Size of Coarse Agg. (mm)	Amounts Finer than Each Standard Sieve Percentage by Weight (JIS A1102)										
	100 mm	80 mm	60 mm	50 mm	40 mm	25 mm	20 mm	15 mm	10 mm	5 mm	2.5 mm
50 –5	-	-	100	95- 100	-	37- 70	-	10- 35	-	0- 5	-
40 –5	-	-	-	100	95- 100	-	35- 70	-	10- 30	0- 5	-
25 – 5	-	-	-	-	100	95-	-	30- 70	-	0- 10	0- 5
20- 5	-	-	-	-	-	100	90- 100	-	20- 55	0- 10	0- 5
15- 5	-	-	-	-	-	100	100	90-	40- 70	0- 15	0- 5
80- 40	100	90- 100	45- 70	-	0- 15	-	0- 5	100	-	-	-
60- 40	-	100	90- 100	35- 70	0- 15	-	0- 5	-	-	-	-
50- 25	-	-	100	90- 100	35- 70	-	-	-	-	-	-
40- 20	-	-	-	100	90- 100	0- 15 20- 55	0- 15	0- 5 -	0- 5	-	-

Sieve analysis of coarse aggregate shall be made in accordance with JIS A1102 (Method of Test for Sieve Analysis of Aggregate) or AASHTO -T27.

The amount of deleterious substance in coarse aggregate shall not exceed the limits prescribed in the table below Treatment of the other deleterious substances which are not shown in the table shall be determined by the direction of the Engineer.

Limits of Deleterious Substance in Coarse Aggregate

Item	Maximum % byWeight
Clay lumps	0.25
Soft particles	5.0
Material finer than 0.075 mm. sieve	1.0 [1]
Material floating on a liquid having a specific gravity of 1.95	1.0 [2]

Note : [1]In the case of crushed aggregate, if the material finer than 0.075 mm. sieve consists of the dust of fracture essentially free from clay or shale, this percentage may be increased to 1.5.
[2]This requirement does not apply to manufactured sand produced from blast furnace slag.

Test for material finer than 0.075 mm sieve shall be made in accordance with JIS A1103) (Method of Test for Amount of Material Passing Standard Sieve 0.075 mm in Aggregates), or AASHTO - T11. Test for soft particles shall be made in accordance with JIS A1126 (Method of Test for Soft Particles in Coarse Aggregate by Use of Scratch Tester), or AASHTO - T12.

8.12 Test of Aggregate

Before use, results of the foregoing tests of aggregate from each source shall be submitted to and approved by the Engineer. Tests for aggregate in use shall be made when required by the Engineer.

Expansion Joint Filler (Asphaltic Joint Filler)

Expansion joint filler shall conform to the requirements of AASHTO - M33.

The filler for each joint shall be furnished in a single piece for the full depth and width required for the joint unless otherwise authorized by the Engineer. When the use of more than one piece is authorized for a joint, the abutting ends shall be fastened securely, and held accurately to shape by stapling or other positive fastening satisfactory to the Engineer.

8.13 Storage of cement

Cement may be shipped from pretested and approved bins at the mill. Cement shall be stored in a damp-proof warehouse with a floor raised at least 30 cm from the ground so as to permit easy access for inspection and for use in the delivered order. Bagged cement shall not be piled more than 13 sacks high. Cement which has become damp, lumpy or otherwise not in proper condition shall not be used. Cement stored by the Contractor for a period longer than 60 (sixty) days shall require the Engineer's approval before being used on the work. Subject to the Engineer's approval of their use, cement of different brands, types, or from different mills shall be stored separately. The use of cement reclaimed from discarded or used bags shall not be permitted.

Storage of aggregate - Fine and coarse aggregates shall be stored separately to prevent contamination by foreign material. Aggregate shall be stored in such a manner as to keep the moisture content as uniform as possible, and shall be handled in such a manner as to prevent segregation. Aggregate shall be stored so as to protect from the direct rays of the sun. Aggregate from different sources of supply shall not be stored in the same place without permission from the Engineer.

8.14 Adhesive

Epoxy resin adhesive shall be used for the jointing of precast concrete blocks. It shall comply with the following requirements.

	Item	Unit	Quality Standards	Testing Conditions	Curing Conditions
UNHARDENED ADHESIVE	External appearance		No foreign matter recognized as to be harmful shall be mixed in. No separation of material shall be observed.		
	Specific gravity	-	.2 – 1.6	Room temperature [1]	
	Viscosity	cp	$1 \times 10^4 - 5 \times 10^4$	Standard working temperature 2/	
	Pot life [3]	hr	2, or more	Standard working temperature [2]	
	Minimum Thickness of Slack [4]	mm	0.3, or more	Standard working temperature [2]	
HARDENED ADHESIVE	Tensile Strength	kg/ cm^2	125, or more	Age: 7 days, Room Temperature [1]	Room Temperature [1]
	Compressive strength	kg/ cm^2	700, or more	Age: 7 days, Room Temperature [1]	Room Temperature [1]
	Adhesive strength [5]	kg/ cm^2	60, or more	Age: 7 days, Room Temperature [1]	Room Temperature [1]

Note : [1]"Room temperature" refers to the Class-2, Standard Temperature Condition specified in JIS Z8703 (Standard Condition of Testing Location) i.e. 20°C ± 2°C.

[2]"Standard Working Temperature" refers to 3 categories (summer type, spring-and-autumn type and winter type) according to working temperatures and are respectively 30°C ± 2°C, 20°C +2°C and 10°C ± 2°C.

[3]"Pot life" refers to 70% of the time from mixing to the start of gelation.

[4]"Minimum slack thickness" refers to the minimum thickness of the adhesive layer formed by the application of the adhesive to a perpendicular surface to a thickness of approximately 1 mm, and measured after the adhesive has slackened downward.

[5]The adhesive strength shall be obtained from a shearing test.

8.15 Equipment and Tools Generally

Equipment and tools necessary for handling materials and performing the work, and satisfactory to the Engineer as to design, capacity, and mechanical condition, shall be at the site of the work before work is started.

If any equipment is not maintained in full working order or if the equipment as used by the Contractor proves inadequate to obtain the results prescribed, such equipment shall be improved or other satisfactory equipment substituted or added at the direction of the Engineer.

8.15.1 Batching Plant and Equipment

All material in the mix shall be proportioned wholly by weight. The batching plant shall include bins, weighing hoppers and scales for the fine aggregate and for each separated size of coarse aggregate. If cement is used in bulk, a bin, hopper and scales for the cement shall be included. The container shall be watertight.

Provision satisfactory to the Engineer shall be made for batching other components of the mix at the batching plant, which may be either stationary or mobile type. It shall be always properly levelled within the accuracy required for the proper operation of weighing mechanisms.

8.15.2 Bins and Hoppers

Bins with adequate separate compartments for fine aggregate and for each required size of coarse aggregate shall be provided in the batching plant. Each compartment shall discharge efficiently and freely into the weighing hopper. Means of control shall be provided so that as the quantity desired in the weighing hopper is being approached, the material may be added slowly and shut off with precision. A port or other opening for removing any overload of the several materials from the hopper shall be provided. Weighing hopper shall be constructed so as to discharge completely.

8.15.3 Scales

The scales for weighing aggregates and cement shall be of either the beam type or the springless dial type. They shall be accurate within one-half of 1% under operating conditions throughout the range of use. Ten weights of 25 kilograms each shall be available for checking accuracy. All exposed fulcrums, clevises and similar working parts of scales shall be kept clean. When beam-type scales are used, provision shall be made for indicating to the operator that the required load in the weighing hopper is being approached. The device shall indicate at least the last 100 kilograms of load and up to 25 kilograms overload.

All weighing and indicating devices shall be in full view of the operator while charging the hopper and he shall have convenient access to all controls.

Cement may be measured by weight, or in standard sacks considered to weigh 50 kilograms net. When measured by weight a separate, satisfactory scale and hopper shall be provided together with a boot or other approved device to transfer the

cement from the weighing hopper. Satisfactory methods of handling shall be employed.

Batching shall be so conducted as to result in the weights of material required, within tolerances of 1% for cement and 2% for aggregates.

8.16 Mixers Generally

All concrete shall be mixed in batch mixers. It may be mixed at the site of construction, at a central plant, or in transit. Each mixer shall have attached to it in' a prominent place a manufacturer's plate showing the capacity of the drum in terms of volume of mixed concrete and the speed of rotation of mixing drum.

8.16.1 Mixers at site of construction

Mixers at the site shall be approved drum-type capable of combining the aggregate cement and water into a thoroughly mixed and uniform mass within the specified mixing period and of discharging the mixture without segregation. The mixer shall be equipped with a suitable charging hopper, water storage, and a Water measuring device, accurate within 1%. Controls shall be so arranged that the water can be applied only while the mixer is being charged. The discharge level shall lock automatically until the batch has been mixed the required time after all materials are in the mixer. Suitable equipment for discharging the concrete on the roadbed shall be provided. The mixer shall be cleaned at suitable intervals. The pick-up and throw-over blades in the drum shall be replaced when they have lost 10% of their depth.

8.16.2 Central Plant Mixers

Central plant mixers shall be of approved drum type capable, of combining the aggregate, cement and water into the thoroughly mixed and uniform mass within the specified mixing period and of discharging the mixture without segregation. Central plant mixers shall be equipped with an acceptable timing device that shall not permit the batch to be discharged until the specified mixing time has elapsed. The water system for a central mixer shall be either a calibrated measuring tank or a meter and shall not necessarily be an integral part of the mixer.

The mixers shall be cleaned at suitable intervals. They shall be examined daily for changes in interior condition. The pick-up and throw- over blades in the drum shall be replaced when they have lost 10% of their depth.

8.16.3 Truck or Transit Mixers

These shall be equipped with electrically actuated counters by which the number of revolutions of the drum or blades may readily be verified and the counters shall be actuated at the commencement of mixing operations at designated mixing speeds. The mixer when loaded shall not be filled to more than 60% of the drum gross volume. The mixer shall be capable of combining the ingredients of the concrete into a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity.

Except when intended for use exclusively as agitators, truck mixers shall be provided with a -water measuring device to measure accurately the quantity of water

for each batch. The delivered amount of water shall be within plus or minus 1% of the indicated amount.

8.17 Vibrators

Unless otherwise directed, the concrete shall be consolidated with approved mechanical vibrators operating within the concrete. When required, vibrating shall be supplemented by hand spading with suitable tools to assure proper and adequate compaction.

The vibrators shall be of a type approved by the Engineer, with a minimum frequency of 3500 impulses per minute and shall be capable of visibly affecting a properly designed concrete with a 2 centimeter slump over a circular area of 45 centimeters radius. The number of vibrators used shall be sufficient to consolidate the concrete properly within 10 minutes after it is deposited in the forms and in addition at least 3 spare vibrators shall be available on standby at the site of the pour to maintain immediate continuity in case of breakdown.

8.18 Forms

Forms shall be made of timber or metal, shall conform to the shape, lines and dimensions of the members shown on the Drawings, and shall be so constructed as to prevent deformation due to load, drying and wetting, vibration, and other causes.

Forms shall be properly equipped with braces, ties and other devices, so as to maintain them in the positions and the shape as shown on the Drawings.

Forms shall be so constructed that they can be removed easily and safely. Joints in linings or panels shall be either horizontal or vertical as far as possible, and shall be sufficiently tight to prevent any leakage of mortar.

Curved forms shall be of the radius called for on the Drawings and acceptable flexible forms shall be installed with that radius.

After forms have been set in the correct location, they shall be inspected and approved by the Engineer before concrete is placed.

Care shall be exercised to keep forms free from dust, grease or other foreign matter. No material or treatment that shall adhere to concrete or discolour concrete shall be used. All forms shall be treated with an approved form-release-oil prior to placing reinforcement and in addition, wood forms shall be flushed with water immediately before placing concrete.

For narrow walls, columns, etc., where the bottom of the form is inaccessible, lower form boards or parts thereof shall be left loose so that they may be removed for cleaning out extraneous material immediately before placing concrete.

Forms for exposed surfaces shall be constructed with triangular fillets not less than 25 mm x 25 mm attached so as to prevent mortar runs and to produce smooth straight chamfers at all sharp edges of the concrete.

8.19 Batching and Transporting Materials

For mixing at site of construction, aggregates shall be transported from the batching Plant to the mixer in batch boxes, vehicle bodies, or other containers adequate in design and construction to properly carry the batch required. Partitions separating batches shall be adequate and effective to prevent spilling from one compartment to another while in transit or while being dumped.

Cement in original shipping containers may be transported on top of the aggregates. The number of sacks of cement required for each batch shall be placed on the aggregates for that batch. Sacked cement shall be emptied into the aggregates prior to dumping into mixer.

Batches shall be delivered to the mixer separately and intact. Each batch container shall be dumped cleanly into the mixer without loss of cement or mixing or spilling of material from one batch compartment into another.

8.20 Mixing Concrete Generally

Concrete shall be mixed at the construction site, at a central mixing plant, in a truck mixer, or by a combination of central plant and truck mixing. Handmixing may be used when approved by the Engineer. No concrete shall be mixed, placed, or finished when the natural light is insufficient, unless an adequate and approved artificial lighting system is operated.

8.20.1 Mixing at Site of Concrete Construction

Concrete shall be mixed in a batch mixer of the type and capacity approved by the Engineer. Mixing time shall be determined by the Engineer in accordance with JIS A1119 (Method of Test for Variation in Unit Weight of Air Free Mortar in Freshly Mixed Concrete). When results of the above tests are not available, the mixing time shall be longer than 1 1/2 minutes after all the materials have been introduced into the mixer, but in no case shall the mixing time exceed three times the mixing time prescribed above. Charging of water into the mixer shall begin before the cement and aggregates enter the drum. During mixing the drum shall be operated at speeds specified by manufacturers. Pick-up blades in the drum of the mixer which are worn down 2 cm or more at any part must be replaced.

The volume of a batch shall not exceed the manufacturer's rated capacity of the mixer without written permission of the Engineer. No mixer whose rated capacity is less than a one bag batch shall be used.

Concrete shall be mixed only in such quantities as are required for immediate use, and concrete which is not of the required consistency at the time of placement shall not be used.

Retempering of concrete shall not be permitted. Entire content of the mixer shall be removed from the drum before materials for the next batch are placed therein. Upon cessation of mixing for a considerable length of time, the mixer shall be cleaned thoroughly. Upon resumption of mixing, the first batch of concrete material placed in the mixer shall contain sufficient sand, cement, and water to coat the inside surface

of the drum without diminishing the required mortar content of the mix.

8.20.2 Central plant mixing

Mixed concrete shall be transported from the central mixing plant to the site of work in agitator or non-agitator trucks approved by the Engineer.

Unless otherwise permitted in writing by the Engineer, agitator trucks shall be equipped with a water tight revolving drum and shall be capable of transporting and discharging concrete without segregation. The agitation speed of the drum shall be between 2 and 6 revolutions per minute. The volume of mixed concrete permitted in the drum shall not exceed the manufacturer's rating nor exceed 70% of the gross volume of the drum. Upon approval of the Engineer, truck mixers may be used in lieu of agitator trucks for transportation of central plant mixed concrete. Gross volume of agitator bodies, expressed in cubic meters, shall be as determined by the mixer manufacturer. The interval between introduction of water into mixer drum and final discharge time shall be a maximum of 45 minutes unless the use of additives have been approved. Depending on the type and usage of the approved additives this interval may be extended up to a maximum of 2 hours. During this interval the mixture shall be agitated continuously.

Bodies of non-agitator trucks shall be smooth and water-tight. Covers shall be provided when needed for protection against rainfall. The non-agitator trucks shall deliver concrete to the work site in a thoroughly mixed and uniform mass. Uniformity shall be deemed satisfactory if samples from the one-quarter and three-quarter points of the load do not differ more than 2.5 cm in slump. Placing of concrete shall be completed within 30 minutes after introduction of mixing water into the cement and aggregates or if admixture is used at a time to be determined by the Engineer.

8.20.3 Truck Mixing

Concrete may. be mixed in truck mixers of approved design. Truck mixing shall be in accordance with the following provisions. The truck mixer shall be either a closed, water-tight, revolving drum or an open-top revolving-blade or paddle type. It shall combine all ingredients into a thoroughly mixed and uniform mass, and shall discharge the concrete with satisfactory uniformity. A maximum difference of 2.5 cm between slumps of samples from the one-quarter and three-quarter points of the discharge load shall be deemed satisfactory.

Mixing speed for revolving drum type mixers shall not be less than 4 revolutions per minute of the drum nor greater than a speed resulting in a peripheral velocity of the drum of 1 meter per second. For the open-top type mixer, mixing speed shall be between 4 and 16 revolutions per minute of the mixing blades or paddles. Agitation speed for both the revolving drum and revolving blade type mixers shall be between 2 and 6 revolutions per minute of the drum or mixing blades or paddles.

The capacities of truck mixer shall be in accordance with the manufacturer's ratings except that they shall not exceed the limitation herein. Standard for normal rated capacity, expressed as percentage of the gross volume of the drum, shall not be more than 50% for truck mixing and 70% for agitating.

The concrete shall be delivered to the Site of the work and discharge shall be completed within 45 minutes after the introduction of the mixing water into cement and aggregates unless the use of additives have been approved by the Engineer. Depending on the type and usage of the approved additives this interval may be extended up to a maximum of 2 hours. During this interval the mixture shall be agitated continuously.

When the concrete is mixed in a truck mixer, the mixing operation shall begin within 30 minutes after the cement has been mixed with the aggregates. Except when intended for use exclusively as agitators, truck mixers shall be provided with a water measuring device which shall measure accurately the quantity of water for each batch. The delivered amount of water shall be within plus or minus 1% of the indicated amount when the tank, if mounted on the truck mixer, is satisfactorily and practically level.

8.20.4 Hand Mixing

Hand mixing shall not be permitted, except in case of emergency, without written permission from the Engineer. When permitted, it shall be performed only on water tight mixing platforms made of metal, etc. Concrete shall be turned and returned on the platform at least six times and until all particles of the coarse aggregate are covered thoroughly with mortar and the mixture is uniform.

8.21 Retempering Concrete

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

8.22 Consistency

Slump shall be measured in accordance with AASHTO -T119 or JIS A1101 and shall be in accordance with Clause 8.5.

8.23 Concrete Construction Generally

The Contractor shall maintain an adequate number of trained and experienced supervisors and foremen at the site to supervise and control the work. All construction, other than the concrete, shall conform to the requirements prescribed in other sections or clauses for the several items of work entering into the complete structure.

8.23.1 Preparation of Foundations

Preparation of foundations shall conform to the details as shown on the Drawings in accordance with the requirements of Clause 3.10.2. The elevations of the bottoms of footings as shown on the Drawings are approximate only and the Engineer may order further excavation as necessary to obtain satisfactory foundations.

Pile foundations shall be constructed in accordance with the provisions set out in the other relevant Clauses and as shown on the Drawings.

8.23.2 Falsework

Falsework shall be built on foundations of sufficient strength to carry the loads without appreciable settlement. Falsework that cannot be founded on solid footings must be supported by ample falsework piling provided at the Contractor's expense.

Before constructing forms or falsework the Contractor, if required, shall submit detailed drawings of proposed forms or falsework for approval by the Engineer, but such approval shall not relieve the Contractor of any of his responsibilities under the Contract for the successful completion of the structure.

8.23.3 Formwork

No formwork shall be fabricated or erected until the drawings have been approved by the Engineer.

Before concrete is placed the Engineer shall inspect all formwork and falsework and no concrete shall be placed until the Engineer has inspected and approved such formwork and falsework. Such approval shall not relieve the Contractor of any of his responsibilities under the Contract for the successful completion of the structure.

Internal formwork for hollow slab construction shall be made of plywood, thin metal plate or other materials. These materials shall have sufficient strength to resist the pressure and the buoyancy' effects of fresh concrete.

Type and structure of joint and cover for the cylindrical form shall be tight to prevent any leakage of concrete, and shall be approved by the Engineer. Nominal diameter of cylindrical forms shall be the outer diameter, or the outer diameter of projecting portion in case of thin metal plate having projection. The height of the projection shall be less than 10 mm.

Internal forms shall be fixed in the correct position such that they shall not displace or deform during placing concrete.

U-shape bolts shall be used to fix the internal forms and the method of supporting and fixing the internal forms shall be approved by the Engineer. Care shall be taken to ensure that U-shape bolts and other items can resist the buoyancy forces on the formwork.

In falsework, bridge camber shall be considered in accordance with the Working Drawings prepared by the Contractor and approved by the Engineer.

Concrete shall not be placed in any formwork until such formwork has been inspected and approved by the Engineer.

8.23.4 Reinforcement

The Engineer shall inspect and approve all reinforcement in place before concrete is placed. An experienced steel fixer shall be present while all concrete is placed to ensure that no reinforcement becomes displaced during placing and if it does to reposition reinforcement before placing continues.

The positioning and fixing of reinforcing in particular sections of the work may be required to be inspected by the Engineer prior to any concrete being poured in the section. The Engineer will advise the Contractor of these particular sections at the time the Contractor is preparing its Quality Plan, and from time to time during the progress of the works. Ample notice shall be given by the Contractor to allow time for inspection by the Engineer of such sections.

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

8.24 Placing Concrete Generally

Concrete shall be placed in such a manner as to avoid segregation and the displacement of reinforcing bars and shall be spread in horizontal layers where practicable. Concrete shall be placed where necessary inside forms by hand shovels and in no instance shall vibrator be so manipulated to transport concrete inside formwork. Care shall be taken to prevent mortar from spattering forms and reinforcing steel and form drying ahead of the final covering with concrete. When spattering has occurred the forms and steel shall be cleaned with wire brushes or scrapers before concrete is placed around steel or in forms which have been spattered.

Troughs, pipes, or short chutes used as aids in placing concrete shall be positioned in such a manner that segregation of the concrete shall not occur. All chutes, troughs, and pipes shall be kept clean and free from coating of hardened concrete or mortar.

Concrete shall not be dropped freely over a vertical distance of more than 1.5 meters.

Concrete shall be placed continuously throughout each section of the structure or between indicated joints if shown on the Drawings or as directed by the Engineer.

If in an emergency it is necessary to stop placing concrete before a section is completed, bulkheads shall be placed as the Engineer may direct and the resulting joint shall be deemed a construction joint, and treated as specified herein below.

8.24.1 Placing Concrete to Concrete Columns

Concrete in columns or bents shall be placed in one continuous operation unless shown on the Drawings or permitted by the Engineer.

8.24.2 Placing Concrete to Slab and Girder Spans

Slabs and girders having spans of 10 meters or less shall be placed in one continuous operation unless otherwise stated on the Drawings. Concrete preferably shall be deposited by beginning at the centre of the span working from the centre toward the ends.

Concrete in slab spans shall be placed in one continuous operation and in one layer for each span, unless otherwise stated on the Drawings.

Concrete in girders spanning more than 10 meters may be placed in two operations, the first operation being the placing of concrete in the girder stems to the bottom of

the slab haunches or the bottom of the slab whichever is applicable. A period of at least 24 hours shall elapse between the completion of placing concrete in the girder and. the commencement of placing concrete in slab.

The construction procedure for the concrete deck slab on steel box girders shall be so arranged as to eliminate excessive stress in new or recently placed concrete.

Immediately before placing concrete, the top surface of the previously placed concrete shall be hammered with a sharp hand tool (scabbled) until the aggregate is exposed and cleaned. The Contractor shall check all falsework for shrinkage and settlement, and shall tighten all wedges to ensure minimum deflection of all formwork.

8.24.3 Placing Concrete to Walls, Piers, etc.

Where walls, piers, columns, struts, posts and other such structural members allow horizontal construction joints, concrete shall not be placed on top of other concrete which has not been allowed to set for 12 hours or more.

Work shall not be discontinued within 45 centimeters of the top of any face, unless provision has been made for a coping less than 45 centimeters thick, in which case, if permitted by the Engineer, the construction joint may be made at the underside of the coping.

8.24.4 Placing Concrete to Culverts

The slabs of box culverts shall be placed for their full depth in one mass or layer and allowed to set not less than 12 hours before any additional work is done on them.

Before concrete is placed in sidewalls, bottom slabs, shall be cleaned of all shavings, sticks, sawdust and other extraneous material.

The Contractor shall submit to the Engineer for approval his proposals for pouring culvert walls before commencing culvert construction. Concrete shall not be placed in layers more than one meter high relative to the concrete already placed. Deposition shall proceed in a systematic manner.

8.24.5 Depositing Concrete under Water

Concrete shall not be deposited in water except with the approval of the Engineer and with his immediate supervision, and by the method described in this paragraph.

At least four weeks prior to the proposed date for commencement of supply of the concrete for tremie operations, the Contractor shall submit to the Engineer for approval full details of its proposed methods.

To prevent segregation, the concrete shall be carefully placed in- a compact mass in its final position by means of a tremie tube or pipe and shall not be disturbed after being deposited. Special care must be exercised to maintain still water at the point of deposit. Concrete shall not be placed in running water. The method of depositing concrete shall be so regulated as to produce approximately horizontal surfaces.

Placement of tremie concrete shall not commence until full evidence of successful trials of tremie concrete placement methods and the testing of the concrete is provided to the Engineer.

Concrete seals shall be placed in one continuous operation. When a tremie tube or pipe is used, it shall consist of a tube or pipe not less than 25 centimeters in diameter, constructed in sections having flanged couplings fitted with gaskets. The means of supporting the tremie shall be such as to permit free movement of the discharge end over the entire top of the concrete and permit its being lowered rapidly when necessary to choke off or retard the flow. The tremie shall be filled by a method that shall prevent washing of the concrete. The discharge end shall be completely submerged in concrete at all times and the tremie shall contain sufficient concrete to prevent any water entry.

Dewatering shall proceed only when the concrete seal is considered strong enough to withstand any pressures to be exerted upon it. This time will be decided by the Engineer. All laitance or other unsatisfactory material shall be removed from the exposed surface by scraping, jetting, chipping or other means which shall not unduly injure the seal.

8.25 Construction Joints in Concrete

Construction, joints shall be located where shown on the Drawings or permitted or instructed by the Engineer. Construction joints shall be perpendicular to the principal lines of stress and in general shall be located at points of minimum shear.

At horizontal construction joints, details shall be as approved by the Engineer. Before placing fresh concrete, the surfaces of construction joints shall be sandblasted or washed and scrubbed with a wire brush to expose clean aggregate, drenched with water until saturated, and kept saturated until the new concrete is placed. Immediately prior to placing new concrete the forms shall be drawn tight against the concrete already in place and the old surface shall be coated thoroughly with a 1.5mm thick coating of neat cement mortar. Concrete in substructures shall be placed in such a manner that all horizontal construction joints shall be truly horizontal.

Where vertical construction joints are necessary, reinforcing bars shall extend across the joint in such a manner as to make the structure monolithic. Special care shall be taken to avoid construction joints through panelled wing walls or other large surfaces which are to have an architectural finish.

Necessary dowel, load-transfer devices, and bonding devices shall be placed as shown on the Drawings or directed by the Engineer.

8.25.1 Expansion Joints in Concrete

Expansion joints shall be filled with an asphaltic or poly-sulphide type joint filler, 20 mm thick and shall be located and formed as required on the Drawings.

Cut-off plate for water stops used for the expansion joints shall be flexible PVC to JIS K6773 and shall be placed in accordance with the Drawings.

The water stops shall be held firmly in place to prevent displacement during

concreting. If after placing concrete water stops are materially out of position or shape, the surrounding concrete shall be removed, the water stop reset, and the concrete replaced, all at the Contractor's expense.

Water stop shall be furnished full length for each straight portion of the joint, without field splices. Water stop shall be cut and spliced at changes in direction as may be necessary to avoid buckling or distortion. All field splices shall be performed by heat sealing or hot-air welding the adjacent surfaces in accordance with the manufacturer's recommendations to form continuous watertight joints.

8.25.2 Open Joints in Concrete

Open joints shall be constructed where shown on the Drawings by insertion and subsequent removal of a wooden strip, metal plate, or other approved material. The insertion and removal of the template shall be accomplished without chipping or breaking the corners of the concrete. Reinforcement shall not extend across an open joint unless so specified on the Drawings.

8.25.3 Steel Joints in Concrete

The plates, or other structural shapes shall be accurately shaped at the shop to conform to the section of the concrete floor. The fabrication and painting shall conform to the requirements of this Specification covering those items. When called for on the Drawings or in the Specifications, the material shall be galvanized in lieu of painting. Care shall be taken to ensure that the surface in the finished plane is true and free of warping. Positive methods shall be employed in placing the joints to keep them in correct position during the placing of the concrete. The opening at expansion joints shall be that designated on the Drawings at normal temperature, and care shall be taken to avoid impairment of the clearance in any manner.

8.26 Anchor Bolts in Concrete

All necessary anchor bolts in piers or abutments shall be accurately set in holes formed while the concrete is being placed. Holes may be formed by inserting in the fresh concrete oiled wooden plugs, metal pipe sleeves, or other approved devices, and withdrawing them after the concrete has partially set. Holes so formed shall be at least 10 cm in diameter. Bolts shall be set accurately and fixed with grout completely filling the holes. The grout shall be non-shrink mortar of a type approved by the Engineer.

Anchor bolts used in connection with expansion shoes, rollers, and rockers shall be located with due regard to the temperature at the time of erection. Care shall be taken that full and free movement of the superstructure at the moveable bearings is not restricted by improper setting or adjustment of bearings or anchor bolt and nuts.

8.27 Shoes and Bearing Plates in Concrete

Bridge seat bearing areas shall preferably be finished high and ground to level required. Shoes and bearing plates shall be set as provided in the drawings.

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 anncaled 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.