8.80 Pretensioning Method

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

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

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

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

8.81 Curing

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

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

8.82 Post-tensioning Method

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

8.83 Grouting of Prestressing Tendons and Bars

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

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

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

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

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

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

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

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

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

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

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

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

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

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

8.84 Protection of Pre-stressing Anchorage

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

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

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

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

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

8.85 Handling, Transport and Storage of Precast Prestressed Concrete

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

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

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

8.86 Marking of Precast Prestressed Member

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

8.87 Testing of Precast Prestressed Members

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

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

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

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

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

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

8.88 Prestressed Concrete for In-Situ Box Girder

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

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

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

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

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

8.89 Reinforcing Bars for In-Situ Box Girder

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

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

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

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

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

8.91 Tendon Extension for In-Situ Box Girder

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

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

8.92 Waterproofing to Bridge Deck Slab

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

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

8.92.1 Storage of Fabric for Waterproofing to Bridge Deck Slab

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

8.92.2 Preparation of Surface for Waterproofing to Bridge Deck Slab

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

8.92.3 Application of Waterproofing to Bridge Deck Slab

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

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

In applying the waterproofing, the Contractor shall:

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

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

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

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

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

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

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

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

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

8.92.4 Protection Course for Waterproofing to Bridge Deck Slab

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

8.93 Measurement and Payment

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

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

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

9 STRUCTURAL STEELWORK

9.1 Bridge Steel Work Generally

This work shall consist of the supply, fabrication, shop painting, delivery to the site, erection and field painting complete, of all bridge structures, in strict accordance with the Specifications and Drawings or as established by the Engineer.

9.2 Standards and Specifications

If not otherwise indicated on the drawings or elsewhere in this Specification, the fabrication and erection of the steel superstructure shall conform to the requirements of AASHTO's Standard Specifications for Highway Bridges, 1992, (AASHTO LRFD Bridge Design Specification 1998) and AWS D1.1- 88, Structural Welding Code, as modified by the AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges, 1992.

In case of conflict between the above referenced specifications and this Specification, this Specification shall govern.

9.3 Inspection Authority

The Employer has the right to appoint an Inspection Authority to inspect, examine and test materials, workmanship and performance of any part of the works at the manufacturer's works or the site of fabrication.

The Contractor shall furnish all facilities for the inspection of material and workmanship at the place of fabrication and the Principal, the Engineer or their delegate shall be allowed free access to all parts of the premises upon request.

The Inspection Authority will be selected by the Employer but all fees and expenses for this work shall be paid by the Contractor and shall be deemed to be included in the unit prices for this work. Should the Employer decide to waive his right to appoint an Inspection Authority this shall be notified at the time of tenderding.

The Inspection Authority shall take instructions from the Engineer and his representatives and shall submit monthly reports to the Engineer. The Inspection Authority shall certify that all works up to the stage of fabrication shop painting after trial assemblage, have been carried out in accordance with this Specification and the approved shop Drawings. Certain authority of the Engineer will be delegated to the Inspection Authority, for the purpose of quality control and testing. The limits of this Authority will be notified to the Contractor in writing when the Inspection Authority is appointed.

The inspection Authority's certificates shall not relieve the Contractor of any of his obligations under the contract.

9.4 Inspection by the Contractor

Irrespective of the appointment of an Inspection Authority, the Contractor shall himself inspect or have inspected all materials, shop work and field work to determine that the requirements of the Drawings and Specifications are met and that the Works are carried out in a first class and workmanlike manner.

The Contractor shall provide the necessary assistants, labour, materials, electricity, fuel, stores, apparatus and instruments and any other materials required to ensure that all testing and inspection by the Engineer or the Inspection Authority can be carried out efficiently.

9.5 Hiring the Third Party Inspectors and Subcontractor

The Contractor shall submit a list of authorized /licensed steel structure fabrication inspectors from the third party organization, who will be full time during a period of fabrication at the Contractor's fabrication yard for inspection on behalf of the Consultant. Referring to this list the Consultant will nominate one third party inspector who will be hired by the Contractor using the Contractor's own expense.

The Contractor shall not sublet the fabrication of structural steelwork or any part thereof without prior consent in writing of the Consultant. Only those workshops that have been specifically approved by the Consultant to carry out the Work will be authorized to perform the work on the structural steel.

9.6 Submittal of Overall Schedule

Before any technical submittals are made, the Contractor shall submit his proposed schedule for all shop drawing submissions, materials submissions, fabrication processes and reporting system including email communications from fabrication shop to the Engineer. In this schedule, the Contractor shall allow the Engineer 4 weeks from receipt of any submittal or resubmittal, for his review.

9.6.1 Necessity of Approvals

The Contractor shall not proceed with any purchase or fabrication of materials until the relevant shop drawings have been approved by the Engineer.

Prior to the use of any materials, the Contractor shall submit for the Engineer's approval, 2 copies of the Manufacture's certificates for:

- bolts, nuts, washers, and filler for welding.
- mill test certificates for structural steel. These shall include the names and locations of steel mills, analysis of chemical and physical properties, and shall be properly correlated to the various grades of structural steel to be used in the project.

9.6.2 Submittal of Welding plan

The Contractor shall not proceed with any welding until the Engineer has approved his Welding Plan which shall include the following.

- All information on welding procedures: equipment, additives and preheating during the welding operations.
- Details of non-destructive testing methods to be used for specific typical joints.
- Precautions with regard to welding shrinkage.
- Possible treatment of completed welds by grinding with indication of grinding direction, etc.
- Procedures and programme of welding sequence (for each component and for welding components together).

After approval of this submittal, welding procedures and sequences shall be followed without deviation.

The Engineer will require confirmation as to the suitability of the details contained in the welding plan, by tests as prescribed in the AWS "Standard Qualification Procedure".

9.6.3 Submittal of Painting Plan

The Contractor shall in ample time before the commencement of the surface treatment, prepare and submit for approval a detailed programme relating to the execution of the works, in the workshop, at the site, etc., as well as the methods used, and a time schedule for the individual treatments. The programme shall be subject to approval by the Engineer.

9.6.4 Submittal of Erection Plan

Prior to the start of Fabrication the Contractor shall submit for the Engineer's approval a full description of his proposed erection method including:

- sequence of erection
- use of temporary or permanent stanchions, beams and bracing
- connection details
- erection camber diagrams to show the vertical position of the structure at each stage of the erection process
- design calculation to cover the various stages in the erection process
- type of equipment to be used during erection.

The Engineer's approval of the above details shall not relieve the Contractor of his contractual obligations or of his responsibility for providing proper methods, equipment, workmanship and safety precautions.

9.6.5 Submittal of Painting Certification

The Contractor shall submit to the Engineer, 2 copies of certification stating that requirements pertaining to prepaint cleaning and painting of steel have been performed in accordance with the specifications.

9.6.6 Submittal of Connection Records

The Contractor shall maintain records of shop welding procedures, welders employed with date of qualification and identification symbol. Records shall also be maintained of all bolts tested and the corresponding torque values if torque control is used. These records shall be freely available for the use of the Inspection Authority and shall be submitted to the Engineer on completion of all shop fabrication work.

9.6.7 Submittal of As-built Drawings

Within 4 weeks of completion of the related works, the Contractor shall submit 2 plastics and 4 prints of the as-built drawings. These drawings shall include details of actual camber achieved, details of temporary bracing left in the works, etc.

9.7 Matters to be considered by the Contractor

In this preparation of shop drawings and in all his fabrication works the Contractor shall give careful consideration to the following.

- the need for trial assemblage at the fabrication shop
- problems on the weight and size of elements for transportation between fabrication yard and the construction site temperature variation between the fabrication yard and the site temperature of 28oC, assumed for the purposes of the Contract drawings
- the need for certain dimensions of structural steel work to be verified by measurement at site.
- the prohibition of the use of site welding except for fixtures

9.8 Material and Workmanship Generally

Steel shall be ordered at the earliest possible time in consultation with the Suppliers and according to the fabrication priorities. The order shall be submitted to the Suppliers with the name of the project for which the steel is to be used and the nature of the work e.g. "welding steel plate girder". Prior to the purchase order being made, the Contractor shall furnish the Consultant with a copy of the order.

Structural steel shall be newly rolled and shall conform to the requirements of the following specifications.

9.9 Standards for Materials

Plates, Sections, Bars and Bar sized Sections

Plates, sections, bars and bar sized sections shall comply with JIS or equivalent standard and shall be of the grades shown on the Drawings.

The weathering steel shall be used for the superstructures.

Kinds		Standard	Symbol of steels
Structural Steels	JIS G3114	Hot rolled Asmostpheric Corrosion Resisting Steel for Welded Structure	SMA400 II, SMA490W, SMA570
Steel Tubes	JIS G3444	Carbon Steel Tubes for General Structural Purposes	STK 400
	JIS G 3452	Carbon Steel Pipes for Ordinary Piping	SGP
Steel Bar	JIS G 3112	Steel Bars for Concrete Reinforcement	SR 235, SD 345
Special Steel	JIS 64303	Stainless Steel Bars	SUS 304
	JIS K 6888	Carbon Steel Castings	STFESC 410
	JIS 65101		

All steel shall be delivered with certificates and delivery shall be in accordance with the requirement of the current edition of JIS Standard G3191, G3192, G3193 and G0303 including the requirement to produce analysis, carbon equivalent, tolerances, inspection and testing, and marking.

Structural steel shall be stored above the ground upon platforms, skids, or other supports. It shall be kept free from dirt, grease and other foreign matter, and shall be properly protected in order to minimize corrosion.

All steel shall be delivered with certificates and delivery shall be in accordance with the requirement of the current edition of JIS Standard G 3191, G 3192, G 3193 and G 0303 including the requirement to produce analysis, carbon equivalent, tolerances, inspection and testing, and marking.

9.10 Bolts

High strength steel bolts with associated nuts and end washers shall comply with JIS B 1186 and shall incorporate load indicating devices acceptable to the Engineer.

Commercial grade bolts and screws shall comply with JIS B 1180. Nuts shall comply with JIS B 1181.

9.11 Filler Metal Requirements

Filler metal requirements shall conform to Structural Welding code ANSI/AASHTO/ AWS D1.5-96 Bridge Welding Code or equivalent standard.

If the base metal is not included in the group of ASTM steel covered by Table 4.1.1 of ANSI/AASHTO/AWS D1.5-96, then the properties of the welding metal used for filler material shall correspond to the properties of the base metal used for the parts to be welded. The Contractor shall in this respect submit his proposal for the Engineer's approval.

All materials to be used for welding shall be of a recognized manufacture, and the Contractor shall when requested by the Engineer furnish manufacturer's certification that the electrodes and other products used for welding meet the requirement of this Specification.

9.12 Headed Studs

Headed studs shall conform to JIS B 1198, minimum yield point of 24 kgf/mm2 and minimum tensile strength of 41 kgf/mm2, and to the applicable requirements of AWS D1.5, section 4, part F, Plug and Slot Welds.

9.13 Storage of Materials

All steel whether fabricated or not shall be stored above the ground upon platforms, skids, or other supports. It shall be kept free from dirt, grease and other foreign matter, and shall be properly protected in order to minimize corrosion. Excessively rusted bent or damaged steel will be rejected.

Protected or coated steel surfaces shall not be stored with the faces in contact but shall be separated by spacers.

9.14 Workmanship

Exept as otherwise denoted herein or on the drawings, all work shall be executed in accordance with the relevant sections of this Specification.

The Contractor shall be responsible for any damage caused to other components of the structure including the substructures, by his operations for the duration of this Contract. In particular he shall take all necessary precautions to minimize concrete splash onto completed steelwork or rust staining of concrete due to erected steelwork. He shall clean and/or repair all stains and other damage to completed work, before acceptance.

9.15 Tolerances

The Contractor shall, through -appropriate planning and continuous measurements in the workshop and at the erection site, ensure that the tolerances given in the Special Specifications are strictly observed. The Engineer shall require any specific working procedure changed in case such procedure appears not to afford sufficient security against exceeding the tolerances.

The Contractor is fully responsible for the calculation and provision of the necessary camber in the preassembled elements to obtain the correct levels in the completed, bridge, duly considering the applied erection procedure and the sequence in the installation of the various dead load components.

The roadway levels given on the drawings or defined by the given inclination and curvature are the required roadway levels to top of asphalt surfacing in bridge axis of the completed bridge, when loaded only with the dead loads of the installed and completed structure. In fixing the geometry of the superstructure, the Contractor shall make compensation for the difference between workshop temperature and the temperature of the bridge in normal position (27°C).

9.15.1 Templates and Measurements

The Contractor shall supply all templates, jigs and other appliances necessary to ensure the accuracy of the work.

9.15.2 Cutting of Steel

Edges may be cut by either planing, machining, flame cutting or shearing, but edges to be welded shall nevertheless comply with the welding clauses of this Specification. Cut edges shall be free of gouges, burrs and other defects which are greater than 5 mm deep, or which would otherwise adversely affect the serviceability of the member. Occasional notches or gouges not more than 5 mm deep on otherwise satisfactory surfaces shall be removed by machining or grinding. Correction to defects shall be faired to the surface with a slope not exceeding 1 in 10.

Oxygen cutting of steel and weld metal shall be permitted provided a smooth and regular surface free from cracks and notches is secured, and provided that an accurate profile is secured by the use of a mechanical guide. Free-hand oxygen cutting shall be done only where approved by the Consultant.

In all oxygen cutting the cutting flame shall be so adjusted and manipulated as to avoid cutting inside the prescribed lines. The surface roughness of oxygen cut surfaces shall be equivalent to or better than the standard classes of replicas of flame cut surfaces as existing on JIS B 0601.

Roughness exceeding allowable values and occasional notches or gouges not more than 2 mm deep, on otherwise satisfactory surfaces, shall be removed by machining or grinding. Cut surfaces and edges shall be left free of adhering slag. Corrections of defects shall be faired to the oxygen cut surface with a slope not exceeding 1 in 10. Defects of oxygen cut edges shall not be repaired by welding except with the express approval of the Consultant for occasional notches or gouges less than 5 mm deep. Such weld repair shall be made by suitably preparing the defect, welding with low hydrogen electrodes not exceeding 4 mm in diameter, observing the applicable requirements of the welding clauses of this Specification, and grinding the completed weld smooth and flush with the adjacent surface to produce a workmanlike finish.

9.15.3 Straightening of Steel

All material before being assembled, shall be straightened or formed to the specified configuration by methods specified below.

Straightening or bending of either fabricated or un-fabricated steel, if necessary, shall be done by means of steady pressure applied by rolled or presses. Straightening and bending shall not be done by hammering or, unless the Consultant's approval has been obtained by heating. If straightening by heating is allowed, the steel shall in no case be heated to a higher temperature than 600°C as measured by indicating crayons, liquids or bimetal thermometers. After heating the metal shall be cooled slowly in air without any forced cooling.

Following the straightening of a bend or buckle, the surface of the metal shall be carefully inspected for evidence of fracture. Depending on the location in the Work, the Consultant shall have the right to reject the metal or to direct that the defects be repaired in a manner that shall be approved by the Consultant. The cost of replacement of repair shall be borne by the Contractor.

9.15.4 Bending

Bending of plate may be machined by cold processes, provided that the bending inner radius is at least 15 times the thickness of the plate.

9.15.5 Welding

All welding shall be planned and executed using the most suitable materials and working methods for the particular purpose.

Welding requirements shall in all respects conform to the following sections of ANSI/AASHTO/AWS D1.5, Bridge Welding Code.

All welding shall be executed by skilled, experienced welders holding valid welder examination qualifications based on the qualification tests specified in part C of Section 5 of ANSI/AASHTO/AWS D1.5, Bridge Welding Code or JIS Z 3801or similar internationally recognized qualification tests. A welder shall be qualified for each process used.

Prior to commencement of any welding, the joint shall be carefully freed from rust, scale, slag, and burrs. Where two welds for structural reasons have to cross each other the former has to be ground flush. Where a flush surface is required, the excess weld metal shall be ground.

During the assembly work, the components shall be held in position and supported in such a manner that no unfavourable inherent stresses or deformation shall develop. Drilling of holes for temporary assembly for welding purposes shall not be accepted.

Minimum preheating and interpass temperature shall comply with the welding procedure in question and shall be approved by the Engineer.

9.15.6 Welding Tolerances

The members to be connected by welding shall be so prepared that they fit exactly together, without being forced into position.

The tolerance concerning gap between parts to be welded, eccentricity and departure from theoretical alignment, dimensions of the cross section of groove welded joints, etc. shall conform to AWS D1.5, Bridge Welding Code, except that the gap between parts to be jointed by fillet welds shall not exceed 1 mm for fillet welds connecting flange to web and 5 mm for all other fillet welds. Tolerances of weld profiles shall correspond to section 3.6 of AWS D 1.5.

9.16 Welding Procedure Qualification Tests

The Contractor shall perform test welds of the types of welding seams to be applied in the structure, according to a programme to be agreed upon with the Engineer. The quality of the test welds shall be approved by the Engineer prior to execution of the welding work in question. The test welding shall be made from working positions corresponding to the actual working positions during construction.

9.16.1 Welding Inspection

The Contractor shall prepare a detailed programme for control of welds in consultation with the Engineer and the established programme must not be deviated from without the Engineer's consent.

The Contractor's control programme shall ensure satisfactory inspection in the workshops to fulfill the stipulations laid down in AWS D1.5. The Contractor's control shall correspond to the following schedule:

- Preparation for Welding

  Visual inspection of edge preparation
  Visual inspection including the use of penetrative dyes of surface conditions for cracks, gaps and other items that may cause any defect of welding.

- Visual Inspection before and after Welding

  All welds shall be visually inspected including the use of penetrative dyes in accordance with AWS D 1.5
  Radiographic inspection
  Ultrasonic inspection

9.16.2 Radiographic Inspection

Radiographs will be made by X ray or gamma ray in accordance with JIS Z 3104 and AWS D1.1 – 75. The reinforcement on the weld that is to be radiographed shall be ground smooth and flush.

The minimum, extent of the testing (control) shall be as follows:

- Box member:

  Transverse butt weld in top and bottom flange plate:

Welds subject to tensile stress and reversal stress	100%
Weld subject to compressive stress	25%
Transverse butt weld in web plate	50%
(The major part of the control to be performed in the tension zone)	

- Diaphragm:

All butt weld	25%
Fillet weld	10%

- Other welds not mentioned above 10%

The above figures are the minimum extent of testing and the Engineer may require additional tests if these are considered necessary to ensure compliance with this Specification. Where less than 1005 of a weld type is inspected the Engineer will select those portions of welds to be subject to radiographic inspection.

9.16.3 Magnetic Particle Inspection

The minimum, extent of the testing (control) shall be as follows:

- Longitudinal fillet weld:

Top and bottom flange to web	25%
Longitudinal rib to top and bottom flange	10%
Horizontal stiffener to web	10%

9.16.4 Ultrasonic Inspection

Ultrasonic inspection shall be carried out in accordance with JIS Z 3060 and the AWS Dl.l-75.

Ultrasonic inspection shall be used on Flange/web and Flange/Flange fillet, butt welds and in any other areas directed by the Consultant.

Defects revealed by non-destructive tests will be compared with the standards for allowable porosity and fusion type defects set out herein. Where weld defects exceed the limits specified the weld will be rejected. If approved by the Consultant the Contractor shall carry out the corrective measure specified herein.

The Contractor shall program his work to the satisfaction of the Consultant in order to keep visits to a minimum.

The cost of providing welding inspections, and equipment and operators for non-destructive testing will be borne by the Contractor.

After the repair of any defective weld, further non-destructive tests of the corrected weld will be made at the Contractor's expense. The cost of any further corrective measures and subsequent non-destructive testing of the weld will be borne by the Contractor.

9.16.5 Stud Welding

After the studs have been welded to the beams a visual inspection shall be made and each stud shall be given a light blow with a hammer. Any stud which does not have a complete end weld, which does not emit a ringing sound when given a light blow with a hammer, which has been repaired by welding, or which has less than normal height due to welding, shall be struck with a hammer and bent 15 degrees from the correct axis of installation, and in the case of a defective or repaired weld, the stud shall be bent 15 degrees in the direction that shall place that defective portion of the weld in the greatest tension. Studs that crack either in the weld or in the shank shall be replaced.

The Contractor is obliged to show the exact extent of the control on the shop drawings to be approved by the Engineer. Two sets of reports describing the inspection and comprising all the results have to be handed over to the Engineer concurrently with the execution of the inspection. The Contractor shall execute, at his own expense, the repair of unsatisfactory welds, and the repaired welds shall be tested anew on the Contractor's account.

9.16.6 Holes for Bolts

All holes shall be drilled. Punching of holes shall not be permitted. Reamed and fitted holes shall be sub-drilled 3 mm less in diameter than that of the finished holes and reamed to size.

Reamed and fitted holes and drilled holes shall be made through steel templates or after assembly or by other approved means, to ensure complete matching between the plys of the joints.

All steel templates shall have hardened steel bushings in holes accurately dimensioned from the centerlines of the connection. The centerlines shall be used to accurately locate the template.

Reaming or drilling full-size holes for filed connections through templates shall be done after the templates have been located with the utmost care as to position and angle, and firmly bolted. Templates used for the reaming of holes in matching members, or of opposite faces of one member, shall be exact duplicates. Templates for connections which duplicate shall be so accurately located that like members are duplicates.

All finished holes shall be cylindrical and perpendicular to the member unless otherwise specified. All burrs and other defects shall be removed.

The diameter of the completed hole shall be 2mm larger than the nominal diameter of the bolt unless otherwise specified except that for the inner plies of a structural connection fastened by high-strength bolts the diameter of the hole shall not be larger than 3mm larger than the nominal diameter of the bolt.

All matching holes shall register with each other so that a gauge or drift 2mm less in diameter than the hole shall pass freely through the assembled contact faces at right angles to them.

Burrs, fins and other defects shall be removed. Drifting to align holes shall be done in a manner that will not distort the metal or enlarge the hole.

9.16.7 Bolted Connection

Contact surfaces in bolted joints shall not be painted. When assembled in the field, the rust on joint surfaces, including those adjacent to bolt head, nut and washer, shall be removed by wire brushing. The separation between fraying surfaces of bolted connections shall be not greater than 1 mm. If the separation is between 1 mm and 3 mm, the surface shall be tapered to eliminate the separation. Over 3mm separation shall be filled with filler plate as required.

Each bolt shall be tightened to provide, when all bolts in the joint are tight, the minimum bolt tension shown in the following Table.

Grade	Bolt size	Minimum Bolt Tension (tonne)
F8T	M 20	13.3
	M 22	16.5
	M 24	19.2
F10T	M 20	16.5
	M 22	20.5
	M 24	23.8

High strength bolts shall not be reused. Retightening previously tightened bolts which may have been loosened by the tightening of adjacent bolts shall not be considered for re-use.

All high strength bolts shall be tightened by properly calibrated wrenches and their setting shall be such as to induce a bolt tension 10% in excess of the above value. These wrenches shall be calibrated at least once each working day by tightening in a device of the diameter of each bolt to be installed. Power wrenches shall be adjusted to stall or cut-out at the selected tension. If manual torque wrenches are used the torque indication corresponding to the calibrating tension shall be noted and used in the installation of all bolts of the tested lot. The nut shall be turned in the tightening direction when torque is measured. "Turn of the nut" method may be used for F10T bolts if the Engineer is satisfied that climatic conditions make the torque control method unsuitable.

For F8T bolts tightening may be by "Turn of the nut" method. When this method is used there shall first be enough bolts brought to a "snug tight" condition to insure that the parts of the joint are brought into full contact with each other. Snug tight shall be defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench.

Nut Rotation from Snug-Tight Condition

Disposition of outer faces of bolted parts		
Both faces normal to bolt axis, or one face normal to axis and other face sloped 1/		Both faces sloped from-normal to bolt axis
Bolt length not exceeding 8 x diameter or 20 cm	Bolt length Exceeding 8 x diameter or 20 cm	For all lengths of bolts
1/2 turn	2/3 turn	3/4 turn

9.17 Marking for Trial Assembly

Each part shall be carefully marked to facilitate final erection. Such marking shall be durable but shall not injure the material. Such marks shall not be injured, defaced or removed by any person. The marking of components shall be in accordance with that shown on the workshop drawings submitted.

9.17.1 Shop Assemblage

The Contractor shall carry out shop assemblage in his regular workshop.

Shop assemblage shall be understood as placing of prefabricated elements together to control the fit. The Contractor shall submit his proposal for shop assemblage for the approval of the Engineer. The shop assemblage shall verify that the individual elements have the shape to fit exactly into adjoining elements. Also, the shop assemblage shall verify that the camber aimed at, or prescribed, actually exists, and that the geometry is generally correct.

The Contractor shall perform measurement of the structural members, and the results shall be recorded and submitted to the Engineer. The Contractor shall inform the Engineer that the shop assemblage of major components have been completed and measured, and the structure shall not be dismantled until the Engineer has approved the shop assemblage.

9.18 Tolerances for Steel Structures

All fabrication shall be executed accurately to the shapes and dimensions shown on the Drawings, and, unless otherwise indicated on the Drawings, shall be within the tolerances listed below. Where, in the opinion of the Consultant, there is evidence that the application of the following tolerances would adversely affect the serviceability of the structure, the Consultant shall have the right to reduce the tolerances.

Tolerance shall be measured and applied in accordance with Article 15.3.4 in Standard Specification of Highway Bridges in Japan Vol. II.

Unless otherwise specified, the following tolerances shall apply:

- General

  The tolerance on all structural dimensions shall be plus 2 mm, minus 2 mm.

- Straightness

  A structural member before erection shall not deviate from straightness for the specified configuration by more than the following:

Struts	:	1/1000 of the length
Tubes	:	1/600 of the length
Plates	:	1/200 of the lesser dimension of the plate panel
Other members	:	1/500 of the length

- The length of member shall not deviate from the specified length by more than the following:

For lengths 9 meters and under	+0 ~ 3 mm
For lengths over 9 meters	+0 ~ 5 mm

- Twist

The twist of a member shall not be greater than the following:

Main girders and heavy columns	1/500 of the length
Other members	1/1000 of the length

- Camber

The camber of a member shall not deviate from that specified by more than plus 3 mm, minus 3 mm when measured fully supported and unloaded.

- Squareness of Ends

The deviation from squareness of ends (other than butt joints in compression) shall not exceed the following:

Members 800 mm deep and less	1 mm
Members over 800 mm deep	1 mm per 800 mm of depth to a maximum of 2 mm

- Butt Joint in Compression

Over at least 60 percent of the bearing surfaces, the clearance between the surfaces shall not exceed 0.25 mm.

Over the remainder of the surface, the measurable gap between the surfaces shall not exceed 0.50 mm.

Web stiffeners in bearing with flanges shall have position contact over not less than half their bearing area. The remainder of the contact face shall not have a gap exceeding 0.25 mm.

The deviation from squareness of ends of members in compression shall not exceed 1 mm.

The abutting ends of two members in compression shall be aligned to within 1/1000 of their combined length.

- Deviation of Web from Flange Centerline

The maximum deviation of the centerline of the web from the flange centerline in built up members shall not exceed 6 mm.

- Depth of Built up Members

The tolerance on the overall depth of a built up members shall not exceed the following:

Depth 900 mm and less	±3 mm
Depth over 900 mm up to 1800 mm	±5 mm Depths over 1800 +8 mm -5 mm

- Flatness of Web Plate

  The deviation from flatness of girder web plates shall not exceed 1/200 of the lesser dimension of the web panel.

- Tilt and Warp of Flange Plate

  The maximum combined warpage and tilt on the flanges of built up members shall not exceed 1/200 of the total width of the flange or 3mm whichever is the greater.

9.19 Transport Handling and Storage

Before shop assembling is dismantled, all adjacent sections shall be marked with paint. The Contractor shall submit to the Engineer drawings of the finished structure showing all part and match marks.

All materials shall be delivered to the Site at such time or times as they are required for incorporation in the Works. Bolts and small or loose pieces shall be bagged and close crated. Bolts, nuts and washers shall be separately bundled for each size and each bundle clearly marked with the size and purpose of the bolts. The batch number of each bag of bolts shall be clearly marked to facilitate reference to the test certificates.

During delivery all component materials shall be adequately protected from damage and the Contractor shall be responsible for any damage which may occur. In particular, the Contractor shall adequately strut the bottom flange of plate girders.

All straps and chains used in lifting shall be adequately padded to prevent damage to the steelwork and its protective coating.

No fabricated steel shall leave the Contractor's works without being inspected and passed by the Consultant at the place of fabrication or be placed in the Work without being inspected and passed by the Consultant after delivery.

The methods of transporting and handing shall be subject to the approval of the Engineer. Special care shall be taken in the packing, methods of supporting, lifting during handling and transporting of structural steel work which is shop assembled before delivery, to ensure protection from damage.

Immediately following delivery to the site, the Contractor shall check the material and bring immediately to the notice of the Engineer or his representative any damage or defects therein. He shall also report in writing to the Engineer any such damage or defects, and give his proposals for the rectification or replacement or damaged sections.

Material to be stored shall be placed on skids above the ground and shall be kept clean and properly drained. Girders and beams shall be placed upright and shored. Long members shall be supported on skids placed closely enough together to prevent injury from deflection.

Any structural steel materials (whether painted or unpainted) shipped to the site by sea transport, and positioned on board in such a way as to come into contact with salt water spray, shall be thoroughly washed with clean fresh water, using pressure hoses and stiff bristle brushes, prior to erection or application of finish coats of paint.

9.20 Erection Procedures

At least ten (10) weeks before he intends to launch the superstructure the Contractor shall provide full calculations and detailed drawings for his intended procedure for the Consultant's approval.

The drawings shall show all temporary works necessary for the launching including bearings, supports and incidentals, and include full method statements for each stage of the launch.

Launching shall not commence until the Consultant has indicated that he has no further comments on the Contractor's proposals.

Steelwork shall be stored on timber bearers, clear of the ground and in such a way as to permit checking and to avoid excessive handling and damage to the steelwork or its protective coating.

Unless otherwise directed by the Consultant, all surfaces to be brought together to form a joint or splice shall be free of paint or any other applied finish, oil, dirt, loose rust, loose scale, burrs and other defects which would prevent solid seating of the parts or would interfere with the development of friction between them.

9.20.1 Field Erection

The position of field splices as shown on the drawings is for information only and the Contractor is free to propose alternative procedures providing they comply with all the relevant requirements of this Specification. The preparation of the calculations and detailed design to support the proposed alternative shall be at the Contractor's responsibility and cost.

The Contractor shall provide setting drawings, templates, and directions for the installation of anchor bolts or other items to be embedded in concrete.

During erection, the parts shall be accurately assembled as shown on the approved Shop Drawings and any matchmarks shall be followed.

The material shall be carefully handled so that no parts shall be bent, broken or otherwise damaged. Hammering which will injure or distort the members shall not be done. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before the members are assembled. Splices and field connections shall have one half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins) before bolting with high-strength bolts. Fitting-up bolts shall be of the same nominal diameter as the high-strength bolts, and cylindrical erection pins shall be 1 mm larger.

The correction of minor misfits involving harmless amounts of reaming, cutting and chipping shall, be considered a legitimate part of the erection. However, any error in the shop fabrication or deformation resulting from handling and transportation which prevents the proper assembling and fitting up of parts by the moderate use of drift pins or by a moderate amount of reaming and slight chipping or cutting, shall be reported immediately to the Engineer and his approval of the method of correction obtained. The correction shall be made in his presence. The Contractor hall bc responsible for all misfits, errors and injuries and shall make the necessary corrections and replacements.

The straightening of plates, angles, other shapes and built-up members, then permitted by the Engineer, shall be done by methods that shall not produce fracture or other injury. Distorted, members shall be straightened by mechanical means or, if approved by the Engineer, by the careful planned and supervised application of a limited amount of localised heat, each application subject to the approval of the Engineer.

Each joint shall be bolted up with service bolts and parallel drifts so that the various sections and plates are in close contact throughout. Service bolts shall not remain in the completed structure.

Drifts shall be parallel barrel drifts. The barrels shall be drawn or machined to a diameter equal to the full diameter of the hole subject to a tolerance of +0 to -0.13mm. The length of the barrels shall not be less than the combined thickness of the material, plus one diameter. The ends of the drift, for a length of 1.5 barrel diameters, shall be tapered down to an end diameter equal to half the barrel diameter. Heavy drifting that would distort the holes shall not be carried out.

High tensile bolts shall be assembled with one hardened washer under the turned element (nut or bolt head). The washer shall be assembled with any convexity outwards. The inserting and tensioning of the high tensile bolts shall be so arranged that the close contact established by the service bolts in maintained at all times. The tensioning of high tensile bolts shall not commence until the joint has been inspected by the Consultant.

The slope of surfaces of bolts parts in contact with the bolt head and nut shall not exceed 1:20 (2°51) with respect to a plane normal to the bolt axis; in cases where the shape of the member is such that this slope is exceeded, taper washers shall be used.

9.21 Surface Treatment of Steel Generally

This work covers the complete surface treatment of all steel parts, including surface preparation, priming, thermal sprayed coating and final protective coatings. Surface treatment of structural steel work shall be considered in the classes as shown on the drawings and as described below:

- System I : Generally, all external steel work which will be exposed to the atmospheric conditions.
- System II : All external surfaces of box members and cantilever slab (fairing) except steel plate deck under asphalt pavement which will be exposed to the atmospheric conditions.

- System III : Internal surfaces of box girders.
- System IV : Internal surface of joint members and external steel plate deck to be encased, or in contact, with concrete/asphalt.
- System V : Bolted joint.
- System VI : Galvanised surfaces

9.21.1 Surface Preparation

Before the application of any paint, the surfaces to be treated shall be thoroughly cleaned and freed from all scale, loose paint, rust and other deleterious matters. Oil and grease shall be removed from the surface by washing with solvents or with a detergent solution before any blast cleaning operation. If any traces of oil or grease remain after blasting, they shall be removed by solvent cleaning and the area reblasted.

All welding areas shall be given special attention for removal of weld flux slag, weld metal splatter, weld head oxides, weld flux fumes, slivers and other foreign objects before blasting. If deemed necessary by the Engineer acid washing and subsequent washing with clean water shall be used.

If cleaned surfaces rust or are contaminated with foreign material before painting or galvanizing is accomplished, they shall be recleaned.

Any rough welding seams shall be ground and inspected and approved by the Engineer before application of the coatings.

All structural steel which shall be painted shall be cleaned by blast cleaning in accordance with SSPC (Steel Structures Painting Council in the USA) -SP 10 Near-White Blast cleaning. Mill scale, rust and foreign matter shall be removed to the extent that the only traces remaining are light stains in the form of spots or stripes. Finally, the surface is cleaned with a vacuum cleaner or clean, dry and non-oily compressed air.

The blast cleaning shall produce a surface roughness complying with the one specified by the paint manufacturer for the primer concerned. If cleaned surfaces rust or are contaminated with foreign material before painting is accomplished, they shall be recleaned by the Contractor at his expense.

9.22 Galvanizing

Galvanizing shall in general conform to the requirements of AASHTO M-111 or JIS H8641 class 3-55C and JIS H0401. Material thinner than 3.2 mm may be galvanized before fabrication in conformance with the requirements of ASTM A525. Galvanizing of iron and steel hardware and nuts and bolts shall conform to the specifications of AASHTO M232 or equal.

Except for pre-galvanized standard pipe, galvanizing of material 3.2 mm thick or thicker shall be performed after fabrication into the largest practical sections.

All welded areas shall be thoroughly cleaned prior to galvanizing to remove all slag or other material that would interfere with the adherence of the zinc. When it is necessary to straighten any sections after galvanizing, such work shall be performed without damage to the zinc coating.

Galvanizing surfaces that are abraded or damaged at any time after the application of the zinc coating shall be repaired by thoroughly wire brushing the damaged areas and removing all loose and cracked coating, after which the cleaned areas shall be painted with three applications of zinc anticorrosive paint as approved by the Engineer.

9.23 Painting Materials

Materials used in painting of steel structures except thermal sprayed Galvarium (Al 55%/ Zn 45%) shall be as shown on the drawings or specified elsewhere and shall conform to the requirements of the following specifications or equivalent standards.

JIS K 5400	Testing Methods for Organic Coatings
JIS K 5421	Boiled Oil and Boiled Linseed Oil
JIS K 5516	Ready Mixed Paint
JIS K 5492	Aluminium Paint
JIS K 5621	Anticorrosive Paint for General Use
JIS K 5622	Red-Lead Anticorrosive Paint
JIS K 5623	Lead Suboxide Anticorrosive Paint (Class 1)
JIS K 5624	Basic Lead Chromate Anticorrosive Paint (Class 1)
JIS K 5625	Lead Cyanamide Anticorrosive Paint (Class 1)
JIS K 5626	Zinc Dust Anticorrosive Paint
JIS K 5627	Zinc Chromate Anticorrosive Paint
JIS K 5628	Red-Lead Zinc Chromate Anticorrosive Paint
JIS K 5633	Etching Primer (Class 2)
JIS K 5664	Tar-Epoxy Resin Paint

Where paints are specified that do not comply with any of the above specifications, they shall be supplied only by recognized manufacturers, and samples and technical data shall be submitted to the Engineer for his approval.

In particular this clause is applicable to any coating of stabilized treatment primer or tar epoxy resin controller applied to hot rolled atmospheric corrosion resisting steel structures.

In any paint system (viz. primer, undercoats, intermediate coat and finishing coats) each coat of paint shall be compatible with the other, and to ensure this, all paint shall be obtained from the same approved manufacturer with a guarantee of compatibility.

The materials to be used in the thermal sprayed coating of Galvarium shall be subject to the Engineer's approval.

Succeeding applications of paint shall be of such shade as to contrast with the paint being covered.

The colours of all paint coats shall be as instructed by the Engineer.

9.24 Painting

The execution of the painting works shall be carried out in a neat and workmanlike manner by experienced labour to the satisfaction of the Engineer. Furthermore, the application of the paints shall be carried out in accordance with the manufacturer's recommendations.

Planning and execution of the painting work shall be in conformity with the supplier's specifications in respect to minimum and maximum intervals between the application of the individual coats.

If a coating material requires the addition of a curing agent, the pot life under application conditions shall be clearly stated on the container label, and this pot life shall not be exceeded. When the pot life limit is reached, the spray equipment shall be emptied, remaining material discarded, the equipment cleaned and new material prepared.

Each coat shall be applied uniformly over the entire surface. Skips, runs, sags and drips shall be avoided. When these occur, they shall be brushed out immediately or the material shall be removed and the surface recoated. Each coat shall be allowed to dry for the time specified by the manufacturer or as directed by the Engineer before application of any succeeding coat.

The surface must be completely dry, and its temperature should be at least 5oC above the dew point. Paint should only be applied in suitable weather conditions and any fresh paint damaged by weather shall be repaired or replaced at the Contractor's expense. Measures shall be taken to prevent dust or other extraneous matter from adhering to wet paint.

Brushes, when used, shall have sufficient body and length of bristle to spread the paint in a uniform film. Paint shall be even]y spread and thoroughly brushed out. On all surfaces which are inaccessible for painting by regular means, the paint shall be applied by sheepskin daubers, bottle brushes, or by any other means approved by the Engineer. Rollers, when used, shall be of a type which do not leave a stippled texture in the paint film.

A water trap acceptable to the Engineer shall be furnished and installed on all equipment used in spray painting. Mechanical mixers shall be used to mix paint. Prior to applying, the paint shall be mixed a sufficient length of time to thoroughly mix the pigment and vehicle together and shall be kept thoroughly mixed during its application. The dry film thickness of the paint shall be measured in place with a calibrated magnetic film thickness gauge. The thickness of each application shall be limited to that specified in the Paint Systems.

9.25 Film Thickness

The specified film thicknesses for coating materials shall be strictly observed and shall be checked with appropriate film thickness gauges furnished by the Contractor. The Contractor shall calibrate the gauges for the thickness range to be checked.

Calibration shall generally be carried out on a ground and polished steel plate of a quality corresponding to the structural steel to be coated.

Number of coats, type of paint and dry film thickness of the paint shall be specified or noted on the Drawings.

The dry film thickness shown on the painting systems are the minimum according to the specification "Steel Bridge Painting Manual" (Japan Highway Association), Measurement of Dry Paint Thickness with Magnetic Gauges.

When dry film thickness is less than specified, additional coats shall be applied as required at no additional cost to the Employer. Particular attention shall be paid to the film thickness on edges, weldings, etc.

9.26 Protection of Paintwork

The Contractor shall provide protective measures as necessary to prevent damage to the work and to other property or persons from all cleaning and painting operations. Paint or paint stains which result in an unsightly appearance on surfaces not designated to be painted shall be removed or obliterated by the Contractor at his expense. All painted surfaces that in the opinion of the Engineer are marred or damaged in any way, shall be repaired by the Contractor with materials and to a condition equal to that of the coating specified herein. The Contractor's proposal for retreatment of areas damaged by flame cutting and welding operations should be clearly stated in the detailed painting plan.

Upon completion of all painting operations and of any other work that would cause dust, grease, or other foreign materials to be deposited upon the painted surfaces, the painted surfaces shall be thoroughly cleaned. At the time of opening structures to public traffic, the painting shall be completed, and the surfaces shall be undamaged and clean.

9.27 Types of Surface Treatment

The application of each system of surface treatment within the structure shall be as shown on the drawings.

The attached table is prepared on the assumption that the painting sequence is as follows:

- Mill shop — shot blasting and etching primer
- Fabrication shop — painting to be after satisfactory completion of trial assemblage.
- Site — painting to be after final erection.

Where the Contractor requests permission to deviate from the above sequence, this shall be clearly stated in the detailed painting plan.

The areas for HSFG bolts shall be protected by masking at the time of the fabrication shop undercoats. Immediately prior to final erection, any rust in the joint area shall be removed by power wire brushing to a standard equivalent to "Steel Bridge Painting Manual".

9.28 Measurement and Payment

The items for "Structural Steelwork, supply, fabrication, shop painting and delivery to the Site" and "Erection" shall be measured for payment as the weight of steel permanently remaining in the structure. The unit will normally be the tonne. This item shall include all bolts, nuts and washers other than holding down bolts where they are measured separately, but exclude bearings which shall be measured separately. In addition, the density of steel shall be measured in accordance with the Clause 13 of the Preamble.

The rates for structural steelwork shall include for complying with Clause 13 of the Preamble.

10 CABLE STAYS WORK

10.1 Cable Stays Generally

This section covers the supply, fabrication, delivery, testing, installation, stressing and permanent protection of the cable stays and associated components.

The Contractor shall provide a parallel strand stay cable system, based on the type, size, geometry, and arrangement depicted on the Drawings. The details given on the Drawings illustrate the principles upon which the reinforcement detailing can be achieved. The Contractor shall determine the exact reinforcement and concrete dimensions necessary to suit the proposed stay cable system.

Stay cables, anchorages and all necessary and associated materials and devices shall have a past history and service record of satisfactory previous performance on cable stayed bridges.

The stay cables shall comprise monostrands encapsulated in individual Polyethylene sleeves, which are supported by spacers, or equivalent, at regular intervals and contained in a robust outer HDPE pipe. The outer pipe shall have an external layer of coloured HDPE.

Each stay cable shall consist of seven wire strands protected by at least three levels of corrosion protection with conical wedge anchorage and an additional corrosion protection system consisting of an outer polyethylene is pipe. The corrosion protection system to be provided shall be submitted to and approved by the Engineer. Cement grouting of the free length part of any stay cable shall not be permitted.

The stay cable system shall be such that the re-tension or replacement of any cable can be accomplished strand by strand at any time during the life of the bridge. Strands shall be protected in the anchorage zone, to avoid damage due to any protection defect. Blocking of strands with a hardening material will not be permitted.

Stay cable installation and bridge construction procedures shall incorporate requirements and provisions for the assessment and adjustment of stay cable tension. Such shall include stipulations for stay cable geometric control in accordance with applicable provisions of this Specification.

Tensioning operations may be accomplished strand by strand during the phases of construction with full consideration for geometric control of stay cables in accordance with applicable provisions of this Specification.

Final adjustments of stay cables shall be done in accordance with a method(s) proposed by the Contractor and approved by the Engineer. To accomplish final adjustments, stay cable anchorage shall be constructed to allow the use multi-strand jacks capable of pulling the complete anchorage.

Prior to commencement of pylon construction the Contractor shall verify all details of the stay cable system and provide design calculations and working drawings to define the reinforcement details and concrete dimensions to accommodate the cable stay system.

Prior to delivery of any stay cable to site, the Contractor shall submit to the Engineer records of the number of strands from each coil that are installed in each stay cable, together with the calculated elongation of each stay.

10.1.1 Erection Method Statement

The Contractor shall submit to the Engineer a detailed proposal outlining the proposed construction sequence. The submission shall incorporate detailed methodology, shop and erection drawings of the proposed construction sequence, together with the corresponding complete and checked erection design calculations. The package shall be submitted at least twelve weeks prior to the commencement of construction of the cable stayed superstructure.

The Contractor shall be responsible for the detailed design of the erection plant, equipment and temporary works and be responsible for ensuring the structural adequacy and stability of all such items when used in its chosen construction sequence or in the construction sequence depicted on the Drawings.

The Contractor shall be responsible for the static and dynamic stability of the structure during all stages of construction. In the development of the Design, detailed computational dynamic analyses were conducted to investigate the behaviour of the main bridge under different wind regimes, both during construction and in service. Wind tunnel testing using a sectional model was also carried out to augment the numerical modelling. The results of these studies will be made available for information purposes. However the Contractor shall conduct its own assessment of the data and material contained therein. The Contractor shall confirm with its Erection Method Statement that the erection scheme will adequately provide for stability of the structure at all stages of construction.

The construction engineering Method Statement shall comprise:

A summary of all design loads and assumptions.

A step-by-step confirmation of the strength and serviceability of the structure at each stage of construction.

Calculations of the required cambers taking into account the effects of creep, shrinkage and temperature.

Full design details of temporary structures such as erection carriers and temporary bracing.

Proposed methods for the calculation of the jacking forces and extensions for the say cables.

Sufficient detail to allow a review of the effects of the proposed erection procedure on the structure.

The submission shall define setting out and construction data of each in situ segment at all stages of construction. The data shall include the vertical offsets of the form traveller measured from a corresponding point in the previous segment. These offsets shall be given for the setting out of the unloaded form traveller, prior and subsequent to stay tensioning, concerning of segments, and deck prestressing.

The Contractor's Construction Engineering shall take account of all load and material effects. It shall prescribe theoretical vertical deck profiles for all stages of construction, and the application of superimposed dead loads such as bridge furniture and deck wearing surface. Vertical profiles shall also be predicted to beyond completion, at one-year intervals up to the Reference Time (10 years after bridge completion), and thereafter at 5-year intervals up to 30 years after completion, at which time all time-dependent rheological effects can be assumed to have taken place.

10.2 Submittals

The Contractor submit to the Engineer the following item works.

- Full details of the proposed cable stay system, supported by all applicable calculations for the parallel strand stay cable system in accordance with the type, size, strength, geometry and arrangement depicted on the Drawings.

- Prior to ordering stay cables or any associated equipment or devices for Engineer's approval full details of the proposed Stay cables including cable protection systems and devices.

- Prior to final adjustment of stay cables for Engineer's review and approval full details and procedures for all final cable adjustments. Such details shall include all calculations and data necessary to accomplish final adjustments, as well as equipment and devises proposed for use.

- Complete information and documentation detailing the past history and service record of previous use on cable stay bridges of all materials.

- Complete manufacturer's data, information and documentation for Cable Stay Strands verifying that the material meets requirements in accordance with this Specification including material properties as follows:

    - Load-strain tests.
    - Ductility test results.
    - Fatigue tests.

- Complete manufactures data, information and documentation for DHPE Strand Coating verifying that the material meets requirements in accordance with this Specification as follows:

    - Chemical Resistance tests.
    - Chloride permeability test results.
    - Impact test
    - Abrasion resistance tests

- Salt spray test results

- Complete manufactures data, information and documentation for Stay Cable Protective Filler Material verifying that the protective filler compound/ material meets requirements of this Specification and filler material tests.

- Complete manufactures data, information and documentation for Stay Cable Sheathing verifying that the material meets requirements.

  Prior to the start of sheeting manufacturing for Engineer's review and approval proposed sheeting coloring and verification of requirements of this Specification, along with manufacture's certification and certified and report on tests results

- Complete manufactures data, information and documentation for Neoprene Boots and Dampers verifying that the material meets requirements.

- Complete manufactures data, information and documentation for Damping Devices verifying that damping devices to be permanently installed meets requirements in accordance with this Specification.

- Prior to the commencement of stay cable work and before the ordering of any stay cable materials the Contractor shall furnish to the Engineer for review and approval complete stay cable anchorage specifications

- Prior to the commencement of stay cable work for Engineer's review and approval design calculations and stay cable anchorage assembly drawings.

- Prior to commencing with any stay cable work the contractor shall submit a complete test program to verify the design and performance of the cable system with anchorage devices.

- Prior to starting work the Contractor shall prepare and submit to the Engineer for review and approval a stay cable installation Method Statement and shop and working drawings.

- Detailed damping device shop drawings.

- Details of the electro-fusion system for HDPE sheathing joints, along with welded joint samples in accordance with requirements of this Specification.

10.2.1 Construction engineering

The Contractor is required to engage a Construction Engineering Consultant with experience in the design and construction of concrete cable stayed bridges.

The Construction Engineering Consultant will be required to provide detailed engineering services to the Contractor during the construction of the main bridge towers and superstructure.

The Contractor shall nominate full details of the proposed Construction Engineering Consultant including details of key personnel both on the site and elsewhere.

The Contractor is required to have a suitably qualified representative of the Construction Engineering Consultant resident on site full time during the construction of the main deck.

The Contractor's Construction Engineering responsibilities defined in this clause shall include but not be limited to:

- a step-by-step confirmation of the strength and serviceability of the structure for gravity and wind loads and the effects of creep, shrinkage and temperature at every construction stage.
- a summary of all design loads and the assumptions made in deriving them, design calculations, detailed shop and erection Drawings, including full details of the erection travellers and all other construction equipment, falsework, temporary bracing and methods proposed, calculated cable tensions in each cable at all construction stages and details of the proposed cable lengths and allowance for shims. Sufficient details shall be provided to allow a review of the effects of the proposed erection procedure on the structure.
- ongoing participation during the construction of the bridge deck and stay cable system.

The construction engineering shall be carried out by a Construction Engineering Consultant who has recent experience in the construction stage analysis of major cable stayed bridges. All design, plans and shop drawings shall be prepared under the direct supervision of professional engineers who are experienced in the construction engineering of major cable stayed bridges.

10.3 Strands for Stay Cables General Requirements

Strand materials for the stay cables shall be in accordance with Drawings, this Specification and Section 5 of "Recommendations for Stay Cable Design, Testing and Installation", American Post-Tensioning Institute Committee on Cable-Stayed Bridges (PTI), Third Edition, dated August 1993.

They shall be 15.2 mm nominal diameter seven wire strands conforming to the requirements of AASHTO M203 (ASTM A 416M-90a), Grade 270 (guaranteed ultimate tensile strength 1,860 MPa), low-relaxation grade, or equivalent, except where the requirements below differ form those of AASHTO M203 (ASTM A416M).

All cable stay strands shall be:

- factory galvanized with a zinc coating (applied before the last wire drawing operation) that is of uniform thickness (without drops or local thickenings) - the weight of galvanizing shall be measured in accordance with requirements of ASTM A 90,
- coated with high density polyethylene (HDPE), and
- provided with a protective filler inside the interstices between the core wire and the outer wires and around the outer wires.

Prestressing strands shall comply with the following material requirements:

Material Characteristic	Value	Testing Frequency
Nominal Diameter	15.2 mm	*
Minimum Ultimate Tensile Strength	Fpu =1,860 MPa	*
Minimum 0.1 °% Proof Stress	1,580 MPa	**
Nominal section	140 mm2 ±2%	*
Modulus of Elasticity (tolerance)	E =195 kN/mm^2 ±10 kN/mm^2	**
Ductility	One Pin Test	*
Minimum elongation at Rupture	3.5%	**
Maximum relaxation after 1000h and load 70 GUTS	2.5%	*
Fatigue Strength Test:		*
No of Cycles	2 x 10^6	
Upper Stress	0.45 ‰	
Stress Range	280 N/mm^2	
Galvanizing	Minimum 180 g/m^2 Maximum 340 g/m^2	*
Curvature of Strand	15mm	*

‰ = nominal tensile strength of strand
* Test frequency - for every unit of production
** Test frequency - for every unit or every 10 tons of strands

In addition to the material requirement as noted above, strands shall be in accordance with to all test requirements of this Specification section.

10.4 Testing and Quality Control of Strands for Stay Cables

Prior to ordering stay cables the Contractor shall submit documentation of previous use of the same materials in cable stayed bridges for review and comment by the Engineer.

The Contractor shall furnish to the Engineer for review and approval, complete mill test reports and certificates for the strands from each heat, including stress-strain curves and modulus of elasticity.

All strands and strand specimens derived for testing shall be clearly identifiable to ensure tractability during manufacture, delivery, storage, testing and installation.

All testing shall be by a recognized independent testing laboratory approved by the Engineer.

The Engineer shall be advised in writing at least 4 working days prior to the commencement of any and all strand testing. Unless otherwise advised by the Engineer, a representative of the Engineer shall witness the followings tests:

- Testing of fully assembled cables for fatigue, ultimate strength and acceptance.
- Testing of individual strands for fatigue, ultimate strength and acceptance.
- Strand anchorage acceptance tests.

All testing data and testing results shall be submitted to the Engineer for review and approval.

Fabrication of anchors and stay cable strands shall not begin until the tests as indicated below are successfully completed and the Engineer gives written approval of the material(s).

10.5 Load-Strain Tests on Strands for Stay Cables

Strands for use in stay cables shall be subjected to a tension test, conducted at a laboratory approved by the Engineer. The acceptance criteria of the testing are as follows:

- the minimum Ultimate Tensile Strength shall be 260 kN
- the modulus of elasticity shall be 195 GPa + 7.5% and - 5%

The test pieces shall be representative specimens which shall be selected by the Contractor from each continuous manufactured length of strand to be used in the Works, on the basis of one sample for each six (6) tonnes or part thereof. The free length of test piece shall be 4.0m to 5.5m. Should a test piece fail to meet any of the test criteria, the strands represented by that sample shall not be incorporated into the Works.

If any specimen fails within the test anchorage zone the test shall be discarded and another specimin tested from the same sample.

10.6 Ductility Tests on Strands

The Contractor shall select one representative specimen from each continuous manufactured length of strand to be used in the Works, for each six (6) tonnes or part thereof, and shall conduct a "One-Pin Test" as detailed in "Recommendations for Stay Cable Design, Testing and Installation" by the American Post-Tensioning Institute Committee on Cable-Stayed Bridges, Third Edition, August 1993.

The specimen sampled shall be of sufficient length for three (3) "One-Pin" tests. The acceptance criteria of the "One-Pin Test" shall be as follows. The tensile strength measured in the test piece shall be at least 80% of the actual ultimate tensile strength of the strand in that coil. Should the first test piece fail the test, two additional tests shall be conducted. If both of the extra test pieces demonstrate adequate tensile strength, the material represented by the specimen is acceptable, otherwise that coil shall not be incorporated into the Works.

10.7 Fatigue Tests of Strands

Fatigue tests on individual strands shall be conducted at a laboratory approved by the Engineer.

A specimen 5 metres in length shall be sampled from every ten (10) tonnes, or part thereof, of strands manufactured from each heat of steel. A test piece of minimum length one (1) metre shall be derived from this specimen and subjected to cycle loading in accordance with the testing and acceptance criteria in Section 6.3 Quality Control of Stay Cable Material in "Recommendations for Stay Cable Design, Testing and Installation" by the American Post-Tensioning Institute Committee on Cable-Stayed Bridges, Third Edition, August 1993.

The dynamic testing shall be halted either at 2 million cycles, or upon premature failure of a strand.

Should the first test piece fail the fatigue test, two additional tests shall be conducted. If both of the extra test pieces demonstrate adequate tensile strength, the material represented by the specimen is acceptable, otherwise that coil shall not be incorporated into the Works.

Prior to delivering any stay cable to site, the Contractor shall submit to the Engineer all relevant test results to demonstrate conformance of the strands to the above fatigue tests.

10.8 HDPE Strand Coating

Cable sheathing for each individual parallel strand cable shall be high density polyethylene (HDPE) plastic pipe confirming to ASTM F 714 and to Section 3.4.3 of the 1993 Edition of the PTI "Recommendations for Stay Cable Design, Testing and Installation".

The HDPE coating shall be extruded around the strand and the protective filler. It shall tightly follow the outer contour of the strand, and have minimum thickness of 1.5 mm (-0, +0.25). The final thickness of the HDPE strand coating will be such that the outer diameter of the coated strand does not exceed 19.2 mm.

Unless otherwise approved by the Engineer the HDPE coating shall be black in color.

The stay cable supplier shall demonstrate that no cracking of the HDPE/coating shall occur due to stress variations.

10.9 Testing and Quality Control of Strand Coating

At least one of each of the following noted tests shall be carried out per each unit of production.

- The chemical resistance of the sheathing shall be evaluated in accordance with ASTM standard G20 by immersing coated strands in each of the following:

  a 3M aqueous solution of CaCl2,
  a 3M aqueous solution of NaOH, and
  a solution saturated with CA (OH)2.

  In addition, to simulate cementitious grout, an aqueous solution of potassium hydroxide and an aqueous solution of sodium hydroxide shall be utilized for this test.

  Tests, with specimens without damage to the sheathing and specimens with intentional 0.25-in (6.4 mm) diametei holes drilled through the sheathing, shall be performed at 24 ± 2°C.

  Minimum test time shall be 45 days.

Acceptance criteria is that the polyethylene must not soften, crack, or be visually deteriorated and that intentionally made holes shall exhibit no undercutting during the 45-day period.

- The chloride permeability characteristics of the films of cured coating having the minimum thickness as proposed for use shall be measured by the methods outlined in FHWA-RD-74-018.

  The test shall be performed at 24 ± 2°C for 45 days.

  The accumulative concentration of chloride ion permeating through the film shall be less than 1 x 10-4M.

- The resistance of a strand sheathing to mechanical damage shall be determined by the falling weight test.

  A test apparatus similar to that described in ASTM G14 shall be used along with a 4-1b (1.8-kg) tup.

  Impact shall occur on the crown areas of the sheathed strand.

  The test shall be performed at room temperature.

  With an impact of 80-in-lbf (9N.m), no shattering, cracking, of sheathing shall occur except at the impact area, that is, the area permanently deformed by the tup.

- The resistance of the strand sheathing to abrasion shall be determined by the falling sand method of ASTM D968 adopted for testing sheathed strand. The net loss of sheathing shall not exceed 10 mils (0.25mm) per 1,000 L.

- Sheathed strand specimens shall be tensioned to 70 percent of the minimum ultimate tensile strength and exposed to salt fog for 3,000 hours in accordance with ASTM B117.

  Care shall be taken to protect the end anchorage used from salt fog or corrosion so as not to influence the test results.

  Observations for signs of corrosion shall be made and recorded every 250 hours. After 3,000 hours of exposure, no evidence of rust shall be present, and the specimen shall be holiday free.

  After the salt spray (fog) test is completed, the specimen shall undergo a tensile test, in conformance with ASTM A416. No cracks visible to the unaided eye shall occur in the polyethylene up to an elongation of 1 percent (yield point).

10.10 Protective Filler

The protective filler compound shall be corrosion inhibiting grease, a petroleum wax or an approved equivalent. Suitable measures shall be taken to assured that the protective filler (with provided spacers) shall fill the inter-wire voids, and the voids between the outer wires and the strand sheathing.

The weight of grease or wax per unit length of strand shall be a minimum of 12 grams/ meter length of strand.

10.10.1 Testing and Quality Control of Protective Filler

For each unit of production, the weight of the filler shall be confirmed by a testing a known length of strand.

The test procedure shall consist of weighing a length of strand, which has been cut longitudinally and measured to the nearest millimeter, and weighing the cleaned and degreased wires and HDPE sheath.

10.11 Stay Cable Sheathing

Stay cable outer sheathing shall consist of polyethylene (HDPE) pipe conforming to the requirements as noted herein.

Procedures for packaging, handling and shipping the pipe shall ensure the pipe will not be damaged when delivered to the site.

Due to high level of risk of rain and wind induced vibration, the HDPE sheathing shall incorporate a double helical rib which shall be incorporated onto the external surface of the sheathing by lap joints with fusion welds, or be continuous extrusion of the whole pipe during fabrication of the sheath.

The lower part of the cable stay sheath, immediately above the deck anchorage shall be protected by an anti-vandalism steel casing. Details of the steel casing and of the proposed connection details with the anchorage and with the main body of the HDPE sheathing shall be submitted to the Engineer for review and approval.

10.11.1 Stay Cable Sheath Coloring

Prior to commencing with initial manufacturing of sheathing, the Contractor shall submit details of the proposed sheathing coloring to the Engineer for approval. These shall be submitted along with test evidence of the colored sheathing's resistance against ultraviolet degradation and color change for a minimum of 15 years. The specified color, as approved by the Engineer, shall be achieved by either:

Fully colored HDPE pipes, with UV stabilizer or

HDPE pipe obtained by the extrusion method in which a coating of colored polyethylene is extruded over a black HDPE pipe.

10.11.2 Testing and Qualtty Control of Stay Cable Sheathing

HDPE pipe sheathing shall meet specific cell category requirements for PE 3406 and PE 3408 materials as defined by Table XI of ASTM D3350. The acceptable criteria for the primary properties for the PE materials shall as follows. (refer to Table 1 in ASTM D 3350)

Property	Test Method	Value
Density, gm/cm^2	ASTM D 1505	0.941 to 0.955
Melt Index	ASTM D 1238	Max. of 1
Flexural modulus, N/mm^2	ASTM D 790	550 <_ 1100
Tensile Strength at Yield, N/ mm^2	ASTM D 638	21 <_ 28
Environmental Stress Crack Resistance FZO hrs, min.	ASTM D 1639 (Condition C)	192
Hydrostatic Design Basis, N/mm^2	ASTM D 2837	8.62 to 11.0

A manufacture's certification clearly stating that the material meets this Specification requirements along with certified results of tests required in accordance with this Specification section shall be furnished for each shipment of sheathing.

Verification tests shall be performed on each size of pipe used. Samples for verification testing shall consist of one 2-meter lengths of pipe per size thickness per 1000 meter.

10.11.3 Stay Cable Sheathing Joints

The required length of the HDPE pipe shall be obtained by continuous extrusion or by fusion welding. Fusion welding of the HDPE pipe shall be performed in accordance with ASTM D 2657. The Contractor shall submit samples to qualify the fusion welding procedure. The samples shall consist of three (3) meter lengths of pipe per each pipe size thickness.

Stay cable sheath joints, at the ends of the stay cable shall be permanently sealed on site by an Electro-fusion welding procedure, incorporating electric welding of bands within the joint. The details of the Electro-fusion system shall be submitted to the Engineer for review and approval.

Welded joints shall be capable of developing the full yield strength of the pipe cross section.

10.12 Neoprene Boots and Dampers

The stays shall accommodate the effects of rotation at the anchorages under both static and dynamic loads. Neoprene boots, dampers or similar devices shall be installed at each anchorage to limit the local effects of rotation such that the

combined stresses in flexure and axial tension shall not exceed 56% of the characteristic breaking stress of the strand (the characteristic breaking stress of a strand is defined as the specified characteristic breaking load divided by the nominal area).

Neoprene boots and dampers shall be manufactured from 100% virgin chloroprene. The sole polymer shall be 100% virgin chloroprene which shall comprise no less than 60% by volume of the total compound.

The neoprene material shall comply with the following standards (> JIS):

Property	Method of Test	Requirements
Hardness Durometer A	D2240	60 + 5
Ultimate Elongation	D412 Die C	250%
Tensile Strength	D412 Die C	17.0 MPa minimum
Tear Resistance	D624 Die C	40.0 kN/metre minimum
Compression Set (22 hours 70 degree C)	D395	30% maximum
Ozone Resistance 20% strain at 400C±10C, 1ppm	D1149	No visible cracking after 100 hours
Accelerated Ageing 70 hrs at 1000C	D573	Maximum permissible change in properties Hardness ±4 Durometer Tensile Strength ± 10% Tensile Strain -15% Elongation -40%max

The testing shall be based on three samples collected from every 250 kg of mixed neoprene material. Any batch of material represented by a sample which fails to comply with the requirements herein shall not be incorporated in the Works.

10.13 Stay Cable Anchorage

Prior to the commencement of stay cable work and before the ordering of any stay cable materials the Contractor shall furnish to the Engineer for review and approval complete stay cable anchorage specifications to supplement requirements noted herein and on drawings. Materials, accessory and assembly requirements of this Specification shall be in accordance with and make reference to relevant AASHTO and ASTM, or equivalent requirements, and clearly indicate such reference by standard designation number(s).
The stay cable anchorage system shall be a parallel strand system.

Stay cable anchorage shall be in accordance with acceptance criteria specified in Section 6 of 1993 Edition of the Post-Tensioning Institute (PTI) "Recommendations for Stay Cable Design, Testing and Installation".

The level of protection within the anchorage assembly devices shall be consistent with the level of protection required in the stay cables.

Anchorage and fixings shall be capable of providing at least the guaranteed minimum breaking load of the stay cables.

The stay anchorage system and devices shall be such that strand-by-strand replacement of stay cables may be accomplished.

All exposed steel parts of the cable stay system shall receive a minimum protection in accordance with the following:

- For anchor blocks, transition pipes, anchorage nuts - Bichromatic electrolytic galvanization, or equivalent
- For protection caps, deviators, bearing plats, steel guide pipe, anti-vandalism tubes - 550 g/m2 galvanization (plus paint if required)

To prevent any fretting corrosion, the anchoring system and system components shall be such that the steel strands of the stay cables are not in contact with any other steel elements, except in the jaws of anchoring devices.

The anchorage and/or the transition zone shall include to reduce the flexural stress variations in the cable at the jaw under the stay oscillations. The contractor shall submit efficiency document to the satisfaction by the Engineer.

10.13.1 Drawings, Calculations and Testing of Stay Cable Anchorage

Prior to commencing with any stay cable work the Contractor shall submit to the Engineer for review and approval:

- complete design calculations for the cable anchorage systems, devices and components, and
- complete anchorage assembly drawings clearly detailing the sizes and types of anchorage used in the construction, with all dimensions and details of all components including bearing plates, steel guide pipe, steel flanges, deviates and guides.

Prior to commencing with any stay cable work the Contractor shall propose a complete test program to verify the design and performance of the cable system with anchorage devices. The test program shall detail full instrument, testing and monitoring requirements. The program shall be submitted to the Engineer for review and approval. After approval, the test program shall be carried out in accordance with the frequency, locations and conditions as approved by the Engineer.

10.13.2 Fatigue Testing of Stay Cable Anchorage System

Acceptance of the anchorage system shall be based on fatigue and ultimate strength of fully assembled cables. Test parameters and acceptance criteria shall be as detailed in Section 6.1 of the 1993 Edition of the Post Tensioning Institute (PTI) "Recommendation for Stay Cable Design, Testing and Installation" carried out at a laboratory approved by the Engineer and in accordance with the following:

- Three complete fully assembled stay cable specimens shall be fabricated for testing, one specimen shall be made representing the smaller stay cable, a mid-range stay cable and a larger stay cable in the bridge. Each specimen shall be fully representative of all details and procedures for anchorage production.

- Stay cables shall be tested with complete load bearing appurtenances and assemblies including dampers, protective sheathing and strand deviators.

- The method of construction and assembly of the cable and socket to be tested shall be the same as that used in the structure. Active anchorage and a passive anchorage shall be included.

- Strand deviators shall be representative of the actual installed stay cable deviators. The anchorage of the test specimens will be equipped with all corrosion protection.

- The number of tests to be conducted shall be as instructed by the Engineer with consideration for with past stay cable test results on the material.

If, in the opinion of the Engineer, past testing does not established satisfactory results, additional tests shall be conducted at the Contractor's expense.

10.14 Arrangement and Handling of Stay Cable Materials

The Contractor shall adopt procedures to ensure that stay cable components are not damaged during handling. All stay cables, cable sheathing, anchorage devices and associated materials and apparatus shall be arranged, transported and stored in such a manner so as to prevent any damage or deterioration of the material(s). They shall be protected from corrosion, heat, abrasion and other harmful effects during fabrication, transportation, storage and installation.

Damaged strands and/or damaged load carrying components shall be replaced. Damaged non-load carrying components shall (subject to the Engineer's approval) be repaired prior to installation. When directed by the Engineer, damaged components shall be replaced.

All damage to stay cable cables or components thereof shall be remedied prior to installation.

The coiling diameter of parallel strands shall not be less than 50 times the diameter of the outer coating of the strand. The parallel strands shall be arranged on wooden reels with coils that can be handled without damage when transported by forklifts and trucks. In the case of cables fabricated in-situ, the minimum reel diameter for the HDPE outer sheath shall be 25 times its outside diameter during fabrication, transport storage and erection of stay cables, unless otherwise agreed by the Engineer. The sheath shall be warmed to a minimum temperature of 24°C prior to coiling or uncoiling.

During fabrication, transport, storage and erection the minimum bending radius for the HDPE outer sheath shall be 25 times its outside diameter.

The Contractor shall assure that all material orders clearly convey necessary requirements for arrangement and packaging to assure preservation of materials, protection from damage and specific requirements as stated herein.

10.15 Stay Cable Installation

At all times the Contractor shall conduct his activates with due regard for the safety and stability of the Works.

The installation of all stay cables, including necessary anchorage and associated requirements and procedures shall be the responsibility of the Contractor. Construction shall be in accordance with this Specification and the latest internationally recognized references and procedures for stay cable construction by a Contractor and sub-contractors that have recent experience with similar work.

Stay cables installation shall be in accordance with detailed engineered installation procedures prepared by the Contractor and approved by the Engineer. Installation procedures shall be prepared with full consideration of construction loads and static conditions during the course of construction and the segmental construction procedures and requirements as given under this Specification.

If the fabrication of cable stays is to be undertaken at the site, appropriate measures (which shall be fully described in the Contractors Method Statement) shall be taken to ensure that all stay cable elements are installed parallel to one another.

10.15.1 Method Statement, Shop and Working Drawings for Stay Cable Installation

Prior to starting work the Contractor shall prepare and submit to the Engineer for review and approval a Method Statement that fully describes in detail all stay cable installation operations and procedures. The Method Statement shall include a description and documentation of the main items of the equipment the Contractor proposes to use as well as a detailed engineered cable installation program prescribing cable forces and the elongation of each stay cable.

The Method Statement shall fully detail the construction sequence together with complete corresponding erection design calculations. In the Method Statement the Contractor shall confirm and certify that the proposed erection scheme shall adequately provide for structure stability during all stages of construction.

With full consideration for procedures and requirements of the Contractors Method Statement, the Contractor shall provide complete detailed shop and working drawings noting all materials, dimensions, calculations and procedures for stay cable installation to the Engineer for review and approval.

The Contractors Method Statement, shop drawings, working drawings as well as all erection and design calculations shall be prepared under the direction of and be certified by a Registered Professional Engineer with past experience in the design and construction of cable stay bridges.

The Contractor's Method Statement, with due consideration the construction requirements noted in this Specification section, shall include the following:

- A summary of all design loads and assumptions.
- A step-by-step confirmation of the strength and serviceability of the structure at each stage of construction.

- Full calculation details of temporary structures such as erection carries and temporary bracing.
- Proposed methods for calculation of jacking forces and extensions for the stay cables.
- Sufficient detail to allow a review of the effects of the proposed erection procedures on the structure.

10.16 Construction Requirements for Stay Cables

Stay cable construction procedures shall be compatible with the bridge construction sequence and erection procedures.

The Contractor shall provide the determination of forces and deflections in the permanent structure at all erection stages.

A package tensioning, as a final adjustment, shall be done after completion of bridge surfacing works.

Jacks and gauges for stay cable installation shall be calibrated using a load cell or a static load machine calibrated not less than one month prior to the beginning of cable installation. All jacks and gauges shall be calibrated every 6 months thereafter, for the duration of cable installation. The 6-month re-calibration may be performed using a master gauge, provided that the master gauge is calibrated with the field gauges at the time of initial jack calibration.

In-situ erected stay cable strands may be tensioned one by one provided that it can be demonstrated to the satisfaction of the Engineer that the final tension and elongation of each strand is equalized within a 2% range. The stay cable system must be compatible with the strand by strand tensioning procedure. Fully trained specialists who have had relevant past experience on similar type projects shall accomplish the strand by strand tensioning and installation.

Stay cables shall capable of being tensioned, de-tensioned or re-tensioned more than once during the construction of the structure. These operations may be carried out either by full jacking of the live anchorage and adjustable ring setting, or strand by strand.

Maximum cable tension during construction shall not exceed 56 percent of the cable's minimum ultimate tensile strength.

Stay cable shall be installed with sufficient adjustment devices to permit de-tensioning without relaxing stay anchorage component devices. No cable shall be de-tensioned in such a way that any part of the strands that has been previously "gripped" by the anchorage wedges is incorporated in the stressed portion of the strands.

All permanent corrosion protection inside the anchorage shall be suitable approved grease type or equivalent.

10.17 Installation of Stay Cable Vibration and Damping Devices

During all stages of construction, restraints such as secondary ropes tied around individual stays and anchored to the deck shall be employed at necessary locations to control stay cable vibration.

If cable oscillations persist after the stay system has been completed, permanent damping devices, which have a natural frequency of vibration mode of less than 30 Hz. shall be installed on the stay cables.

The Logarithmic dampening frequency of installed dampers shall not be less than 0.02, with full consideration for rain, wind velocity, bridge design criteria, ambient temperatures and other subjective conditions.

In addition to above noted criteria, permanent damping device shall comply with the following:

- they shall not be insensitive to the frequency and the amplitude of vibrations;
- they shall not be temperature dependant;
- they shall be adjustable during the life of the bridge; and
- they and the components they are comprised of shall give full consideration for future maintenance access, inspection, and replacement.

The Contractor shall submit shop drawings with full details of proposed damping devices to the Engineer for review and approval. Drawings shall fully describe the damping devices proposed and how they will be fitted to and incorporated in the stay cable system.

10.18 Steel Guide Pipe and Transition Pipes

The steel guide pipes and transition pipes at stay cable anchorages shall be hot dip galvanised after fabrication and the exposed edges of the steel plate shall be smooth and rounded to a radius of 3 mm before galvanising.

Installation tolerances shall be specified in advance by the Contractor and developed in relation to the stay system, pipe and neoprene damper details such that a close tolerance fit can be achieved between these components in the stay cable system.

Nevertheless the angular deviation between the steel pipe and actual stay centrelines shall in no case exceed ±0.25 degrees. The thrust plates shall be installed perpendicular to the axis of the guide pipe within a tolerance of ±0.15 degrees.

A close tolerance fit between the stay pipe, neoprene damper and steel guide pipe shall be provided at each stay anchor to ensure proper functioning of the stay anchors. Any gap between neoprene damper and stay pipe shall be less than 1 mm. Overheating (melting) and wear of the stay pipe and damper, due to relative movements between the two parts, shall be prevented by proper detailing.

The details shown on the Drawings illustrate one proposal to comply with the above performance criteria. The Contractor shall provide, and be responsible for, all detailing. The Contractor's details shall provide similar components, robustness and capability of adjustment as those depicted on the drawings.

10.19 Tests on Overall Stay Cable System

In addition to tests on individual strands and other components noted above, a programme for static and dynamic testing shall be conducted on at least three (3) representative specimen stay cables. The specimens shall be a truthful representation of the stays in the permanent Works and they shall be tested with their load bearing appurtenances and assemblies comprising neoprene boots and dampers, protective sheathing together with spacers and any grouted medium if grouting is adopted by the Contractor in the cable system. The method of construction and assembly of the cable and anchorage shall be identical to that employed in the Works. The size of the specimen shall be a minimum of 4 metres between anchor plates. The test procedures and the testing laboratory shall be approved by the Engineer.

The specimens shall be subjected to cyclic loading in accordance with the testing criteria in Section 6.1 - Acceptance Testing of Stay Cables in "Recommendations for Stay Cable Design, Testing and Installation" by the American Post-Tensioning Institute Committee on Cable-Stayed Bridges, Third Edition, August 1993.

Upon completion of the dynamic testing, the stay cable shall be unloaded and the outer HDPE pipe, individual PE sheathing and any protective medium (and also the grout, should there be any) removed to enable the strands to be examined. No more than two (2) percent of the number of individual wires (rounded to the nearest integer) shall have failed. No failure shall be permitted in the anchorage material, or in any other component of the cable and anchorage system. The maximum permissible anchor slip shall be limited to 4mm.

Subsequent to thorough inspection, the test piece shall be reloaded and it shall develop a minimum tensile force equal to 95 percent of the ultimate tensile strength of the test cable (number of strands time the specified characteristic breaking load of one strand).

Should any test cable fail to comply with the specified acceptance criteria, the Contractor may provide, at its own cost, another cable for testing at the same laboratory. This option may only be exercised once for each cable size.

If the tests reveal a stay cable does not comply with the Specification, the Contractor shall develop remedial measures and modify the stay cable system. Upon approval by the Engineer, new cable specimens shall be prepared and tested in accordance with this Specification at the Contractor's own cost until conclusive proofs have been reached.

If the acceptance criteria cannot be met by the proposed stay cable system, the Contractor shall be required to change the supplier at no additional cost or extension of time.

10.20 Measurement and Payment

(1) Stay cable installation

Measurement and payment for stay cable installation shall be measured by the weight of net stay cable. The rates for stay cable installation shall include for

complying with the Clause 12 of the Preamble.

(2) Dumper

Measurement and payment for dumper shall be by number. The rates for dumper shall include for complying with the Clause 12 of the Preamble.