.

7. Falsework and centering shall be designed and constructed to provide the necessary rigidity to support all loads placed upon it without undue settlement or deformation. Falsework columns shall be supported on bases not on any part of the structure, except the permanent foundations.

8. Timber shall be of straight, sound wood, and free from defects. Ends of the vertical members shall be cut square for full bearing to preclude the use of wedges. If vertical splices are necessary, the abutting members shall be of the same size, the ends shall be cut square for full bearing.

9. The Contractor shall estimate, and allow for, the form settlement and deflection so that when it occurs, the structure will conform to the required camber, section and elevation as shown on the Drawings. The Contractor shall provide means for accurately measuring the settlement during placement of concrete.

10. Long, tapered hardwood wedges or screw jacks shall be used in falsework construction and shall be so placed that they can be adjusted to give proper form alignment. The Contractor shall, if required by the Engineer, provide means for adjusting forms to offset any excessive settlement. If screw jacks are used, they shall be adequately braced and secured.

3.0.4.3 Formwork

11. Forms shall conform to the requirements of BS-5400 : Clause 3.11.2 and shall be watertight, mortar tight and sufficiently rigid to prevent distortion due to the pressure of the concrete, and incidental loads and vibration during placing, compacting, setting and hardening. They shall be designed to permit easy removal without damage to the concrete. Curved surfaces shall be formed with approved plywood or steel. The Contractor shall submit samples and manufacturer's specification to the Engineer for prior approval of the proposed formwork system.

    Forms shall be designed to withstand the effects of weather, particularly steel forms which are affected by hot sunlight.

12. Form lining material shall not bulge, warp or blister, nor stain the concrete. Form lining shall be used in the largest practicable panels to minimize joints. Adjacent panels of wooden form lining shall be so placed that the grain of the wood will be in the same direction (all horizontal or all vertical). Thin metal form lining will not be permitted. Undressed timber of uniform thickness may be used for backing to form lining.

13. Forms shall be maintained after erection to eliminate bending, warping and shrinking. They shall be checked for dimensions and conditions immediately prior to the placement of concrete. The Engineer may at any time refuse permission to place concrete within the forms until they are satisfactorily constructed. If, at any period of the work during or after placing the concrete, the forms show signs of sagging or bulging, the concrete shall be removed as instructed by the Engineer, the forms brought to the proper position and new concrete placed.

14. **Metal forms** shall be of such thickness that they remain true to shape. Bolt and rivet heads shall be countersunk. Clamps, pins or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without damage to the concrete. Metal forms shall be free from rust, grease or other foreign matter.

15. The **surface of forms** shall be oiled with a light, clear, paraffin base release oil that will not discolour or otherwise injure the surface of the concrete. The oiling shall be done prior to placement of the concrete reinforcement. Forms that are to be re-used shall be thoroughly cleaned, re-oiled and, if necessary, reconditioned to the approval of the Engineer.

16. **Form bolts, rods or ties** shall be made of steel. They shall be the type which permit the major part of the tie to remain permanently in the structure. They shall be held in place by devices attached to walling capable of developing the strength of the ties. The ties shall be removed on all surfaces to a depth of at least 50 mm below the concrete surface, or the specified cover where this is greater. The cavities shall be filled with cement mortar and the surface left sound, smooth, and uniform in color, so when dry, it will match the surrounding concrete. Wire ties shall not be used.

~~17. Deleted~~

18. Where the bottom of the form is inaccessible, the lower form boards shall be left loose or other provisions made so that extraneous material may be removed from the forms immediately before placing the concrete. Exposed edges shall be beveled by using planed triangular molding, having 20 mm minimum sides.

19 Where formwork is to be reused, it shall be thoroughly cleaned and repaired in a manner which will make it fit to produce the required surface finish.(chanfer)

All forms shall be sound, free from wraps and twists, sap, shakes, large or loose

knots, wavy edges or other deffects affecting the strength or apperance of the finished structure.

All forms shall be set and maintained true to the line designated until the concrete is sufficiently hardened. Forms shall remain in place for periods which shall be determined by the Engineer. When forms appear to

Slip Form

20 If the Contractor proposes a slipforming technique for casting the pylons or other elements, in addition to the information required above, he shall clearly set out his intended rate of lift and the measures to be taken to ensure smooth progress. This shall include, inter alia, control of evenness of shutter lift to avoid jamming, and to maintain verticality, slopes and staggering of reinforcement laps, methods to ensure correct position of box-outs and inserts, any adjustments necessary to concrete mix and test results for the adjusted mix. He shall also set forth his method of starting the slip, including changes in the mix at the start, internal vibration techniques to blend and knit the successive lifts, and procedures for stopping and jacking off the forms at the top.

Climbing Formwork

21 The Climbing Formwork method of formwork may be used for forming the bridge pylons and piers. The climbing formwork shall comply with B.S. 5400, Part 7.

The Contractor shall submit a full set of drawings and calculations to the Engineer at least 10 weeks before commencement of fabrication of the lift gantry. The design calculations for the steelworks and fixings shall take full account of dynamic enhancement of loads and be based in accordance with B.S. 5400.

To avoid cracking of the fresh concrete at the joint between the previously placed concrete, and to avoid other undesirable distortions, the lift gantry and the formwork which it supports shall be of rigid construction.

Apart from the weight and rigidity requirements stated above, the design of the gantry shall incorporate the following:

(a) Easily operated and robust adjusters to permit rapid accurate setting and locking of the formwork to line and level. These adjusters shall be operable in the event adjustments are required during concreteing.

(b) Adequate working platforms with closed boarding walkways and guard rails.

(c) Waterproof opaque canopy to protect concreting from direct sunshine and rain.

(d) Climbing jack supports.

(e) Formwork lining which is either durable enough to produce the required surfaces finishes without replacement or which is easily replaceable before the quality of finish falls below that required.

Tolerance of Form Work

The tolerances of the formwork shall be as shown in Table 3.6.

Table 3.6 TOLERANCES FOR FORMWORK

Item	Tolerances
1. Variations from the plumb:	In any 3 m of length ... 6 mm
a. In the lines and surfaces of columns, piers, walls and in arises.	Maximum for entire length ... 25 mm
b. For exposed corner columns, control-joint grooves, and other conspicuous lines	In any 6 m of length ... 6 mm Maximum for entire length 13 mm
2. Variation from the level or from the grades indicated on the drawings:	In any 3 m of length ... 20 mm In any bay or in any 6 m of length 10 mm
a. In slabs, soffits, ceilings, beam soffits, and in arises,	Maximum for entire length ... 20 mm measured before removal of supporting shores
b. In exposed lintels, sills, parapets, horizontal grooves, and other conspicuous lines.	In any bay or in any 6m of length 6 mm Maximum for entire length ... 13 mm
3. Variation of the linear building lines from established position in plan.	In any 6 m ... 13 mm Maximum ... 25 mm
4. Variation of distance between walls, columns, partitions	6 mm per 3 m of distance, but not more than 13 mm in any one bay, and not more than 25 mm total variation
5. Variation in the sizes and locations of sleeves, floor openings, and wall opening	Minus ... 6 mm Plus ... 13 mm
6. Variation in cross-sectional dimensions of columns and beams and in the thickness of slabs and walls	Minus ... 6 mm Plus ... 13 mm
7. Footings:	
a. Variations of dimensions in plan when formed or plus 75 mm when placed against unformed excavation	Minus ... 13 mm Plus ... 50 mm
b. Misplacement of eccentricity	2 percent of the footing width in the direction of misplacement but not more than 50 mm
c. Reduction in thickness	Minus ... 5 percent of specified thickness
8. Variation in steps:	Riser ... 3 mm
a. In a flight of stairs.	Tread ... 6 mm
b. In consecutive steps	Riser ... 2 mm Tread ... 3 mm
9. Slipform shutters for pylon works:	The rotation of any point from a fixed point at the base of the pylon shall not exceed **1/600** times the height above 30.0m with 100 mm maximum deviation. A system of "tracking" the slipform must be initiated to ensure early warning of variances from plumb so that corrections may be made.

Formed Finishes

19 The following Classes of formed finishes shall be provided.

Class F1 Application ; Visible surface of walls, exposed surfaces of piers and abutment, visible outside surface of bridge deck except parapet plinth.
Requirement ; as for Class F2 except that internal ties and embedded metal parts shall be permitted. The ties shall be positioned in a regular pattern in rebates or pockets in position as described in the Contract or in other positions agreed by the Engineer.

Class F2 Application ; Exposed surface of parapet plinths
Requirement ; The formwork shall be lined with a material approved by the Engineer to provide a smooth finish of uniform texture and appearance. The material shall leave no stain on the concrete and shall be so joined and fixed to its backing that it imparts no blemishes. It shall be of the same type and obtained from only one source throughout any structure. The Contractor shall make good any imperfections in the finishes as required by the Engineer. Internal ties and embedded metal part shall not be allowed.

Class F3 Application ; Surface which are not visible , faces of joints
Requirement ; The irregularities in the finish shall be no greater than those obtained from the use of 2.4 m x 1.2 m unfaced plywood panels arranged in a uniform pattern to the satisfaction of the Engineer. Appropriate measures shall be taken to ensure continuity of line and surface at joints between panels and to avoid grout leakage. The finish is intended to be left as struck but imperfections such as fins and surface discoloration shall , if required, be made good by methods approved by the Engineer.

Class F4 Application ; Buried and other hidden surfaces, faces of expansion joints incorporating joint filler
Requirement : Nil. Except that where a protective membrane or a waterproofing membrane is to be applied to the concrete, any sharp fins or other excrescence which might damage the membrane, shall be removed.

20. Unless otherwise shown on the Drawings, Class F4 shall be provided.

21. When Class F1 and F2 finishes are required the Contractor shall make trial panels on site. These panels shall be not less than 2.5m high, 1.5m wide and 200mm thick and shall be cast in the manner and with the materials proposed for the Permanent Works.

22. As many panels as required shall be prepared until a satisfactory trial panel has been accepted by the Engineer. When approved this shall be the standard against which the corresponding finishes on the actual work will be judged for acceptance.

23. If the required finish is not subsequently obtained in the Works, the Contractor shall carry out at his own expense any remedial measures required by the Engineer. When a remedial action is agreed with the Engineer, the entire exposed surface shall be treated irrespective of the extent of the defective area.

24. The following Classes of exposed unformed surface finishes shall be provided as shown on the Drawings.

    (i) Class U1. The concrete shall be leveled and screeded to produce a plain or uniformly ridged surface. No further work shall be applied to the surface unless it is used as the first stage for Class U2 or Class U3 finish.

    (ii) Class U2. After the concrete has hardened sufficiently, the surface shall be floated by hand or machine to produce a uniform surface free from screed marks.

    (iii) Class U3. When the moisture film has disappeared and the concrete has hardened sufficiently, the surface shall be steel-trowled to produce a dense smooth uniform surface.

25. Unless otherwise shown on the Drawings. Class U1 shall be provided.

26. Surfaces which are to receive waterproofing shall be finished to a level accuracy so that when tested with a 3m long straight edge, the maximum change shall not exceed 5 mm.

Removal of Forms and Falsework

~~27. Deleted.~~

Forms and scaffoldings shall not be removed without the approval of the Engineer. the Engineer's approval shall not relieve the Contractor's responsibility for the safety of the work. Blocks and bracing shall be removed at the same time as the forms and in no case shall any portion of the wood forms be left in the concrete.

Forms used on exposed vertical faces shall remain in place for periods which shall be determined by the Engineer and normally not earlier than 2-3 days.

Supporting scaffolding (falsework) and forms under slabs, beams and girders shall normally remain in place until the full required strength of the concrete has been obtained. If a shorter period is required, this may be permitted by the Engineer. In such case special test specimens shall be cast to control the hardening.

All structures shall be fully stripped before superjacent structures are cast.

28. Where the concrete compressive strength is confirmed by tests on cylinders or cubes stored under conditions simulating site conditions, form-work supporting concrete in bending may be struck when the cylinder strength is $8N/mm^2$ (cube, $10N/mm^2$) or 2.5 (cube, 3) times the stress to which it will be subjected, whichever is the greater. For structural concrete made with ordinary Portland cement and without admixtures the period before striking shall be as Table 3.7 in the absence of control cylinders or cubes.

Table 3.7: Removal of form work

Concrete element	Minimum time
Soffit form work to arches and beams	7 days
Floor Slabs	5 days
Columns, walls, sides of beams, vertical surfaces	2-3 days

29. If a high early strength concrete mix is used, the time limits may be decreased by the Engineer. Notes on the Drawings relating to the removal of forms and false work under arches, continuous spans and other special structures shall take precedence over the minimum times indicated on Table 3.6.

3.0.4.4 Placing Concrete

30. No concrete shall be placed until forms and reinforcing steel have been checked, and the method and sequence of the placing approved by the Engineer.

31. Concrete shall not be allowed to free fall more than 1.5m, unless confined by chutes or pipes. Concrete shall be placed, whether by gravity or by pumping, so as to avoid segregation of the materials. It shall not be deposited in large quantities at one point and then run or worked along the forms. Concrete shall be deposited in horizontal layers and the work shall be carried on rapidly and continuously between predetermined levels agreed with the Engineer.

32. If long steeply inclined discharge chutes are required for placing concrete, the chutes shall be equipped with baffle boards or be in short lengths that reverse the direction of flow. The use of chutes shall be to the approval of the Engineer.

33. Chutes, troughs and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. The water used for flushing shall be discharged clear of the concrete already in place.

34. When concrete is to be poured into a bored and cased hole, the casing shall be smooth and shall extend above the top level of the finished shaft. When the casing is to be pulled, the concrete placed shall have a high workability requiring a minimum amount of vibrating.

35. Concrete for simple slabs, T-beams or simple deck girders shall be placed in one continuous operation. When shown on the Drawings concrete may be placed in 2 separate operations, each of which shall be continuous. First, to the top of the girder stems, and second, to completion. Where a construction joint is permitted between the girder stem and the slab, details of the key or other methods of bonding shall be as shown on the Drawings. In this case, deck concrete shall not be placed until the concrete in the girder stems has attained 75% of the design strength.

36. The concrete in arch rings shall be placed in such a manner as to load the centering uniformly. The rings, shall be poured in transverse sections of such size that each section can be cast in a continuous operation. The arrangement of the section and the sequence of placing shall be as approved by the Engineer, and shall avoid the creation of initial stress in the reinforcement. The section shall be bonded together by suitable keys or dowels.

3.0.4.5 Compacting Concrete

37. Concrete shall be compacted with mechanical poker vibrators operating within the concrete unless otherwise agreed by the Engineer. Sufficient number shall be provided and operated in keeping with the volume of pour.

38. Concrete shall be thoroughly worked around the reinforcement and embedded fixtures and into corners and angles of the forms. The vibration at any point shall be of sufficient duration to accomplish compaction, but shall not be prolonged to the point where segregation occurs. Concrete shall be worked around the reinforcement without displacing the bars or cages. Vibration shall not be applied by way of the reinforcement. Contact between the immersed vibrators, reinforcement and inserts shall be avoided.

39. Fresh concrete shall not be placed against in-situ concrete that has been in position for more than 30 minutes unless a construction joint is formed as described in this sub-Clause.

40. After the initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of projecting reinforcement for at least 24 hours.

    Retempering concrete by adding water or by other means will not be permitted. Concrete that is not within the specified slump limits at the time of placement shall not be used. Admixtures for increasing the workability or for accelerating the set will be permitted only with the written approval of the Engineer.

3.0.4.6 Concreting Under Water

41. Concrete deposited in water shall have the minimum cement content for the class of concrete increased by 10%.

42. The concrete shall be carefully placed in a compact mass, by means of a tremie, bottom-dumping bucket or other approved method that does not permit the concrete to free-fall through the water. The concrete shall not be disturbed after being deposited. No concrete shall be placed in running water, and forms which are not watertight, shall not be used for holding concrete deposited under water.

43. Pumping of water from the inside of the foundation forms while concrete is being placed will not be permitted. If necessary a seal of concrete shall first be placed through a closed chute or tremie and allowed to set for at least 7 days.

44. The method used for transporting concrete batches, materials, or equipment over previously placed slabs or units of structures of continuous design type shall be subject to approval by the Engineer. Trucks, heavy equipment and heavy concentrations of materials will be prohibited on slabs until the concrete has attained its full design strength.

3.0.4.7 Joints in Concrete

45. Whenever concrete placing is stopped until the concrete takes its initial set, that face shall be deemed a construction joint. The location of construction joints shall be as shown on the Drawings or planned in advance, and the placing of concrete carried continuously from joint to joint. The joints shall be perpendicular to the principal lines of stress and generally be located at points of minimum shear.

46. Where concreting has to be suspended part way through a pour, a joint shall be formed. Where necessary, the concrete shall be removed or cut to form a satisfactory construction joint of exposed , but undamaged aggregate.

47. Joints should preferably match features in the finished work. No concrete pour shall be stopped within 450 mm of any final level, unless a coping having a thickness less than 450 mm is to be provided, in which case the joint shall be made at the under edge of the coping.

48. Where dowels, reinforcing bars or other ties are not required by the Drawings, keys of suitable dimension shall be made by embedding water soaked beveled timber into the fresh concrete, and removing them when the concrete has set.

49. Kickers shall be cast at the same time as the lift of concrete beneath them.

50. While the concrete is still green, the surface of the construction joint shall be thoroughly cleaned with a stiff wire brush to expose the coarse aggregate. Alternatively where this preparation is impractical, the hardened surface skin shall be removed by needle gun. Immediately prior to placing fresh concrete the joint surface shall be washed with clean water and a thin coat of cement grout applied.

51. Expansion joints shall be formed at the locations, of the materials, and to the dimensions shown on the Drawings.

3.0.4.8 Concreting in Hot Weather

52. Concreting shall conform with the requirements of 'Recommended Practice for Hot Weather Concreting'. (ACI 305). No concrete shall be placed if its temperature under shade is over 33 °C. When the air temperature is expected to reach 35 °C or higher, the Contractor shall schedule operations to place and finish concreting during the hours that the temperature will be below 35 °C. When the overnight temperature is not expected to fall below 35 °C, then concreting may be permitted after sunset

53. Concrete materials shall be stored in a cool shaded position away from direct rays of the sun. The Contractor shall, when required by the Engineer, cool the water prior to mixing. If the Engineer considers it necessary, the Contractor shall also cool the aggregates prior to mixing.

54. Retarding admixtures may be used if approved by the Engineer, and shall conform to AASHTO M 194, Type D.

    Form work shall be shaded from direct exposure to the sun both prior to the placement of concrete and during its setting. The Contractor shall take appropriate measures to ensure that reinforcement in and projecting from the section to be concreted is maintained at the lowest temperature practicable.

3.0.4.9 Concrete Curing

55. Immediately after compaction and for not less than 7 consecutive days thereafter, concrete shall be protected against rain, rapid temperature changes, and from drying out. The method, procedure, materials and equipment for curing shall be subject to prior approval by the Engineer.

56. No concrete forms, whatever the curing method being used, shall be moved or removed within 18 hours of completion of pouring or without the approval of the Engineer.

57. Exposed surfaces shall be covered with plastic, hessian or other approved fabric kept in close contact with the concrete, or sprayed with curing membrane. If the forms are removed before the end of the curing period, curing shall also be applied to the formed surfaces. The protection shall not cause any undesirable finish or discoloring of the concrete.

58. Curing membranes shall conform to AASHTO M 148 and shall be applied in accordance with the manufacturer's instructions. Two applications shall be made to vertical surfaces to obtain a uniform coating. If the curing membrane is applied over construction joints, the membrane shall be completely removed at the joint prior to placing further concrete.

3.0.4.10 Quality Tolerance

59. Irrespective of the quantity, every day's production of concrete shall be tested both for strength and for slump for each structure and component where it is being placed. The checking and testing of the concrete shall be the prerogative of the Engineer, and he may increase the number of tests to be made or make other tests as he may deem necessary to ensure that the concrete is of the specified strength and condition as required for the project.

60 Samples shall be taken from each "lot" of concrete pouring, which shall be as given in Table 3.8 as a maximum lot for a concrete of a same grade of each day. Curing of test specimens shall be by the same methods as proposed for concrete in the Works twice a day.

Table 3.8: Sampling concrete

Concrete Application	Maximum Sampled Volume
Prestressed	$10m^3$ or 10 batches
Reinforced	$20m^3$ or 20 batches
Mass	$40m^3$ or 40 batches

61. Slumps shall be measured for each lot of concrete and shall be within ± 25 mm or ± one-third of the required value whichever is greater.

62. Each truck of concrete delivered to the Site shall be accompanied by a time slip issued at the batching plant, bearing the exact time of adding water to the cement and aggregates in the mixer.

63 The Contractor shall prepare test specimens for conforming compressive strength which will be cured and tested at 7 days and 28 days, or at any other interval that the Engineer may direct in order to determine the strength of the concrete.

64 Minimum 8 (eight) test specimens shall be made against one lot of concrete and cured in accordance with "the Provisions of BS 1881" or AASHTO T 22 (ASTM C 39). 4 (four) of the above 8 (eight) specimens shall be tested at 7 days and the other four at 28 days.

65 The Contractor shall ensure that all test specimens are carefully protected during the transportation from the site to the laboratory and the cost of providing such and all costs associated with the normal sampling preparing and testing of samples shall be included in the concrete rates. The Contractor shall make all arrangements and take every precaution to prevent damage to the test specimens during handling, transporting and storing.

66 The concrete test specimens will be tested by the Contractor at a fully equipped laboratory located or the Site, or at an independent laboratory approved in writing by the Engineer.

67 The characteristic strength σ_c of the various classes of concrete is determined on the basis of the results of a set of compression tests performed on test specimens taken from the same sample.

68 The characteristic strength of the concrete is obtained as a function of the mean experimental value of the strength, the number of tests performed and the scatter of the results, with the following formula:

$$\sigma_c = \sigma_{av} - K.\sigma$$

where:

$$\sigma_{av} = \frac{\sum_{i=1}^{n} \sigma i}{n}$$ is the mean experimental strength

$$\sigma = \frac{\sum_{i=1}^{n} (\sigma i - \sigma av)^2}{n - 1}$$ is the standard deviation

σi = is the result of the test on the specimen

n = is the number of specimens tested

K = is a numerical coefficient which assumes the values shown in the following table:

Table 3.9

n	4	6	8	10	12	14	16
K	1.17	0.83	0.67	0.58	0.52	0.48	0.44

69. The results at 7 days curing and 28 days curing shall be:

(i) the average strength determined from any 4 consecutive lots shall exceed the concrete characteristic strength by not less than 0.5 times the current margin;

(ii) each individual lot result shall be greater than 85% of the specified characteristic strength.

70 If only one lot fails to meet requirement (ii) at 7 days curing, then the countermeasures shall be taken immediately.

71. If the average strength at 7 days curing fails to meet the first requirement (i), then the work shall be stopped and the reasons shall be studied. The prompt action by the Contractor shall be taken after getting the acceptance from the Engineer. If the average strength at 28 days fails to meet the first requirement (I), then cylindrical core specimens of 150 millimetres nominal diameter shall be cut

perpendicular to the face of the hardened concrete as and where directed by the Engineer for the purpose of examination and testing.

72 The procedure for drilling, examination, measurement and testing for compressive strength shall be in accordance with BS 1881. Prior to preparation for testing, the specimen shall be made available for examination by the Engineer.

73 If such tests show strength in compliance with the requirements herein specified, the concrete will be considered satisfactory.

74 If the crushing strength of the specimen determined in accordance with paragraph 114 of BS 1881 is less than the specified characteristic strength at 28 days or if in the opinion of the Engineer the concrete fails to meet the specified requirements in other respects, the concrete in that 4 consecutive lot of the works of which it is a sample shall be considered not to comply with the specified requirements and shall be broken out and replaced.

75 Records of all tests shall be maintained on site by the Contractor, and copies of such records shall be regularly submitted to the Engineer.

76 The Contractor shall be responsible for ensuring that all concrete produced is in compliance with the Specification, and of adjusting mixes as necessary to achieve this compliance. No such adjustments to the approved mix shall however be made without full test results and approval of the Engineer.

77 All costs consequent upon non-compliance with the specified requirements shall be borne by the Contractor.

3.0.4.11 Surface Tolerances for Concrete

78. The dimensions of finished work shall be within the tolerances given in Table 3.9. The location of cast-in holding-down bolts and other fixtures to locate steel work shall also comply with these tolerances, and shall meet the specified tolerances for steel work given in Section of Steel Works, if appropriate.

Table 3.9: Concrete Structure Tolerances

Concrete element	Allowable Limits on dimensions
Visible members	
dimensions > 3m	± 6 mm
dimensions ≤ 3m	± 3 mm
elevation	± 6 mm
line	± 3 mm
verticality	±5m per 15m of height
Non-visible members	As for visible members, but may be relaxed with the agreement of the Engineer.

3.0.5 Method of Measurement

79. The approved work shall be measured by the cubic metric of placed concrete as shown on the Drawings and accepted except Concrete Class 18. The cost of Concrete Class 18 shall be included in the Cost of Concrete Class 24 for Piles Capes. Deductions for haunches and volumes of reinforcing steel will not be taken into account.

80. The payment methods for the Foundation such as piling and diaphragm wall, drainage are described in the Section of Foundation, and the payment for Safety Facilities such as median, road side concrete curb shall be applied as described in the Section of Safety Facilities.

3.0.6 Basis of Payment

81. The amount of completed and accepted material, measured as provided for above, will be paid for at the unit rate for 'Concrete (Class and places to be used)', in the Bill of Quantities of the Concrete structures, which rate shall include for all preparation, mixing, placing, curing and quality control including all materials, labour, equipment, tools and other items necessary for the proper completion of the Works.

3.0.7 Items in the Bill of Quantities

Item No. 3.0.2 Concrete Class 24 for Pile Caps

Item No. 3.0.3 Concrete Class 24 for Columns

Item No. 3.0.4 Concrete Class 30 for Pylons
Item No. 3.0.5 Concrete Class 35 for Pylons
Item No. 3.0.6 Concrete Class 35 for PSC Girders

3.1 Reinforcing Steel

3.1.1 Description

1. This Work shall consist of supplying and fixing concrete reinforcing steel in accordance with the Drawings.

3.1.2 Materials

2. Reinforcing bars shall be deformed bars to AASHTO M 31M, except where shown on the Drawings. Mild steel bars shall be Grade 300 and high tensile bars shall be Grade 400.

3. Welded steel wire fabric shall conform to the size and dimensions shown on the Drawings and to the requirements of AASHTO M55.

Certification

4. Two copies of a mill test report shall be submitted to the Engineer for each lot of billet-steel reinforcement bars proposed for use in the Works. The mill test report shall give the following information:

   (i) The process used in the manufacture of steel from which the bars were rolled

   (ii) Identification of each heat of open-hearth, basic oxygen or electric furnace steel from which the bars were rolled.

   (iii) Chemical and physical properties of the heat from which the bars were rolled.

5. The bars in each lot shall be legibly tagged by the manufacturer or fabricator before being offered for inspection. The tag shall show the manufacturer's test and lot number. The fabricator shall supply 3 copies of a certificate showing the heat number from which each size of bar in the shipment was fabricated.

6. The sampling, testing, and inspection of reinforcement bars may be made at the source of supply when the quantity to be shipped or other conditions warrant such

inspection. Bars not inspected before shipment will be inspected after arrival on the Site. Test samples provided shall be replicate bars not less than 1m long.

Protective Coating

~~7. Deleted~~

3.1.3 Construction Requirements

Protection and Storage

8. Reinforcing steel shall be protected from damage and shall be stored above ground on platforms, skids, or other supports.

9. The bars shall be free from detrimental dirt, mill scale, paint, grease, oil or other foreign substance. Loose scale shall be removed before the bars are used. There shall be no evidence of pitting or visual flaw in the bar or on the sheared ends.

Cutting and Bending

10. Reinforcement shall be bent to the dimensions given in the Bar Bending Schedule. The minimum bending radii for high tensile steel and mild steel bars shall be not less than 3 times and 2 times the nominal bar diameter respectively. Reinforcement shall be bent within the temperature range of 5°C to 100°C.

11. Cold worked bars and hot rolled high yield bars shall not be straightened or bent again once having been bent. Where it is necessary to bend mild steel reinforcement projecting from the concrete, the internal radius of bend shall be not less than twice the diameter of the bar.

Placing, Supporting and Fastening

12. Reinforcement shall be placed as shown on the Drawings. Bar intersections shall be securely tied together with the ends of the tying wire turned into the main body of the concrete.. Soft annealed iron wire shall be used to tie reinforcing steel bars..

13. The cover to reinforcement on exposed faces of concrete shall be maintained by using approved plastic or fiber cement spacers.

14. Concrete cover blocks shall be as small as possible consistent with their purpose, and designed so that they will not overturn when the concrete is placed. They shall be made with 10mm aggregate and the mix design shall produce the same strength as the adjacent concrete. Soft annealed iron tying wire approved by the Engineer shall be cast in the blocks for subsequent tying to the reinforcement.

Splicing

15. Whenever it is necessary to splice reinforcement at points other than those shown on the Drawings, shop drawings showing the locations of each splice shall be submitted by the Contractor for approval before the reinforcing steel is placed. No measurement shall be made for additional reinforcement steel used for splices.. Splices shall be avoided at points of maximum stress. They shall, where possible, be staggered, and shall be designed to develop the strength of the bar without exceeding the allowable bond stress. Unless otherwise shown on the Drawings, bars shall be lapped 35 diameters to make the splice. Mechanical couplers may be used in lieu of welding for splicing reinforcing steel, if approved.

Bored Pile Reinforcing

16. Shaft reinforcing steel consisting of longitudinal bars and spiral hoops or lateral ties shall be assembled and placed into position as a unit.. Bars shall be tied at all intersections. The lower end of each vertical bar shall be supported upon a suitable precast concrete block. Side spacer blocks of concrete shall be used at suitable intervals along the unit to give accurate spacing for the entire length of the shaft.

Welding of Reinforcement

17. Bar reinforcement in concrete structures shall not be welded unless shown on the Drawings. Welding of reinforcing steel for lap and butt welding of reinforcing steel where approved by the Engineer, shall conform to AWS D1.4.

3.1.4 Method of Measurement

18. The approved work shall be measured by the number of metric tones of reinforcing steel fixed in concrete as shown on the Drawings and accepted.The quantity in the Bill of quantity and Contract drawings are as sshown in the following Tables.

19 The measured weight shall not include the length of any kind of splice. No allowance will be made for the bending curves or the clips, wire or other fastening devices.

20 In computing the weight to be measured, the theoretical weights of bars of the cross section shown on the Drawings or authorized, shall be used. The weights are given in the following tables:

Table 3.9

Size(mm)	12	16	18	20	25	28	32	40
Weight(kg/m)	0.888	1.58	2.00	2.47	3.85	4.83	6.31	9.86

21 The computed weight shall not include the extra material incurred when bars larger than those specified are used, or the extra material necessary for splices when bars shorter than those specified are used with the permission of the Engineer, or the weight of any devices used to support of fasten the reinforcing steel in correct position.

22 Reinforcement in 'Concrete Pavement', will not be paid for directly, but shall be considered subsidiary to the item.

23 The quantity shown in the Bill of Quantity and Drawings are based on the following conditiond for calculation of the lap splice length.

Rate of Increase for Reinforcing Quantities

Diameter of Re-bar	CLASSIFICATION OF STRUCTURES			
	SUBSTRUCTURE			SUPERSTRUCTURE
	PILE	FOOTING	COLUMN	
T12	1.00	1.00	1.00	1.02
T14	1.00	1.00	1.00	1.02
T16	1.00	1.03	1.00	1.03
T18	0.00	1.04	0.00	1.04
T20	1.05	1.04	1.04	1.04
T22	1.05	1.04	1.04	1.05
T25	1.06	1.05	1.05	1.05
T28	1.07	1.06	1.05	1.06
T32	1.08	1.06	1.06	1.06
T35	1.09	1.07	1.07	1.07
T40	1.10	1.08	1.08	1.08

3.1.5 Basis of Payment

19. The amount of completed and accepted material, measured as provided for above, will be paid for at the unit rate for 'Reinforcing Steel' (places to be used), in the Bill of Quantities, which rate shall include for all supplying, fabricating, transporting, delivering, erecting, and fixing (including couplers, etc.), materials, labour, equipment, tools and other items necessary for the proper completion of the Works.

3.1.6 Items in the Bill of Quantities

Item No. 3.1.1	High yield steel bar for Pile Caps for Auxiliary Piers
Item No. 3.1.2	High yield steel bar for Pile Caps for Approach Bridges
Item No. 3.1.3	High yield steel bar for Columns for Auxiliary Piers
Item No. 3.1.4	High yield steel bar for Columns for Approach Bridges
Item No. 3.1.5	High yield steel bar for Pylons
Item No. 3.1.6	High yield steel bar for PSC Girders for Approach Bridges

3.2 Prestressing Tendons

3.2.1 Description

1. This work shall consist of mixing, placing and curing of concrete, and supplying, testing, installing, stressing and grouting of pre-stressing cables in the concrete.

3.2.2 Materials

Concrete

2. Concrete for pre-stressing shall be in accordance with Clauses related to previous Clauses.

Tendons

3. Pre-stressing wire or strand shall comply with the requirements of AASHTO M203 or M204, or BS 5896 as shown on the Drawings.

4. High tensile alloy steel bars shall comply with AASHTO M275, or BS 4486 as shown on the Drawings.

5. Tendons shall be tested for chemical composition, strength, and physical characteristics. The Engineer will require samples, selected at random from each

coil supplied, to be tested. When compression grips are used, not less than six samples of strands to be used in the Works shall be tested to failure.

Accessories

6. Stressing Tendons for the ducts, capable of transmitting forces from grout to the surrounding concrete, flexible enough to conform to the tendon profile and strong enough to maintain their shape without deforming, sagging, or collapsing during concrete placement and vibration. The inside diameter of the ducts shall be large enough to provide an internal area at least twice the gross area of multiple wire, bar or strand assemblies. Ducts shall be designed for watertight connections with all fittings. Galvanized ducts shall not be permitted.

Anchorages

7. Anchorages shall be cast and satisfy the requirements of BS 4447.

8. If proprietary systems of anchorage are used, the anchoring procedure shall be in accordance with the manufacturer's instructions and recommendations.

Grout

9. Grout shall consist of ordinary Portland cement conforming to BS 12 or AASHTO M85 Type 1 mixed with clean water. The water cement ratio shall be as low as is possible with the desired workability.

10. The grout shall not be subject to bleeding in excess of 2% after 3 hours or 4% maximum, when measured at 18 °C in a covered cylinder approximately 100 mm diameter with a height of grout of approximately 100 mm. The water shall be re-absorbed by the grout within 24 hours of mixing.

11. Grout shall be mixed for a minimum of two minutes and until a uniform consistency is obtained. The pumpability of the grout shall be determined in accordance with the US Corps of Engineers Method CRD-C79.

12. Admixtures containing chlorides or nitrates shall not be used, and others may be used only with the approval of the Engineer and in accordance with the manufacturer's instructions.

13. A suitable expanding admixture shall be used to produce an unrestrained

expansion of between 2 and 6%. It shall be free of fluorides, sulphites and nitrates, and shall not contain chlorides in excess of 0.005% of the mass of cement.

Ducts

14. Ducts shall be formed by metal sheathing, unless otherwise agreed by the Engineer.

3.2.3 Construction Requirements

Tendons

15. Wires and strands stressed at the same time shall be taken from the same parcel. Each cable shall be tagged with its number and the coil number of the steel used. Tendons shall not be welded within the length to be tensioned and, tendons shall be sawn or cropped using an abrasive disc cutter.

16. Tendons shall not be kinked or twisted and individual wires and strands shall be readily identifiable at each end of the member. No strand which has become unraveled shall be used in the Works.

Ducts

17. Ducts shall be maintained in their correct positions during placing of the concrete. The tolerance in the location of the sheath shall be 10mm in any direction.

18. Joints shall be kept to a practicable minimum and each joint adequately sealed against the ingress of any material. Joints in adjacent sheaths shall be staggered by at least 300 mm.

19. Ducts shall be kept free of matter detrimental to the bond between the duct and the grout and, except for material sealing a joint, between the duct and the concrete.

20. The ends of ducts shall be sealed and protected until the tendon is threaded through and the stressing operations are commenced. Pre-stressing tendons and internal and external surfaces of ducts shall be clean and free from pitting, loose rust and loose scale at the time of incorporation in the Work. Slight rusting is acceptable. Where rust inhibitors are used they shall not affect the bond between the tendon or duct and the grout.

21. Air vents shall be provided at troughs and crests in the duct profile and elsewhere as necessary.

Anchorages

22. Anchor cones, blocks and plates shall be positioned and maintained during concreting so that the centerline of the duct passes axially through the anchorage assembly.

23. Bearing surfaces of the anchorages shall be cleaned prior to concreting and tensioning.

Jacks

24. Jacks used for pre-stressing shall be appropriate for the system adopted. Each jack shall be accompanied by a test certificate indicating that it has been tested and calibrated by the manufacturer or by an approved testing laboratory up to a load equal to the full capacity of the jack within a period of one year prior to the commencement of prestressing.

25. Load measuring devices shall have an accuracy of ±1.5% and be checked before the tensioning operation starts and at intervals approved by the Engineer. Elongation of the tendon shall be measured to an accuracy within 1.5% or 2 mm, whichever is the more accurate.

Post-tensioning

26. Immediately before tensioning, the Contractor shall prove that the tendons are free to move between jacking points and that members are free to accommodate the horizontal and vertical movements due to the application of prestress.

27. Concrete shall not be stressed until it has reached the designed transfer strength. Test cylinders or cubes shall be made and cured in similar conditions to the concrete to which they relate. The Contractor shall cast sufficient test specimens to demonstrate that the required strength of the concrete at transfer has been reached.

28. The Contractor shall add to the specified forces an allowance, where necessary, for anchorage friction, wedge pull-in, jack losses and friction due to duct

alignment and curvature. The total forces and calculated extensions shall be approved by the Engineer before stressing is commenced. The actual pull-in that occurs shall be recorded for each individual anchorage.

29. Immediately after anchoring, the stresses in the tendons shall not exceed 70% of their ultimate tensile strength. During stressing the value shall not exceed 80%.

30. The tendons shall be stressed at a gradual and steady rate until they attain the force and extension designed. If the measured extension differs by more than 5% from the estimated extension, corrective action shall be taken.

31. When stressing from one end only, the pull-in at the end remote from the jack shall be accurately measured and the appropriate allowance made in the measured extension at the jacking end.

32. When the specified force, including any overload of short duration, has been applied to the satisfaction of the Engineer, the tendons shall be anchored. The jack pressures shall then be released in such a way as to avoid shock to the anchorage of tendons. If the pull-in of the tendons on completion is greater than the design, tensioning shall be carried out afresh.

33. If it is necessary to cut the tendons to enable the ducts to be grouted, this shall be delayed as long as practicable. In other cases, the tendons shall not be cropped less than three days after grouting.

Pretensioning

34. to 37 Deletred.

Grouting

38. Grouting trials shall be arranged and carried out by the Contractor prior to grouting in the permanent works, if required by the Engineer.

39. The grout mixer shall produce a grout of colloidal consistency. The grout injector shall be capable of continuous operation at a constant pressure not exceeding $1N/mm^2$. There shall be a system of circulating or agitating the grout while actual grouting is not in progress. Baffles to the pump shall be fitted with a sieve strainer of 1.18 mm nominal aperture size to BS 410 or AASHTO M92.

The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a nozzle which can be locked off without loss of pressure in the duct.

40. The pressure gauges shall be calibrated before they are first used in the Works and thereafter as required by the Engineer. Equipment shall be thoroughly washed with clean water at least once every three hours during the grouting operations and at the end of use each day.

41. Anchorages shall be sealed before grouting. Grout shall not be above 32 °C during mixing or pumping, and if necessary the mixing water shall be cooled.

42. Ducts shall be thoroughly cleaned by means of compressed air.

43. Ducts shall be grouted as soon as practicable after the tendons have been stressed. The ducts shall be completely filled with grout. Grout shall be injected in one continuous operation and allowed to flow from the vents until the consistency is equivalent to that being injected. Two days after grouting, the level of grout in the injection and vent tubes shall be inspected and made good if necessary.

44. The Contractor shall keep detailed records of grouting and copies shall be supplied to the Engineer within three days of grouting.

3.2.4 Method of Measurement

46. 'Pre-stressed Concrete Tendons' shall be measured by metric tonnes for each size of strand, wire or bars supplied and installed in the concrete. The theoretical weight is in accordance with BS 3617:1971 in metric tones of the pre-stressing tendons as shown on the Drawings without sheathings, anchorages, etc. and measured between the outer face of the anchorage blocks.

47 No measurement will be made of excess tendon length required for threading or stressing, or for cable ducts, cable supports, grouting and testing required in connection with pre-stressing. Anchorages and couplers shall not be measured separately but shall be deemed to be included in the item.

3.2.5 Basis of Payment

48 The amount of completed and accepted work measured as provided for above shall be paid at the rates in the Bill of Quantities. These rates shall include the provision of all materials(tendons, sheathings, anchorages, couplers, spirals, supports, for tendons tensioning, grouting and finish works, equipment, labour, tools, testing and other items necessary for proper completion of the Work.

3.2.6 Items in the Bill of Quantities

Item No. 3.2.1	Pre-stressing (Strand 12T 15.2 for PSC Girders)
Item No. 3.2.2	Pre-stressing (Strand 12T 15.2 for Pylons)
Item No. 3.2.3	Pre-stressing (Bar D32 for Pylons)

3.3 Pier Column and Abutment

3.3.1 Description

1. Intermediate bridge pier support of the superstructure for the bridge with two or more openings; and end support abutment shall have the additional function of retaining earth fill for the bridge approach. The bridge pier columns shall be constructed as shown in the Drawings..

3.3.2 Materials

2. The materials shall conform to the requirements of previous relevant clauses.

3.3.3 Construction Requirements

3. The construction shall conform with the clause of concrete mixtures, reinforcing steel and pre-stressing and as shown in the Drawing.

4. The Contractor shall use the laser instrument to keep the accuracy of the vertical of the center line of the pier columns.

5. The tolerance of variations from the plumb shall be 0.1 % or less.

3.3.4 Method of Measurement

6. The approved work of concrete, reinforcement, excavation, backfill, drainage, ducts shall be measured in accordance with the relevant Sections of this Specification.

3.3.5 Basis of Payment

7. The amount of completed and accepted work, measured as provided for above, will be paid for at the unit rate of concrete , reinforcement, excavation, backfill, drainage, ducts in the Bill of Quantities, which rate shall be full compensation for supplying materials, transporting and placing, for labour, equipment, tools and other items necessary for the proper completion of the work.

3.4 Pylon

3.4.1 Description

1. Pylon fixed to the pier at the base shall be as shown in the Drawing.

3.4.2 Materials

2. The materials shall conform to the requirements of previous relevant clauses.

3.4.3 Construction Requirements

3 The Pylon shall be constructed using climbing forms. Fabrication and erection of the Pylon Tower shall be closely related to the erection of the bridge as a complete structure.

4 The Contractor shall submit his proposed method for the construction of Pylon Tower and obtain the approval of the Engineer prior to commencing any work thereon.

5. The tolerance of variations from the plumbs shall be 0.1 % or less.

3.4.4 Method of Measurement

6. The approved work of concrete, reinforcement, prestressing, excavation, backfill, , drainage, ducts shall be measured in accordance with the relevant Sections of this Specification.

3.4.5 Basis of Payment

6. The amount of completed and accepted work, measured as provided for above, will be paid for at the unit rate' of concrete, reinforcement, prestressing, drainage, ducts in the Bill of Quantities, which rate shall be full compensation for supplying materials, transporting and placing, for labour, equipment, tools and other items necessary for the proper completion of the work.

3.5 Prestressed Concrete Bridge

3.5.1 Description

1. This work shall consist of erecting prestressed concrete bridge in accordance with the lines, levels and dimensions shown on the Drawings.

3.5.2 Materials

2. The materials shall conform to the requirements of previous relevant clauses.

3.5.3 Construction Requirements

Precast Prestressed Beam and Slab Bridge

3. The details of the method of manufacture shall be approved by the Engineer before work is started. The date of commencement of manufacture and the dates when tensioning of tendons, casting of members and transfer of stress will be undertaken for the first time for each type of beam shall also be submitted in advance.

4. The Contractor shall submit to the Engineer, not more than 7 days after the transfer of stress, a Certificate showing the force and strain in the tendons immediately after they were anchored, the strength and age of the concrete test cylinders or cubes cast and the minimum age of the concrete at the time the stress was applied.

5. If the Engineer requires tests to be carried out on beams, the beams to which those tests relate shall not be dispatched to Site until the results have been approved.

6. Prestressed concrete members shall be securely supported so that the stresses induced in them are less than the permissible design stresses. Members shall be

lifted or supported only at identified points and shall be handled and placed without impact.

7. The requirements for pre-stressing materials and construction procedures shall be as specified in ***Clause*** of pre-stressing.

8. Dimensional inaccuracies on prestressed members shall not exceed the limits given in Table 3.11.

Table 3.11: Prestressed Bridge Beam Tolerances

Dimension	Allowable Limit (mm)
Length	±25
Width	±10
Thickness	±20
Bow in vertical plane	±6m in 1.5 m
Bow in horizontal plane	±6m in 1.5 m
Flatness (gap with 1.5m straight edge)	6 mm
Reinforcement cover thickness	as shown in drawings

9. Beams for cast in-situ concrete deck shall be installed so that when the beams are laid side by side after erection the difference in soffit level between adjacent beams shall not exceed 5 mm for spans up to 5m long, and 10mm for longer spans. If permanent soffit shutters are used, they shall be to the approval of the Engineer and they shall be fixed securely so that there is no movement or grout loss during deck concreting.

10. In-situ concrete deck in one span shall be poured in one continuous operation unless otherwise approved, and shall be placed in such a sequence that the advancing edge of the freshly deposited concrete over the full width of deck is approximately parallel to the deck supports. Lateral displacement of beams shall be prevented during the placing of in-situ concrete.

11. Tolerances on the in-situ slab construction shall be as shown in Clause 31-2 sub-clause 52.

Cast In-situ Bridge

12. Cast in-situ bridge shall be constructed to the tolerances given in Table 3.12 and otherwise to the tolerances given in Table 3.8.

Table 3.12: Cast in-situ bridge deck tolerances

Dimension	Allowable Limit (mm)
Elevation	+-25 mm

3.5.4 Method of Measurement

13. The approved work of concrete, reinforcement, prestressing, excavation, backfill, drainage, ducts shall be measured in accordance with the relevant Sections of this Specification.

3.5.5 Basis of Payment

14. The amount of completed and accepted work, measured as provided for above, will be paid for at the unit rate' of concrete, reinforcement, prestressing, excavation, backfill, drainage, ducts in the Bill of Quantities, which rate shall be full compensation for supplying materials, transporting and placing, for labour, equipment, tools and other items necessary for the proper completion of the work.

3.15 LOADING TEST OF BRIDGE

3.6.16 General

The bridge shall be load tested to verify the predicted stresses and deflections of deck induced in the structure under the critical design live load. The theoretical predictions for dead loads plus critical live load shall be determined for reference purposes.

The necessary location for testing are as follows :

	Central Section	West Bank section	East Bank Section
On Steel Bridge	1	-	-
On PSC Bridge	-	1	1

The bridge shall be loaded with the critical design traffic loading as ascertained from design. For the purpose of actual loading, equivalent truck loading inducing the same effects (strains and deflections) shall be determined and used in the test.

The critical design sections of all key members shall be mentioned. The strains and deflections shall be recorded with approved electric and mechanical strain gauges, deflectometers and precise levels.

The contractor shall submit for the Engineer's approval, a detailed method statement for the test showing loading to be used in the test, sections to be monitored, measurements to be taken and equipment to be used in the test.

Testing shall not be carried out until written approval has been given. Testing shall only be carried out under the full supervision of the Engineer.

3.6.2 **Basis of Payment**

The cost for loading test shall be paid by the rate described in the Bill of Quantities , and the cost shall include all relevant items for testing.

3.6.3 **Pay Items**

Item 3.6 Loading Test on Concrete Bridge

4.0 Foundations

4.1 Piling

4.1.1 Description

1. This Work consists of one pre-boring test for each foundation, supplying and installing precast, prestressed concrete, cast in-situ concrete and steel piles by boring and driving methods.

Materials

2. Concrete shall be as specified in Clauses of Concrete Mixtures.

3. Concrete forms and curing for piles shall be as specified in Clauses of Concrete Works.

4. Prestressed concrete for piles shall be as specified in Clause of Prestressing.

5. Bentonite for drilling fluid shall be pulverized (powder or granular) premium grade sodium grade sodium cation montmorillonite and shall conform to American Petroleum Institute (API) "13A" API Specification for Oil-Well drilling-Fluid Materials.

4.1.2 Construction Requirements

General

6. The Contractor shall submit for prior approval full information or methods, plant and programme to completion proposed. In addition prior to commencing piling at any foundation he shall submit full records of the pre-boring test carried out including the strata encountered the SPT values, and any other relevant information. The test boring is to terminate when it has penetrated a minimum of 5m below the designed toe level of the pile group in sand strata, or until it has penetrated at least 5m beyond any clay a silt strata encountered at the proposed toe level of the pile(s).

7. The Contractor shall inform the Engineer each day of the work programme for the following day and shall give adequate notice of any intention to work outside normal site hours.

8. The Contractor shall carry out the piling work in such a manner and at such times to minimize noise and disturbance to the general public. If, during execution of the

work, damage is likely to be caused to utilities or adjacent structures, the Contractor shall submit to the Engineer proposals for the repair or avoidance of such damage.

9. Piles shall be installed to the tolerances given in Table 6.1.

Table 6.1: Installed Pile Tolerances

Characteristic	Allowable Limit
Position	75 mm in any direction at the pile head
Verticality	1 in 75 deviation
Rake	1 in 25 deviation

10. The contractor shall submit daily records to the Engineer within 24 hours giving the information listed in Table 6.2.

11. On completion of piling for the Works, the Contractor shall deliver a schedule of installed piles giving the information listing toe levels.

Cast in Place Piles

12. Temporary casings or linings shall be used when needed to maintain the stability of the pile bore during excavation. Castings shall be free from distortion and projections, and shall be of uniform section throughout their length.

13. The drilling fluid shall be maintained at an adequate viscosity and density. Action shall be taken to prevent the spillage of bentonite slurry onto the site. Disposal of used slurry shall be made to a tip approved by the Engineer.

14. Pumping of ground water from boreholes will only be permitted where there is no risk of removal of fines from the subsoil. Water which cannot be sealed off shall be maintained in the borehole at a level above the standing ground water.

15. On completion of boring, loose soil and debris shall be removed from the base of the pile and the Contractor shall provide facilities required by the Engineer to facilitate inspection of the pile base. The method of descent and the equipment used shall comply with BS 5573.

16. If reinforcement cages are used they shall be rigid and installed and maintained in the correct position during concreting.

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Table 6.2: Piling Records

<table>
<tr><th>All Piles</th><th>Driven Precast Concrete & Steel piles</th><th>Driven Cast-in Place Concrete Piles</th><th>Bored Cast-in-Place Concrete Piles</th></tr>
<tr><td rowspan="3">Date.
Contract identification.
Pile identification.
Pile type.
Working load.
Ground level at commencement of operations.
Working platform level.
Pile toe level.</td><td>Cross-sectional dimensions.
Total length of preformed pile.
Driven length of preformed pile.
Sequence of driving in groups.
Final set.
Sections and joints used.</td><td>Cross-section dimensions of driving tube (temporary casing).
Cross-sectional dimensions of completed pile.
Length of permanent casing.
Length of finished pile excluding any enlarged base.</td><td>Diameter of completed pile.
Diameter of any enlarged base.
Length of temporary casing.
Length of permanent casing.
Length of finished pile including any enlarged base.
Type of boring.
Time of commencement of boring.</td></tr>
<tr><td colspan="2">Time of commencement and completion of driving or redriving.
Type, weight, drop and mechanical condition of hammer used.
Number, type and condition of the packing on the pile head.
Type and condition of the dolly in the helmet.
For a single acting hammer, the final drop.
For a double acting hammer, the final frequency of blows.
The sets taken at intervals during the last 3 m of driving, if required.
Details of any interruption in driving.
Details of redriving</td><td>Time of completion of boring.
Details of soil strata penetrated.
Details of soil samples taken and in situ tests carried out.
Details of any interruption in boring.
Standing ground water level and water strikes during boring.</td></tr>
<tr><td>Details of any obstructions, delays or other interruptions to the sequence of work including times.
Cut-off level.
Head level of completed pile.
Ground heave</td><td colspan="3">Method of placing concrete.
Concrete mix details:
• Grade of concrete.
• Nominal maximum aggregate size.
• Cement content.
• Type and quantity of admixtures.
• Water/cement ratio.
Measured slumps.
Batch times.
Time of commencement of concrete pour.
Time of completion of concrete pour.
Volume of concrete placed in enlarged base.
Volume of concrete placed in pile shaft.
Reinforcement details:
• Number type and size of main reinforcing bars.
• Type, size and pitch or spacing of helical binding or link bars.
• Length of individual reinforcement cages.
• Total reinforced length of pile</td></tr>
</table>

Notes:

1. The 24 hour clock shall be used.
2. For any pile not completed in the working day the date shall be entered in the records together with the times of commencement and completion.
3. For driving operations not using a piling hammer, equivalent information to that required on type, weight, drop etc. of hammer, packing and dolly shall be provided.

Placing Concrete

17. The concrete shall be placed without interruption. Records shall be kept of the workability of the approved mix. Underwater, concrete shall be placed only by tremie. The tremie pipe shall be clean and watertight throughout and not less than 200 mm internal diameter. The end of the tremie pipe shall be kept immersed in the concrete a minimum depth of 1m.

18. Permanent casing shall be checked for damage. If necessary the casing shall be withdrawn, repaired, redriven, or other action taken to allow the construction of the pile.

19. Temporary casings shall be extracted while the concrete remains sufficiently workable. While the casing is being extracted a sufficient head of concrete shall be maintained within it to avoid noking in the pile. No concreting shall be done once the casing has been lifted above the top of the concrete.

20. Casings for drive cast-in-place piles shall be installed to the approved set or specified depth and in the sequence approved by the Engineer. Each length shall be driven continuously. Levels shall be taken immediately after the final depth is approved, before concreting is begun. The casings shall be watertight.

21. After a pile has been cast, the date of casting and reference number shall be permanently inscribed on the head of the pile. Each pile shall be marked at intervals of 250 mm along the top 3m of its length before being driven.

22. Only the designed lifting and support points shall be used during transport, and piles shall be stored on adequate supports located under these lifting points of the piles. Piles within a stack shall be in groups of the same length. Packings of uniform thickness shall be provided between piles at the lifting points.

23. During driving, piles shall be adequately supported and restrained by means of leaders, trestles, or other guide arrangements to maintain position and alignment and to prevent buckling. The Contractor shall satisfy the Engineer regarding the suitability, efficiency and energy of the driving equipment. Piles shall be driven continuously until the prescribed set or depth has been reached.

24. The final set of the pile shall be recorded either as the penetration in millimetres per 10 blows or as the number of blows required to produce a penetration of 25 mm.

25. When a final set is being measured, the following requirements shall be met:

    (i) The exposed part of the pile shall be in good condition without damage or distortion.

    (ii) The dolly and packing, if any, shall be in sound condition.

    (iii) The hammer blow shall be in line with the pile axis and the impact surfaces shall be flat and at right angles to the pile and hammer axis.

    (iv) The hammer shall be in good condition and operating correctly.

    (v) The temporary compression of the pile shall be recorded if required.

26. Piles shall be driven in an approved sequence to minimize the detrimental effects of heave and lateral displacement of the ground. When a pile has risen as result of a adjacent piles being driven, the Contractor shall submit to the Engineer proposals for correcting this and its avoidance in subsequent work.

27. If repairs are needed during driving to the head of a pile, it shall be cut off square at sound concrete, and loose material removed by wire brushing, followed by washing with water. If the pile is to be subjected to further driving, the head shall be replaced by concrete of an approved Class.

28. Piles shall be lengthened, if required, by stripping off concrete from the reinforcement and lapping, coupling or welding additional steel in place. Laps shall be at least 40 x pile diameter. Couplers shall be approved by the Engineer. Steel to be welded shall be free of concrete for at least 300 mm below the weld. Welded joints shall be made in accordance with Clause of Steel Work.

29. Prestressed piles shall be lengthened by a method approved by the Engineer.

30. Repaired or lengthened piles shall be driven until the added concrete has reached the specified characteristic strength of the concrete of the pile.

31. Piles shall be clearly marked in white paint with their number and overall length. In addition, each pile shall be marked at intervals of 250 mm along the top 3m of its length before being driven.

32. If steel piles are to be pre-coated, the preparation of surfaces and the application of the coating shall be carried out by experienced specialist labour.

33. Surface preparation, priming and protective coats shall conform to the requirements of Clause of Steel Work.

34. Rolled steel sections shall be within the tolerances specified in BS 4. For steel sheet piles and proprietary rolled sections, the deviation from straightness shall not exceed 1/1000 of the length of the section.

35. Cylindrical steel piles shall not deviate from straightness by more than 1/600 the length up to 10m and 1/1000 for lengths greater than 10m. The actual mass of each section shall be within +5% and -2.5% of the theoretical computed mass in accordance with Clause of Steel Work.

36. Sheet piles shall be pitched and supported as a panel before driving and be securely interlocked. Piles shall not overlap each other and no pile in a panel shall be more than 1m in advance of another.

37. Sheet piles previously driven shall not be used in the permanent Works unless approved.

38. Steel piles shall be driven to a prescribed set or depth in a sequence approved by the Engineer. Driving shall be continuous.

39. If approved, piles shall be lengthened by full penetration butt welding. Lengthening sections shall be of the same rolling. Longitudinal and spiral seam welding of cylindrical piles shall be staggered.

Pile Testing

40. The Contractor shall submit a full method statement including loading arrangement details and any specialist data required by the Engineer for approval before commencing pile testing work.

Pile tests will be required as follows: One full test or a selected pile in the each Construction Section.

One full test as a selected pile in the Egyptian Contract on the West Bank.

One full test as a selected pile on both the East Bank and West Bank of the Japanese Contract.

The piles proposed for these load tests are to be approved by the Engineer prior to commencement of testing.

41. The maximum loads to be applied shall be as follows:

(i) Expendable piles in compression and horizontal tests: 2.5 x working load.

(ii) Expendable piles in tension: 2.0 x working load.

(iii) Working piles in compression, tension and horizontal tests: 1.5 x working load.

(iv) Constant rate of penetration: 3.5 x working load.

Expendable piles shall be tested in advance of the commencement of piling for the Permanent Works.

42. The test load shall be applied by jacking against kentledge, ground anchors or reaction piles. The distance of vertical reaction piles or anchors from a test pile shall not be less than three times the diameter of the test pile.

43. The total capacity of the jacking system shall be at least equal to the required maximum load plus 20%. In maintained load tests the required jack pressure shall be held constant during the test loading by an automatic pressure transducer control system. In constant rate of penetration tests the hydraulic pressure to the jack shall be provided by a motor driven pump of sufficient volume and pressure output to maintain the load at a penetration rate of 0.5 mm/min.

44. The load shall be measured by load cell or proving ring with a calibrated pressure gauge included in the hydraulic system. In interpreting the test data, the values given by the load cell or ring shall be used; the pressure gauge readings are required as a check.

45. The load measuring system shall be calibrated before and after each series of tests and whenever adjustments are made. The pressure gauge and hydraulic jack shall be calibrated together. Certificates of calibration shall be supplied to the Engineer.

46. The vertical movement of the pile head under load shall be made from an independent reference frame by dial gauges or by use of precise leveling, in which case 3 points on the pile head and 2 fixed reference points shall be leveled at each reading.

47. Each increment of load shall be measured with an accuracy of 2% and movement shall be measured to an accuracy of 0.25 mm.

48. For a maintained load test:

    (i) The value of the test load and the number of increments shall be as described on the Drawings.

    (ii) The load after each increment shall be kept constant until the rate of movement is reducing and does not exceed 0.25 mm/h.

    (iii) At working load the load shall be maintained for 12 hours.

    (iv) Proceed in increments as before to the full test load.

    (v) Maintain the full test load for at least 24 hours.

    (vi) Reduce the load in increments equal to the loading increments. Keep constant after each reduction until the rate of recovery is reducing and does not exceed 0.25 mm/h.

    (vii) While the load is constant, the time and movement shall be recorded:

    - on reaching the load
    - at 15 minute intervals for 1 hour
    - 30 minute intervals between 1h and 4h
    - 1h intervals after 4h

    (viii) The total movement of the pile under full test load and its recovery shall be within the limits shown on the Drawings.

49. For constant rate load tests:

(i) The rate of loading shall be such that a constant rate of movement is maintained throughout the test, as agreed by the Engineer before the start of the test.

(ii) Readings of load, movement and time shall be made simultaneously at regular intervals and agreed with the Engineer.

(iii) Loading shall be continued until one of the following results is obtained:

- the test load is reached

- a constant or reducing load has been recorded for an interval of movement of 10 mm

- The total movement of the pile base is equal to 10% of the base diameter

50. Within 24 hours of completion of the test, results shall be submitted to the Engineer in the form of tabulated site readings plus the following plotted data:

(i) For maintained load tests:

Load v movement
Time v load (for applied and recovery loads)
Recovery load v movement

(ii) For constant rate of penetration:

Load v settlement

4.1.3 Method of Measurement

52. Piles shall be measured by linear metres of actual length placed in the Permanent Works. The length shall be from the tip to the underside of the foundation, plus the penetration into the foundation specified on the Drawings. Where additional length is required as a result of the test boring this shall be paid as an extra payment per linear m of the prices entered in the Bill of Quantities and as agreed by the Engineer.

4.1.4 Basis of Payment

55. The amount of completed and accepted work measured as provided for above will be paid for at the unit rate for 'Piling' in the Bill of Quantities, which rate shall be full

compensation for supplying and installing piles and for materials, labour, equipment, tools, records and other items necessary for the proper completion of the work.

56. The amount of completed work of 'Pile Testing' will be paid for at the unit rate for one test in the Bill of Quantities which rate shall be full compensation for designing, setting up, carrying out, reporting and for labour, equipment, tools and other item necessary for the proper completion of the work.

4.1.5 Items in the Bill of Quantities

Item No. 4.1.1	Piling	linear metre
Item No. 4.1.2	Loading test	numbers

4.2 DIAPHRAGM WALLS

4.2.1 GENERAL

This work shall consist of constructions of diaphragm wall caissons and top slabs in corporated with groundwater lowering by deep well sanctions.

Work Included.

1 This section covers materials, equipment and workmanship requirements for the construction of diaphragm walls for underground structures shown on the drawings.

Qualifications.

2 The work shall be performed by a specialty subcontractor, specializing in the specified foundation system and having experience installing the specified foundation system under similar subsurface conditions.

Site Conditions.

3 Subsurface soil data logs are shown in the soil investigation report prepared by the Engineer. The subsurface investigation report and samples of materials, as taken from subsurface investigations, are available for examination at the office of the Engineer.

General

4 The Contractor shall submit to the Engineer for approval full details of his proposed methods materials, plant and operation for undertaking the work.

The Contractor shall prepare detailed drawings showing construction sequence and connection of diaphragm wall panel and shall submit copies for the approval of the Engineer. These drawings shall be based upon his erection sequence equipment and methods which have been consented to by the Engineer in accordance with the requirements of the Contract.

5 It shall include details of:

(a) Guide wall details, showing reinforcing if used, width and height;

(b) The methods of forming and cleaning the joints between panels;

(c) the length of panels and details of reinforcement cages;

(d) Provisions of all features required to be connected to or built through the walls;

(e) Schedule of guide wall construction and utilities relocation;

(f) The sequence of excavation and concreting of panels;

(g) the methods of monitoring and maintaining the stability of the diaphragm wall trench;

(h) The methods of monitoring plumbness and deviation of wall panels during excavation, and details of proposed corrective measures to be implemented if necessary.

(i) Equipment and method of checking and providing the cleanliness of trench bottoms prior to concreting.

(j) The mixing, transporting and placing equipment for the bentonite slurry.

(k) The method of treatment and disposal of contaminated bentonite slurry;

(l) The type, source, chemical and physical properties of the bentonite to be used;

(m) The method and sequence of work to form the trench in the area occupied by an existing gravity retaining wall.

6 The Contractor shall submit records of the following to the Engineer on a daily basis.

(a) Panel No;

(b) Date and time of start of panel excavation;

(c) Date and time of finish of panel excavation;

(d) Details of any obstruction encountered and the time spent in dealing with obstructions;

(e) Date and time of start and completion of cage placement;

(f) Date and time of start and completion of panel concreting;

(g) Length of panel and width and depth of panel from top of guide wall level;

(h) A log of soil type encountered from start to finish of excavation, water and slurry levels;

(i) Volume of concrete used and time of any interruptions recorded in concrete supply where these exceed 15 minutes. Volumes of normal and lean mix concrete;

(j) Cut-off level of concrete below top of guide wall level;

(k) Date, place and time of slurry control tests and results recorded;

(l) Concrete test cylinder markings, date and results obtained on testing;

(m) Details of cage type for reinforcement;

(n) Quantity of slurry removed from site and spoil removed from site recorded by date;

(o) A graph of theoretical and placed concrete volumes with depth;

(p) Levels of top of reinforcement cage and measured distance from these level points down to any feature for future connections or openings.

7 Longitudinal tolerance at cage head measured along the trench 25 mm $\pm$25 mm

8 Vertical tolerance at cage head in relation to top of guide wall $\pm$25 mm

9 A minimum cover to reinforcement of 75 mm shall be maintained at all levels.

10 Tolerances may be aggregated only to the extent that they do not exceed 50 mm.

11 Tremied Concrete

(a) Displacement of heavy contaminated material from the bottom of the trench can be carried out by an air-lift pump system after the design trench profile has been formed. Density tests shall be carried out to ensure that the density of the slurry near the trench bottom is less than 1.25 g/ml prior to concrete placement.

(b) Start placement of tremie concrete in excavated panels within 8 hours of completion of excavating panels, and within 2 hours after placing reinforcement cage, and proceed continuously until completion of concreting. If these time limits are exceeded, remove reinforcement cage, clean, and reinstall.

(c) The tremie pipe shall be clean, watertight, and be of adequate diameter to allow the free flow of concrete. The tremie shall extend to the bottom of the trench.

(d) The Contractor shall ensure that an adequate supply of concrete to the tremie is available at all times so that placement is continuous.

12 The extraction of stop shall be carried out at such a time and in such a manner as to avoid causing damage to the concrete placed against it.

Diaphragm wall Excavation.

13 Excavation of diaphragm walls panels or groups of panels shall be performed so that reinforcing steel and concrete placement is a continuous operation. Excavation shall not be left open at any time after completion of the excavation cycle.

4.2.2 MATERIALS

14 The concrete, reinforcing steel, and grout to be used in the concrete work shall conform to the requirements of Clause of Concrete works.

15 The separators, and supplemental steel for fabrication of the diaphragm walls shall be in accordance with BS 1449 or JIS G-3101, Steel plate, sheet, and strip.

4.2.3 Construction Requirements

(1) Construction Plan

The Contractor shall prepare the construction plan describing his team organization, schedule, construction method, equipment arrangement, recording forms, environmental measures and safety measures and submit prior to the construction work for the approval of the Engineer.

(2) Preparation of Construction Base and Protection Against Suez Canal Structures

Elevation of construction base shall be 0.5 m and its space shall be minimum necessary area for the construction purpose. The structures of Suez Canal banks shall be protected against any construction activities during the construction work by appropriate measures approved by the Engineer.

(3) Test Diaphragm Wall Panel Construction

Prior to the diaphragm wall construction, test diaphragm wall shall be constructed at west bank side near caisson location. Test diaphragm wall is 1.2 m thickness, 2.5 meters width and 30.5 meters depth from the construction base. During the excavation, soil condition, excavation speed and accuracy, loss and durability of stabilizing liquid, etc. shall be examined.

After completing test diaphragm wall panel, loading test shall be done upto 1.5 times of design bearing capacity. Vertical load and deformation shall be measured and the bearing capacity shall be analyzed.

(4) Construction Accuracy

The vertical accuracy of diaphragm wall shall be within 5 cm.

(5) Guide Wall Construction

In order to maintain the construction gauge and accuracy, the Contractor shall construct guide wall on top of diaphragm wall, which shall have enough size and rigidity to ensure the working circumstances during the work.

(6) Temporary Facilities

Following temporary facilities shall be prepared and maintained during the work so as to complete the work safely.

a) Electro Power Supply
b) Water Supply
c) Wall Stabilizing Liquid Plant
d) Sand Sedimentation Plant
e) Waste Liquid Treatment Plant

(7) Excavation

a) Excavation for diaphragm wall shall be determined taking into account soil condition, excavating depth/thickness, construction accuracy, etc.

b) In order to maintain the wall stability during wall excavation, appropriate stabilizing liquid shall be used. Mix proportion shall be determined based on the construction record of test diaphragm wall panel, as well as the change of construction condition during excavation. Amount of stabilizing liquid shall be careful controlled during construction not to loose the head nor to change the quality of the liquid. Waste disposal of the stabilizing liquid during/after construction shall be treated not to make any pollution on the environment around the construction area.

c) The excavated soil shall be transported to a designated area by the Engineer and shall be deposited not to make any influence against the properties of third parties.

(8) Removal of Slime

After excavation of diaphragm wall, slime on the wall bottom shall be removed carefully using excavator and sanctioned pump/air lift.

(9) Reinforcing Bar Cage

a) Prior to the fabrication of reinforcing bar cage, the Contractor shall prepare the working drawings taking into consideration design of re-bar arrangement, tremie pipe position, steel reinforcing frame arrangement, etc., and shall submit for the approval of the Engineer.

b) The fabrication of reinforcing bar cage shall be made in fabrication yard and be transported to site not to make any deformation by using proper stiffener during transportation.

c) Reinforcing bar cage shall be placed in site using hanging jig and crane equipment of enough capacity within 5 cm of positioning accuracy.

d) The connections of vertical/lateral reinforcing bars, re-bar/steel plate, etc. shall be done by arc welding method.

(10) Concreting

a) For placement of concrete, tremie pipe shall be used. The inner diameter of pipe shall be more than 200 mm and shall be distributed one pipe per some 3 meters in diaphragm wall.

b) Concrete shall be placed upto minimum 2 meters from top slab base line and this part of concrete shall be removed carefully not to harm the lower side concrete as well as reinforcing bars.

(11) Deep Well

In order to construct the top slab (4 m depth), groundwater level shall be lowered by arranging deep wells around the diaphragm wall. Deep well shall be designed not to disturb the bearing soil strata around the diaphragm wall.

16 The diaphragm wall excavation equipment shall have the necessary power and downward force suitable for the site conditions, and shall be of the pivoting grab type, capable of cutting to dimensions of 1.2m x (2.4 ~ 2.8m).

17 Performance of the work shall be in accordance with the Japan Road Association, Guideline and Commentary for the Design of Continuous Diaphragm Wall Foundations.

4.2.4 LOADING TEST

18 Perform diaphragm wall load test in a location indicated on the drawings.

19 Test shall be performed under the supervision of a registered engineer provided by the Contractor and in the presence of the Engineer.

20 Prior to construction of the diaphragm walls, a test panel diaphragm wall 1.2m x 2.8m approx. shall be installed and load tests shall be performed to confirm the capacity. The panel shall be founded at a design depth of 30.5m, and the maximum test load shall not exceed 200 percent of the design load. The load test procedure shall be submitted to the Engineer for his review, and his approval shall be obtained prior to commencement of work.

21 Replacements Construct and re-test, at no additional cost to the Client, test diaphragm wall panels found inadequate because of improper instrumentation, testing, or construction procedures. Load test shall be made for diaphragm wall load tests. The Engineer reserves the right to increase or decrease the number of diaphragm wall load tests. Adjustments in the contract price will be made for such increase or decreases.

4.2.5 METHOD OF MEASUREMENT

Diaphragm wall shall be measured by cubic metres of concrete separately for Wall and Top slab, which is calculated with theoretical dimensions, installed and accepted.

4.2.6 BASIS OF PAYMENT

22 The amount of completed and accepted work measured as provided for above will be paid for at the unit rate for "Diaphragm walls" in the Bill of Quantities, which rate shall include for supplying and installing all diaphragm walls and for materials, labour, equipment, tools, records and other items necessary for the proper completion of the work.

4.2.6 ITEMS IN THE BILL OF QUANTITIES

Item No. 4.2.1	Diaphragm wall	c.m.
Item No. 4.2.2	Top slab	c.m.
Item No. 4.2.3	Loading test of a panel	number.