8.28 Drainage Holes and Weep Holes in Concrete

Drainage holes and weep holes shall be constructed in the manner and at the locations indicated on the Drawings or required by the Engineer. Ports or vents for equalizing hydrostatic pressure shall be placed below low water.

Forms for weep holes through concrete shall be PVC pipe. Exposed surfaces of weep drain pipe shall be flush with the concrete.

8.29 Pipe, Conduits and Ducts in Concrete

Pipes, conduits, and ducts that are to be encased in concrete shall be installed by the Contractor before the concrete is placed. Unless otherwise indicated, pipe embedded in concrete shall be standard, light-weight, non-corrosive pipes. Pipes shall be held or braced rigidly during concrete placement in order to prevent their displacement.

8.30 Loads to Piers and Abutments

No superstructure load shall be placed upon finished bents, piers, or abutments until the Engineer so directs, but the minimum time allowed for the hardening of concrete in the substructure before any load of the superstructure is placed thereon shall be 7 days when normal Portland cement is used.

8.31 Placement of Concrete in Hot Weather

Concrete shall not be placed in the Works if the air temperature in the shade measured one metre above ground level is above 35°C. Steel formwork, reinforcing steel and any other steel surface that comes in contact with the concrete shall be cooled to 35°C before the concrete is placed.

The temperature of concrete placed in the Works, measured immediately prior to placing, shall not exceed 32°C.

Concrete placing shall not be commenced in conditions where the rate of evaporation at the site of the concrete pour, as determined from Figure 1 (attached at the end of this Part of the Specification) exceeds 1.0 kg/m^2/hour, one hour prior to the batching of the first load of concrete. If the rate of evaporation rises to above 0.75 kg/m^2/hr during the progress of a concrete pour, suitable measures shall be taken to prevent excessive moisture loss which may include:

- The form shall be continuously sprayed with cold water (conforming to the requirements of Clause 8.11.3 of this Specification) in advance of the concreting and excess water shall be removed from the inside of the forms immediately prior to the placement of concrete.
- The reinforcement, and the formwork if metal forms are used, shall be protected from the effects of hot winds and direct sunlight.
- Suitable barriers shall be provided to protect the freshly placed concrete from wind, until curing commenced.
- Shading of aggregate stockpiles.
- Shading of the container/pipeline in which the concrete is transported to the forms.

- Olephatic Alcohol (MBT or similar) as an additive to reduce surface drying before setting of plastic concrete.

8.32 Placement of Concrete in Wet Weather

Concrete shall not be placed during rain or when the Engineer considers that rain is imminent.

Suitable equipment shall be provided at the concreting site to allow finishing and curing operations to be completed should rain interrupt placing of concrete. Provision shall also be made for the full protection of sections of concrete recently poured. The equipment shall be kept on site and be capable of being fully operational at short notice. Equipment which causes damage to the concrete shall not be used.

Concrete affected by rain shall be removed and replaced with sound concrete at the Contractor's cost.

8.33 Curing Concrete Generally

Immediately after forms have been removed and finishing completed, all concrete shall be cured by one of the following methods. The Engineer will specify the concrete surface which may be cured by either method.

8.33.1 Curing Concrete using Water Method

The entire exposed surfaces other than slabs shall be protected from the sun and the whole structure shall be covered with wet burlap, cotton mats, or other suitable fabric for a period of at least seven days. These materials shall be kept thoroughly wet for the entire curing period. Curbs, walls, and other surfaces requiring a rubbed finish may have the covering temporarily removed for finishing, but the covering must be restored as soon as possible. All concrete slabs shall be covered as soon as possible with sand, earth or other suitable material and kept thoroughly wet for at least seven days. This covering material shall not be cleared from the surface of the concrete slabs for a period of twenty one days.

If wood forms are allowed to remain in place during the curing period, they shall be kept moist at all times to prevent them from shrinking.

8.33.2 Curing Concrete using Membrane Forming Curing Compound

All surfaces shall be given the required surface finish prior to application of the compound. During the finishing period, the concrete shall be protected by the water method of curing.

Curing compounds shall conform to JIS and the material and method of application shall be subject to the approval of the Engineer.

The use of curing compounds shall be limited to the following generic types:

- Wax emulsion
- Hydrocarbon resin

Wax emulsion curing compounds shall not be applied to the top surfaces of the bridge deck.

The curing compound shall have an Efficiency Index of not less than 95%.

The curing compound shall not discolour concrete surfaces due to the compound or have interaction between it and any additive, form coating, or release agent.

The intensity of application of the curing compound shall be shall be not less than that recommended by the manufacturer. Two coats shall be applied at the full rate.

The curing compound shall be applied to unformed surfaces immediately after the surface is firm and free of bleed water, and to formed surfaces within half an hour of removal of formwork from the section.

The curing compound shall be applied as a fine spray by a pressurised sprayer to give a uniform cover. The sprayer shall incorporate a device for continuous agitation and mixing of the compound in its container during spraying.

The application rate shall be checked by calculating the amount of curing compound falling on felt mats, each approximately 0.25 m^2 in area, placed on the concrete surface.

Membrane curing compound shall be applied after the removal of forms, or after the disappearance of surface water. It can be sprayed or applied to the concrete surface by means of an applicator in one or more coats at the rate instructed by the manufacturer. Should the membrane seal be broken or damaged before the expiration of the curing period, the damaged area shall be immediately repaired by the application of additional membrane material.

The Contractor's proposals for the use of liquid membrane curing compound and the locations shall be subject to the approval of the Engineer.

8.33.3 Steam Curing of Concrete

Concrete may be steam cured for the purpose of obtaining high early strength. The steam shall be at 100% relative humidity to prevent loss of moisture and to provide moisture for proper hydration of the cement. Application of the steam shall not be directly on the concrete.

Two to four hours after placing concrete and after the concrete has undergone initial set, the first application of steam shall be made. If retarding admixtures have been used, the delay before application of the steam shall be increased to four to six hours.

Water curing methods shall be used from the time the concrete is placed until steam is first applied.

The steam shall be at 100% relative humidity to prevent loss of moisture and to provide moisture for proper hydration of the cement.

During the application of the steam, the ambient air temperature shall increase at a

rate not to exceed 22°C per hour until the maximum temperature is reached and shall be held until the concrete has reached the desired strength.

In discontinuing the steam application, the ambient air temperature shall not decrease at a rate to exceed 22°C per hour until a temperature has been reached 10°C above the temperature of the air to which the concrete shall be exposed. The maximum curing temperature shall be from 60°C to 67°C.

If steam curing is to be employed the following particulars shall be submitted by the Contractor with its concrete mix proposals for subsequent approval by the Engineer:

- Any additives to be used in the concrete to be steam cured.
- The duration of the presetting period (ie the interval between placing the last concrete and commencement of steam curing). This period shall not be less than three hours.
- The rate at which the temperature of the air space surrounding the units shall be raised.
- The maximum temperature of the air space during the application of steam. The nominated temperature shall be maintained within +3°C.
- The maximum and minimum temperatures occurring, and the variation of temperature with time, shall be recorded using a suitable thermograph.

The steam inlets shall be placed in such a manner and/or the concrete members shall be protected in such a way that steam will not be blown directly against the concrete, or cause uneven heating of the members at any point.

The enclosing arrangements shall be completely airtight during the whole period of steam curing to prevent steam escaping or the entry of cool air at any time, and so that the variation of temperature throughout the steam chamber at any time shall not exceed 6°C.

Curing of associated concrete test cylinders shall be achieved by placing the cylinders within the enclosure in a position adjacent to the lower face of the structural units which they represent. The cylinders shall be located midway between steam entry points and shall be distant at least half the width of the structural unit from these points. The cylinders shall not be placed on top of the structural units or on the steam jet lines and shall not be in line with any steam jet. The test cylinders shall be marked to identify them with particular structural units.

Steaming shall be continued until at least 7 days strength (under normal curing) is obtained.

After completion of curing the steam supply shall be cut off, and the members shall be allowed to cool gradually and evenly for a period of 8 hours to avoid concrete cracking. Special care shall be exercised to prevent any rain falling on the concrete during the cooling period.

Steam cured sections shall not be lifted within 36 hours after the completion of concreting unless otherwise agreed with the Engineer for pretensioned members.

Temperature shall be recorded by means of recording thermometers supplied and

installed by the Contractor. They shall be maintained in good condition and regularly calibrated. The temperature sensitive parts of the thermometers shall be so positioned under the steam covers as to cause the thermometers to record the minimum temperature under the covers. One recording thermometer shall be used for each unit or group of units in line up to a total length of 25 m. For greater lengths, additional recording thermometers shall be used and the distance between the temperature sensitive parts of the thermometer shall not exceed 25 m.

The recording thermometers shall be set in operation immediately upon completion of the casting and screeding, the temperature sensitive part of each thermometer being installed in position at the same time.

Charts shall not be removed from any recording thermometers, nor the recording thermometers disturbed or moved in any way until after the removal of the steam covers.

The following information shall be recorded on the chart:

- Date on which steaming commenced
- Description of concrete unit
- Temperature correction, if any
- Time correction, if any
- Time of completion of placing concrete
- Temperature of concrete when placed
- Ambient temperature at time of removal of steam covers
- Name of Contractor or Manufacturer
- Name of Engineer

8.33.4 Thermal Curing of Pile Caps

The Contractor shall provide 50 mm polystyrene insulation to the top of the pile cap which is maintained in place for at least 150 hours. Moist curing of the top surface shall also be conducted.

The pooling of large volumes of water on the surface, especially if flowing, will lead to cooling which will have a detrimental effect. Therefore, the polystyrene insulation shall be covered by polythene sheeting and provision shall be made for the application of a trickle feed of water (maintained at 27°C, +/- 2° temperature). The formwork to the sides of the pile cap shall also be maintained in place for 150 hours. If steel side formwork is used it shall also be insulated using 50mm polystyrene.

8.34 Time of Removal of Formwork and Falsework

Formwork and falsework shall not be removed without the approval of the Engineer. The Engineer's approval shall not relieve the Contractor of 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. Falsework removal for continuous or cantilevered structures shall be as directed by the Engineer or shall be such that the structure is gradually subjected to its working stress.

When the time for removal of forms and supports is determined based on concrete strength tests, such removal shall not begin until the concrete has attained the percentage of the specified design strength shown in the table below.

If field operations are not controlled by compressive strength tests, the time shown below for removal of forms and supports shall be used as a minimum:

	Standard Concrete	Early -Strength Concrete	Percentage of Design Strength
Centering under girders, beams, frames or arches	14 days	7 days	80%
Floor slabs	14 days	7 days	70%
Walls	I day	12 hours	-
Columns	2 days	1 day	
Side of beams and all other vertical Surfaces	1 day	12 hours	

In continuous structures, falsework shall not be released in any span until the first and second adjoining spans on each side have reached the strength specified herein or in the special provisions. When cast-in-place post tensioned bridges are constructed, falsework shall remain in place until all post tensioning has been accomplished.

Falsework under all spans of continuous structures shall be completely released before concrete is placed in railings and bridge parapets.

Forms and falsework shall not be released from under concrete without first determining if the concrete has gained adequate strength without regard to the time element. In the absence of strength determinations, the forms and falsework are to remain in place until removal is permitted by the Engineer.

The forms for footings constructed within cofferdams or cribs may be left in place when, in the opinion of the Engineer, their removal would endanger the safety of the cofferdam or crib, and when the forms so left intact will not be exposed to view in the finished structure. All other forms shall be removed whether above or below the ground line or water level.

All formwork shall be removed from the cells of concrete box girders within which utilities are required, and all formwork except that necessary to support the deck slab shall be removed from the remaining cells of the box girder.

To facilitate finishing, forms used on ornamental work, railings parapets, and exposed vertical surfaces shall be removed at least 12 but not more than 48 hours later depending upon weather conditions.

In order to determine the condition of concrete in columns, forms to columns shall always be removed before releasing supports from beneath beams and girders.

Falsework supporting the deck of rigid frame structures shall not be removed until fill has been placed behind the vertical legs.

8.35 Patching of Concrete

Immediately following removal of the forms all projecting wires or metal devices that have been used for holding the forms in place shall be removed or cut back at least 2.5 cm beneath the surface of the concrete.

Fins or runs of mortar and all irregularities caused by form joints shall be removed. Small holes, depressions, and voids that show on the concrete shall be filled with non-shrink cement mortar and epoxy resin adhesive shall be used in accordance with this Specification to prepare the surface of the area to be patched.

The surface of this mortar shall be floated with a wooden float before initial set takes place. It shall be uniform in colour with the surrounding concrete and neat and workmanlike in appearance.

8.36 Cause for Rejection of Concrete

Honeycombing shall be sufficient cause for rejection of portions of the structure containing this honeycombing. The Contractor, on receipt of written orders from the Engineer, shall remove and rebuild such portions of the structure at his own expense.

8.37 Finishing Concrete Generally

All concrete surfaces exposed in the completed work shall comply with the requirements of Ordinary Finish herein except where otherwise shown or specified.

8.37.1 Finishing Concrete Decks

Immediately after placing concrete, concrete decks shall be struck off with templates to provide proper transverse sections and shall be hand finished smooth to the concrete levels. Finish shall be slightly but uniformly-roughened by brooming. The finished surface shall not vary more than 10 millimeters from a 4 meter straightedge placed parallel to the centreline of the roadway and 10 millimeters from a transverse template cut to the true cross section of the roadway.

8.37.2 Finishing Curb and Footpath Surface

Exposed faces of kerbs and footpath shall be finished true to lines and grades, The kerb surface shall be wood floated to a smooth but non-slippery finish. Footpath surfaces shall be slightly but uniformly roughened by brooming across the direction of travel.

8.37.3 Ordinary Finish to Concrete

An ordinary finish is defined as the finish left on a surface after the removal of the forms when all holes left by form ties have been filled, and any minor surface defects have been repaired. The surface shall be true and even, free from depressions or projections and of reasonably uniform colour.

Repaired surfaces, the appearance of which is not satisfactory, shall be "rubbed" as specified in Rubbed finish.

The concrete in bridge seats, caps, and tops of walls shall be struck off with a straightedge and floated to true grade. Unless shown on the Drawings the use of mortar topping for concrete surfaces shall not be permitted.

8.37.4 Rubbed Finish to Concrete

After the removal of forms the rubbing of concrete shall be started as soon as its condition shall permit.

Immediately before starting this work the concrete shall be kept thoroughly saturated with water. Sufficient time shall have elapsed before the wetting down to allow the mortar used in patching to set thoroughly. Surfaces to be finished shall be rubbed with a medium coarse carborundum stone, using a small amount of mortar on its face. The mortar shall be composed of cement and fine sand mixed in the same proportions as those used in the concrete being finished. Rubbing shall be continued until all form marks, projections and irregularities have been removed, all voids filled, and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place. After all concrete above the surface being treated has been cast, the final finish shall be obtained by rubbing with a fine carborundum stone and water. This rubbing shall be continued until the entire surface is of a smooth texture and uniform colour.

After the final rubbing has been completed and the surface has dried, it shall be rubbed with burlap to remove loose particles and laitance. The final surface shall be free from all unsound patches, paste, powder. and objectionable marks.

8.37.5 Backfill to Concrete

All spaces which have been excavated and the volumes of which are not occupied by the concrete structure shall be backfilled and compacted in accordance with the provisions of this Specification.

If there is likelihood of water accumulating behind any wall, the backfill shall not be placed until after the retaining, diaphragm, or spandrel walls are 28 days old. No fill shall be placed over arches and slabs until the concrete is 28 days old or until test specimens indicate the concrete has attained the required 28 day strength.

8.38 Loadings on Concrete

Traffic or heavy construction equipment shall not be allowed on reinforced concrete structures until 28 days have elapsed from the last placing of concrete or when tests of extra test specimens show that the concrete has attained its specified 28-day strength.

8.39 Preparation of Concrete Surfaces to Receive Adhesive

The block surface to which adhesive is to be applied shall be wire brushed till smooth, removing any sheath ends that may be projecting beyond the jointing surface.

After treating the jointing surface to a smooth and flat surface, dust and dirt shall be removed using compressed air or other means. If any form of releasing agent or

grease has been deposited, the surface shall be degreased using an organic solvent.

After separating the form from the PC block, the surface to receive adhesive shall be covered with a sheet cover, etc., as protection against rainwater, in order to maintain the bonded blocks in a dried condition. If bonding work must be performed when the PC blocks to be bonded are in a wet condition, forced drying by means of a torch lamp, gas burner, etc., must be performed.

8.39.1 Application of Adhesive

On completion of surface treatment the base agent and hardener shall be mixed according to the specified mix proportion and thoroughly stirred.

The adhesive is to be applied thoroughly to both bonding surfaces using a rubber, or metallic spatula. The optimum coat thickness for each concrete surface is about 1mm and the adhesive should ooze out beyond the joints when the blocks are jointed and prestressing is introduced.

The air temperature during block jointing should preferably be in the range from 5 - 35 degrees Celsius and work should proceed so that the first prestressing should be completed at least within the adhesive's pot life time. Since with the introduction of prestressing, the adhesive will ooze out beyond the joints, and at the same time, will be pushed inside the sheath, it is advisable to leave an uncoated area of 10 - 20 mm around the sheath.

Satisfactory results can be obtained also by covering the sheath holes by means of gum tape, etc.

8.39.2 Curing of Adhesive

For at least 24 hours after bonding, the jointed section should be protected against rainwater or excessive impact.

8.39.3 Cleaning Up at Conclusion of Concreting

Upon completion of structure and before final acceptance the Contractor shall remove all falsework, falsework piling, etc., down to 1.0 meter below the finished ground line. Excavated, or useless materials, rubbish, etc. shall be removed from the site and the site shall be left in a neat and presentable condition satisfactory to the Engineer.

8.40 Tolerances for Concrete Structures

The following tolerances of concrete structures after completion of the work shall not be exceeded. All concrete work shall be executed in the required dimensions, shapes, positions and levels shown on the drawings. The Engineer may apply other tolerances as he may deem necessary and as are appropriate for the case at hand.

- Level and Positions

Top of lean concrete under foundations	+10 mm, -20 mm.
Plan position of substructures	+10 mm

Span length	-25 mm, +30 mm.
- Plumb Alignment and Appearance	
Plumb alignment for substructures and walls	0.2%
- Appearance of Covered, Vertical Surfaces	
Tolerance for offset at form joints	3 mm
Tolerance on flatness	5 mm over 2 m
- Appearance of Exposed Vertical Surfaces	
Tolerance for joint offsets	0 mm (nominal)
Tolerance for flatness	5 mm over 2 m
- Dimensions	
Tolerance for dimensions of piers, walls, girders, abutments, slabs, etc.	+10 mm
- Flatness of Slabs	
Bridge deck slabs, top and bottom slabs of culverts	10 mm over 4 m
- Concrete Cover and Space for Reinforcing Steel	
Concrete cover for superstructures	0 mm, + 5mm
Concrete cover for other structures	+ 10mm
Space	+ 10 mm
- Position for Prestressing Tendons	
Horizontal and vertical	±10 mm.

8.41 Reinforcing Steel Bars

This work shall consist of furnishing, fabricating, and placing reinforcing steel bars of the type and size provided in accordance with as this Specification and in conformity with the Drawings or as directed by the Engineer.

Reinforcing steel shall conform to the requirements of the following specifications except that the weights of the standard bar sizes shall be taken as per Table 10-2-1 and 10-2-2, irrespective of the specification used in manufacture.

- Bar specified as being 9 mm diameter or less:

  SII 0136-80 (Grade BJTP 24); or
  JIS G3112 (Grade SR 24); or
  AASHTO M31 (Grade 40) or equivalent

- Bars specified as being 10 mm diameter or more:

  SII 0136-80 (Grade BJTD 3.0); or
  JIS G3112 (Grade SD 390); or
  (Vina Kyoei) JIS Grade SD295A, SD390
  AASHTO M31 (Grade 60) or equivalent

Reinforcing bars shall be kept off the ground and clear of saline river water and stored within a building or provided with suitable cover.

8.41.1 Reinforcing Steel Bending

Reinforcing bars shall be accurately formed to the shapes and dimensions indicated in the design, and shall be fabricated in a manner that shall not injure the material.

Unless otherwise permitted, all reinforcing bars requiring bending shall be bent cold. When reinforcing bars are bent by heating, the entire operation shall be approved by the Engineer. Should the Engineer approve the application of heat for field bending reinforcing bars, precautions shall be taken to ensure that the physical properties of the steel shall not be materially altered.

Reinforcing bars that cannot be straightened by means of fabrication shall not be used. Bars partially embedded in concrete shall not be bent except as shown on the Drawings or otherwise permitted.

Qualified personnel shall be employed for cutting and bending, and proper appliances shall be provided for such work.

If it is necessary for the Engineer to ascertain the quality of reinforcing bars, the Contractor shall test reinforcing bars, at his own expense, by means as directed by the Engineer.

8.41.2 Reinforcing Steel Fixing

Reinforcing bars before being positioned shall be cleaned and free from rust, dirt, mud and loose scale and from paint, oil, or any other foreign substance that destroys or reduces the bond.

Reinforcing bars shall be accurately placed in proper position so that they shall be firmly held during placing concrete. Reinforcing bars for erecting shall be used when needed.

Bars shall be tied at all intersections by using annealed iron wire 0.9 mm or larger diameter or suitable clips.

Distances from the forms shall be maintained correctly by means of metal hangers, mortar blocks, metal supports, or other supports approved by the Engineer.

Reinforcing bars shall be inspected by the Engineer after placing. When a long time has elapsed after placing reinforcing bars, they shall be cleaned and inspected again by the Engineer before placing concrete.

8.41.3 Splicing of Reinforcement

When it is necessary to splice reinforcing bar at points other than shown on the designs, positions and methods of splicing shall be determined based on strength calculations approved by the Engineer.

In lapped splices, the bars shall be lapped the required length and wired together at several points by using annealed iron wire larger than 0.9 mm.

Exposed reinforcing bars intended for bonding with future extensions shall be effectively protected from injury and corrosion.

Welding of reinforcing steel shall be done only if detailed on the Drawings or if authorized by the Engineer in writing.

Welding shall not commence until the welding procedure has been qualified and reviewed by the Engineer.

Substitution of different size bars shall be permitted only upon the specific authorization of the Engineer. If steel is substituted, it shall be of a size equivalent to the design size or larger.

8.42 Concrete Works for Pylons

This section covers the construction and monitoring of pylon works above the main pier, including provision for all materials, construction, necessary equipment, testing, pylon deflection monitoring, and providing, operating and maintaining passenger hoists.

8.42.1 Pylon Concrete

The provisions of this Specification shall be applicable for all pylon and cross bracing concrete work unless otherwise noted in this Specification section or applicable drawings.

Concrete used for pylon works shall class B in accordance with this Specification, but shall be "high fluidity" concrete.

Admixtures in accordance with ASTM C1017 shall be used to provide a "high fluidity" concrete mix.

A concrete mix design, in accordance with the provisions this Specification, shall be provided by the Contractor with a slump corresponding to the "high fluidity" of the mix, concurrent with the use of an approved ASTM C1017 admixture.

The Contractor shall properly control the use and application (including admixture application and mix transport times) of "high fluidity" concrete, so as to assure concrete quality and a "high fluidity" slump during placement and finishing.

Concrete testing shall be in accordance with provisions of this Specification and the following:

- The method of performing slump tests shall be in accordance with ASTM C 143 and
- Slump flow tests shall be carried out for high fluidity concrete. The test method shall be proposed by the Contractor or as directed by the Engineer. The test method shall include slump (height after subsidence), slump flow (horizontal direction, JIS B 7516), spreading time up to 500 mm or to an established flow length, settling time of flow (JIS Z 8401) and inspection for segregation.

8.42.2 Pylon Construction

The pylon structure is sensitive to environmental loads throughout the construction period, particularly in the transverse direction. On the Drawings, pylons are detailed for construction by the use of the whole scaffolding method with nominated construction joint locations. Other alternatives such as a slip-form method etc. may be acceptable subject to the Engineer's approval.

It shall be the Contractor's responsibility to:

- verify the structural adequacy of the pylon at each stage of construction,
- to employ suitable and acceptable pylon construction methods,
- to provide acceptable equipment for construction and monitoring the pylon work and
- to provide suitable construction joints at proper locations.

Factory fabricated steel frames as shown on the drawings shall be provided in accordance with the provisions of this Specification.

The reinforcement details shown on the Drawings assume the crossbeams are cast-in-situ. The Contractor may propose an alternative pre-cast construction method that will be subject to the Engineer's approval.

8.42.3 Pylon Construction Method Statement

Based on the construction sequence concept shown on the Drawings, the Contractor shall submit to the Engineer for review and approval, details of the construction methods he intends to employ. These shall be provided with Working Drawings provided in accordance with the provisions of this Specification. The submission shall include but not necessarily be limited the following:

- A detailed staging sequence, location of all construction joints;
- High fluidity concrete details for mixing, testing, placing and curing;
- Formwork details;
- Temporary bracket details;
- Structural steel detail;
- Reinforcement details;
- temporary bracing arrangements;
- crossbeam castings;
- stay cable anchorage details;
- structure steel strut details;
- tower crane details with safety attachments such as grounding, grounding rods;
- foundation requirements and

- construction geometry control procedures.

8.42.4 Construction Joints in Pylon

Construction joints shall be provided in accordance with applicable provisions of this Specification and the following:

- the joints shall be made on a horizontal line;
- assembled forms around all joints shall be checked for proper fixing prior to concrete placement and
- joints shall be completely bonded between the initial and preceding pours with an approved mortar placed at the joint surface.

8.43 Deflection Control in Pylon

During the period of the construction until the date of Provisional Hand-over, the Contractor shall monitor and control the deflection of all pylons.

8.43.1 Deflection Criteria for Pylon

Prior to the commencement of pylon construction the Contractor shall establish deflection criteria and allowances which shall be submitted to and approved by the Engineer. The criteria and allowances shall take into consideration the following criteria:

- The Contractor shall maintain a minimum horizontal deflection of the pylon -during construction.
- The established allowed deflection shall have no effect on the bridge structure.
- Bending tensile stresses in pylon concrete shall be kept within allowable -limits during installation of box girders and stay cables prestressing.
- Pylon construction tolerances shall be in accordance with the following:
  Global, horizontal-longitudinal: 50 mm
  Global, horizontal-transverse: 25 mm
- For analysis a final creep coefficient based on seventy (70) years shall be used, unless otherwise required by the Engineer.

8.43.2 Deflection Monitoring in Pylon

Prior to the commencement of any Pylon work, the Contractor shall establish and submit to the Engineer for review and approval a deflection monitoring system, including embedded monitoring inserts in the pylon concrete, for measuring stress and establishing pylon deflections.

Using the approved deflection monitoring system the Contractor shall establish, with the approval of the Engineer, proper monitoring sequences, times and procedures for stress measurements for deflection calculations and deflection control.

The deflections at the each construction stage and deflection forecast for the proceeding stage shall be analyzed and submitted to the Engineer for review and approval along with deflection survey data and calculations.

8.44 Passenger Hoists to Pylons General Requirements

The Contractor shall provide passenger hoists (construction and access elevators) for each pylon, which shall be utilized by the Engineer and the Contractor during construction.

Passenger hoists (elevator systems) shall be provided, installed and maintained in accordance with ASME A17.1, the United States National Electrical Code (NEC) and applicable Building Codes.

Passenger hoists shall extend along the height of all pylons with a traveling distance of approximately 78 meters from pile caps.

The Contractor shall be responsible for providing all necessary passenger hoist equipment and incidentals as well as installation, adjustments, painting, lubrication, maintenance and testing to provide suitable, safe and properly operating passenger hoists.

Passenger hoists shall be provided and maintained during construction until the completion of pylon work, or until otherwise required by the Engineer.

Passenger hoists shall include all necessary apparatus and provisions for the safe operation and control of the elevator system including one or more elevator control rooms.

Passenger hoists shall be provided with adequate primary and emergency power supply including all necessary conduits, boxes, wiring, cables, equipment, materials and incidentals.

All components of each passenger hoist system shall be properly sized and selected to provide a smooth acceleration and deceleration without any oscillation, vibration and/or power cuts occurring during operation.

A quality maintenance service performed on a daily base consisting of regular examinations, adjustments and lubrication of the elevator equipment as well as initial and periodic testing of electric currents for elevator operation.

8.44.1 Additional Requirements Passenger Hoists to Pylons

Each complete passenger hoist system shall include the following:

A passenger hoist car with a capacity of at least 1,000-kg and an operating speed of approximately 50 meters per minutes with adequate lighting.

Platforms along the length of the passenger hoist at required intervals so as to provide necessary maintenance, service and inspection. The Engineer shall approve all platform locations.

Properly framed and enclosed and supported hoistway and platforms with adequate ventilation.

All necessary guide mast brackets and supports.

A fused disconnect switch or circuit breaker with feeder or branch wiring to a controller for each passenger hoist in accordance with the requirements of the United States National Electrical Code (NEC).

A 220-volt, 50 Hertz, single-phase power supply, with feeder wiring to each controller for car lights.

A convenience outlet and light fixture in each elevator pit with a switch located adjacent to an access door.

A communicating or signaling system within the hoist car to an accessible point outside the hoistway in a central communication exchange location.

A transfer switch for each feeder for switching from normal power to emergency power and a contact on each transfer switch closed on normal power supply with two wires from this contact to one elevator controller.

Means for absorbing power regenerated by the elevator system when running with overhauling loads such as full load down, or provisions for a manually operated emergency access ladder.

Hoistway guards and protection that shall include panels surrounding each hoistway opening.

8.45 Shop And Working Drawings for Passenger Hoists to Pylons

In accordance with the provisions of this Specification the Contractor shall submit to the Engineer for review and comment all manufacture's information and data for all materials plant and equipment to be provided for each passenger hoist system.

The Contractor shall prepare and submit to the Engineer for review and comment complete Shop and Working Drawings for each passenger hoist system, which shall be approved (prior to submission to the Engineer) by a registered, electrical, mechanical and structural engineer and be endorsed by the Contractor's safety officer. The Contractor's Working Drawings, or a supplement thereto, shall fully describe passenger hoist operation and maintenance procedures and requirements.

8.46 Precast Concrete (PC-Box) Segments

This Specification section describes requirements and procedures for furnishing constructing and installation of PC box segments for cable stay bridges as well as geometric control for bridge and stay cable construction.

Except as otherwise specified, indicated on the drawings, or approved by the Engineer the following materials may be used for PC segmental box girders:

- Non-grout external PC cables: 15.2 mm nominal diameter, JIS G SWPR 7B
- Longitudinal PC Bars: 32 mm nominal diameter, JIS G 3109, Grade B SBPR 930/1180

All requirements, procedures; materials furnishings and installations shall be in accordance with Drawings, this Specification section, applicable sections of the

General and Technical Specifications and Division II Construction Specifications, Guide Specifications for Design and Construction of Segmental Concrete Bridges, AASHTO", and PTI Guide Specification, Acceptance Standards for Post-Tensioning Systems".

Construction of PC box segment shall be carried out under the geometric control analysis by personnel that are specialists and experienced in the use of the type of equipment proposed.

Necessary structural precautions shall be provided for when working with or near strands that have been tensioned or are in the process of being tensioned.

Unless otherwise approved by the Engineer, the formwork systems shall not separate castings between segment bodies and deviators of external cable, or segment bodies and blisters of the anchorage parts of internal cables. They shall not in any way effect the full bonding of segments.

Safety netting shall be provided in accordance with safety requirements and shall be fully explained in the Contractor's safety plan provided in accordance with requirements of this Specification.

8.47 Equipment Listing for PC Segments

The Contractor shall submit to the Engineer for review and approval a complete listing of all equipment proposed to be used for PC Box Girder Segmental Construction.

8.48 Personnel Listing for PC Segments

The Contractor shall submit to the Engineer review and approval a complete listing of personnel proposed to be employed on the PC Box Girder Segmental work, noting names and positions of all individuals. Attached to the listing the Contractor shall provide details of experience, training and education of all listed personnel.

8.49 Shop and Working Drawings for PC Segments

The Contractor shall submit to the Engineer for review and oval complete detailed shop and working drawings with structural analysis and applicable schedules and tables for all segments. Dimensions and complete descriptions of all devices such as sheath guide pipe, necessary inserts and anchorage not specified or detailed on the Drawings shall be indicated.

8.50 Method Statement for PC Segments

The Contractor shall submit to the Engineer for review and approval a complete method statement for the fabrication, construction and erection all of PC box segment work. The method statement shall include, but not necessary be limited to the following:

- Contractor's details of proposed manufacture, storage, transport, erection and construction.
- Sequence of proposed operations.

- Geometric control procedures, including equipment to be used, means and methods, geometric control documentation including casting control, casting curve data and structural calculations.
- Formwork, including systems and materials.
- Precast manufacturing methods, including equipment to be used and casting beds.
- Erections positioning of segments (taking into account the achieved, as-cast alignments) so as to produce the required alignment upon completion.
- A summary of all calculation loads and assumptions including calculations of the required cambers taking into account the effects of creep, shrinkage, and temperature.
- Full details and calculations for temporary structures including erection carriers and temporary bracing.
- Proposed method for the calculation of the jacking forces and extensions for the stay cables.
- A step-by-step confirmation of the strength and serviceability of the structure at each stage construction.
- Joint installation procedures and materials, including joints between ends of the pier tables and the succeeding segments.
- Procedures, including proposed equipment for positioning and aligning cantilevered precast sections.
- Full details of support brackets for temporary construction.
- Provisions for vertical offsets of the erection nose measured from a corresponding point in the previous segment.
- Considerations for loads and effects of materials to be employed.

8.51 PC Segment Handling, Transport and Storage Procedures

The Contractor shall submit full details of his proposed lifting, handling and transport and storage methods and procedures for precast PC box segments to the Engineer for review and approval. These shall be provided together with proposed procedures for limiting torsion stress of the members (to a safe value against cracking) while in transit.

8.52 Epoxy Material for PC Segments

The Contractor shall submit full details of the epoxy material proposed for use for review and approval by the Engineer. Such shall include, but not necessary be limited to:

- the manufacturer's name, address and contact numbers,
- manufactures data noting pass usage of the material for similar applications,
- material components and composition of each component,
- manufacture instructions for storage, handling, mixing and application of the material
- application temperatures and conditions, requirements and restraints,
- material creep, tensile strength and water resistance characteristics and
- certified past test reports on the material.

For each manufactured lot of material, the Contractor shall furnish to the Engineer certified reports (by an independent laboratory approved by the Engineer) of all tests performed on the material(s).

The Contractor shall submit to the Engineer, samples of the all material components, which shall be provided in containers and boxing supplied by the manufacture.

8.53 Non-Grout External Cable and PC Bar for PC Segments

The Contractor shall submit to the Engineer for review and approval:

- certified test certificates from an approved testing laboratory verifying the physical properties of the proposed material,
- manufacture certifications noting all details of the design and the steel quality and
- data and information certifying the history of previous use on similar type work, demonstrating proper functioning and durability of the proposed material.

If deemed necessary by the Engineer for approval, the Contractor shall carry out additional testing by an approved testing laboratory at his own expense according to a testing program supplied by the Engineer.

8.54 PC Segment Data and Information

After completion and storage of each PC box segment, the Contractor shall provide to the Engineer a certification detailing:

- the dimensions,
- the force and strain in strands,
- the strength and age of the test cylinders cast and the minimum age in hours of the concrete at the time stress were applied to the members.

8.55 Submittals

The Contractor shall submit to the Engineer for approval and proposal, information and comment or review and consent in the following item works.

- for the approval of the Engineer details of the curing method(s) and procedures to be used for PC Box Segments.
- for information and comment all "field cured" concrete cylinder test results as used for establishing the commencement of prestressing operations
- information and comment all "field cured" concrete test results as used for establishing the removal of precast PC Box Segments from forms
- for review and consent falsework plans for cast in situ PC box segments.
- for approval, proposed temporary restraints for fixing of pier table segments.
- for review and consent detailed plans for PC Box Segment installation falsework.
- PC Box Segment Joint records and information
- Before the start of casting operations the Contractor shall submit a geometric control plan in accordance with requirements of this Specification for review and approval by the Engineer.
- Prior to casting any PC Box segment the Contractor shall submit details of the set-up, formwork, equipment and geometry control for the Engineer's approval.
- casting control surveys and data for each PC segment casting.
- erection sequence drawings and tables of anticipated cable tensions with calculations, data of box girder.

8.56 Material Tests and Data for PC Segments

In accordance with requirements of Specification, the Contractor shall submit test reports, manufacture's data and certifications and other pertinent information and data to substantiate that all proposed materials to be used on prefabricated segments meet or exceed this Specification requirements. The Engineer before incorporation into the work shall approve all materials.

8.57 Concrete for PC Segments

No concrete shall be cast until the Engineer has approved the Contractor's shop drawings, concrete mix designs, methods of concrete placing, concrete curing and protection procedures, formwork, method of application of prestressing forces, and methods of handling and erecting segmental section members and inspection all preparations has been accomplished.

8.58 Prestressing Reinforcement for PC Segments

The prestressing reinforcement and all accessories shall be supplied from a single approved manufacturer.

8.59 Non-Shrink Material for PC Segments

Non-shrink grout shall conform to the requirements of ASTM C1107-91a.

8.60 Joint Epoxy for PC Segments

Joints between abutting precast segments shall be made using an approved normal set epoxy-bonding agent.

The epoxy-bonding agent shall conform to and meet the requirements of ASTM C881 Type VI unless otherwise modified herein.

The epoxy-bonding agent shall be of two components, a resin and a hardener. The two components shall be distinctly pigmented, so that mixing produces a third color similar to the concrete in the segments.

The composition of the components shall be thermosetting and 100 percent solid. They shall not contain solvents or any non-reactive organic ingredients, except for pigments that are required for coloring.

The epoxy-bonding agent shall be insensitive to damp conditions during application and after curing. It shall:

- exhibit a high bonding strength to cured concrete,
- have good water resistance,
- have low creep characteristics and
- have a tensile strength greater than the concrete.

The components shall be pre-packaged in two parts. They shall be in sealed containers and be pre-proportioned in the proper reaction ratios, ready for combining and mixing in accordance with the manufacturer's instructions.

Each container shall bear a label clearly indicating:

- the manufacturers name,
- the type component (resin or hardener),
- the range of substrate (concrete surface) temperature over which application is suitable,
- the date of formulation,
- the shelf life of the material and
- the manufacturers lot number.

Material from containers, which are damaged or have previously been opened, shall not be used.

The combining of epoxy bonding agent components from bulk supplies will not be permitted. Only full containers of components will be mixed immediately after opening.

Manufacture's instructions shall be provided clearly noting:

- the safe storage requirements, procedures and cautions,
- proper handling requirements and procedures,
- material mixing procedures and requirements, and
- material application procedures, requirements, conditions and cautions.

8.61 Bonding Agent

8.61.1 Temperature Range for Bonding Agents for PC Segments

The epoxy-bonding agent shall be formulated to provide application temperature ranges, which are suitable for erection of segments with substrate temperatures between 5 degrees, centigrade and 40 degrees centigrade. There shall be a minimum of two, and preferably three, formulations dividing the overall range into equal subranges that overlap by 15 degrees centigrade.

8.61.2 Physical Requirements for Bonding Agents for PC Segments

The epoxy-bonding agent (proportioned and mixed in accordance with the manufacturer's recommendations) shall meet the physical requirements as noted below. Prior to testing and before test specimen mixing, epoxy-bonding agent components shall be conditioned to the mix sample temperature.

- Consistency

  Mixed epoxy-bonding agent shall be tested for conformance to the prescribed consistency in accordance with ASTM C881, at the maximum temperature of the temperature range for the formulation being tested.

- Gel Time

  Mixed epoxy-bonding agent shall be tested for conformance to the prescribed gel time in accordance with ASTM C881, at the maximum temperature of the temperature range for the formulation being tested.

- Contact Time

This property is the allowable workable period of time between mixing of the components of the epoxy bonding agent and the application of a minimum 0.4 MPa compression force over the cross section of the joining segments.

The contact time of the epoxy bonding agent, determined in accordance with the test procedure set out below, shall be: Normal - Set Epoxy 60 Minutes, Minimum.

The test procedure for determining contact time shall be in accordance with the test procedure used for determining the compressive and shear strength of the cured epoxy-bonding agent modified as follows:

Soaking of the concrete specimens prior to application of the epoxy bonding agent shall be for 24 hours in water that is at the maximum temperature of the application temperature range for the formulation being tested.

Joining of the sloped surfaces shall be delayed from the time of epoxy mixing for: Normal - Set Epoxy 60 Minutes

During the delay period between the mixing of the epoxy and the joining of the sloped surfaces, the specimens shall be uncovered and maintained at the maximum temperature of the application range for the formulation being tested.

The joined specimen shall be cured at the maximum temperature of the application temperature range for the formulation being tested.

The formulation of epoxy bonding agent being tested will be acceptable if the specimen when tested sustains the following compressive stress: Normal - Set Epoxy 10 MPa at 48 Hours.

- Compressive Yield Strength

The compressive yield strength of the epoxy-bonding agent shall be at least 20 MPa at 24 hours and 60 MPa at 48 hours as determined in accordance with ASTM C881 with the modification that the epoxy-bonding agent shall be poured into specimen molds within ten minutes after the start of component mixing.

- Bond Strength

The bond strength of the epoxy-bonding agent shall be at least 10 Mpa at 48 hours and 50 Mpa at seven days, as determined in accordance with ASTM C882 with the modification that test specimens shall be conditioned by soaking for a period of at least 24 hours in water that is at the minimum temperature of the application temperature range for the formulation being tested.

- Heat Deflection

  Heat deflection shall be in accordance with requirements of ASTM C881 for Type VI epoxy-resin. Testing shall be in accordance with requirements and procedures of ASTM 0881.

8.62 Non-Grouted External Cable for PC Segments

All materials used with prestressing tendons shall be especially designed for the actual type of tendon used. They shall have a history of previous use on similar type work, demonstrating proper functioning and durability.

Strands for non-grout external post-tensioning shall be 15.2mm nominal diameter according to JIS G 3536 SWPR 7B. All strands shall be individually coated with a thermo plastic polymer resin, injected under high pressure during the manufacturing process. The polymer shall fill all gaps between individual wires and render the strands completely corrosion resistant for the life of the strand.

Minimum load requirements shall be as follows:

- Tensile load: 261 kN
- Yield load: 222 kN

The surface coating thickness of polymer resin shall be 0.4 mm. (- 0.2 mm and + 0.4 mm).

External sheathing shall be a high-density polyethylene (HDPE) pipe. The overall maximum outer diameter of the sheathing shall be 140 mm, and the minimum thickness shall be 4.4 mm.

8.63 Stressing Bars for PC Segments

The longitudinal stressing bars shall be 32 mm nominal diameter in accordance with JIS G 3109 Grade B SBPR 930/ 1180 with a minimum tensile strength of 1180 N/mm and a minimum proof stress of 930 N/mm^2.

Stressing bars shall be provided with the following accessories all supplied by the same manufacture:

- Steel bearing plates pre drilled with "center holes" and machined spherical seat for nuts,
- Spherical nuts,
- Sealing ring for suit nuts,
- Bar couplers in accordance with JIS G 4051,
- Wrap on grout vent,
- Galvanized ducts,
- HDPE transition pieces and
- Grout injection inlets/ outlets.

The coupler shall enable a new tendon to be connected an already placed and stressed tendon. Each strand shall be individually coupled to the coupling head by means of compression fittings.

8.64 Commencement of Manufacturing of PC Segments

The Contractor shall inform the Engineer in advance of the date of commencement of manufacture and the dates when tensioning of strands, casting of members and transfer of stress will be undertaken for the first time for each type of segment.

8.64.1 Method of Manufacture of PC Segments

Precast PC box segment shall be manufactured using the short line match casting method. The Engineer shall approve details of manufacturing, including equipment and casting bed before commencing with the work. When the method has been approved no changes shall be made without the consent of the Engineer in writing.

At the start of segment manufacturing, the upper and lower surfaces of at least the first three initial units shall be thoroughly measured and surveyed. Shrinkage during manufacturing and storage and other effects as established from these surveys shall be established and taken into account during the manufacturing of succeeding segments.

During segment manufacturing, the relative geometry and positioning shall be surveyed for all segments with respect to succeeding and proceeding segments. Based on these surveys, necessary corrections shall be taken to assure proper alignment and positioning.

Prior to manufacture of precast PC box segment, casting control measures shall be carried out based on the test results of elasticity modulus and creep coefficient obtained from actual manufactured concrete using the approved concrete mix design. Guide pipes, anchor plates, ducts and other required attachments shall be precisely positioned prior to the manufacture of segments.

8.64.2 Certificates and Records of PC Segments

A copy of all cylinder test results relating to the work shall be provided to the Engineer in accordance with requirements of the Contractors Quality Control Plan and Specification.

The Contractor shall maintain records detailing all aspects of the placement, and stressing of strains as well as the placement of concrete and transfer of stress. In addition to identifying all materials, quality control operations and inspections, dates, times and materials, such records shall also identify personnel responsible for all segments of the operation and be so organized so that all details for any member or line of members can be fully traced. These records shall be maintained in the Contractor's field office and be available for inspection by the Engineer. At the conclusion of the work and/or at any time during the execution of the work the Contractor shall provide a certified copy to the records to the Engineer.

8.64.3 Curing

Except as specified herein or otherwise approved, steam curing may be provided in compliance with the requirements of this Specification. If the Contractor elects to cure by any other method(s), the method and details shall be subject to the approval of the Engineer.

8.64.4 Prestressing Works for PC Segments

The method of tensioning shall ensure that the required force is applied to all tendons.

All strands shall be marked at both the jacking and dead ends of stressing beds for measurement of elongation.

Prestressing forces shall be transferred from tensioning jack to the abutments of the stressing beds immediately after the required force has been reached. The jack pressure shall be relaxed before any other operation commences.

Prestressing strand shall not be released before concrete has reach the minimum established strength required for transfer of the prestressing force as determined using "field cured" concrete cylinders. The procedure of release shall be continuous and the stress shall be transferred to the members in such a manner that the strands are released gradually and simultaneously and the eccentricity of stress is kept to a minimum.

Prior to transfer of the prestressing force from the abutments of the casting beds to the members, all strands shall be tested for tightness. All loose strands found shall be reported to the Engineer who shall decide whether the members affected are acceptable.

All strands shall be cut off and ground flush with the concrete surface. The strands shall be protected against rust by applying neat epoxy resin of a suitable quality or an epoxy mortar to the ends of tendons. The method of application and the thickness of the protective coating shall be to the satisfaction of the Engineer.

Transverse prestressing shall not be carried out until the concrete has reached a compressive strength of at least 38 MPa based on "field cured cylinders" unless otherwise approved by the Engineer.

Post-tensioned members shall be fully stressed as shown in the Drawings, and in general, all stressed tendons shall be grouted at least 7 days prior to lifting or handling of the precast PC box segments.

In the case of members being steam cured, stress shall be transferred while a member is still warm and moist.

8.64.5 Concrete Strength Determination for Stressing PC Segments

To establish when adequate concrete strength has been attained, prior to stressing operations, the Contractor shall provide one or more pairs of "field cured" test cylinders for each line of member. (a line member being any segment that is cast with a set of post-tensioned strands).

Concrete cylinders prepared for determining concrete strength for stressing operations shall be "field cured" in the same manner as the line member. The cylinders shall be cast from concrete being placed on the day the line of members are cast and completed. The cylinders shall be tested in pairs at progressive ages as selected by the Contractor. Upon a satisfactory test result being obtained, the strands

may be released.

As an alternative, the Contractor may wait for the 28 days concrete test results before releasing prestressing strands. In this case the concrete strength shall comply with the full 28-day strength requirement.

8.65 Marking, Handling, Storage and Transportation of PC Segments

All precast segmental box girder shall be marked with a numbering system that fully and individually identifies each segment. All markings shall be uniformly located on the inside of the segments.

Precast PC box segments shall not be moved from their casting position until fully stressed.

Unless otherwise approved by the Engineer, no precast segments shall be removed their forms or moved until the concrete has reached an approved strength as established by the Engineer, based on "field cured" cylinders.

Segments shall be lifted and supported only at points and by methods approved by the Engineer.

All segments shall be handled and stored in a manner to prevent torsion or other undue stress.

Segments shall be transported in an upright position. Transportation shall be in a manner (with necessary protection) avoiding shock to the segments being transported. Movement shall be from support points, and directions as indicated on approved working drawings.

The method of storage for precast PC box segment shall include full safety for all personnel. Non-staining support pads shall be used. Storage beds shall be capable of sustaining imposed loads. Any projecting reinforcing bars shall be coated with cement wash or other approved coating to prevent rust staining to permanently exposed concrete faces.

Any damage to precast segments shall be subject to assessment by the Engineer. The Contractor may propose remedial repair measures for consideration by the Engineer. If such repair measures receive the concurrence of the Engineer, the Contractor shall provide any and all tests and inspections that are required by the Engineer for approval of repairs. If, in the opinion of the Engineer, damaged segments can not be adequately repaired or if repairs that have the concurrence of the Engineer are not accomplished to the satisfaction of the Engineer, the Engineer may reject the segment.

8.66 Construction of PC Segments on Pylons

When pylon construction has sufficiently progressed so as to permit the stressing and anchoring of stay cables, the installation of segments shall commence from pier tables on the bridge pylons using a balanced cantilevering method of construction.

In order to avoid unbalanced moments on pier heads, the construction shall proceed

symmetrically on each side of each pier.

In accordance with drawings the three separate segments of piertables (at each pylon) shall be installed with the center pier table (constructed on temporary vertical PC bars embedded into the pierhead and the outer piertables adequately supported by bracketed falsework).

Temporary supports, and/or falseworks, will be used as required to erect the structure, such as for the construction of pier tables and closures.

Falsework will be properly designed based on calculations considering all anticipated loads.

The Contractor shall submit detailed plans for all falsework to the Engineer for review and consent, showing all loading assumed by the Contractor's design. Review and consent of these plans by the Engineer shall not relieve the Contractor of his responsibility for the works.

Removal of temporary attachments by burning shall be on the waste side with an ample allowance for finishing by grinding. This requirement applies equally to exposed and subsequently embedded parts.

Prior to commencing with cable stressing, the piertable segments shall be securely fixed with temporary restraints (designed by the Contractor and approved by the Engineer) to inhibit longitudinal and transverse movement and resist all dead and live loads during all stages of erection, including transient loads arising from temperature and wind.

The temporary vertical PC bars shall be removed after completion of mid-span closure segment and the joints (the details shall be proposed by the Contractor and approved by the Engineer) have been installed between the ends of the pier tables and the succeeding segment.

8.67 Installation of Precast PC Segments

It is assumed that the precast PC box segment will be installed by cantilever construction, utilizing erection noses. In the required method statement, the Contractor shall submit full and detailed descriptions and drawings of this proposed procedure and equipment, together with supporting calculations for geometric control.

The Engineer's consent and/or approval of the Contractor's erection procedure shall in no way relieve the Contractor of his responsibilities under the Contract.

The erection procedures shall be such that at datum temperature (when the bridge is completed and with full permanent load applied) the profiles of the cable and roadways shall correspond to those given on the drawings.

Erection setting-out calculations shall take into account the load/extension relationships of the stay cables.

Construction loads such as equipment and materials shall not exceed the sectional

capacity of the box girder.

Workmanship, inspection and testing during and after erection shall comply with the requirements of this Specification section and applicable requirements of all other General and Technical Specification sections.

Prior to erecting any segment, the match cast faces of the segment shall be lightly sand blasted to remove any deleterious material. This shall be accomplished without damaging the match cast nature of the surface and such that a dry, clean surface is obtained.

During erection the Contractor shall take special care to avoid permanent distortion, the locking-in of secondary stresses and impairment of the fatigue resistance of the permanent works.

The Contractor shall provide an adequate communication system between strategic points during erection, which shall be maintained at all times to the satisfaction of the Engineer.

8.68 Construction Tolerances for PC Segments

The construction tolerances shall be as noted herein and Division 11 -Construction Specifications, Guide specifications for Design and Construction of Segmental Concrete Bridges, AASHTO.

- The construction tolerance on the finished deck profile immediately after completion but before installation of wearing surface and bridge furniture shall be f 30 mm.
- The maximum deviation from the theoretical deck profile shall not exceed t 50 mm for any construction stage.

If upon completion of the superstructure construction, the deck profile is outside the specified tolerance, the Contractor shall investigate the cause(s) and submit to the Engineer for review and consideration a full proposal detailing corrective measure to be taken to achieve the required deck profile.

The Engineer reserves the right to instruct the Contractor to remove and reconstruct (at the Contractor's expense) any segments not within allowable tolerance, which the Engineer does not feel, can be suitably repaired, or that are not repaired to the satisfaction of the Engineer.

8.69 Epoxy Joining of PC Segments

This work covers the furnishing, mixing and application of a two component epoxy-bonding system to the match cast face of joints between precast PC box segments through which embedded post-tensioning tendons (provided and installed in accordance with details shown on the drawings and this Specification requirements) shall pass. The work covered also includes temporary post tensioning across joints, if required.

In its workable state, the epoxy-bonding agent must provide lubrication along the keys as the precast PC box segments are brought together. In its hardened state, the

epoxy-bonding agent must provide a watertight seal between the precast PC box segments. The hardened epoxy-bonding agent, although not a stress-carrying component, must provide a friction mechanism to transfer shearing stresses across joints at the shear keys - which shall be established prior to removing supports of the erection nose from segments in each span.

8.70 Construction Requirements for Joining PC Segments

An epoxy-bonding agent meeting the requirements of this Specification section shall be applied to joining surfaces of all precast PC box segments through which embedded post-tensioning duct pass.

The epoxy-bonding agent shall be applied only when the substrate temperature of both surfaces to be joined is between 5°C and 40°C.

The level and alignment of each segment shall be checked against the previous segment prior to application of the epoxy-bonding agent. If necessary, the Contractor may make proposals concerning alignment corrections, subject to the approval of the Engineer.

The bonding agent used shall have an application temperature range that conforms to the substrate temperature of the surfaces to be joined. If the surfaces have different substrate temperatures, the formulation for the higher temperature shall be used.

The Contractor shall plan his erection and post-tensioning operations so that for the particular formulation of epoxy bonding agent, the time elapsing between initial mixing of the components for the first batch of epoxy bonding agent and application of a minimum of 0.4 MPa compression over the entire joint of precast PC box segments shall not exceed 70 percent of the contact time. In his method statement the Contractor shall submit to the Engineer for review, details covering how compliance with this time limit will be achieved during the erection of segments.

For superstructure segments, the compressive force across a joint (contact pressure) may be accomplished through temporary post-tensioning or permanent post-tensioning.

For precast box pier segments, the specified contact pressure may be accomplished through temporary post tensioning, permanent post tensioning or the weight of segments above the joint.

For superstructure segments the specified contact pressure shall be continuously maintained across a joint. For precast concrete box pier segments, the contact pressure may be released after the epoxy-bonding agent hardens.

8.71 Qualifications of Contractor's Personnel for Joining PC Segments

The work of mixing, handling and applying the epoxy-bonding agent shall be under the direct supervision of a person who has had suitable experience (in the opinion of the Engineer) with the material being used.

The Contractor shall arrange for a technical representative of the manufacturer of the approved epoxy-bonding agent to be on the site to oversee and advise during initial

operations.

The Contractor shall ensure that all personnel who will be working with the epoxy-bonding agent are thoroughly familiar with the safety precautions necessary for handling the material of Clause 8.6.1.

8.72 Cleaning of PC Segment Surfaces to be Joined

The surfaces to which the epoxy bonding agent are to be applied shall be free from oil, form release agent, Latinate or any other material that would prevent the epoxy-bonding agent from bonding to the concrete surface. Detrimental materials shall be removed by light sandblasting or by water blasting with a minimum pressure of 45 MPa.

Surfaces shall be free moisture at the time of epoxy bonding agent application. Free moisture will be considered to be present if a dray rag becomes damp, after being wiped over a surface.

The Contractor shall provide a working platform that will prevent the dropping of epoxy materials in the river.

8.73 Epoxy Bonding of PC Segments General Requirements

Only approved epoxy-bonding agent components meting the requirements of this Specification section from full containers opened immediately prior to combining shall be used.

Only epoxy-bonding agent components, for which the shelf life as indicated on the containers has not expired, shall be used.

Each container of each component shall be thoroughly mixed prior to combining the components.

The two components of the epoxy-bonding agent shall be combined and thoroughly mixed in a mechanical mixer, strictly accordance with manufacturers recommendations.

The mixing of the epoxy-bonding agent shall be so that the material in any batch is applied to the face of the joint within 20 minutes after the components are combined.

The Contractor shall provide a working area platform for cleaning of epoxy materials to prevent the epoxy materials from falling into the river. The working platform shall be provided with all necessary safety encumbrances.

8.73.1 Epoxy-Bonding Agent Application to PC Segments

The epoxy-bonding agent shall be uniformly applied with a nominal thickness of 1 to 2 mm, unless otherwise required by the manufacturer and approved by the Engineer.

Unless otherwise recommended by the manufacture and approved by the Engineer, the material shall be applied only to one of the faces to be joined.

No material shall be placed within 12 mm of a post tensioning duct, except that a bead of epoxy bonding agent shall be applied between all adjacent post-tensioning ducts.

No epoxy-bonding agent shall be used after the combination of components has exceeded 20 minutes.

A discernable bead line of epoxy bonding agent shall be apparent along the entire exposed segmental joint edges.

All excess epoxy-bonding agent shall be cleaned from visible surfaces in such a manner so as not to damage or stain the concrete surfaces.

At shared joint keys, an exit for all excess epoxy shall be provided. Excess epoxy removed from the joint shall not be allowed to free-fall from the structure.

Immediately after concrete segments are joined, a swab shall be passed through each empty post-tensioning duct to smooth out any epoxy-bonding agent in the duct.

8.73.2 Failure to Comply with Time Limits for bonding PC Segments

If the time limit between mixing of the epoxy bonding agent and application of contract pressure to a joint is exceeded, the concrete segments shall be moved apart and all epoxy bonding agent shall be removed from both faces of the joint. If solvent is used to remove the epoxy-bonding agent, reapplication of the epoxy-bonding agent to the joint surfaces shall not be done for at least 24 hours after removal is completed.

8.74 Removal of Erection Nose from PC Segments

When erection is accomplished by the cantilever method, precast PC box segments shall remain fully supported by the erection nose and the internal erection tendons for a period of time as approved by the Engineer, based on the demonstrated establishment of adequate shear and flexural stress transfer at all joints.

8.75 PC Segment Jointing Records

The Contractor shall maintain daily records of all jointing operations indicating all of the following noted data and information. The Contractor's representative responsible for the segmental construction and the Contractor's Quality Control representative responsible for inspecting the work shall sign all records. Copies of all daily records shall be submitted to the Engineer at the start of the next working day after the work has been accomplished.

- General Information
  Weather conditions.
  Air temperature at the site on an hourly basis.

- For Each Joint (identified as to Location in the Structure)
  Lot number(s) of the epoxy bonding agent components.
  Temperature of the concrete on the surface of each concrete segment when application of epoxy bonding agent was started.

Time of mixing the first batch of epoxy bonding agent applied to the joint.
Time of applying the specified contact pressure to the joint.
Date of joining segments with epoxy.

8.76 Geometric Controls on Cable Stayed Bridge Generally

The Contractor shall be responsible for all geometric controls.

The Contractor shall furnish competent engineering personnel and all necessary equipment and devices to establish and verify dimensions, elevations and the alignment of the structure and cable stays during every stage of construction.

The structure shall have a geometric configuration at 25 degrees C (as a basic temperature) and be in general conformance with the dimensions shown on the drawings for dead load conditions.

The Contractor shall provide all necessary computations and analysis, to assure that proper adjustments are made for dead load cable stress and deck elevations in accordance with specified tolerances.

In establishing geometric control computations the Contractor shall take into consideration, the age of each segment and temperature effects on the deck, pylons, and stay cables.

Material properties such as elasticity, creep, shrinkage and relaxation effects should be considered, with assumptions validated by testing on site.

Girder stresses and conditions based on checks made during storage, handling and lifting should be taken into consideration.

Segments deformation computations considering thermal effects during casting, creep and shrinkage of individual segments should also be considered.

The temperature of all superstructure members shall be checked in the morning to establish adjustment requirements.

8.76.1 Geometric Control during Segment Casting

Before the start of casting operations the Contractor shall submit a geometric control plan in coordination with his casting operation, for review and approval by the Engineer. The geometric control plan shall include, but not be limited to the following;

- Details of the geometry control theory.
- A detailed step by step geometry control procedure.
- Detailed calculation sets and systems with sample calculations.
- Details of proposed measuring procedures and locations of the control points on each segment and permanent benchmarks.
- Details of all equipment including total stations, computer hardware and software and radio transmission and receiving equipment and their application and operation with inserts.

Prior to casting any segment the Contractor shall submit details of the set-up, formwork, equipment and geometric control for the Engineers approval. Formwork system shall be adopted to the project and to the approved geometry control plan.

Survey targets, survey inserts and independent-cross-checking marks shall be provided throughout the production of segments. These shall be positioned at locations so that they will not be disturbed during operations.

Galvanized geometric control inserts shall be embedded in segments, at each face, on center line and above the webs or any portions in accordance with the geometric control plan and software approved by the Engineer.

A competent surveyor who is familiar with short line mach cast technology shall be on site daily. To minimize human errors, two independent survey teams shall independently perform all surveys, under his supervision.

The misplacement and/or displacement of inserts during casting shall be taken into account when cross-checking survey data.

Proper surveying methods shall be used to reduce systematic errors. Preventive measures such as provisions for minimizing settlement in the casting beds, using appropriate formwork facilities and up-to-date computation, should be employed.

All software used shall be applicable for the application and have a history for previous use in similar applications. Software shall be able to simulate at any time the position of inserts after erection and compare them with theoretical curves. It shall be provide both old and new segment positioning data immediately after inputs of previous cycle survey data. In addition, it shall be able to accommodate any changes in the theoretical casting curves (on which was based the production of former segments) during pre-casting operations.

After a segment has been cast, the relative position of the two adjoining segments shall be determined from established control points. This information shall then be used to determine the required alignment of the adjacent matching segment.

Segmental box girders shall be within the tolerances indicated on Table 9-1 of the AASHTO, Guide Specifications for segmental Concrete Bridge, Division II Section 9.0.

If the required tolerances are exceeded, acceptance of a segment shall be at the discretion of the Engineer.

For all segmental box girder castings the Contractor shall submit to the Engineer all survey data, error data, corrections and analyses, before and after castings.

8.76.2 Geometric Control during Girder Installation

The deck elevation at cable attachment points shall be within a tolerance of -L 30 mm. A smooth parabolic curve shall pass through the final deck elevation at the centerline of the bridge and the deck elevations at the contract limits.

Any unexpected discrepancies between expected geometry and as-built conditions after erection shall be precisely monitored and explained. Due to limited remedial measure, a high level of precision is required in surveying the control point positions, and placement of segments. Remedial measures (after a proper analysis of the discrepancy causes has been made) may be taken after structural calculation checks, if approved by the Engineer.

8.76.3 Geometric Control for Stay Cables

Cables shall be adjusted for the dead load conditions so that each individual cable does not exceed ±5 percent of the cable dead load as computed from approved working drawings.

If tolerance forecasts exceed ± 30 mm (regardless of above noted adjustment) suitable countermeasure that are approved by the Engineer may be taken. If such measures are not successful, the Engineer may require the Contractor to replace related structures.

The cable cross sections and geometric lengths shown on the drawings are approximate. Final fabrication lengths shall be calculated by the Contractor after erection loads and methods are known and detailed erection stress calculations have been completed. The tolerance in the fabrication length of cables in the unstressed condition, shall be as follows:

Length between bearing faces (m)	Permissible Tolerance (mm)
50	Plus 25, minus 0.0
100	Plus 40, minus 0.0
150 and over	Plus 50, minus 0.0

Intermediate values may be interpolated. Differences between the actual and planned fabricated length shall be compensated by suitable methods.

The Contractor shall prepare and furnish to the Engineer complete detailed erection sequence drawings. Based on these drawings and the Contractor's construction equipment and procedures, the Contractor shall compute and prepare tables of anticipated cable tensions in each cable at corresponding stages of erection including, but not limited to the stages of:

- Precast PC box segment erection,
- After full dead load including concrete parapets, and barriers.

The tables of anticipated cable tensions and computations shall be submitted to the Engineer for review and comment.

If cable forces exceed the design forces as shown in the Drawings, the Contractor shall investigate adequacy of all cable components and anchorage. The cost for any additional materials required shall be borne by the Contractor.

At some intermediate stage of superstructure erection, which the Engineer will designate depending on the approved sequence and method of erection, the tension in each cable shall be checked to ensure that it is within the anticipated range. Any cable requiring adjustment at this stage shall be properly jacked and shimmed. Each

pair of cables anchoring at the same segment of deck shall be installed and stressed simultaneously.

Promptly after erection of each cable, the tension in the cable shall be checked to ascertain that they are within the range of anticipated tension for the corresponding stage of superstructure erection. Maximum cable tension during construction shall not exceed 56 % of the cable's guaranteed ultimate tensile strength.

Stay cables shall be erected at the appropriate times to suit the Contractor's erection scheme. In general, the lower (superstructure) end shall be the "stressing" end of the cable and the upper (pylon) end shall be the " dead" end.

Care shall be exercised during cable erection to prevent damage to the polyethylene sheathing and to prevent damage to the steel components of the cable. All damage to the polyethylene pipe sheathing or steel cable anchorage pipe shall be immediately repaired to the satisfaction of the Engineer. Severely damaged sheathing shall be replaced, if directed by the Engineer, at the Contractor's expense.

Deflection of the superstructure shall be controlled during construction and after completion of the work. The Contractor shall submit the full details of deflection control measures including camber calculations of each segment in consideration of;

- Deflection due to the concrete weight
- Deflection due to prestressing force
- Deflection due to further concrete weight and prestressing force for the further precast PC box segments
- Deflection due to bridge furniture weight such as pavement, and barrier, etc.
- Deflection due to long term creep and shrinkage in concrete

8.77 Stress Measuring Devices in Pylons and Deck Slabs

In accordance with provisions of this Specification, the Contractor shall provide and set up all necessary devices and equipment for measuring, recording and analyzing strains and stress in pylons and deck slabs. The measuring devices shall be connected to a Contractor supplied computer by radio transmission. The computer shall be supplied with all necessary software and hardware for receiving, reading, recording and analyzing readings transmitted by radio signalling.

8.78 Prestressed Concrete Generally

This work shall consist of prestressed concrete structures and the prestressed concrete portions of composite structures, constructed in close conformity with the lines, grades, design, and dimensions shown on the Drawings, or established by the Engineer and in accordance with this and other specification items involved.

The work shall include the finishing and installing of any appurtenant items necessary for the particular prestressing system to be used, including but not limited to ducts, anchorage assemblies and grout used for pressure grouting ducts.

It shall include the manufacture, transportation, and storage of beams, slabs, and other structural members of precast concrete prestressed by either pretensioning or

posttensioning methods. It shall also include the installation of all precast pre-stressed members.

For cast-in-place prestressed concrete the term "member" as used in this section shall be considered to mean the concrete which is to be prestressed.

Post-tensioning is defined as any method of pre-stressing concrete in which the tensioned reinforcement is tensioned after the concrete is placed. Pre-tensioning is defined as any method of pre-stressing concrete in which the tensioned reinforcement is tensioned before the concrete is placed. Pre-stressing reinforcement is defined as any reinforcement to which pre-stress is applied by post-tensioning or pre-tensioning.

8.78.1 Aggregate for Pre-Stressed Concrete

The maximum size of aggregate for use in the manufacture of pre-stressed concrete shall be 20 millimeters.

8.78.2 Prestressing Steel and Prestressing Quality Reinforcement

Prestressing steel and prestressing quality reinforcement shall be high tensile strength steel wire, high tensile strength steel strand or high tensile strength steel bar.

High tensile strength steel wire shall be weld free and stress relieved and shall conform to the requirements of AASHTO M204 or JIS G3536 "Uncoated Stress Relieved Wire for Prestressed Concrete".

High tensile steel strand shall be weld free and stress relieved after stranding and shall conform to the requirements of AASHTO M4203 or JIS G3536 "Uncoated Seven Wire Stress Relieved Strand for Prestressed Concrete".

High tensile steel bar shall be stress relieved and shall conform to the requirements of ASTM A722 or JIS G109.

The testing of prestressing reinforcement shall be in accordance with the requirements of the AASHTO Specifications for the type of system intended to be used.

8.78.3 Prestressing Anchorages

The Contractor shall submit all anchorage assemblies at least 2 months prior to commencement of the work to the Consultant's approval.

All post-tensioned pre-stressing steel shall be secured at the ends by means of approved permanent type anchoring devices.

The anchorage details for external tendons should provide complete removability of the tendon at any stage of the design life of the structure without modification or damage to the structure. The prestressing system should have the ability to replace the removed tendon via the same anchorage casting within the diaphragm segment of the span.

All anchorage devices for post-tensioning shall be capable of holding the pre-stressing steel at a load producing a stress of not less than 95 percent of the guaranteed minimum tensile strength of the pre-stressing steel.

All externally exposed steel parts shall be protected from corrosion. All threaded parts and fittings shall be protected by approved material by the Consultant or plugs until used. Anchorages shall be kept free from dirt, mortar, loose rust or other deleterious materials. Damaged anchorage parts shall not be used.

8.78.4 Prestressing Ducts for Internal Tendons

Ducting for internal tendons shall be fully compatible with the proposed prestressing system. The ducting shall form an airtight and watertight barrier to the tendons and shall be fabricated from corrugated galvanized sheet steel or semi-rigid conduit. Duct diameter shall be at least 6 mm larger than the nominal diameter of strand, wire or bar and the cross sectional area shall be at least 2.5 times that of the net tendon area or subject to the Consultant's approval.

Minimum duct thickness shall be as follows:

- 0.32 mm for duct dia less than or equal to 85 mm
- 0.40 mm for duct dia. greater than 85 mm
- 0.60 mm for bar tendons

Ducts shall have grouting connections at each end and shall have vent/drains at all intermediate high and low points, to the approval of the Consultant. The ducts not meeting the above requirement shall be subject to the Consultant's approval.

8.78.5 Prestressing Ducts for External Tendons Ducting for Tendons

Ducting for external tendons (or Overcoat Pipes for Stay Cable) shall be formed from smooth, rigid pipe made of high density polyethylene conforming to the material requirements of ASTM D 3350 and manufactured in accordance with ASTM D 2447, ASTM F 714 or ASTM D 2239.

Unless stated otherwise in the Contract, the internal cross sectional area of the ducts shall be at least 2.5 times that of the net tendon area.

The ducting shall be tightly connected to the anchorages and shall be continuous between anchorages. The number of joints in the ducting shall be kept to a practicable minimum and the method of connection at the joints shall be to the approval of the Consultant.

The ducting shall have vent/drain at all high and low points and at deviator positions to the approval of the Consultant.

The completed ducting system, including joints, shall be airtight and watertight and shall effectively contain pressurized grout during grouting operations.

8.78.6 Prestressing Grout

Grout shall consist of Portland cement, water, and an expansive admixture plus retarder as approved by the Engineer. Water shall be potable. No admixtures containing chlorides, nitrates or similar electrolytic conducting materials shall be used.

The Contractor shall submit the proportion of mixing for approval of the Engineer.

Water shall be first added to the mixer followed by cement and admixture. The grout shall be mixed in mechanical mixing equipment of a type that shall produce uniform and thoroughly mixed grout. Retempering of grout shall not be permitted. Grout shall be continuously agitated until it is pumped.

Grout for Ducts

Unless otherwise directed or approved by the Consultant as a result of grouting trials, the grout shall have a water to cement ratio, as low as possible consistent with the necessary workability, and under no circumstances shall the water: cement ratio exceed 0.40.

The grout shall not be subject to bleeding in excess of 2 percent after 3 hours, or 4 per cent maximum when measured at 30°C in a covered glass cylinder approximately 100 millimeters diameter with a height of grout of approximately 100 millimeters, and the water shall be re-absorbed by the grout during the 24 hours after mixing.

Not contain admixtures containing chlorides, nitrates.

The minimum compressive strength of a test cylinder shall be 20 MPa at 28 days.

8.78.7 Prestressing Operations

The Contractor shall provide a Technician skilled in the use of the system of prestressing to be used, who shall supervise the work and give the Engineer such assistance as the Engineer may consider necessary.

The Contractor shall nominate the prestressing sub-contractor to be used and provide details of the sub-contractor's previous experience. At least 14 days prior to the placing of formwork for in-situ elements for post-tensioning, the Contractor shall submit to the Engineer for approval full details of the proposed prestressing system. This shall include design calculations and working drawings to define the reinforcement details and concrete dimensions to accommodate the system.

The Contractor shall provide all equipment necessary for the construction and the prestressing. Prestressing shall be done with an approved proprietary jacking equipment. If hydraulic jacks are used they shall be equipped with accurately reading pressure gauges. The combination of jack and gauge shall be calibrated and a graph or table showing the calibration shall be furnished to the Engineer. Should other types of jacks be used, calibrated proving rings or other devices shall be furnished so that the jacking forces may be accurately known.

All of the applicable requirements of this Specification shall be complied with except as may be modified in the clauses below.

Prestressed concrete shall be formed, stressed, placed, cured, and protected at shops, manufacturing plants, and locations approved by the Engineer, where the fabrication of such members may be properly inspected and controlled.

8.78.8 Approvals prior to Pouring Prestressed Concrete

The Contractor shall prepare, check and submit to the Engineer complete detailed calculations, working drawings and schedules showing:

- Contractor's alternative designs if the submission of alternatives is approved;
- Contractor's details of proposed manufacture and construction,
- sequence of operations proposed; and
- dimensions and complete descriptions of all devices, joints, bearings, and anchorages not specified or detailed in the Contract Documents.

These stressing calculations, working drawings and schedules shall be submitted to the Engineer at least 7 days before commencement of stressing for approval.

Concrete shall not be cast prior to the Engineer's approval of the Contractor's Drawings, if any, of concrete mixtures, of formwork, of method of application of prestressing forces, of methods of placing, of curing, of protecting, of handling and of erecting members. Any alternative to the design in the Contract Documents, shall be subject to the Engineer's approval before manufacture or construction.

The Contractor shall inform the Engineer not less than 7 days in advance of the probable date of commencement of manufacture and the dates when tensioning of steel, casting of units and transfer of stress shall be undertaken for the first time.

The Engineer shall be given 7 days' notice of the commencement of each phase of stressing operations. The Contractor shall make available full conformance records for the relevant tendons, stressing equipment and the concrete to be stressed.

The Engineer will wish to witness particular stressing operations. The Engineer will advise the Contractor of the particular operations, which it wants to witness at the time the Contractor is preparing its Quality Plan and from time to time during the progress of the Works.

8.79 Reinforcement, Ducts and Other Inserts

All reinforcement, ducts and other inserts shall be accurately placed in the position shown on the Drawings and rigidly held during placing and setting of the concrete. Distance from the forms shall be maintained by stays, blocks, ties, hangers, or other approved support. Blocks for holding units from contact with the forms shall be precast mortar blocks of approved shape and dimensions. Layers of units shall be separated by mortar blocks or other equally suitable devices. Wooden blocks shall not be used.

8.80 Pretensioning Method

The prestressing elements shall be accurately held in position and stressed by jacks. Stressing shall be applied to produce the stresses required in the wires or strands immediately after the anchorage as shown on the Drawings or as directed by the Engineer. Suitable allowances shall be made for friction in the jacks and for slip and yield in the grips or anchorages.

A record shall be kept of the jacking forces and the elongations produced thereby and the minimum age in hours of the concrete in the unit at the time the tendons were released.

Several units may be cast in one continuous line and stressed at one time, in which case sufficient space shall be left between ends of units to permit access for cutting after the concrete has attained the required strength. No bond stress shall be transferred to the concrete, nor shall end anchors be released, until the concrete has attained a compressive strength not less than 85% of the specified 28-day strength as shown by standard specimens made and cured identically with the members. The elements shall be cut or released in such an order that eccentricity of prestress shall be a minimum.

The method of tensioning tendons including the arrangement and layout of each line, calculations of forces at anchorages, and estimated friction losses, shall be submitted to the Engineer for approval before manufacture commences. Tensioning shall not be commenced until the Engineer has approved the proposed method.

8.81 Curing

If steam curing is adopted the casting bed for any unit cured with steam shall be completely enclosed to prevent steam escaping and exclude outside atmosphere. Two to four hours after placing concrete and after the concrete has undergone initial set, the first application of steam shall be made. If retarding admixtures have been used, the delay before application of the steam shall be increased to four to six hours. Water curing methods shall be used from the time the concrete is placed until steam is first applied.

If the Contractor elects to cure by any other special method, the method and details shall be subject to the approval of the Engineer.

8.82 Post-tensioning Method

Tensioning of the prestressing reinforcement shall not be commenced until tests on concrete cylinders, manufactured of the same concrete of the particular member to be prestressed has attained compressive strength indicated in the Drawings or directed by the Engineer.

After all concrete has attained the required strength, the prestressing reinforcement shall be stressed by means of jacks to the desired tension and the stress transferred to the end anchorage:

Post-tensioning shall be carried out in accordance with an approved method and in the presence of the Consultant unless permission has been obtained to the contrary.

Immediately before tensioning the Contractor shall prove that all tendons are free to move in the ducts.

Each anchorage device shall be set square to the line of action of the corresponding post-tensioning tendon and shall be securely fixed in position and gradient to prevent movement during the placing and compacting of concrete.

Cast in place concrete shall not be post-tensioned until at least 10 days after the last concrete has been placed in the member to be post-tensioned and until the compressive strength of said placed concrete has reached the strength specified for the concrete at the time of stressing.

All side and inside forms for girders shall be removed before post-tensioning. The falsework under the bottom slab supporting the superstructure shall not be released until a minimum of 48 hours have elapsed after grouting of the post-tension tendons nor until all other conditions of this Specification have been met. The supporting falsework shall be constructed in such a manner that the superstructure shall be free lift off the falsework and shorten during post-tensioning.

The tensioning process shall be so conducted that the tension being applied and the elongation of the prestressing elements may be measured at all times.

A record shall be kept of gauge pressures and elongation at all times and submitted to the Engineer for his approval.

The load from the anchoring device shall be distributed to the concrete by means of approved devices that shall effectively distribute the load to the concrete.

Where the end of a post-tensioned assembly shall not be covered by concrete, the anchoring devices shall be recessed so that the ends of the prestressing steel and all parts of the anchoring devices shall be at least 50 mm inside of the end surface of the members, unless a greater embedment is shown on the plans. Following post-tensioning, the recesses shall be filled with concrete, and finished as shown in the Drawings.

Except where dead-end anchorages are cast in the concrete, tendons shall not be installed until just prior to stressing. Tendons shall be pulled or pushed through the ducting in such a manner as to avoid damage to either tendon or ducting. Unless approved otherwise, concrete shall not be stressed until it has reached at least the age at which 2 test cylinders taken from it have attained the specified transfer strength. The test cylinders shall be cured in similar conditions to the concrete to which they relate in a manner approved by the Consultant.

Where members consist of jointed elements the strength of transfer of the jointing material shall be at least equivalent to the specified transfer strength of the member. The Contractor shall establish the datum point for measuring extension and jack pressure to the satisfaction of the Consultant. Allowance shall be made for the friction in the jack and anchorage for pull-in of the tendon during anchorage.

The tendons shall be stressed at a gradual and steady rate until the required extension and tendon load is reached or is approved by the Consultant. The sequence of

stressing shall be as shown on the drawings or directed by the Consultant.

The force in the tendons shall be obtained from readings on a load cell or pressure gauge incorporated in the equipment and the extension of the tendons measured. Unless stated otherwise to the contrary the extension of the tendons under the approved total forces shall be within ± 5%of the agreed calculated extension.

If the measured extensions are not within the specified tolerance then the Contractor shall submit to the Consultant his method of rectifying the discrepancy.

When the prestressing force has been applied to the satisfaction of the Consultant, the tendons shall be anchored. The force exerted by the tensioning apparatus shall then be decreased gradually and steadily so as to avoid shock to the tendon or anchorage.

Full records shall be kept of all tensioning operations including measured extensions, pressure gauge or load cell readings and draw-in at anchorage. Copies of records shall be supplied to the Consultant within'24 hours of each tensioning operation.

Unless otherwise agreed by the Consultant, tendons shall not be cut less than 2 days after stressing.

Notwithstanding the above, no tendon shall be grouted until the stressing conformance by the Engineer for the particular tendon.

8.83 Grouting of Prestressing Tendons and Bars

Prestressing steel shall be bonded to the concrete by filling the void space between the duct and the tendon with a non-shrink (expanding) grout. All prestressing steel to be bonded to the concrete shall be free of dirt, loose rust, grease or other deleterious substances.

The grout mixer shall produce a grout of colloidal consistency. The grout injector shall be capable of continuous operation with a sensibly constant pressure up to 0.70 N/sq.mm, and shall include a system of circulating or agitating the grout whilst actual grouting is not in progress.

All grout shall pass through a screen with 1.20mm maximum clear openings prior to being introduced into the grout pump and all baffles to the pump shall be fitted with 1.20 mm sieve strainers.

Grout injection pipes shall be fitted with positive mechanical shutoff valves. Vents and ejection pipes shall be fitted with valves, caps, or other devices capable of withstanding the pumping pressure. Valves and caps shall not be removed or opened until the grout has set.

The pressure gauges shall be calibrated before they are first used in the Works, and thereafter as required by the Consultant. All equipment shall be thoroughly cleaned and washed with clean water at the end of use for each day.

During the grouting operation, the Contractor shall provide adequate flushing-out plant to facilitate complete removal of the grout in the event of a breakdown of the

grouting equipment or other disruption before the grouting operation has been completed.

Grouting trials shall be undertaken when directed by the Consultant. The Contractor shall submit a detailed method statement prior to use in any trials or in the works covering proposed materials, sheathing, anchorage and vent arrangement equipment, grouting procedures and Quality Control for the approval of the Consultant.

All ducts shall be thoroughly cleaned out by means of flushing with water and/or water/compressed air.

Grouting of ducts shall be carried out as soon as practicable more than 4 weeks after the tendons in them have been stressed and the Consultant's permission to commence has been obtained. If due to the requirements of the stressing procedure tendons cannot be grouted within this period the sheathing shall be sealed to protect the tendons from corrosion.

Injection shall be continuous and it shall be slow enough to avoid producing segregation of the grout. The method of injecting grout shall ensure complete filling of the ducts and complete surrounding of the steel. Grout shall be allowed to flow from the free end of the duct until its consistency is equivalent to that of the grout injected. The opening shall then be firmly closed. Any air vents shall be closed in a similar manner one after the other in the direction of flow. The injection tubes shall then be sealed off under pressure until the grout has set.

The filled ducts shall not be subjected to shock or vibration within 1 day of grouting. Not less than 2 days after grouting, the level of grout in the injection and vent tubes shall be inspected and made good as necessary.

The Contractor shall keep full records of grouting including the date each duct was grouted, the proportion of the grout and any admixtures used, the pressure, details of any interruptions and topping up required. Copies of these records shall be supplied to the Consultant within 3 days of grouting.

The fluidity of the grout shall be tested on site at the time of mixing using the Marsh Cone Test to ensure practicality of pumping and minimize the risk of blockage during grouting operators. A target flow time of 10-15 seconds should be achieved.

8.84 Protection of Pre-stressing Anchorage

As soon as possible after tensioning and grouting is completed, exposed end anchorage, strands and other metal accessories shall be cleaned of rust, misplaced mortar, grout and other such materials.

Immediately following the cleaning operation the entire surface of the anchorage recess and all exposed metal shall be thoroughly dried and uniformly coated with an epoxy bonding agent conforming to AASHTO M235 Class III in accordance with the manufacturers recommendations.

The anchorage recess shall then be filled with an approved non shrinkage mortar. The mortar shall not contain aluminum powder, iron particles, chlorides, sulfates, fluorides or nitrates.

Where the protection will form part of the exposed works the anchorage recess shall be filled with concrete of the same quality and color as that of the adjacent concrete and shall be applied and cured in accordance with the related subsection.

Exposed surfaces of anchorage not in an anchorage recess shall be coated for corrosion protection with a coal tar epoxy or equivalent as approved by the Consultant. Prior to coating, all surfaces shall be wire brushed to remove all loose rust, mill scale or other deleterious substances, and the surfaces cleaned with a suitable solvent to remove oil and grease.

8.85 Handling, Transport and Storage of Precast Prestressed Concrete

Precast prestressed concrete shall not be moved from the casting position or transported until the concrete has attained a compressive strength of 90% of the specified 28-day strength.

The proposed details at the lifting points of the beams and the proposed method of lifting and supporting the beams shall be submitted to the Engineer for approval at least 7 days before manufacture of beams commences.

Extreme care shall be exercised in handling and moving precast prestressed concrete members. Precast girders and slabs shall be transported in an upright position, shock shall be avoided and the points of support and directions of the reactions with respect to the member shall be approximately the same during transporting and storage as when the member is in its final position. If the Contractor deems it expedient to transport or store precast prestressed units in other than this position, it shall be done at his own risk after notifying the Engineer of his intention to do so. Any unit considered by the Engineer to have become substandard shall be rejected and replaced at the Contractor's expense by an acceptable unit.

8.86 Marking of Precast Prestressed Member

Each precast prestressed member is to be uniquely and permanently marked so as to show its type, date of casting and reinforcement.

8.87 Testing of Precast Prestressed Members

When directed by the Engineer one or more beams shall be subjected to a loading test. The Contractor shall obtain the prior approval of the Engineer to the detailed arrangements for the testing. A beam which is to undergo testing shall be supported at its design points of bearing and the upward deflection due to the prestressing force measured relative to a line joining these points. Equal loads shall then be applied at the third points in ten equal increments, the total being sustained for 5 minutes. The beam shall then be unloaded.

The midspan deflection relative to the reference line shall be measured for each increment of load. The load deflection curve plotted from these values must show no appreciable variation from a straight line. The Drawings shall show, or the Engineer shall direct, the loads to be applied and the corresponding deflections which must not be exceeded.

Any beam which fails to satisfy the Engineer under the prescribed test shall be

rejected and all other beams cast in the same line as the rejected beam shall also be rejected unless tested at the Contractor's expense and found satisfactory.

The Contractor shall supply to the Engineer record sheets of the tests showing date of test, the loads, deflections, and load deflection curves, calculated values of "E" and the strength of the concrete at release as indicated by the relevant cube or cylinder test results.

The tests are to be carried out on units selected by and in the presence of the Engineer after he has agreed to the method of testing and form of records. The cost of such tests and records shall be included in the unit prices.

8.88 Prestressed Concrete for In-Situ Box Girder

This work shall consist of the forming of in-situ pre-stressed concrete box girders constructed in conformity with the lines, grades, design, and dimensions shown on the Drawings or established by the Engineer and in accordance with this Specification.

The Contractor shall, prepare, check and submit to the Engineer for approval complete detailed Working (Shop) Drawings or Schedules together with calculations as required by the Engineer showing, but not limited to, the following:

- Sequence of operation proposed at each stage of construction;
- Dimensions and complete descriptions of all devices, joints, bearings, and anchorage's not specified or detailed in the Contract Documents;
- Proposed jacking force at each stage of construction and camber control measures with supporting calculation
- Details of travelling forms, suspended scaffolding beam erection gantries and the like;
- Method and timing of the insertion of the stay cables and
- Method statement for grouting of ducting.

Concrete shall not be cast prior to the Consultant's approval of the Contractor's Drawings, of concrete mixtures, of form-work and false-work, of methods of application of pre-stressing forces, of methods of placing, of curing, of protecting, of handling and of erecting members.

The Contractor shall inform the Consultant not less than 7 days in advance of the probable date of commencement of manufacture and the dates when casting of units, tensioning of steel and transfer of stress will be undertaken for the first time.

8.89 Reinforcing Bars for In-Situ Box Girder

Reinforcing bars shall be deformed and shall meet the requirements of JIS 63112 or AASHTO M 31(ASTM A 615), Grade 40 or equivalent.

8.90 Prestressing Steel and Prestressing Quality Reinforcement for In-Situ Box Girder

High tensile steel strand shall be weld free and stress relieved after stranding and shall conform to the requirements of JIS G 3536-1994 "Un-coated stress relieved

steel and strands for pre-stressed concrete" or ASTM A 421-91 "Un-coated Stress Relieved Wire for Pre-stressed Concrete" and ASTM A 416-90 "Un-coated Seven Wire Stress Relieved Strand for Pre-stressed Concrete".

High tensile steel bar shall be stress relieved and shall conform to the requirements of JIS G 3109 Steel bars for pre-stressed concrete or ASTM A 722.

8.91 Tendon Extension for In-Situ Box Girder

The extension of the tendons in the in-situ box girder under the approved total forces shall not exceed:

Transverse Tendons for Segments:	± 10% average for one tendon
	± 7% for average of one segment
Longitudinal Tendons for Segments	± 5%

8.92 Waterproofing to Bridge Deck Slab

This work shall consist of applying waterproofing materials to bridge deck slab concrete surfaces as required by the Drawings, this Specification, or the Engineer.

Waterproofing fabric shall be a saturated cotton fabric meeting the requirements of ASTM D 173, Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing.

8.92.1 Storage of Fabric for Waterproofing to Bridge Deck Slab

The fabric shall be stored in a dry, protected place. Rolls shall not be stored standing on end.

8.92.2 Preparation of Surface for Waterproofing to Bridge Deck Slab

Concrete surfaces shall be reasonably smooth and without projections or holes that might puncture the waterproofing membrane. The surfaces shall be dry, with all dust and loose material removed. The Contractor shall not apply waterproofing in wet weather or when the air temperature is below 2°C unless the Engineer approves in writing.

8.92.3 Application of Waterproofing to Bridge Deck Slab

Waterproofing asphalt shall be stirred frequently as it is heated to between 150°C and 180°C. Each heating kettle shall have a thermometer.

Each coat of primer or asphalt shall begin at the low point of the surface so that water will run over (not against or along the laps.

In applying the waterproofing, the Contractor shall:

- Apply a coat of primer and let it dry before applying the first asphalt coat.
- Mop hot asphalt on a band about 510 millimeters wide across the full length of the surface.
- Immediately roll a starter strip of half-width fabric into the asphalt, pressing it

into place to rid it of all air bubbles and to conform it closely to the surface.

- Mop hot asphalt over the starter strip and an adjacent section of surface so that the fresh asphalt forms a band slightly wider than the full width of the fabric.
- Immediately roll a full-width strip of fabric into the fresh asphalt, pressing it into place as before.
- Mop hot asphalt on the latest strip and on an adjacent band of the surface slightly wider that the full width of the fabric.
- Immediately roll another strip of fabric into the asphalt, lapping the earlier strip by at least 50 millimeters and pressing it into place as before.
- Repeat mopping and rolling until the entire surface is covered.
- Mop the entire surface with a final coating of hot asphalt.

The three complete moppings of asphalt shall ensure that no fabric layer ever touches another fabric layer or the concrete surface. The Contractor shall examine all laps and ensure that they are thoroughly sealed down.

Each mopping shall cover completely, with a coat heavy enough to hide the fabric weave and all gray spots from the concrete. On horizontal surfaces, at least 48 liters of asphalt shall be used for every 10 square meters of finished work. On vertical surfaces, at least 6 liters per 10 square meters shall be used.

At the end of each day's work, all fabric that was laid shall have received its final mopping of asphalt.

Wherever the membrane ends or is punctured by drains, pipes, etc., the Contractor shall seal the area to prevent water from entering between the waterproofing and the concrete surface.

All flashing (at kerbs, against girders, spandrel walls, etc.) shall be made of separate sheets that lap the main membrane by at least 300 millimeters. Flashing shall be sealed closely with full metal flashing or by imbedding its upper edges in a groove poured full of an acceptable joint cement.

At each expansion joint, the membrane shall not be broken but shall be folded to permit movement. At either end of the bridge, the membrane shall run well down abutments and shall allow for expansion and contraction.

8.92.4 Protection Course for Waterproofing to Bridge Deck Slab

If the Plans require, the Contractor shall place a layer of mortar at least 38 millimeters thick over the whole surface of the membrane just after it has cooled to air temperature. This layer shall be a mix of one part Portland cement to two parts sand. It shall be distributed evenly over the membrane, tamped gently into place, finished by hand to a smooth, hard surface, then covered and kept moist for one week.

8.93 Measurement and Payment

The quantity of concrete shall be measured by net volume and in accordance with Clause 12 (Concrete) of the Preamble.

Payment shall not be made separately for grout and mortar used in association with holding bolts and bearings but shall be deemed to be included in the items for holding down bolts and bearings.

The work measured as provided above for the various grades of concrete shall be paid for at the scheduled rate according to the particular purpose provided in the Bill of Quantities per cubic metre. The rates shall include for complying with the Clause 12 of the Preamble.

11 BRIDGE BEARING

11.1 Bridge Bearings

This Specification section provides requirements and procedures for the supply and installation of bridge bearing pads required as indicated on the Drawings, as or as directed by the Engineer.

11.2 Elastomeric Bearings Generally

Elastomeric bearing types are different on the main bridge from those on the approach bridges. The main bridge bearings shall have a dispersion function for horizontal reaction, and shall have durability for long term life as well as bridge life without maintenance.

Elastomeric bearings shall consist of laminated elastomeric pads or assemblies of laminated elastomeric pads as indicated on the Drawings and as specified herein.

Variation in thickness of an individual elastomer lamination shall not exceed 3 mm within the width or length of a bearing pad and the variation in thickness of all elastomer laminations within a bearing pad shall be such that each metal or fabric lamination will not vary by more than 3 mm from a plane parallel to the top or bottom surface of the bearing pad.

The total out to out thickness of a bearing pad shall not be less than the thickness indicated on the Drawings nor more than 6 mm greater than that thickness. Variation of total thickness within an individual bearing pad shall not exceed 3 mm.

The length and width of a bearing pad shall not vary more than 3 mm from the dimensions indicated on the Drawings.

The bond between the elastomer and the steel laminate shall be such that, when a sample is tested for separation, failure shall occur within the elastomer and not between the elastomer and the steel.

11.2.1 Elastomeric Bearings Materials

All materials used in the manufacture of the bearing assemblies shall be new and unused with no reclaimed material incorporated into the finished assembly. All bonding of components shall be done under heat and pressure during the vulcanizing process. The bond shall be continuous throughout the plan area with no air spaces greater than 0.25 mm within the bonding material. The bearing assemblies shall be furnished as complete units from one manufacturing source.

The materials for the elastomeric bearings and assemblies shall comply with the following requirements:

11.2.2 Elastomeric Materials for Bearings

The elastomeric materials of the compounds shall be 100°% virgin polychloroprene synthetic rubber meeting the requirements of Table No.1. The properties of the elastomeric compounds shall be determined from test specimens complying with

ASTM D3182 through D3190 inclusive and D3192. A variation of ± 10% in tensile strength and ultimate elongation under "physical properties" will be permitted when test specimens are cut from the finished product.

11.2.3 Internal Steel Laminates for Bearings

The internal steel laminates for the laminated elastomeric bearing pads shall be rolled carbon steel sheets complying with ASTM A 570 or AASHTO N183 (ASTM A36).

11.2.4 Laminated Elastomeric Bearing Pads

Laminated elastomeric bearing pads shall be individually molded to the required size. Corners and edges may be rounded with a radius at the corners not exceeding 9 mm and a radius at the edges not exceeding 6 mm. All edges of the steel laminations shall be covered with not less than 4 mm and not more than 6 mm of elastomer. The characteristics of the elastomeric bearing pads shall be within the following listed tolerances:

ASTM Standard	Physical Properties	Value
D2240	Hardness, ASTM D2240	60 ± 5
D412	Tensile strength, min.kg/cm2Ultimate elongation, min. %	175 425
D573, 70 HR. 03100°C	Heat Resistance Change in durometer hardness, max.points Change in tensile strength, max.% Change in ultimate elongation, max. %	 + 15 - 15 - 40
D395 Method B	Compressive Set 22 hours 03100 °C max. %	 35
	Ozone	
D1149	100 pphm ozone in air by volume, 20% strain, 37.7°C t 1C,100 hours mounting Procedure D 518, Procedure A	No Cracks
D429, A D429, B	Adhesion to Steel Bond made during vulcanization Bond Strength (per square cm) Peel Strength (per cm of width)	 80% R(Z1) 2.8kg 7 kg
D429, B	Adhesion to TFE Bond made during vulcanization Peel Strength	
Low Temperature Test-Durometer Change	Bearing or sample to be exposed for 96 hrs.@-28 °C, ±2 °C. (The specimen shall have a24 hr. conditioning period at roomtemperature prior to low temperatureexposure). The durometer test shall bemade at-28 °C on an unbuffed surface.Durometer hardness increase, Max. ASTMD2240, 30 second reading. Durometer to beplaced in freezer with test specimen	+ 15(Z2)
D746	Brittleness temp, 3 min., at -40 °C	No cracks

ASTM Standard	Physical Properties	Value
	Structural Steel. The internal steel laminates	for the laminated elastomeric bearings shall be rolled mild steel sheets conforming to SAE 1020 or AASHTO M183
	Laminated elastomeric bearings shall be individually molded to the required size.Corners and edges may be rounded with aradius at the corners not exceeding 9 mmand radius at the edges not exceeding 6mm. All edges of the steel laminations shallbe covered with not less than 3 mm and notmore than 6 mm of elastorner. Thedimensions of the elastomeric bearings shallbe within the following listed tolerances:	

Overall Vertical Rubber Dimension

Average total rubber thickness 32 mm or less	-0, +3 mm
Average total rubber thickness over 32 mm	-0, +6 mm

Overall Horizontal Rubber Dimension

90 cm or less	-0, + 3 mm

Thickness of individual layers of elastomer (60 Durometer Only) ± 20%

Variation from a plane parallel to the theoretical surface 1.5 mm per 300 mm, Tops 6 mm, Sides.

Edge cover of embedded metallic laminate 4 mm min, 6 mm max.

The rubber laminates shall be of uniform integral units, capable of being separated by mechanical means into separate, well-defined elastomeric layers. The ultimate breakdown limit of the elastomeric bearing under compressive loading shall be not less than 140 kgs/cm2. In addition to the requirements of Table No. 1, the stress-strain relationship of the finished elastomeric bearings at room temperature shall not exceed the following limitations.

Compression Stress	35 kgs/sq.cm	56 kgs./sq.cm
Strain (Percent of total thickness of all elastomer laminations)	5%	7%

In addition, shear resistance of the bearing shall not exceed 2.1kg/cm for 60 durometer, Table No. 1 compounds at 25% strain of the total effective rubber thickness after an extended four-day ambient temperature of -28 °C.

The Contractor shall furnish to the Engineer a certification by the manufacturer that the elastomer, in the elastomeric bearing pads to be furnished conforms to all of the above requirements. The certification shall be supported by a certified copy of the results of tests performed by the manufacturer upon samples of the elastomer to be used in the pads.

11.3 Rubber Bearings with Dispersion Function

The rubber bearings on the main bridge shall have a function of force dispersion with a large deformation capacity. The basic components of the bearing shall consists of rubber material, a weatherproof rubber cover, internal laminates steel sheets, upper and lower steel plates with anchored connection rods, and guide device for shear deformation.

The rubber shall be a natural rubber derivative meeting the requirements in accordance with the following Standards for Malaysian Rubber:

Description	Unit	Grade
Rubbish content	%	< 0.05
Ash content	%	< 0.5
Copper content	p.p.m.	< 8
Manganese content	p.p.m.	< 10
Nitrogen content	%	< 0.7
Volatile content	%	< 1.0

Bearing material shall meet the following requirements:

- Design Conditions:

Capacity of bearing stress (calculated by valid bearing area)	:	fmin=80kgf/cm2, f'min,=15kgf/cmz
Amplitude of a stress	:	50kgf/cm^2
Capacity of shear strain	:	70%, and 150%(seismic design)
Rotation angle	:	1/300 at end support, 1/600 at mid span support

- Requirements of bearing material made from natural rubber:

Item	Unit	Value	Remarks
Static modulus of share elasticity	Kgf/cm^2	13.5-L1.3	JISK 6301-13
Hardness		65±5	D2240, JISK 6301-5
Ultimate Elongation, min.	%	>500	D412, JISK 6301-3
Tensile strength, min.	Kgf/cm^2	>150	D412, JISK 6301-3
Heart Resistance for change in tensile strength at 25 % elongation	°%	-10 to +30	D573, 70 hours at 70°C JISK 6301-6,13
Heat Resistance for change in ultimate elongation, max.	%	> - 50	D573, 70 hours at 70°C JISK 6301-6,13
Compressive set	%	< 25	D395, 22 hours at 70°C JISK 6301-10
Ozone Endurance D1149	-	No cracks by visual inspection	50pphm ozone in air by volume, 20% strain, 40 °C ± 1 °C, 96 hours mounting Procedure D518, Procedure A JISK 6301-16
Water Endurance	%	< 10	72 hours at 50°C, D471 JISK 6011-5
Coldproof	-	< - 30 °C	D746, JISK 6301-14
Peel Strength	Kgf/cm^2	> 7	D429, JISK 6301-8
Chemical proof etc.			D471, D1460
Bond strength between steel			D413, D429

- Bearing rubber surface material shall be weatherproof and provide ozone protection of the bearing material and protect the bearing laminate steel from rust. The surface material shall provide such protection for the life of the bearings.

Internal laminate sheets, sole, bed, upper and lower plates and guide devices shall be high-strength low-alloy steel complying with AASHTO M270 grade 50 (ASTM A 709, grade 50) or an approved stainless steel.

- The Contractor shall provide test certifications supposing testing by two million repeated (2Hz) loads for compressive shear fatigue test.

The anchor bolts for sole and bed plates shall:

- be zinc coated in accordance with requirements of AISI 1035, or an approved equivalent,
- be threaded,
- have a diameter not less than 25 mm,
- have an embedded depth not be less than 10 times the bolt diameter and
- have a shear strength of not less than 80 Mpa.

11.3.1 Mechanical Bearings

Mechanical Bearings shall be pot type and will have an elastomeric rotational element. Movement bearings will normally have sliding surfaces of stainless steel

and polytetrafluorethylene and may also have been fitted with guide bars or keyways. The bearings will have been designed in accordance with the requirements of the 1989 and/any Edition of AASHTO "Standard Specifications for Highway Bridges" 1989 and subsequent Interim revisions.

The Contractor shall provide shop drawings and calculations demonstrating the compliance of all bearings with the schedule show on the drawings.

Bearings shall have surface protecting in accordance with requirements and procedures noted under this Specification.

11.4 Packaging, Handling, And Storage Of Mechanical Bearings

Prior to shipment from the point of manufacture, bearings shall be packaged in such a manner to ensure that during shipment and storage the bearings will be protected against damage form handling, weather, or any normal hazard.

Each completed bearing shall have its components clearly identified, be securely bolted, strapped or otherwise fastened to prevent any relative movement, and marked on its top as to location and orientation in each structure in the project in conformity with the plans.

Dismantling at the site shall not be done unless absolutely necessary for inspection or installation.

All bearing devices and components shall be stored at the work site in an area that provides protection form environmental and physical damage.

When installed, bearings shall be clean and free of all foreign substances.

11.5 Galvanized Steel Dowels

I beam and slab galvanized steel dowels shall be provided and installed in accordance with requirements and with accessories noted on the drawings.

Dowels shall be smooth plain billet-steel bars conforming to requirements of ASTM A615, 400 MPa and shall be zinc (hot-dip galvanized) in accordance with ASTM A123.

Dowels may be cast-insitu as shown on the drawings or drilled and grouted with an approved epoxy compound.

If dowels are drilled and grouted:

- holes shall provide at least 10 mm in diameter grater than the largest diameter of the dowel;
- holes shall be thoroughly cleaned with compressed air and water prior to grouting of dowels so as to remove all loose or extraneous materials;
- epoxy grout shall be ASTM C881 Type IV, or approved equivalent.

11.6 Bearing Installation

The bearings will have been clearly marked with their longitudinal and transverse axes, their type number and their intended locations in the Works.

Unless otherwise approved by the Engineer bearing beds shall be of non--shrink grout conforming to ASTM C 1107, Grade A. Proposals for the thickness and type of bearing plinths and beds shall be submitted by the Contractor and approved by the Engineer's in advance of bearing installation.

The Contractor shall submit to the Engineer for approval a detailed statement with respect to the methods for installation of Elastomeric Bearings. Once the Engineer has approved these methods, they shall not be changed without prior approval by the Engineer.

Bearings shall not be dismantled. Any transit bolts, straps or other temporary fixing shall not be removed until the bearing is fixed in its final position and the structure immediately above the bearing is in place. Care shall be taken to ensure that all transit bolts straps or other temporary fixings are finally removed.

All bearings shall be set horizontal in both directions and shall be positioned so that the Inscribed longitudinal axis is parallel to the structure axis at the point of support, unless otherwise noted in the Drawings.

Any devices such as steel packs used to hold bearings level whilst being fixed, must be removed finally, so that the bearings seats only on its mortar bedding.

Where precast beams and segments are placed on elastomeric bearings, immediately prior to the placing of each beam and segment the top of the bearing shall be coated with a sufficient thickness of approved mortar to take up any irregularities between the surface of the beams and segment and the bearings.

Bearings shall be positioned within the following tolerances:

- Alignment, maximum departure from required vertical or horizontal plane.

  Entire assembly 1:400
  Lower part of bearing 1:1000 relative to upper

- Plan Position

  Laterally 3mm
  Longitudinally 6mm

- Center/ Center Spacing 3mm

11.7 Testing of Bearings Generally

The testing of selected bearings shall be arranged with the Engineer prior to their inclusion in the Works. The testing shall be done at an independent testing facility approved by the Engineer.

11.7.1 Vertical Proof Load Test of Complete Mechanical Bearing

The vertical proof load shall be 1.5 times the maximum vertical load specified in the bearing schedule. The proof load shall be maintained for a minimum period of 3 minutes.

11.7.2 Horizontal Vertical Proof Load Test of Complete Mechanical Bearing

Bearings, which are required to resist lateral forces, shall be further tested to 1.5 times the lateral load stated on the Drawings while loaded in compression to the minimum vertical load shown on the drawings. The load shall be maintained for three minutes.

11.7.3 Rotation Test of Complete Mechanical Bearing

The bearing shall be tested in rotation to the value for rotation shown on the drawings while being loaded in compression to the maximum vertical load shown on the drawings. Bearings, which are required to resist lateral forces, shall also have the specified lateral load stated on the drawings applied during this test.

The direction of application of the lateral load and the axis of rotation shall be compatible with the in service loads and rotational requirements. The lateral load shall be applied using a calibrated sliding surface to minimize any frictional restraint. Stainless steel interface shall be lubricated prior to the test. The test loads shall be maintained for three minutes.

11.7.4 Long - Duration Compression Tests on Elastomeric Bearings

Selected bearings shall be loaded in compression to 1.5 times its maximum design load for a minimum period of 15 hours. If, during the test, the load falls below 1.3 times the maximum design load, the test duration shall be increased by the period of time for which the load is below this limit. The bearing shall be examined visually at the end of the test while it is still under load. If the bulging pattern suggests laminate parallelism or a layer thickness that is outside the specified tolerances, or poor laminate bond, the bearing shall be rejected. If there are three or more separate surface cracks that are greater than 0.08 in. (2mm) wide and 0.08 in. (2mm) deep, the bearing shall be rejected.

11.7.5 Shear Modules Tests on Material from Elastomeric Bearings

The shear modulus of the material in the finished bearing shall be evaluated by testing a specimen cut form it using the apparatus and procedure described in Annex A of ASTM D 4014, or, at the discretion of the Engineer, a comparable nondestructive stiffness test may be conducted on a pair of finished bearings. The shear modulus shall fall within 15 percent of the specified value or within the range for its hardness given in Article 14.3 of Division I if no shear modulus is specified. If the test is conducted on finished bearings, the material shear modulus shall be computed from the measured shear stiffness of the bearings, taking due account of the influence on shear stiffness of bearing geometry and compressive load.

11.8 Rejection of Bearings

Any bearing which, as a results of the testing specified, exhibits any signs of failure such as:

- splitting or permanent deformation of the elastomer;
- tearing, cracking or permanent deformation of the PTFE sliding surface;
- cracking or permanent deformation of the sealing ring or other part of the bearing;
- abrasive marks indicating abnormal contact between the metal surfaces of the bearing plates or piston, and the pot;

shall be rejected and replaced.

Bearings damaged during transport, installation or subsequent construction operations shall also be liable for rejection and replacement.

11.9 Measurement and Payment

(1) The measurement and payment for bearing pad with Accessories shall be by number. The rates for bearing pad shall be made in accordance with the Clause 15 of the Preamble.