SECTION 8
CONCRETE STRUCTURE

Replace the whole of the Article 8.2.2 with :

Seven classes of normal weight concrete are provided for in these specifications as listed in Table 8.2.

Replace Table 8.2 with :

Table 8.2

Concrete Class	Specified Compressive Strength at 28 Days (N/mm^2)	Max size of Aggregate (mm)	Min Cementitious Content * (kg/m^3)	Max Free Water / Cement Ratio
40/20	40	20	400	0.4
30/20	30	20	360	0.42
25/20	25	20	320	0.45
20/20	20	20	280	0.6
15/40	15	40	-	0.6
U15/20	15	20	-	0.4
U15/40	15	40	-	0.4
E	7.5	40	See Article 8.2.4	

* "Cementitious Content" includes the total Portland cement and pozzolan constituents

Add new Article :

8.2.4 Concrete for Ancillary Purposes (Class E)

Class E concrete shall be composed of ordinary portland cement and aggregates complying with AASHTO M6 and AASHTO M80. Not more than 0.27 m^3 of combined aggregate shall be mixed with 50 kg of cement.

Water content shall not exceed that required to produce a concrete with sufficient workability to be placed and compacted where required.

Add new Article :

8.3.9 Control of Alkali Aggregate Reaction

The Contractor shall either use non-reactive aggregates (as defined in Article 8.3.9.2 below) or restrict the content of equivalent sodium oxide in the mix. (as defined in Article 8.3.9.6 below) except as follows:

(a) aggregates that are not accepted as wholly non-reactive shall not be used for concrete that will come in contact with seawater, saline groundwater or alkaline groundwater;

(b) concrete containing non-reactive aggregates where there is no restriction on the equivalent sodium oxide shall not be used in locations where it will be in direct contact with concrete containing reactive aggregates.

Coarse and fine aggregates shall be tested for alkali reactivity as follows:

(a) by petrographical examination to identify the presence and proportions of deleterious materials;

(b) in accordance with ASTM C289 for soluble silica;

(c) by the recommended procedure for the pat test described in the National Building Studies Research Paper No 25: Part VI;

(d) in accordance with ASTM C586 for alkali carbonate reactivity where calcitic dolomitic limestone has been identified in (a).

Coarse and fine aggregates shall be considered non-reactive if after testing they are found to comply with the following:

(a) the aggregates individually or in combination do not contain any opal. Tridymite or cristobalite

(b) the aggregates individually or in combination do not contain more than 2% (by weight of chert, flint, chalcedony, microcystalline silica or cryptoczystalline silica taken together.

(c) in the case of aggregates which individually or in combination contain more than 95% by weight) of quartz they shall be considered non reactive provided the quartz is not in the form of quartzite, or contains more than 30% (by weight) of highly strained quartz. Quartz shall be classified as highly strained if the petrographical examination of thin articles of grains gives an average undulatory extinction angle of more than 250. The extinction angle shall be measured on at least 20 separate grains.

Aggregates whose source is variable shall be tested every month for compliance with the above requirements.

The definition of rock types shall be as in ES 812. Feldspar. quartz. chalcedony and opal. Tridymite or cristobalite are minerals, the first two of which shall be as defined in BS 6100.

When the coarse and fine aggregates are not accepted as wholly non-reactive and the concrete will not come into contact with sea-water, saline ground water or alkaline ground water, the amount of alkaline sodium oxide shall not exceed 3.0 kg in any cubic metre of concrete.

The equivalent sodium oxide content of the cement shall be taken as that of the proposed quantity of cement in the mix, with 10 kg of cement added for each cubic metre of concrete to allow for tolerances in batching.

The acid-soluble alkali content of the Portland cement shall be taken as the average of 25 daily determinations of equivalent sodiuth oxide, plus twice the standard deviation for the period in which the cement was manufactured. The Contractor shall submit to the Engineer test certificates furnished by the cement manufacturer giving the results of these tests. The acid-soluble alkali content of the Portland cement shall be determined in accordance with the method recommended for United Kingdom internal purposes in BS 4550 or an x-ray fluorescence technique calibrated against the British Standard.

The acid-soluble alkali content of the GGBFS or the PEA, which shall be determined in accordance with BS 4550, shall be taken as the average of 25 weekly determinations for the period immediately preceding the certificate, plus twice the standard deviation of the results. The Contractor shall submit to the Engineer test certificates furnished by the manufacturer giving the results of these tests.

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.

The equivalent sodium oxide content of admixti.ires shall be taken as the total alkali content of the maximum dosage of admixture used in the mix. The Contractor shall submit to the Engineer certificates furnished by the admixture manufacturer giving details of the alkali content.

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 cement, one half or one sixth the equivalent sodium oxide contributed by the GGBFS or PFA respectively, the chloride (Cl ion).in the aggregate and the amount of equivalent sodium oxide in any admixtures or water to be used in the mix as follows:

Equivalent Na_2O (Concrete) = (A) + (B) + (C) where:

A = Equivalent acid-soluble Na_2O (cement + admixtures + water)

B = 0.76 Cl ion (aggregate)

C = Either one half of the acid-soluble equivalent Na_2O (GGBFS)
or one sixth of the total acid-soluble equivalent Na_2O (PFA)

Sources of cement and replacement materials which have been approved with respect to the calculation of equivalent sodium oxide in the concrete shall not be changed without the prior consent 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 approval of the proposals. After these 10 days the results of weekly testing will be accepted for the source until farther changes are notified.

Delete the following from Article 8.4.1.2 :

For classes A, A(AE) and P concrete,

Replace with :

For classes 40/20, 30/20 and 25/20

Delete Table 8.3 and the following paragraph from Article 8.4.2 :

The amount of water used should not exceed.
When type F or G high range water reducing as permitted by the Engineer.

Replace with :

The water/cement ratio shall be the lowest possible compatible with the required workability but never greater than the value in Table 8.2.

Workability shall be such as to enable the concrete to be fully compacted without segregation around the reinforcement, prestressing ducts and other inserts detailed on the approved working Drawings and to completely fill the formwork and provide the specified surface finish under prevailing climatic conditions. The workability and test method in accordance with BS 1881 (slump, compacting factor, Vebe or flow) shall be agreed with the Engineer prior to or during the trial mixes for each class of concrete and for each application of that class in the Works.

Bleeding shall not exceed 0.5% after 1 hour from completion of mixing nor 1.5% maximum when tested in accordance with ASTM C232 Method B.

Delete the following from Article 8.5.7.3 :

Samples for acceptance tests for each class ..... or once for each placement.

Replace with :

Samples of concrete for cylinder tests shall be taken from designed mixes at random as directed by the Engineer, generally at the following rates :

(a)	columns with less than 1.0m dimensions in any direction, long cantilevers; and other critical structures	One sample per $10m^3$ of concrete for each mix produced.
(b)	concrete to be post-tensioned at less than 28 days	Two samples per $50m^3$ of concrete for each mix produced.
(c)	other concrete	One sample per $50m^3$ of concrete for each mix produced.

At least one sample shall be made per day for each mix produced on that day.

Add new Article :

8.5.8 Comparative Testing of Superstructure Concrete for Shrinkage, Creep and Elastic Modulus

To demonstrate that the Contractor's proposed aggregates and curing regime will not lead to excessive deformations of the prestressed concrete superstructure, tests which compare the performance of the proposed mix with a control mix shall be carried out. Also the elastic modulus of concrete placed in a structure shall be compared with laboratory produced specimens. The Contractor shall propose detailed procedures for tests to be carried out in an approved independent laboratory, in conformance with the following outline procedure.

The control mix shall be designed within the Specification to achieve the same workability and strength as the Contractor's proposed mix. Aggregate for the control mix specimens shall be coarse and fine aggregate from uniform stone of proven low creep and shrinkage complying with Articles 8.3.3 and 8.3.4. The source of the aggregate for control specimens shall be proposed by the Contractor and be subject to approval by the Engineer. Cementitious materials, admixtures and water shall be from the same sources as the proposed mix. Strength tests shall be carried out on samples taken from the control mix as set out in Article 8.4.1.2. Compliance of the control mix shall be assessed on the same basis as for the trial mix.

The shrinkage tests shall be carried out generally in accordance with BS 1881: Part 5:1970, except where the following procedure deviates from the Standard. Three specimens shall be prepared and tested from both the control and trial mixes. Specimens shall be cured to a regime which simulates the specified curing regime for superstructure concrete. The shrinkage of the control mix and test mix shall be compared at an age of 14 days after curing.

For the creep test cylindrical specimens 150mm diameter by 400mm long shall be prepared. Six cylinders shall be prepared from the control mix and six from the trial mix. Specimens shall be cured under conditions which simulate the specified curing of superstructure concrete. Following the specified curing the specimens shall be kept under identical environmental conditions as the bridge deck elements throughout the test period. Three control mix and three trial mix specimens shall be loaded to a constant compressive stress of $10N/mm^2$ in a creep frame. Age of the specimens at loading shall be agreed with the Engineer as representative of the Contractors earliest proposed erection or longitudinal prestress loading of superstructure concrete. Shrinkage, elastic and creep length changes shall be measured along three 250mm gauge lines equally spaced at 120 degrees on the cylinder surface. The other three cylinders of each mix shall be used to determine the shrinkage adjustment. After adjustments for elastic and shrinkage strain, the creep strain of the control mix and the trial mix shall be compared at 28 days and 90 days after loading.

Three specimens from the mix considered most representative of the site superstructure concrete and three control specimens shall continue to be tested throughout the remaining period of the Contract, but in any case for at least a total of two years.

The criteria for acceptance of the relevant trial mix properties are given in Table 8.4.

Table 8.4 Comparative Test Criteria for Shrinkage, Creep and Elastic Modulus of Superstructure Concrete

Property	Performance of Trial Mix Versus Control Mix
Shrinkage, 14 days after end of curing	130% maximum
Creep, 28 days after loading	110% maximum
90 days after loading	110% maximum
Elastic Modulus :	
At time of first loading	95% minimum
At 28 days after first loading	95% minimum

To compare the elastic modulus of concrete cast in a structure with laboratory specimens, cores shall be cut from trial segments and tested. The cores shall be a minimum of 100mm diameter and their length shall be in proportion to the 150 mm diameter specimens such that scale effects and differences in platten friction can be properly taken into account. Three cores shall be cut from the trial segments 28 days after casting and loaded to a compressive stress of 10N/mm^2. The age of the concrete at loading and the rate of loading shall be the same as for the laboratory specimens above and the three cores shall be kept under identical environmental conditions as those specimens. The elastic modulus shall be calculated and compared with the values for the laboratory specimens.

Add new Article :

8.5.9 Acceptance Criteria

Concrete shall be considered non-compliant with the Specification if the following criteria are not met:

(a) Water-cement ratio

Where assessment is by observation of the batching or by autographic records, the water-cement ratio shall be not more than 105% of the required value: where assessment is by analysis tests on fresh concrete, the water-cement ratio shall be not more than 110% of the required value, the quantity of concrete considered not to comply is as defined in respect of cube strength.

(b) Cement Content

Where assessment is by observation of the batching or from autographic records the cement content shall be not less than 95% nor more than 105% of the required amount: where assessment is by analysis tests on fresh concrete, 90% and 110% respectively; the quantity of concrete considered not to comply shall be as defined in respect of cube strength;

(c) Workability

Workability of the fresh concrete shall be such that the concrete is suitable for the

conditions of handling and placing as described in Article 8.7 so that after compaction as described in Article 8.7.4 it surrounds all reinforcement, tendons and ducts and completely fills the formwork.

Workability shall be measured for each batch or at such times as directed by the Engineer using one of the following tests in accordance with BS 1881, and shall be within the following limits of the required values:

(i) Slump test : ± 25mm or ±1/3 of the required value whichever is greater

or

(ii) Compacting Factor ± 0.03, where required value is 0.90 or greater

± 0.04, where required value is between 0.80 and 0.90.

± 0.05 where required value is 0.80 or less.

(d) Temperature

Temperature of fresh concrete at deposition (measured by a type A 110mm immersion thermometer complying with BS 1704 graduated at each 1°C over a range from – 5°C to + 110°C, inserted in a sample within 2 minutes of sampling and recorded 1 minute after reaching a stable temperature) shall be not more than 27°C.

Replace the last paragraph of Article 8.6.1 with :

The temperature of the concrete mix immediately before placement shall be between 10°C and 32°C

Replace the whole of Article 8.6.3 with :

8.6.3 Hot Weather Protection

Concreting shall not be carried out when the shade air temperature rises above 43°C or if the temperature of the fresh concrete rises above 32°C during placing or within 5 minutes of placing.

During periods of hot weather when the shade air temperature rises above 32°C, special precautions shall be taken to prevent a similar rise in temperature of the concrete mix, i.e. by shading aggregate. painting mixer surfaces and pipes white or yellow, chilling the mixing water and liquid nitrogen injection. If ice is added to the mix it shall be well crushed or obtained from a flake ice machine Care shall be taken to ensure that all the ice has completely melted by the time mixing has been completed. Reinforcement and shuttering shall be cooled by shading from direct rays of the sun and spraying the shuttering with clean fresh water, care being taken to remove surplus water before commencing concreting.

Delete the following from Article 8.7.5.1 :

It other than class S concrete is

Replace with :

If other than clauses U15/20 and U15/40 clause is :

Add new Article :

8.7.6 Concreting of Large Pours

For pier and abutment pile caps, and large pours in excess of 100 m^3 the following shall apply

a) The maximum temperature of the concrete during curing shall not exceed 70°C

b) The method of curing used shall minimise temperature gradients and differences within the concrete pour and the concrete adjacent to it, and across construction joints. Unless approved, no temperature gradient shall be allowed to exceed 15°C in a distance of 1 metre and the maximum temperature between two parts of the same pour (except vertical temperature differences in slipformed concrete) shall not be allowed to exceed 20°C.

c) Details of methods of protection, curing and temperature monitoring / control shall be subject to the consent of the Engineer. The details shall be accompanied by supporting calculations of estimated maximum temperatures, temperature gradients and resulting stresses. These calculations shall be based upon temperatures measured during tests and/or elsewhere in the Works.

Add new Article :

8.8.5 Joints in Underwater Concrete

Under water concrete shall be placed in accordance with Article 8.7.5. If, for any reason, concreting is interrupted while placing under water concrete then the Contractor shall (as soon as possible after the concrete has set) remove all laitance and disturbed concrete from the surface of the set concrete and thoroughly clean the surface of all loose material and remove all the resulting debris before recommencing concreting. Concreting shall not be re-commenced until the Engineer has given his written approval. Vertical stop ends of approved design may be provided in underwater concrete They shall be constructed of reinforced concrete planks incorporating horizontal shear keys and shall be left permanently in position. They shall be held securely in position by a steel or reinforced concrete framework which may also be cast into the concrete, subject to the Engineer s consent.

Delete last paragraph from Article 8.11.3.5 :

Unless the ambient temperature .....

Replace with :

After attaining the desired strength, the temperature within the curing enclosure shall be decreased at an average rate not exceeding 40°F (22°C) per hour until the inside temperature is within 20°F (11°C) of the outside ambient temperature. The curing enclosure shall be of such size as to totally enclose both the segment against which casting is being carried out, the segment being cast and any rigid appendages thereto.

Replace the whole of Article 8.12 with :

8.12 Finishing Formed Concrete Surfaces

8.12. 1 Classes of Concrete Finish - Formed Surfaces

The requirements over and above those given in Article 3.2.3 to provide the class of finish described in the Contract shall be:

Class Fl: Nil. Except that where a protective membrane or a waterproofing membrane is to be applied to the concrete, any sharp fins or other excrescences which might damage the membrane, shall be removed.

Class F2: The irregularities in the finish shall be no greater than those obtained from the use of 2.4m x 1.2m 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 discolouration shall, if required, be made good by methods approved by the Engineer.

Class F3: 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 one structure. The Contractor shall make good any imperfections in the finish as required by the Engineer. Internal ties and embedded metal parts shall not be allowed.

Class F4: The requirements for Class F4 are as for Class F3 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 positions as described in the Contract or in other positions agreed by the Engineer.

Unless otherwise described in the Contract, all formwork joints for exposed surfaces of concrete to Class F3 and F4 finish shall form a regular pattern with horizontal and vertical lines continuous throughout each structure and all construction joints where permitted shall coincide with these horizontal or vertical lines.

The Contractor shall ensure that permanently exposed concrete surfaces to Class F4 and F3 finish are protected from rust marks, spillage and stains of all kinds.

The classes of formed concrete finish to be provided in the Works shall be as shown on the approved Working Drawings or as directed by the Engineer. Where the Drawings do not show the Class of finish to be provided the following shall, subject to the Engineer's consent, be used :

Buried and other hidden surfaces, faces of expansion joints incorporating joint filler	F1

Surfaces which are not visible, faces of joints	F2
Exposed surfaces of parapets	F3
Visible surfaces of walls, exposed surfaces of piers and abutments, visible outside surface of bridge deck except parapets	F4

8.12.2 Classes of Finish - Unformed Surfaces

The requirements for the class of finish to unformed concrete surfaces shall be:

Class U1 The concrete shall be uniformly leveled and screeded in an approved manner by means of a steel-shod screed to produce a plain, textured or ridged surface as described in the Contract and dense finish. Care shall be taken to ensure that the surface of the concrete is properly closed. No further work shall be applied to the surface unless it is used as the first stage for Class U2 or Class U3 finish.

Class U2: After the concrete has hardened sufficiently, the concrete Class U1 surface shall be floated by hand or machine sufficiently only to produce a uniform surface free from screed marks.

Class U3: When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, a Class U1 surface shall be lightly steel-troweled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

The classes of unformed concrete finish to be provided in the Works shall be as shown on the Drawings or directed by the Engineer. Where the Drawings do not show the Class of finish to be provided, the following shall be used, subject to the Engineer's consent.

Bridge deck and substructure footings	U2
Surfaces other than those classed as U3 or U1	U2
Upper concrete surfaces of parapet plinths, bearing shelves and tops of bearing plintlis	U3

8.12.3 Trial Panels for Class F3 and Class F4 Surface Finishes

Trial panels shall be cast by the Contractor to set the standard for the classes of finish F3 and F4. The trial panels prepared under Article 8.4. 1.2 to check the mix design may also be used for formwork finish trial panels. The minimum size of panels shall be 3m x 2m and shall contain both horizontal and vertical joints between facing sheets. The trial panels shall be constructed for approval before commencement of the parts of the Works incorporating those finishes. A trial panel shall be constructed using the approved mix for each of the classes of concrete for which the class of formwork is intended.

Where, in the opinion of the Engineer, the finished concrete of a trial panel fails to requirements of the Specification, the panel shall be rebuilt and the trial repeated as necessary until the Engineer's approval is given. Approved panels shall be retained as the standard for the class of finish exhibited by the panel.

The Contractor shall dispose of the trial panels off site when they are no longer required, as agreed with the Engineer.

Add new Article :

8.13.8 Counter - Cast Segmental Construction Using the Balanced Cantilever Erection Technique

8.13.8.1 General

Precasting and erection of deck segments including concrete, concrete ancillaries and prestressing shall comply with applicable provisions in the Specification except as expressly modified or revised in this Article.

8.13.8.2 Shop Drawings and Design Calculations for Construction procedures

8.13.8.2.1 General

Sufficiently in advance of the start of superstructure field construction operations, so as to allow the Engineer not less than a 90-calendar day review period, the Contractor shall submit according to a schedule complete details and information concerning the method, materials, equipment and procedures the Contractor proposes to use in constructing that portion of the super-structure for which the information is furnished. This submittal shall include a step-by-step erection procedure

The Contractor's submittal for approval shall include calculations, drawings and information outlined in Article 8.13.8.2.2 and 8.13.8.2.3. Two sets of all required drawings and calculations shall be submitted and resubmitted if and as necessary until approved by the Engineer. The specified number of distribution copies shall be furnished after approval.

8.13.8.2.2 Design Calculations for Construction Procedure

Design calculations shall be submitted for falsework, erection devices; formwork or other temporary construction which may be required and which will be subject to calculated stresses. The calculation shall include an erection analysis for all stages of construction demonstrating that the stresses and strength at critical sections in the permanent structure meet the allowable stress and strength provisions. Use of additional non-prestressed reinforcement for construction stage will be permitted All extra materials required for construction stages shall be provided by the Contractor at no cost Design shall be in accordance with the provisions of AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges, 1989 and as subsequently amended.

In addition to the above, calculations shall be submitted for approval for the following:

(1) Calculation of deflections and required camber due to dead loads, post-tensioning forces. creep and shrinkage. A tabulation of deflections and camber dimensions shall be included on the shop drawings.

(2) Calculation of jacking forces required at joints during temporary post-tensioning

8.13.8.2.3 Shop Drawings

The Contractor shall submit detailed shop drawings for approval in accordance construction special provisions. The shop drawings shall include but not necessarily be limited to the following information.

(1) Fully and accurately dimensioned views showing the geometry of the segments including all projections, recesses, notches, openings, blockouts and other pertinent details.

(2) Details of nonprestressed steel reinforcement shall be clearly shown as to size, spacing and location including any special reinforcement required but not shown on the plans.

(3) Composite placing drawings to scale and in sufficient detail to show the relative positions of all items that are to be embedded in the concrete, and their embedment depth, for the portions of the structure that are to be prestressed. Such embedded items include the prestressing ducts, vents, anchorage reinforcement and hardware, reinforcing steel anchor bolts, earthquake restrainers, deck joint seal assemblies, drainage systems, utility conduits and other such items. Such drawings shall be adequate to ensure that there will be no conflict between the planned positions of any embedded items, and that the concrete cover will adequate. If during the preparation of such drawings conflicts are discovered, the Contractor shall revise the working drawing for one or more of the embedded items or propose changes in the dimensions of the work as necessary to eliminate the conflicts or provide proper cover. Such revisions shall be reviewed by the Engineer before work on any affected item is started.

All costs involved with the preparation of such drawings and with making the necessary modifications to the work resulting therefrom shall be borne by the Contractor.

(4) Prestressing detail shall include sizes and properties of tendons, anchorages. plates assemblies and stressing equipment as well as details of the stressing procedure and stressing sequence, details and locations of all couplers, and additional reinforcement necessary to resist anchor block stresses.

(5) Details of tie down tendons, and temporary and permanent bearing assemblies as required.

(6) Details of grouting equipment, grout mix design, and method of mixing and placing grout shall be provided.

8.13.8.3 Method Statement Casting and Erection Manuals

The Contractor shall provide for the Engineer's prior approval detailed method statements in the form of casting and erection manuals of his proposed method of segment manufacture and erection. This statements shall include, but not be limited to, the following :

A. Casting Manual

The proposed methods of geometry controls for both the casting and erection operations. This

submittal shall be in the form of a "Casting Manual" and shall include, but not be limited to, a derailed narrative of the geometry control theory, a detailed narrative of the step by step geometry control procedure, detailed calculation forms, and a set of sample calculations. This submittal shall include all measuring equipment, procedures, locations of control points to be established on each segment, and qualification' of personnel who will earn out geometry control.

The casting manual shall cover all geometry control operations necessary for casting and shall be in agreement with the Contractor's chosen methods of casting and erection, including erection elevations, and alignment control. Casting shall not commerce without Engineer's review of the geometry control methods and return of the submittal with permission to proceed.

The casting manual shall also include the following :

a) programme for manufacture of segments;

b) details of the layout of casting yard;

c) schedule of equipment to be used in casting yard;

d) approved Working Drawings of formwork system and full details of the methods which the Contractor proposes to use to avoid deformations and settlements of the formwork and to avoid displacement of inserts and block-outs during casting;

e) methods of ensuring correct alignment and dimensional accuracy during manufacture and erection of the units;

f) details of equipment and method of separating counter-cast segments;

g) method of protecting materials, casting operations, freshly cast segments and jointing operations from adverse effects of weather;

h) method of curing;

i) stripping, identification, handling, storage and preparation of joint surfaces in casting yard:

j) A casting curve prepared in accordance with the actual material properties, casting and erection dates, erection sequence, loads, and construction schedule proposed by the Contractor shall be furnished by the Contractor to the Engineer for review. The casting curve shall be of sufficient accuracy to allow the determination of control point settings for accurately casting the segments. The preparation of the casting curve shall recognize all deviations from a straight line and shall include all deviations associated with the required alignment and deformations due to dead load, future superimposed dead loads, erections loads, post-tensioning stresses, secondary moments, creep, and shrinkage at days 10,000.

B. Erection Manual

Special handling and erection equipment will be required to incorporate the segments into the

structure. The Contract Drawing details show schematic methods for handling and erecting segments; these details are not working drawings but are provided for information only The Contractor shall submit for review by the Engineer an "Erection Manual" incorporating the proposed erection method with details and appropriate calculations showing the equipment and construction load analysis for each erection stage of the various components including method and details for lifting and supporting segments during storage and transport. All handling and erection equipment proposed for use shall be consistent with the concept shown on the schematic erection plans in order to assure compatibility with the overall design.

The erection manual shall include the following :

a) transporting segments to the bridge;

b) lifting and positioning segments for jointing;

c) jointing method and materials;

d) temporary and permanent prestressing;

e) grouting of tendon ducts;

f) span closure method;

g) supporting calculations;

h) proposed quality control procedures and documentation.

i) Erection elevations for cantilever erection shall be computed for each stage of erection taking into account the as-cast profile and the calculated deflection for each stage of erection.

Prior to casting any permanent segments the Contractor shall cast four trial segments to demonstrate the adequacy of his proposed methods of manufacture, handling, jointing and prestressing in accordance with Article 8.13.8.7.

The superstructure shall be erected by the method designed and detailed on the approved Working Drawings. No segments shall be erected without the consent of the Engineer.

8.13.8.4 Experienced and Trained Personnel

To ensure consistent high quality, the Contractor shall employ only qualified engineers and supervisory personnel experienced in the techniques of segmental bridge construction to superintend these works.

The Contractor shall submit to the Engineer full details of the experience and qualifications of the personnel he proposes to superintend these works together with descriptions of their duties, down to foreman level.

Supervisory staff shall be able to communicate clearly in the English language and with their local counterparts and operatives. The Contractor shall provide special practical training to his local staff prior to manufacture of segments for the permanent works. This training shall

be deemed part of the Contractor's obligations under the contract and included in his price for the works.

8.13.8.5 Manufacture of Counter-cast Precast Deck Segments

8.13.8.5.1 General

After the first segment of each unit is cast, all succeeding segments shall be cast against previously cast segments to ensure complete bearing and proper alignment on all mating surfaces. Segments may be produced using either the long-line or short-line technique.

The anchorage system shall permit tendons to be inserted in the member after erection segments. Tendon couplers shall only be used at locations specifically shown on the approved Working Drawings. Not more than 50% of the tendons shall be coupled at any one section.

8.13.8.5.2 Protection from Weather

Special provision shall be made to protect concreting operations and freshly concreted segments from all effects of the weather including wind, rain, hail and direct sunlight to the satisfaction of the Engineer to prevent damage to the finished concrete unit.

8.13.8.5.3 Control of Segment Geometry

Special care shall be taken in the manufacture of counter-cast deck segments to avoid the variations in deformation which may arise from accelerated curing and/or transverse prestressmg.

If accelerated curing is employed, both the previous unit and the newly cast unit shall be cured together (see Article 8.13.8.5.5(g)).

Moulds shall be set up to achieve accurately the required vertical and horizontal alignment in the finished bridge.

For the short-line system, each segment shall be surveyed after casting, and if required, minor adjustments shall be made when setting up the mould for the next segment to compensate for any error. Levels and horizontal alignment shall be measured to an accuracy of $\pm$ 0.25mm. The Contractor shall allow for independent survey measurements by the Engineer before segments are moved from their casting position. Computed coordinates of all segments cast shall be completed before casting a new segment. In addition to the computed as-built casting curves for vertical and horizontal deflections, a cumulative twist curve shall be computed using the measured cross-slopes of the individual units as a check on the extrapolated deflections. The source of any twist errors shall be identified and corrected to the satisfaction of the Engineer before continuing with match cast operation.

For the long-line system surveying of levels and alignment shall be provided to an accuracy of $\pm$2.0mm.

Dimensional tolerances within each segment shall be as set out in Article 8,13.8.6.

8.13.8.5.4 Formwork

Formwork, together with its supports and foundations, shall be designed and maintained to safely support all applied loads with strictly limited deformations or settlements, such that segments produced are within the tolerances specified in Article 8.13.8.6.

All side, bottom, inside and end forms shall be constructed of steel, unless use of other materials is approved by the Engineer. Timber forms may be used for in-situ closure pours after cantilever erection.

All elements of formwork must be robust and able to be struck wthout damage to the concrete. Special consideration shall be given to detailing those parts of the formwork which have variable dimensions so that adjustments can be carried out and to those parts around anchorage blisters, other protrusions and block-outs, to permit easy stripping.

All form surfaces, especially welded joints in contact with the concrete, must be perfectly smooth and free from re-entrant areas, pitting or other discontinuities. To ensure a tight durable surface finish and to avoid discolouration, forms shall be free from rust, grease or other deleterious materials.

Fixings to locate post-tensioning tendon ducts, anchorages and other inserts in position during concreting shall be so designed that these components remain rigidly in position during casting.

Suitable seals shall be provided at formwork joints to prevent leakage of cement paste. Special measures shall be taken to prevent leakage at the joint face with the matching segment and to prevent grout ingress into prestressing ducts.

If accelerated curing is to be used, with temperatures in excess of $55^{0}C$, then effects of the heating and cooling cycles on formwork deformation shall be considered and measures taken so that cracks in concrete due to thermal deformation are prevented.

Whether or not accelerated curing is used, measures shall be taken to avoid the lack of fit which would result from horizontal curvature induced by longitudinal thermal gradients.

8.13.8.5.5 Casting and Curing

a) Preparation of Forms:

All forms shall be cleaned thoroughly prior to each casting operation, with special attention being paid to maintenance of the end form to provide a smooth casting surface.

The faces of all forms, other than the end form and the face of the match segment, shall be treated with shutter release oil prior to concreting.

The bond breaker between counter-cast segments and between the end form and the concrete shall be flax soap and talc or other material approved by the Engineer. The material shall not be detrimental to the concrete and shall permit separation of segments or form and segment without damage due to adhesion.

b) Fixing of Reinforcement:

Reinforcement shall be cut, bent, fabricated and fixed according to the approved Working Drawings and Section 9. Any conflict or interference with the proper location of ducts and/or block-outs shall be drawn to the attention of the Engineer and corrections made to the approval of or as directed by the Engineer. No reinforcement shall be cut to permit proper alignment of prestress ducts. Any bar that cannot be fabricated to clear prestress ducts shall be replaced by additional bars with adequate lap lengths, details of which shall be submitted to the Engineer for prior approval.

c) Fixing of Tendon Ducts and Other Inserts:

Tendon ducts shall be positioned and aligned so as to provide straight runs or smooth curves in the positions shown on the approved Working Drawings. Care shall be taken to ensure smooth duct transitions from unit to unit. Removable polyurethane liners of external diameter approximately 5mm less than duct internal diameter shall be used to stiffen tendon ducts over the full length of a new segment and shall project a minimum of 500mm into the ducts of the match forming segment. Ducts shall be continuous without joints within each segment.

Ducts, anchorages, grout bleed tubes and all other inserts in the concrete article shall be rigidly fixed in position to prevent displacement during concreting. Ducts for longitudinal or transverse post-tensioning in the flanges shall be tied firmly in position to the reinforcement cage at intervals not exceeding 600mm. Longitudinal post-tensioning ducts in the webs shall be tied to stirrups at intervals not exceeding 1.0m.

High point grout vent tubes shall be provided at all crests in tendon ducts and intermediate points as shown on the approved Working Drawings.

d) Identification of Segments, Tendon Locations and Vent Tubes:

All segments shall be marked clearly and indelibly on the inside with a unique identification at the time of form removal. This identification shall be used to identify each segment on approved Working Drawings, post-tensioning details, calculations and any other document pertaining to the fabrication and erection of the precast segments.

Similarly, tendon identification shall be clearly and indelibly marked with unique tendon reference numbers on or adjacent to the tendon anchorages. In the case of tendons anchored on a counter-cast end face of a segment, the tendon reference number shall be marked on the inside face of the web as near to the anchorage as possible.

Grout vent tubes must be clearly and securely tagged or otherwise marked with their tendon reference numbers, such that they can be checked during grouting.

e) Stripping of Forms:

Before stripping the forms or moving the segment while resting on its soffit form in the casting bed, the concrete shall have a minimum compressive strength of $20N/mm^2$, assessed on the basis of test cylinders cured under the same regime as the segment. The

Contractor shall submit calculations to support the minimum concrete strength required for transverse Prestressing for the Prestressing system proposed and by picking of the segments, however the segment shall not be lifted until the concrete has attained a minimum compressive strength, of not less than 25N/mm^2.

Particular care shall be taken to avoid damage when removing the end form from the face which then becomes the mating surface with the next segment. Any remedial measures which affect the end face must have been completed before counter-casting takes place.

f) Separation of Counter-cast Segments:

The Contractor shall provide equipment to be used for uniform separation of counter-cast segments without damage. Details of the equipment as well as the proposed method of operation shall be included in the method statement. Particular care shall be exercised when separating segments to avoid damage to the mating surfaces.

g) Curing:

Curing of freshly cast segments shall be generally in accordance with Article 8.11. Any disturbance to the curing regime which may occur during transporting the segment to the storage area shall be immediately rectified.

Accelerated curing of concrete with low pressure steam or radiant heat shall be in accordance with Article 8.11.3.5.

8.13.8.5.6 Handling and Storage

The Contractor shall submit to the Engineer for prior approval his detailed proposals for handling, lifting, storing, transporting and erection of all segments so that they may be placed in the structure without damage.

Segments shall not be moved from the casting bed until the concrete has attained the required strength for lifting but not less than 25N/mm^2 and shall not be moved from the casting yard until completion of the specified curing regime.

Lifting hooks or other special inserts for lifting must be located carefully to avoid excessive stresses in the deck unit. Details of these devices must be shown on the approved Working Drawings and segments shall be lifted, hoisted or stored using only these approved devices. After erection in the segment's final position any cast-in lifting devices shall be removed to a minimum depth of 55mm below the concrete surface, taking care to keep the disruption to surrounding concrete to a minimum, and the recess filled wit mortar of at least equal strength as the concrete and colour matched to the concrete.

Segments shall be maintained in an upright position at all times and shall be stored, lifted and/or moved in a manner to prevent torsion and other undue stress. In the storage area they shall be evenly supported on a stabilized base on hardwood packers located under the webs, such that the unit is at least 300mm clear of the ground. Temporary supports shall be designed to avoid any distortion of the box units during storage.

Inserts, anchorages and other embedded items must be protected from corrosion. Tendon ducts should be temporarily plugged or capped to prevent ingress of water during storage. Before transporting segments to the erection site, the tendon ducts shall be checked to ensure they are free from water and cleared of all obstructions.

8.13.8.5.7 Preparahon of Joint Surfaces in the Yard

No earlier than 2 days before a segment is to be joined with epoxy resin in the permanent works, surface preparation shall be carried out as follows :

Contract surfaces are to be careffilly lightly grit or water blasted to remove all traces of debonding agent and laitance evenly to a depth of approximately 0.5mm amplitude. Care shall be exercised to avoid excessive etching of the mating surfaces, and the degree of blasting shall be detemimed by trials on precast panels 400x400xl50mm thick of the same concrete as the deck segments. A panel selected by the Engineer as being representative of the standard of surface treatment required shall be kept protected from damage near the site of blasting for use as reference by the blasting operator. A second identical panel shall be kept by the Engineer.

8.13.8.6 Segment Manufacturing Tolerances

8.13.8.6.1 Reinforcement

Reinforcement shall be fabricated and secured against displacement in the forms such that the actual concrete cover shall be not less than the nominal cover minus 5mm. Cover may be greater than the nominal cover by up to 8mm. Provided the total number of bars is maintained, the tolerance in spacing shall be ± 25mm except at openings, inserts, embedded items, etc., where the exact details shall be as agreed with the Engineer.

8.13.8.6.2 Prestressing Ducts and Anchorages

Tendon ducts shall be located and maintained in position both vertically and horizontally as shown on the approved Working Drawings. The tolerance in the location of the center line of ducts and anchorages shall be ± 5mm.

8.13.8.6.3 Completed Segments

Precast segments shall be manufactured within the following tolerances:

Length of counter-cast segment	± l0mm/m (not cumulative)
Web thickness	± 10mm
Top slab thickness	± 10mm
Bottom slab thickness	± 10mm
Overall depth of segment	± 10mm
Overall top slab width	± 20mm
Diaphragm thickness	± 10mm
Longitudinal slope of soffit	± l mm/m
Transverse slope of soffit at end form	± 1mm/m
Tendon hole location at end form	± 3m
Position of shear keys on end form	± 5mm

Dimensions from segment to segment shall be adjusted to compensate for any deviations within a single segment so that the overall alignment of the completed structure will conform to the dimensions shown on the approved Working Drawings. However, adjustments shall always result in segment dimensions and alignment within their above tolerances.

8.13.8.7 Trial Segments and Pier Top

Prior to casting any permanent works segments, the Contractor shall cast four trial segments and the top two metres of a pier to demonstrate the proposed techniques for manufacture, and erection. The four trial segments shall be two pier segments and their adjacent segments. The pier top shall be cast on a stable base in the casting yard.

The four segments shall be identical in every way to segments shown on the approved Working Drawings, complete with all inserts including bearings, earthquake restrainer, temporary stabilizing devices, prestressing ducts, reinforcement, access openings in soffit, etc. The pier top shall have similar reinforcement to the detail on the approved Working Drawing, including bearings, earthquake restrainer, temporary stabilising devices, etc.

As far as possible the trial assembly shall simulate the production and erection of permanent segments. Hence the proposed workforce shall use this opportunity to develop their procedures and skills, the proposed concrete mix shall be produced using the works batching plant and all manufacturing and erection steps as set out in the approved method statement will be followed as closely as possible.

The trial procedures shall be carefully monitored and all defects and shortcomings found during the trial production and erection process shall be carefully noted on the spot. Where defects and shortcomings have been noted, the Contractor shall present in writing to the Engineer his proposed modified method of working to comply with the Specification. If in the opinion solely of the Engineer, either the trial is unsatisfactory or the revised proposal so warrants, then the trial procedure shall be repeated until completed to the satisfaction of the Engineer. No production of permanent segments shall commence until the Engineer has given approval following a satisfactory trial.

8. 13.8.8 Handling, Transportation and Erection of Segments

8.13.8.8.1 General

The Contractor shall include in the submission required in Article 8.13.8.3 above, deflection and camber data for each stage of construction in order to construct the structure to the required final line and level. The procedure shall take proper account of both elastic and time dependent deformations and prestress losses, based on the Contractor's proposed erection sequence, method and programme.

The vertical and horizontal alignment of the structure will be monitored by the Contractor at each stage, and corrective actions as approved by the Engineer shall be taken to provide the required final alignment.

8.13.8.8.2 Handling / Erection Equipment

Segments shall be handled in a manner that limits stresses to values compatible with the strength and age of the concrete. Particular care shall be taken to limit dynamic effects during

lifting and transporting segments. Segments shall not be erected until they are at least 28 days old to limit shrinkage and creep effects.

Lifting and placing equipment shall have an adequate factor of safety and suitably reduced Lifting speed so that safety and control of operations is assured at all times. The equipment should be certified by a recognized certifying authority, and copies of certification forwarded to the Engineer before the equipment is brought on site.

Prior to use any equipment fabricated for the specific purpose of erecting any portion of the Work included in this Contract, the Contractor shall demonstrate by a full scale Load test that this equipment is adequate for its intended use on this project. The Contractor shall submit the proposed load testing program for review and provide advance notice to the Engineer to allow witnessing of the load test.

Observation of load testing of erection trusses or erection equipment or review of design drawings and calculations covering erection trusses or erection equipment by the Engineer shall not be construed as an assumption by the Engineer of responsibility for means, methods, techniques, sequences, or procedures of construction, or for safety precautions or a safety program. The Contractor shall shade the interfaces from direct sunlight, rain and run off water for at least one hour before the epoxy resin is applied and until after the designated prestress load has been applied.

8.13.8.8.3 Joining of Segments

Immediately before applying the bonding agent, the concrete surface to be bonded shall be thoroughly cleaned to remove all traces of dirt, grease or oil. Dust is to be removed using a stiff brush.

Measures shall be taken to prevent rain falling on, or being driven onto, the mating concrete surfaces immediately prior to jointing. At the time of application of the epoxy bonding agent surfaces to be bonded must have no free moisture on them. Free moisture is considered to be present if a rag wiped over the surface gathers any dampness.

813.8.8.4 Alignment Control and Erection Tolerances

The Contractor shall submit to the Engineer for prior approval a geometric control plan which shall indicate in detail how the monitoring survey is to be performed and the proposed actions to assure the required final alignment. The control plan shall provide for regular monitoring of super structure deflections beginning with the addition of the first segments and concluding with the last segments.

Proposed adjustment procedures shall be submitted for the Engineer's prior approval for use if the superstructure should deviate from the predicted vertical or horizontal alignment by more than 25mm. Such adjustments should be by use of a system of hydraulic jacks at the pier which permit horizontal and vertical rotation of the cantilevers.

The Contractor shall check the elevations and alignment of the structure at every stage of construction and must maintain a record of all these checks and of all adjustments and corrections made. All surveying shall be performed at a time which minimises the influence of temperature.

Safe access and working platforms shall be provided for the Engineer's staff to carry out independent survey checks and opportunity as required by the Engineer shall be afforded to carry out such checks.

After erection, final post-tensioning, final corrections and adjustments are completed and the structure has been placed on its permanent bearings, the superstructure shall conform to the horizontal and vertical profiles shown on the approved Working Drawings within the tolerances specified on those approved Working Drawings.

8.13.8.8.5 Epoxy Jointing

The Contractor shall engage and maintain a team of experienced personnel for the fixing and application of the adhesive. This team shall be supervised by a suitably qualified engineer / technician experienced in the use of epoxy bonding of segmental bridges.

Joint surfaces and surface preparation shall be as required in Articles 8.13.8.5.7 and 8.13.8.8.3 above,

Mixing and installation of epoxy shall be as required by Article 8.13.7.2

Temporary prestress combined with other load effects shall provide a minimum compression across the joint during setting of 0.25 N/mm^2.

Following the application of temporary prestress, surplus adhesive extruded from the joint shall be removed without staining or smearing the concrete. During this operation, the chase across the segment joint on the top of the deck slab shall be completely filled with adhesive and finished flush with the surface of the segments to provide a smooth watertight seal. Tendon ducts shall be cleared of any adhesive by drawing a suitably sized mandrel through the duct. The mandrel shall be drawn through again approximately half an hour after the initial clearing.

8.13.8.8.6 Temporary Prestress

When temporary external tendons are required as shown on the approved Working Drawings, the tendons and anchorages shall be in a protective enclosure. This enclosure shall be capable of protecting the tendons from damage by erection equipment and of confining a strand or bar tendon that fails rapidly during or after tensioning and anchoring. Details of the temporary prestress, together with its protective enclosure, shall be submitted to the Engineer for prior approval.

8.13.8.8.7 Permanent Prestress

Permanent prestress shall be as shown on the approved Working Drawings. The Contractor shall provide qualified personnel skilled in prestressing systems to superintend the work and give the Engineer such information as he may require for inspecting the work. Such personnel shall be available full-time on all days when stressing or grouting are being carried out.

A record of gauge pressures, load cell readings and tendon elongations for each tendon shall be provided by the Contractor for review and prior approval by the Engineer. Stressing tails of tendons shall not be cut off until the stressing records have been approved.

8.13.8.8.8 Grouting

Grouting shall be in accordance with Article 10.11. Grouting sequence and times shall be as shown on the approved Working Drawings. Where grouting is delayed until the entire cantilever is stressed, precautions shall be taken to prohibit foreign material entering the ducts and to prevent corrosion of the prestressing steel. Corrosion protection of tendons prior to grouting shall be in accordance with Article 10.6.

SECTION 9
REINFORCING STEEL

Replace the first three paragraphs of Article 9.4.1 with the following :

9.4.1 Bending

Bar reinforcement shall be cut and bent to the shapes shown on the approved working drawings including bending diagrams. Fabrication shall be in accordance with ACI 315. Bars partially embedded in concrete shall not be field bent except as shown on the plans or as directed by the Engineer.

The weight of reinforcing bars will be computed using the following weights.

Bar Size	Weight Kg/m
8	0.3 95
10	0.6 17
12	0.888
13	1.042
16	1.578
19	2.226
20	2.466
22	2.984
25	3.853
28	4.834
29	5.185
32	6.3 13

The weight of reinforcing wire, welded wire fabric and plain bars of sizes other than those listed above, will be computed from tables of weights published by CRSI or computed using nominal dimensions and an assumed unitweight of 0.00785 kilogams per square millimeter. If the weight per square meter of welded wire fabric is given on the plans, that weight will be used.