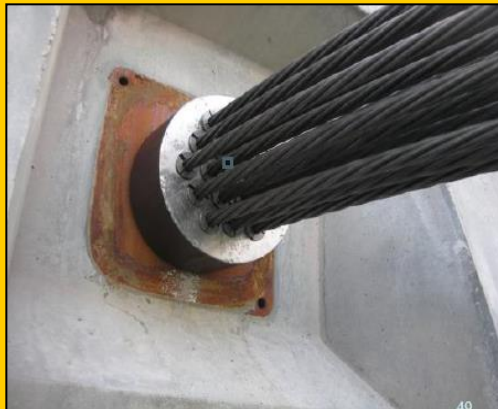




**KERAJAAN MALAYSIA
JABATAN KERJA RAYA MALAYSIA
STANDARD SPECIFICATION
FOR ROAD WORKS**

**Section 11:
PRESTRESSING FOR STRUCTURES**



KETUA PENGARAH KERJA RAYA
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FOREWORD

As practices in road construction change over time, it is imperative for Jabatan Kerja Raya (JKR) to continuously update and improve their standard specifications. These new specifications are not only aimed at keeping abreast with current technologies but also to help improve the quality of construction works and its final product. Consequently, these new specifications will ultimately have a significant positive impact on the construction industry especially with the incorporation of new products and technologies.

The JKR Standard Specification for Road Works is an essential component in the road infrastructure construction industry. This Specification provides an improved guidance in the material selection and quality control of workmanship and products, based on current best practices. The purpose of the JKR Standard Specification is to establish uniformity in road construction to be used by road designers, road authorities, manufacturers and suppliers of road related products.

This particular document, the “**Standard Specification for Road Works – Section 11: Prestressing for Structures**”, is a part of a series of improved specifications in the JKR Standard Specification for Road Works. The compilation of this document was carried out through many discussions that had been held by the technical committee. The draft had also been presented and discussed at length in a specially held workshop to get feedback and comments from relevant parties involved, which were then carefully considered and incorporated into the Specification wherever appropriate or necessary.

The Specification has also gone through the different phases of vetting and approval before the production of its final draft and printed copy. It will be reviewed and updated from time to time to cater for any changes in policies and the inclusion of current requirements, if necessary. Any feedback or improvement to be considered for future revisions should be forwarded to Bahagian Pembangunan Inovasi & Standard, Cawangan Jalan, JKR Malaysia.

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SECTION 11 – PRESTRESSING FOR STRUCTURES

11.1 DESCRIPTION

This work shall consist of the construction of all prestressed concrete structures; including casting, tensioning, grouting, storage, transporting and launching; all the lines, level, grades, dimensions and cross-sections as shown on the Drawings and as directed by the S.O.

11.2 GENERAL REQUIREMENTS

The Contractor shall submit to the S.O. for approval before the commencement of construction, all necessary shop drawings showing the location and number of tendons, wires or strands, prestressing system, and methods of maintaining tendon alignment in the structure or structural element. The Contractor shall also furnish complete outline of construction procedure including the stressing sequences, coefficient of friction, wobble, draw-in, stressing and anchoring forces, bursting reinforcement and other incidental features, which are related to the proposed type of prestressing system and equipment.

In the case of prestressing components used in which the ducts are partially or completely external to the concrete section, they shall be designed to allow the duct and tendon to be replaced.

All installation and fixing of the duct and sheath, anchorage plates, threading of tendon, strand or steel bar, tensioning works and the subsequent grouting operations required shall be carried out under the direction of a competent supervisor and by personnel who have had approved previous experience in the use of the type of system and equipment proposed and subjected to the approval of the S.O. The sub-letting of all or part of this Work to a specialist Sub-Contractor shall be subjected to the prior approval of the S.O.

The Contractor shall be entirely responsible for the safe execution of tensioning operations. Specialist precautions against accident shall be taken when working with or near tendons which have been tensioned or are in the process of being tensioned.

Where any modification are necessary to the reinforcement and/or concrete dimension to suit to the approved or proposed prestressing system, the Contractor shall submit to the S.O. with the supporting design calculations, drawings and related information as required by the S.O. All submissions must be endorsed by a Professional Engineer registered with the Board of Engineer Malaysia.

11.3 TYPES OF PRESTRESSING

The types of prestressing shall be to the details as shown on the Drawings. Below are the typical type of prestressing systems used to apply the compressive force to the structure/ structure element.

11.3.1 Pre-tensioning

A method of prestressing in which tendons are tensioned before the concrete is placed. This shall be done either on or off Site as directed by the S.O.

11.3.2 Post-tensioning

A method of prestressing in which tendons are tensioned after the concrete has attained the transfer concrete cube strength. This method can be for bonded or unbonded tendon. This shall be done on Site unless otherwise directed by the S.O.

11.3.2.1 Bonded tendon

A grouted duct and tendon that provide a perfect bond between the tendon and the concrete section.

11.3.2.2 Unbonded tendon

A post-tensioned members in which the ducts and tendons are permanently ungrouted or surrounded with only protective coating which may be encased in concrete after stressing and provide no bond between the tendon and the concrete section.

11.3.3 Temporary Prestressing

A method of prestressing in which temporary tendons/ steel bars are tensioned during the construction stages for the purpose of completing the final structure after the concrete has attained the required compressive stress at transfer. The method shall be submitted to the S.O. for approval prior to commencement of the related works.

11.4 MATERIALS

11.4.1 Prestressing Tendons, Strands, Wire or Steel Bar

- (i) High tensile steel wire shall comply with the requirements of BS 5896: or EN 10138 - Pt. 2, ASTM A416/A416M.
- (ii) Prestressing steel strand shall comply with the requirement of EN 10138 - Pt 3.
- (iii) High tensile alloy steel bars shall comply with the requirements of BS 4486 or ASTM A722M.
- (iv) Flat duct.

11.4.1.1 Material Testing

The Contractor shall submit the Manufacturers' Certificates of Test of the prestressing strands, wires or steel bars for each batch to be used or delivered to the site for the approval of the S.O.

The Manufacturers' Certificates of Test shall be submitted to the S.O. at least 28 days before installation of the prestressing tendons starts. The Manufacturers' Certificates will show the manufacturer's name, the date and place of manufacture and tendon or steel bar sample batch numbers. It must also include particular details with reference to at least the following items :

- (i) Diameter, cross-sectional area and unit mass.
- (ii) Result of tests for mechanical properties, including the characteristic breaking load, characteristic 0.1% proof load, yield strength, elongation at maximum load, relaxation to 1000 hours, fatigue behaviour test and Modulus of Elasticity and Load versus ϵ Elongation Curve.
- (iii) Result of test for ductility of prestressing wires. When directed by the S.O., the Contractor shall arrange for samples of the steel intended for use in the Works to be tested at an approved accredited independent testing laboratory. If such samples fail to comply with the this Standards specification, notwithstanding any previous acceptance on the manufacturer's test certificate, that steel represented by the sample may be rejected by the S.O. and shall require its removal from Site.

11.4.1.2 Handling and Storage

All prestressing materials shall be stored in such a manner that will not cause any harmful effect. The material shall be stored under suitable weatherproof covers. No contact with the earth ground shall be allowed.

For any prestressing material that does not appear to be in a suitable condition for use in the Works, independent tests shall be carried out to demonstrate the physical properties of the steel. As a result of these tests, the S.O may reject the batch of steel which shall then be removed from the Site.

Care shall be taken to avoid mechanically damaging, work-hardening or heating induction to the prestressing materials. Under no circumstances shall prestressing tendons be subjected to any welding operation, or 'on Site' heat treatment or metallic coating such as galvanizing. This does not preclude cutting as specified in clause 11.4.1.5 of this specification.

The lifting, handling, transporting and storing of the tendons shall be in a manner that ensures no damage is incurred to them.

11.4.1.3 Surface Condition

Prestressing materials shall be free from loose rust, loose mill scale, oil, grease or other harmful and deleterious matter. A slight

film of rust will be accepted, but the steel shall not be pitted. High tensile steel bars shall be individually inspected for superficial tears, nicks, roller marks or any other form of surface imperfection.

Surface condition that shows imperfections that exceed 0.40 mm in depth must be treated as non-conforming and shall be rejected.

11.4.1.4 Straightness of Wires, Strand and Bars

Tendons supplied by the manufacturer shall be in coils large enough to be self-straightening. Kinked or damaged strands or bars shall not be used and shall be removed from the site.

11.4.1.5 Cutting of Wires, Strand and Bars

All cutting of tendons, strands or steel bars shall be carried out using a high-speed abrasive cutting wheel, friction saw or any mechanical method as approved by the S.O. Flame cutting is not allowed.

In post-tensioning system, trimming of ends shall be carried out with high speed cutting discs to within 50 mm of the anchor block or blister.

11.4.2 Non-prestressing Reinforcement

Non-prestressing reinforcement shall comply with all the clauses on steel reinforcement of Section 9 of the Standard Specification for Road Works, except in such respects as they may be modified by the provisions of the remainder of this Section of the specification.

11.4.3 Concrete

Materials and workmanship for concrete shall comply with all the clauses on concrete for structures of Section 9 of the Standard Specification for Road Works, except in such respects as they may be modified by the provisions of the remainder of this Section of the specification.

11.4.4 Duct Systems

The system of tendon ducting system that consists of sheath, sheath connectors, grouting connections, vents, vent connections, drains, transitions to anchorages and caps for anchors shall form a complete encapsulation for the tendons which have resistance to the ingress of air and water. Ducting which may exhibit potential degradation or corrosion during the expected life of the structure shall not be permitted. The

system shall be fully compatible with the prestressing anchorages, couplers and other details.

The design of the duct shall allow for grout to be injected from either end of the cable.

Sheaths and duct formers used to form the duct system must maintain their original cross section and profile during construction. There shall be no sudden changes in the diameter of the duct.

Unless shown otherwise on the drawings, the friction coefficient between the duct and the tendon shall not be higher than 0.20.

The ends of all ducts systems shall be sealed and protected after the tendon is threaded through and until the stressing operations are commenced.

11.4.4.1 Sheaths

All sheaths shall be either as described on the Drawings or proprietary type approved by S.O and shall be of steel type or other materials as approved by S.O. The sheaths shall be rigid and strong enough to retain their shape during the installation of the tendon, fixing, and concreting. Sheaths must be able to withstand the forces from the prestressing tendons without damage.

Sheath material of galvanised steel type shall comply with BS EN 523: 2003 and BS EN 524, Part 1 to Part 6. The minimum thickness for internal prestressing shall be 2.0 mm and minimum thickness for external prestressing shall be 4.0 mm.

Sheath material of plastic type shall comply with ASTM D3350 for HDPE with cell classification 335533C; or ASTM D1784 for rigid PVC with classification 13464B or equivalent as approved by the S.O.. It shall have a corrugated profile and an allowance in the wall thickness to account for abrasion during stressing of the tendon.

Wall thickness shall not be reduced to less than 1.5mm (from original 2mm), to demonstrate the 'evidence of testing' after tensioning of the internal tendons, and proof shall be submitted by the Contractor to the S.O.

The number of joints shall be kept to a practicable minimum and each joint shall be adequately sealed against the ingress of any foreign material. Joints in adjacent sheaths shall be staggered by at least 300mm. Enlarged portions of the sheathing at couplings on anchorages shall be of sufficient length to provide for the extension of the tendons. The joints shall be sealed with unstretchable and water proof adhesive tape prior to the installation of the tendon.

Sheaths shall also be kept free of any matter detrimental to the bond between the sheath and the concrete except for the material sealing a sheath joint. The internal and external surfaces of sheath shall be clean and free from pitting, loose rust and loose scale at the time of incorporation in the Work.

The ends of all sheaths shall be sealed temporarily and protected (temporary work) until the tendon is threaded through and until the stressing operations are commenced.

11.4.4.2 Duct Formers

When duct formers are used, they shall be coated with a release agent only with the approval of the S.O. Duct formers shall not be extracted until the concrete has hardened sufficiently to prevent it from being damaged.

11.4.5 Anchorages

Anchorages for post-tensioning shall comply with the procedure described in BS EN 13391: 2004 or in accordance with that as specified by the manufacture's proprietary system approved by S.O.

Size and shape anchorages or bearing plates to transfer anchor loads to the concrete without overstress, irrespective of whether the load is applied by the anchorage or the stressing jack. All anchorage devices shall withstand a force of not less than 95% of the specified minimum ultimate tensile strength of the tendon without damage from excessive deformation or draw-in. Unless otherwise approved, the steel for anchorage bearing plates must be Grade 250 to BS EN 10025-2:2004 , S235JR.

Anchorages for unbounded tendons shall not cause a reduction in the elongation under ultimate load of the tendon to less than 2% measured in a minimum gauge length of 3000mm.

All anchorage devices shall be free from rust, pitting, blow-holes and shall be in accordance with the proprietary system specified tolerance.

11.4.6 Couplers

All couplers for prestressing tendon shall conform to BS EN13391: 2004. The test certificates shall be submitted to the S.O prior to the commencement of prestressing works.

The couplers used as joints for tendons shall achieved at least 95% of the specified characteristic tensile strength for strand tendons and shall achieved more than 100% of the specified minimum breaking load for tendons.

11.4.7 Grouts for Duct

The Contractor shall undertake full scale trial tests of grout mix together with the grouting operations as directed by S.O. The trials are required to demonstrate that the grouting methods and procedures as proposed by the Contractor are satisfied to ensure that the grout completely fills the ducts and surround the prestressing steel.

Unless otherwise directed or agreed as a result of grouting trials, the grout shall conform to BS EN 446, BS EN 447 and the following requirements:

- (i) Consists only of ordinary Portland Cement (CEM I) complying with BS EN 197-1, Class 42.5 N and water complying with BS EN 1008.
- (ii) Admixtures shall not be used unless permitted by the S.O. and complies with sub-Clause 11.4.7.2
- (iii) The maximum total chloride content of grout, expressed as a percentage relationship between the chloride ion and the cementitious content by mass in the grout, shall not exceed 0.1%.
- (iv) Have a water/cement ratio as low as possible, consistent with the necessary workability and under no circumstances shall the water/cement ratio exceed 0.4.
- (v) Not subject to bleeding in excess of 2% after 3 hours or 4% maximum when measured at 27°C in a transparent tube approximately 60 mm to 80 mm diameter with a height of grout approximately 100mm and shall be re-absorbed after 24 hours. One 7-wire strand approximately and no less than 900 mm long which fits inside the tube
- (vi) Prebagged grout that is used shall be mixed in accordance with the manufacturer's instruction.

Grouting of ducts shall produce no void. However, void which has either a dimension greater than 5% of the duct diameter measured in the radial direction of the duct or greater than 200mm measured in the longitudinal direction of the duct can be acceptable subjected to the S.O. approval.

11.4.7.1 Testing of Grouts

Testing shall be performed in accordance with the test method given in BS EN 445 and the testing requirements are summarised in **Table 11.1** below.

TABLE 11.1 – MINIMUM TEST REQUIREMENTS FOR GROUT

Suitability Testing	
i. Fluidity	i. Sampled immediately after mixing, one test. ii. After estimated time to grout duct or minimum of 90 mins from initial mixing. iii. Two tests averaged in both cases.
i. Bleed ii. Volume change iii. Sedimentation iv. Strength	i. Each sampled immediately after mixing, 3 tests averaged.
Acceptance Testing	
i. Fluidity	i. Sampled immediately after mixing, one test from mixer. After flow through duct, one test from each anchorage outlet. ii. On completion, one test from the mixer.
i. Bleed ii. Volume Change iii. Strength	i. One test per day or one per 1.5 m ³ of grout unless otherwise agreed by the S.O.
i. Sedimentation	i. One test per day for site batched grout, or one test per pre-bagged supplied batch (by manufacturer's reference number); subject to a minimum of one test per continuous grouting operation.

(i) Fluidity

The fluidity of the grout during the injection period have the values given in **Table 11.2** below. Fluidity should not change by more than 20% from immediately after mixing to 30minutes after mixing.

TABLE 11.2 – FLUIDITY TEST REQUIREMENT

Test method	Immediate after mixing	30 mins. after mixing
Cone	$t_0 \leq 25 \text{ s}$	$1,2 t_0 \geq t_{30} \geq 0,8 t_0$ and $t_{30} \leq 25 \text{ s}$
Grout spread	$a_0 \geq 140 \text{ mm}$	$1,2 a_0 \geq a_{30} \geq 0,8 a_0$ and $a_{30} \geq 140 \text{ mm}$

t_0 = time recorded immediately after mixing

t_{30} = time recorded 30 minutes after mixing

a_0 = average spread immediately after mixing

a_{30} = average spread recorded 30 minutes after mixing

(ii) Bleeding

Tested by both wick induced method and inclined tube test given in BS EN 445 for the average of three results. The bleeding shall not exceed 0.3% of the initial volume of the grout after 3 hours kept at rest. Testing shall be carried out at 24 hours .

(iii) Volume Change

The volume change assessed may be either an increase or decrease. When tested in accordance with the method given in BS EN 445 the volume change of the grout at rest for 24 hours shall be within the range of - 0 % and + 5 %.

(iv) Sedimentation

The grout shall not exhibit variation in density from top to bottom of a single test sample in excess of 5%.

(v) Compressive Strength

The compressive strength of grout assessed according to BS EN 445 shall be not less than 30 N/mm² at 28 days or 27 N/mm² at 7 days if it is proposed to estimate the likely 28 day strength at 7 days. Cubes shall be made, cured and tested in accordance with BS EN 12390-1 and BS EN 12390-3.

11.4.7.2 Admixtures

Admixtures shall be used where required to achieve a low water/cement ratio and impart good fluidity, minimum bleed and volume stability or expansion to the grout to comply with sub-Clause 11.4.7.1. For site batched grout, admixtures shall be added on site during the mixing process and used in accordance with the manufacturer's recommendations. For pre-bagged grout the admixtures shall form a pre-blended component.

(i) Types

Admixtures are divided into two types, expanding and non-expanding and they may be used to obtain the required grout performance. Admixtures used in combination shall be checked for compatibility by the Contractor, and reported to the S.O for acceptance.

(ii) Chemical Composition

Admixtures shall not contain substances in quantities that will adversely affect the grout or cause the grout to promote corrosion of the prestressing steel by rusting, pitting, stress corrosion or hydrogen embrittlement.

(iii) Material requirements

The admixture shall not segregate and shall be uniform in colour. The composition shall not change and the supplier shall operate a quality system complying with BS EN ISO 9001. The quality system shall be certified by a third party accredited by an appropriate organisation in accordance with Section 9 of the Standard Specification for Road Works.

Where appropriate, admixtures shall comply with BS EN 934-4. Other admixtures shall be permitted provided they satisfy Clause 8 of BS EN 934-2 and full account is taken of their effects on the finished product and their fitness for purpose. Data on their suitability, including previous experience with such materials, shall be made available and records of the details and performance of such materials shall be maintained.

(iv) Dosage

The optimum dosage of any admixture shall be determined by trial mixes with the cement to be used in the grout. This dosage shall be expressed as percent by mass of the cement. It shall be within the range recommended by the supplier and shall not exceed 5% by mass of the cement. The method of measuring dosage and checking weights of prepacked dry materials shall comply with Section 9 of the Standard Specification for Road Works or as otherwise agreed with the S.O.

11.4.8 Debonding For Prestressed Cables

The sheathing or blanket for pre-tensioned strand, where it is required to prevent bond over a specified length, shall consist of P.V.C. tubing or other materials, of a quality, diameter and thickness such that bonding shall be effectively prevented. The sheathing/ blanket shall be fastened to the strand in such a manner that the entry of cement mortar shall not impair the efficiency of the bond-break and sheathing/blanket shall be continuous through end plate for at least 2mm.

11.5 PRESTRESSING EQUIPMENTS**11.5.1 Mould and Formworks**

The Contractor shall supply and maintain an adequate number of moulds for the casting of prestressed structures. The moulds shall be manufactured from steel forms, coated plywood, wrought boards controlled permeability formwork liner or others approved material by the S.O. The controlled permeability formwork liner if used, shall be complied to Section 9 of this specification.

The moulds shall be rigidly stiffened to prevent any distortion to the structure or structure element during installation and tensioning processes. Where necessary, the mould shall allow for the incorporation of form vibrators of approved capacity.

The void formers shall be able to withstand the pressure due to the height of the concrete during concreting. Release agent shall be used for the void former unless instructed otherwise by S.O. Void formers shall not be extracted until the concrete has hardened sufficiently to prevent it being damaged.

11.5.2 Tensioning Equipment

All tensioning equipment shall be of the type recommended by the manufacturer of the prestressing system, subjected to the approval of the S.O. Stressing shall be done in the manner recommended by the

manufacturer as detailed in the manual and their supplementary publications where applicable.

The tensioning apparatus shall also meet the following general requirements:-

- (i) Tensioning and anchoring of tendon or strand shall only be done with the equipment supplied by the manufacturers of the prestressing system with the approval of the S.O. and their recommended procedure shall be followed.
- (ii) Before commencing tensioning operation and also whenever directed by the S.O., the jack pressure gauges or load cells shall be calibrated against the load produced by dead load tester device apparatus. The accuracy of the pressure gauges and/or load cells throughout the prestressing operations shall be the responsibility of the Contractor. Calibration certificates for the pressure gauges, stressing jacks and load cells shall be duly certified by accredited testing laboratory.
- (iii) The means of attachment of the tendon to the jack or tensioning device shall be safe and secure.
- (iv) Where two or more strands are stressed simultaneously, they shall be approximately of equal length between anchorage points at the datum of load and extension measurement. The degree of variation between the stressed strands shall be not more than 5mm.
- (v) The tensioning apparatus shall be such that a controlled total force is imposed gradually and no dangerous secondary stresses are induced in the tendons, anchorage or concrete. An approved device shall be fit in to the hydraulic system to avoid sudden loss of pressure.
- (vi) The force in the tendons during tensioning shall be measured by direct-reading load cells or obtained indirectly from gauges fitted in the hydraulic system to determine the pressure in the jacks. The diameter of the gauge must not be less than 150 mm and must be of such a type which will allow visual reading to the nearest 0.5 Mpa. Facilities shall be provided for the measurement of the extension of the tendon and any movement of the tendon in the gripping devices. The load-measuring device shall be calibrated to accuracy within $\pm 2\%$ and checked at intervals as appropriate to the approval of the S.O.
- (vii) Elongation of the tendon shall be measured to an accuracy within 2% or 2mm, whichever is more accurate.

- (viii) The tensioning equipment shall be calibrated before the tensioning operation and at intervals to the approval of the S.O.

11.5.3 Grouting Equipment

The mixing equipment shall produce a grout of homogeneous consistency and shall be capable of providing a continuous supply to the injection equipment.

The injection equipment shall be capable of continuous operation with little variation of pressure and shall include a system for recirculation or agitating of the grout while actual grouting is not in progress. Compressed air shall not be used.

The equipment shall provide a constant delivery pressure to the flow of grout and maintained at 1 MPa. The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a valve that can be locked off without loss of pressure in the duct.

All piping to the grout pump shall have a minimum of bends, valves and changes in diameter.

Contractor shall provide adequate flushing-out plant to facilitate complete removal of the grout in the cable in the event of breakdown before the grouting process completed. Contractor to demonstrate to the approval of S.O. that this facility is in full working order.

All baffles to the pump shall be fitted with sieve strainers of $\leq 2.0\text{mm}$ nominal aperture size to BS 410-1: ISO 3310-1. The pressure gauges shall be calibrated before they are first used in the Works and thereafter as required by the S.O.

All grouting equipments, shall be thoroughly washed with clean water after the grouting operation at the end of use for each day. The equipment shall be kept free from build-up of adhering material.

11.6 CONSTRUCTION

11.6.1 Assembly of Cables and Sheaths

Prestressing tendon, prestressing components and ducts shall be accurately located and maintained in the positions shown on the drawings during all operations. Tendons shall be assembled with the individual wires or strands lying parallel to the cable axis, and they shall be bound with stretchable strong adhesive tape or wire to maintain them parallel during handling. All joints shall be sealed by binding with approved stretchable waterproof adhesive tape. Joints in adjacent duct shall be spaced at least 300mm apart. Spacers shall be provided where shown on the Drawings or as directed by the S.O. Before concreting, the lines and levels off all duct shall be subject to the approval of the S.O.

Duct shall be assembled from lengths not less than 3000mm except where make-up lengths are required; couplers shall be fully screwed. Duct shall be screwed into the back of anchorages and, where required, adaptors can be used. The methods of securing the prestressing tendon, prestressing components and duct during all operations shall be submitted to the approval of S.O

The methods of inserting tendons and duct, handling and placing of completed cables shall be to the manufacturer's instructions and to the approval of the S.O. Sheathing, punctured or damaged in any way, shall be re-placed and rectified completely at the Contractor's expense.

Duct shall be checked for leakages to the satisfaction of the S.O. before concreting as according to Cl 11.6.9.1 of this Section.

Duct shall be supported at points not more than 1000 mm apart. The Contractor shall provide such additional supports as necessary and cradles for supporting the sheaths on the reinforcement. The means of supporting and locating the ducts shall not give rise to excessive friction when the tendon is being tensioned.

All ducts shall be checked for blockages due to ingress of grout or damage during placing and the Contractor shall be responsible for all necessary precautions and remedial measures. During concreting and within 24 hours after concreting, the Contractor shall demonstrate that all tendons already in duct before concreting are still completely free to move.

Tendon shall be carefully aligned to the profile height arrangement as shown on the Drawings and the tolerance profile height shall be as follows:-

- i. up to 200mm $\pm D/40$ mm
- ii. 200 to 1000mm ± 5 mm
- iii. over 1000mm ± 10 mm

11.6.1.2 Installation of Grout Vents

Unless otherwise indicated on the Drawings, 15mm minimum internal diameter vent and drainage holes shall be provided at all high and low points on the duct profiles with the interval of not exceeding 15m.

The vents shall be rigidly connected to the ducts, it shall not be blocked and shall be capable of being closed and re-opened during all operations.

For external tendons, the Contractor shall submit for S.O. approval, their proposal for the arrangement and detailing of vents at positions within deflectors or diaphragms, inclusive of detailed testing.

All anchorages shall be sealed by caps and fitted with grouting connections and vents. Sealing of anchorages shall permit the flow of grout through the anchor head.

Vents at high points shall extend to a minimum of 500mm above the highest point on the duct profile.

11.6.2 Preparation of Tendons before Tensioning

All tendons, stressed at the same time shall be taken from the same parcel. Each tendon shall be tagged with its number and the coil number of the strands or steel bar used.

Tendons shall not be welded within the length to be tensioned. Tendon shall be sawn or cropped unless other methods of cutting are agreed by the S.O. Flame cutting of tensioning tendon are not allowed.

Tendons shall be built into the Works strictly in accordance with the system which is being and it shall not be exposed to stray heat from flame torches or welding before stressing.

If the condition of the prestressing tendons, prestressing component and sheaths are deteriorated such that it does not comply with the requirements stated in Clause 11.4, they shall be cleaned with the methods approved by S.O.

11.6.3 Preparation of Anchorages Before Tensioning

Anchorages shall be positioned accurately according to the Drawings in such a manner that the axis of the anchorages shall coincide with the axis of the tendons at the ends.

Anchorages shall be positioned within tolerances of ± 6 mm across and vertically and ± 15 mm along the tendon. The face of an anchorage shall be square to within 0.5° to the line of the tendon.

Any anchorages outside this tolerance shall be deemed non-conforming.

Particular care shall be taken in placing and compacting the concrete around the anchorages and anchorage blisters.

The working surfaces of all anchorages shall be cleaned prior to tensioning.

Proprietary anchorages shall be handled and used strictly in accordance with the proprietary system instructions and recommendations and to the approval of the S.O.

11.6.4 Pre-tensioning

Where pre-tensioning methods are used, the tension force in the strands or wires shall be fully maintained by some positive means during the period between tensioning and transfer. When concrete has reached the age at which tests cubes taken from it had attained the specific transfer strength, the stress shall be transferred gradually, without severance of the strands or wires, to minimise shock. The tendon or strands shall be protected against rust by applying neat epoxy resin of a suitable quality or an epoxy mortar to the ends of the tendons or strands. The method of application and the thickness of the protective coating shall be to the satisfaction of the S.O.

Provisions for the two types of tendon alignments are as follows:-

(i) Straight tendons

In the long-line method of pretensioning, sufficient locator plates shall be distributed throughout the length of the bed to ensure that the wires or strands are maintained in their proper position during concreting. Where a number of units are made in line, they shall be free to slide in the direction of their length and thus permit transfer of the prestressing force to the concrete along the whole line.

In the individual mould system, the moulds shall be sufficiently rigid so as to provide the reaction to the prestressing force without distortion.

(ii) Deflected tendons

Where possible, the mechanisms for holding down or holding up tendons shall ensure that the part in contact with the tendons is free to move in the line of the tendon so that frictional losses are nullified. If, however, a system is used that develops a frictional force, this force shall be determined by test and due allowance made.

For single tendon, the deflector in contact with the tendon shall have a radius of not less than 5 times the tendon diameter for wire or 10 times the tendon diameter for strand, and the total angle of deflection shall not exceed 15°.

The transfer of the prestressing force to the concrete shall be effected in conjunction with the release of hold-down and hold-up forces as approved by the S.O.

11.6.4.1 Tensioning Procedure

The method of tensioning shall ensure that the required force is applied to all tendons especially where more than one tendon is tensioned in a single operation.

The force shall be measured by means of jack pressure gauge readings, or by approved load cells, and shall be checked against the measured extensions of the tendons.

The initial force applied to the tendon to take up the slack shall not exceed 5% of the minimum breaking load of the tendon.

The S.O. shall be notified in the case where the jacking force and elongation values are different by more than 5% than the design values. In such a case, the S.O. shall be advised before any concrete is cast and tendons shall be retested with the calibrated equipment or as instructed by the S.O.

Every endeavour shall be made to obtain the required net force. A tolerance of $\pm 5\%$ in elongation shall then be permitted for individual tendons provided that the member as a whole is within $\pm 2\%$ of the required mean value. Non-compliance of this requirement will result in the Contractor having to justify by means of additional calculation or related information and to be submitted to the S.O. for acceptance and approval.

Tendons shall be located as shown in the drawings and suitable devices shall be provided to ensure that the correct positioning of the tendons is maintained during casting. When tendons are being placed, particular care shall be taken that the tendons do not come into contact with the oiled surface of the forms or otherwise be soiled. Any tendons so soiled shall be cleaned with the methods approved by the S.O.

In the case of a slip occurs to any of the tendon within a group of tendon, the tensioning of that particular group shall be de-tensioned, reset and shall be re-tensioned again. The Contractor shall completely replace any tendon that are broken during the tensioning process. For the breakage of individual tendon in a group of tendons, the process shall be repeated as in the case of a slip.

The prestressing force shall be transferred from the tensioning jack to the abutment of the stressing bed immediately after the required force has been reached and the pressure in the jack shall be relaxed before any other operation is commenced.

Stressing shall be carried out at a smooth and even rate. The maximum permitted loads in the tendons will not normally be more than 80% the characteristic tensile strength but the actual tension to be applied shall, in all cases, be as agreed with the S.O.

The prestressing tendons shall not be released until the concrete has attained the specified compressive strength at transfer as proved by the appropriate test cube under similar condition as the member being stressed.

The test cubes shall be made and tested in accordance with in Section 9: of this Specification and shall be cured under similar conditions as the concrete to which they are related.

Notwithstanding this, compressive strength tests shall be carried out during the progress of Work. The rate of sampling shall be as specified in Section 9: of this Specification. Non-compliance of the concrete strength requirement will result in the tensioning process at transfer to be delayed or the particular member to be discarded, subjected to the instruction of S.O.

Prior to transfer of the prestressing force from the abutments of the casting bed to the members, all tendons shall be tested for tightness and any loose tendons found shall be reported to the S.O. for approval. All tendons shall be marked at each end of every member so as to check the extension.

In the case of members which have been steam cured the prestress shall be transferred while the member is still warm and moist.

The procedure of release shall be continuous and the prestress shall be transferred to the members in such a manner that the tendons are released gradually and simultaneously.

Large differences of tension between the tendons or strands shall be avoided. No shock release of stress is to occur during de-tensioning operations. De-tensioning equipment used shall have adequate capacity to completely release all tendons strands in one operation.

If the tension is released from one end only or if there are several moulds in line, provision shall be made for the members to slide, allowing a transfer of the force all along the tensioned line.

Where there are several moulds in line, cutting strand between members shall proceed after de-tensioning in sequence from the de-tensioned end.

If shock release of stress occurs due to any cause, members adjacent to the shock-released strand may be rejected by the S.O.

All tendons shall be cut off and ground flush with the concrete surface. The system of cutting off the tendons shall be subjected to the approval of the S.O. The tendons shall be protected against rust by applying neat epoxy resin of a suitable quality or an epoxy mortar to the ends of tendons. The method of

application and the thickness of the protective coating shall be to the satisfaction of the S.O.

11.6.5 Post-tensioning

The Contractor shall prepare, check and submit to the S.O. complete detailed working or shop drawings and calculations or schedules showing:

- (i) Contractor's details of proposed manufacture and construction of prestressed member.
- (ii) Proposed sequence of prestressing operations either for permanent or temporary prestressing.
- (iii) Dimensions and complete descriptions of all prestressing materials and devices, joints, bearings and anchorages not specified or detailed in the Contract.
- (iv) Calculated eventual deflections, cambers and rotations of the concrete due to the effects of prestress, elastic shortening, creep and shrinkage in the concrete, strand relaxation, gravity and any other effects.

No stressing shall be done without adequate prior notice being given to the S.O. The Contractor shall prepare complete stressing schedules describing the expected design elongation and jacking forces to be used in tensioning and shall submit to the S.O. prior to commencing stressing.

Under no circumstances shall the maximum jacking force exceed 80% of the characteristic tensile strength of a tendon, or the rated capacity of the jacking equipment used, whichever is the lesser. After the tendons have been anchored, the stress exerted from the tensioning apparatus shall be gradually decreased to avoid any shock to the tendons or the anchorage plate.

Where tendon are not stressed simultaneously, the use of spacers shall be in accordance with the recommendations of the system manufacture and approved by the S.O.

For deflected tendons, the tendon curvature shall, where possible, have a radius of not less than 50 times the diameter of the tendon, and the total angle of deflection shall not exceed 15°. Where the radius is less than 50 times the diameter of the tendon and the angle deflection exceeds 15°, the loss of strength of the tendon shall be determined by tests and due allowance made.

In the case of free or balanced cantilever Method, temporary stress bars could be provided during segment erection prior to the installation of permanent cantilever tendons. These bars shall not be removed upon

permanent stressing prior to the completion of the whole work or work stage cycle. The removal of temporary prestressing can only be done if a minimum factor of safety of 1.5 for the cantilever structure is maintained. Removal of the temporary prestressing must be done with the agreement of the S.O.

The Contractor shall be responsible for the safety of all personnel during stressing and shall provide any safety equipment necessary in accordance with OSHA:18001.

All results and data relating to the tensioning operations shall be recorded on the stressing records.

11.6.5.1 Tensioning Procedure

Tensioning shall be carried out only in the presence of the S.O.

Immediately before tensioning, the Contractor shall prove that all tendons are free to move in their sheaths or ducts and that members are free to accommodate the horizontal and vertical movements due to the application of prestress.

Concrete shall not be stressed until it has reached at least the age at which two test cubes taken from it attain the transfer strength as specified in the Drawings and shall be at least 72 hours age or as directed by the S.O.

The test cubes shall be made and tested in accordance with Section 9: Concrete of Standard Specification for Road Works and shall be cured under similar conditions to the concrete to which they relate.

Notwithstanding this, compressive strength tests shall be carried out during the progress of Work. The rate of sampling shall be as in Section 9: Concrete of Standard Specification for Road Works.

Unless tendons are stressed at both ends, the wedges at the dead ends, shall be checked for tightness when approximately 10% of the full prestressing load has been applied. The pull-in of these wedges shall be measured at the same stages as the stressing end extension is measured.

Grouting shall be done immediately after tensioning, otherwise all anchorage shall be sealed before grouting to prevent ingress of water or moisture.

11.6.6 Records of Stressing

The format of the record shall be approved by the S.O. and shall contain but not be limited to the following information where applicable:

- (i) Identification number of dynamometers, gauges, pumps and jacks;
- (ii) Initial stressing force or pressure when tendons are marked for measurement of elongation;
- (iii) Force applied if a dynamometer is used or, alternatively, the pump or jack pressure and area of the piston;
- (iv) before anchoring; and
- (v) Elongation remaining after anchoring with load-extension curves
- (vi) Records of lift off if required.

The fully completed stressing records shall be made available to the S.O. within 24 hours after the completion of prestressing.

11.6.7 Tensioning

The Contractor shall establish the datum point for measuring extension and jack pressure to the satisfaction of the S.O. The movement of the jack ram will not be taken as the extension of the tendons.

The actual extension of tendons shall be extrapolated from zero to the required jacking pressure to obtain the total extension of the tendons.

The order in which tendons shall be tensioned shall be in accordance with the Drawings or as directed by the S.O.

The Contractor shall provide the stressing sequence and from which ends of the member and submit them to the S.O. for approval. When stressing from one end only the pull-in at the end remote from the jack shall be accurately measured and the appropriate allowance made in the measured extension at the jacking end.

The forces in the tendons shall be determined either by means of jack pressure gauge reading or by approved load cells, and shall be checked against the measured extensions of the tendons.

Reference shall be made to the manufacturer's load-extension curves to determine the correct extension for each tendon, and the effect of the tendon-friction, draw-in, jack and anchorage friction shall be taken into account.

The Contractor shall inform the S.O. immediately, should he be unable to obtain accurate agreement between jack loads and extensions and shall make such necessary adjustments to the loads and/or extensions as instructed by the S.O.

If the friction losses or draw-in of the tendon at anchorage are higher than the calculated or design values, it shall be rejected by the S.O.

After anchoring, the jack force shall be decreased gradually and evenly without shock to the anchorage plate, tendons or concrete.

If it is necessary to crop the tendons to enable the ducts to be grouted, this shall be delayed as long as practicable up to the time of grouting. In all other cases, unless agreed otherwise by the S.O., tendons shall be cropped prior to grouting works.

Recesses' openings for cropped tendons shall be dressed in accordance with the recommendations of anchorage proprietary system.

The Contractor shall keep full record of all tensioning operations including the measured extensions, pressure gauge or load cell readings and amount of pull-in at each anchorage. Copies of these records shall be verified on Site by the Contractor and the S.O. immediately after each tensioning.

11.6.8 Protection and Bond of Prestressing Tendons

The prestressing tendons shall be protected in their permanent positions from both mechanical damage and corrosion in accordance with the recommendations of the anchorage proprietary system.

11.6.9 Grouting Of Ducts

Grouting trials shall be undertaken when required by the S.O. and all grouting works shall be carried out in the presence of the S.O. and grouting procedures shall conform to BS EN 446 or BSISO 14824-2.

Grouting of prestressing tendons shall be carried out as soon as practicably possible. It shall not be more than 5 days after tensioning of the tendons unless as directed by the S.O.

All ducts shall be thoroughly cleaned by using compressed air.

11.6.9.1 Air Testing of Ducts before Grouting

The Contractor shall note that the air testing of ducts before grouting is a critical activity. This test shall be carried out under the supervision of a competent supervisor.

The Contractor shall determine the volume of air in the duct before air testing by taking into account the internal dimensions of the duct and the space taken up by the tendon. Any residual water in the duct shall be blown away with compressed oil-free air.

The anchorage ends should be sealed, and each duct shall be tested as follows:

- (i) With all valves closed, the duct shall be pressurised at the grout inlet with oil-free air to 0.25 MPa to confirm that the installed system has sufficient integrity for grouting;
- (ii) The pressure shall be held at 0.25 MPa for 30 seconds. A sudden drop in pressure of more than 0.1 MPa, or a need to continuously inject compressed air to maintain the pressure system indicates that the duct is not sufficiently sealed for grouting. As such, any leaks shall be located and repaired and the test shall be repeated;
- (iii) The pressure shall be reduced to 0.1 MPa;
- (iv) The air source shall be locked off; and
- (v) The air pressure loss over time shall be recorded. Maximum allowable pressure loss is 40% within a duration of:

$$D = (1.1 \times V + 5)/60$$

where: D = duration in minutes;

V = the volume of the duct minus the strand volume in litres.

If the pressure loss over time is greater than 40%, a thorough inspection shall be made for any evidence of leakage from, or between ducts. Leakages shall be rectified and the duct retested before grouting.

The S.O. shall make an assessment of the entire duct to determine whether grouting can proceed.

Where air testing detects leakage between two adjacent ducts that cannot be practically rectified, both ducts shall be air tested as a single system and the two ducts shall be grouted simultaneously with two lines controlled by individual lock-off valves.

The temperature of freshly mixed grout shall not exceed 32°C. This maximum temperature can only be increased provided trials demonstrate that the grout meets the fluidity requirement in accordance with BS EN 445.

The ducts shall be completely filled with grout.

11.6.9.2 Injecting Grout

Unless instructed by the S.O except in exceptional circumstances, grout shall only be injected from one end of a duct.

The method of injecting grout shall ensure complete filling of the ducts and complete surrounding of the prestressing steel. Grout shall be allowed to flow from each vent and the remote end of the duct until its fluidity is equivalent to that of the grout injected, by visual acceptance. In the event of disagreement, testing for fluidity shall be carried out in accordance with BS EN 445.

Additional 5 litres of grout at each vent shall be vented into a clean receptacle and then discarded. The opening shall be firmly closed. All vents shall be closed in a similar manner one after another in the direction of the flow except that at intermediate crests the vents immediately downstream shall be closed before their associated crest vent.

Grout vents at high points shall be reopened immediately after, while the grout is still fluid, and any escape of air, water or grout recorded and reported immediately to the S.O. A further pumping of grout shall then be carried out to expel bleed water and/or entrapped air. This shall be carried out with the vents open one at a time sequentially in the direction of grouting and a further 5 litres shall be vented at each open vent. A visual inspection of the vented grout shall be carried out and, if there is any doubt about its quality, bleed and fluidity testing shall be carried out immediately.

The injection tubes shall then be sealed off under pressure. A pressure of 0.5 MPa shall be maintained for at least one minute.

The filled ducts shall not be subjected to shock or vibration, construction traffic or similar loads until 24 hours after completion of grouting.

When the grout has set, the grout vents shall be temporarily reopened. If voids are apparent on inspecting vents at end caps, the end caps shall be removed to demonstrate that they are satisfactorily filled with grout. End caps that have been removed shall then be replaced by end caps permanently sealed against ingress of contaminants, and such sealing shall be proven to the satisfaction of the S.O.

If the anchorage caps are removed, the Contractor shall prepare and submit to the S.O. a report on such together with photographic record clearly identifying the individual anchorages.

If, in the opinion of the S.O., there is cause for doubt that the ducts or any part of the system are not satisfactorily filled with grout, the S.O. may require investigations to be carried out.

Grout vents shall be positively sealed to be waterproof on completion of grouting by a means separate from the concrete waterproofing.

If there is any blockage or breakdown or if the grout injection is interrupted, the duct shall immediately be thoroughly washed with clean water and blown dry with oil-free compressed air; regrouting shall start as soon as practicable.

As soon as possible within one month after grouting operations, the anchorage and the anchor plate or blister shall be thoroughly cleaned by abrasive blasting and the contact surfaces of the anchorage and anchorage recess shall be coated with a wet or dry epoxy adhesive.

Non-shrink grout shall be used to patch up the recesses to avoid shrinkage cracks from occurring at the affected area.

Where there are blockages, the Contractor shall carry out repair or remedial works to remove the blockage at the contractor's own cost to the satisfaction of the S.O.

11.6.9.3 Record of Grouting Operations

- (i) Full records of grouting for each duct shall be kept by the Contractor and to supply copies of these records to the S.O. within 24 hours after grouting.
- (ii) These records shall include, but not limited to, the following details:
 - (a) location of grouting operations,
 - (b) date and time of starting and completing grouting operations,
 - (c) weather conditions,
 - (d) technical personnel supervising or carrying out grouting operations,
 - (e) prestressing tendon reference numbers,
 - (f) grout mix, including any admixtures,
 - (g) grout injection pressure,
 - (h) volume of grout used,
 - (i) details of any interruptions and topping up, and
 - (j) batching record, including sampling and testing details.

11.6.9.4 Test : Grout – General Requirements

Grout test shall be performed in accordance with BS EN 445:1997.

11.7 GENERAL REQUIREMENT FOR PRECAST PRESTRESSED CONCRETE MEMBERS

11.7.1 General

The precast prestressed beams members shall be designed to carry the deck formwork and in-situ concrete without propping during the construction of the deck. Should the Contractor chooses to make any adjustments to the quantity and disposition of the prestressing tendons he shall submit his proposals to the S.O. for approval. Although the design of the proposed adjustments shall be checked, it shall not relieve the Contractor of his responsibility for the design.

The precast concrete construction shall comply with Section 9 of the Standard Specification for Road Works, except in such respects as they may be modified by the provisions of the remainder of this Section.

11.7.2 Storage

When members are stored, they shall be firmly supported at such bearing positions to ensure that stress induced in them are always less than the permissible design stresses of the precast prestressed member.

The method of storage for precast prestressed members shall include full safety measures for all personnel, use of non-staining support pads and all shall be approved by the S.O. The storage bed or platform shall be fully capable of sustaining the loads from the precast prestressed members.

Any reinforcing bars, which are projected from the units or members, are to be covered by some approved method (by the S.O.) to prevent rust.

Precast members shall be stacked and supported under each lifting device position.

Units or members shall not rest on any support at locations between the approved support points.

The support timbers shall be sufficiently large to store the units clear off the ground and to avoid subsidence under the supported weight when the ground is wet. The ground beneath the units shall be levelled so as to maintain the same clearance as at the supports.

To avoid twisting and overturning of units, all stacking areas are to be an even plane from one end of the unit to the other. Where units are stacked in layers, they shall be supported by timbers positioned directly above those below. The Contractor is to ensure all units or members are in proper stability while stacking. Where practical, the units shall be stacked so that access for inspection of all units is possible at any time. Inspection of the member condition would be useful to ensure deflection and bows are within tolerance.

11.7.3 Handling and Placing

The method of handling and storage shall be such as to avoid the danger of fracture by impact, undue bending, twisting and whipping.

Prestressed concrete members shall be moved only while fully suspended. In no case shall they be moved by dragging across the floor or terrain.

All Quality Assurance checks shall be performed and repairs carried out prior to placing units in a stack where access to individual units cannot be gained.

No prestressed member shall be transported from a manufacturer's yard until a minimum of 7 days has elapsed from the day of casting.

11.7.3.1 Marking

On each precast element, the following information shall be clearly labelled with undeletable marking on the outer vertical face.

- (i) The date of manufacture
- (ii) The identification number
- (iii) The maximum mass of the element members
- (iv) The manufacturer's name or registered mark, and
- (v) The dimension of precast members

11.7.3.2 Lifting

Members shall be lifted or supported only at the points described on the Drawings and shall be handled and placed without impact.

The Contractor shall submit to the S.O. for his approval, the method and sequence he intends to adopt, for launching or lifting of the precast beams. The Contractor shall be responsible to provide all necessary equipment and machinery for the launching and lifting of the beams.

Should any component in the opinion of the S.O. be so damaged by mishandling as to be rendered inadequate for its purpose, the S.O. may order its removal from the Site and shall be replaced at the Contractor's own expense.

Pretensioned members shall not be lifted or handled until fully stressed.

Post-tensioned members shall be either fully stressed or partially stressed as shown in the Drawings and in general all stressed tendons shall have been grouted for 5 days prior to lifting or handling of the member.

At all times, and especially during transportation, members shall be secured in an upright position by means of suitable packing pieces and braces which shall be provided before transferring the load from lifting gear to the support. Members shall not be braced against each other but shall be provided with independent bracing.

No superimposed load shall be placed on a member except with the permission of the S.O.

The Contractor shall submit full details of the transport arrangements, including means of limiting torsional stresses of the members in transit, to a safe value against cracking, for the S.O.'s prior approval.

Prestressed concrete members shall be held in such a position that the top surface is uppermost at all times during handling, transport and storage.

All units shall be lifted by the lifting devices incorporated in the units. Webs of prestressed concrete members girders shall remain vertical with the top flange uppermost at all times.

When loading or transporting prestressed concrete members, the Contractor shall provide means of restraining the side whip.

11.7.4 Tolerance

The manufacturing tolerances for the precast members shall comply with BS 5606:1990. In addition, where beams are laid side by side in a composite slab deck, the following requirements shall be applicable:-

- (i) The difference in soffit level between adjacent units before the in-situ concrete is placed shall nowhere exceed 5 mm from the designed difference in soffit level for units up to 4.5m long and not more than 10 mm for longer units.
- (ii) In adjacent spans, the continuity of line of the outside members shall be maintained.

- (iii) The width of the gap between individual beams shall not exceed twice the nominal gap described on the Drawing.
- (iv) The alignment of transverse holes shall permit the reinforcement or prestressing tendons to be placed without distortions.

The in-situ concrete shall be placed in such a sequence that the advancing edge of the freshly deposited concrete over the full width of deck or between longitudinal construction joints is approximately parallel to the deck supports.

All edge beams shall be prevented from moving laterally during the placing of the in-situ concrete.

The manufacturer shall make allowance for deflections, pre-camber, creep and shrinkage effects, taking into account effects nominated in the design and actual properties. The length and hog of the first casted units for a structure shall be measured. Adjustments shall be made to the manufacturing process to ensure that all subsequent units are within allowable tolerances.

Tolerance in relation to length and hog shall apply at 28 days from the date of manufacture. The determination of compliance of members in relation to dimensional tolerances shall be based on dimensions measured by the manufacturer during a period of 21 to 35 days from the date of manufacture.

At no section, shall the longitudinal centerline deviate in the transverse direction from a straight line joining the centre points of the ends of the girder (bow) by more than 20 mm.

11.7.4.1 Cross-Section, Length and Out of Square

At any cross-section, the length, out of square and dimensional deviations shall be in accordance with Clause 9, Section 9 of the Standard Specification for Road Works.

11.7.4.2 Camber

A maximum range of 20 mm for spans up to and including 20 metres and 25 mm for spans exceeding 20 metres are the acceptable ranges of hog camber values of similar units and girders of the same age, which are to be used in the same span.

The design camber shall be as shown on the Drawings. Any member or unit that shows the camber value of 1.5 times the design value shall seek approval from S.O. for further instruction.

11.7.5 Off Site Manufacture

The following provisions shall be additional to Section 9 of the Standard Specification for Road Works.

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

The Contractor shall submit the Method Statement of Construction and Quality Assurance at least 14 working days prior to manufacture of precast concrete element.

The details of the method of manufacture shall be approved by the S.O. before work starts. When the method has been approved no changes shall be made without the consent in writing of the S.O.

Within 7 days after the transfer of stress, the Contractor shall send to the S.O. the following documents:

- (i) The record showing the force and extension or elongation in the tendons immediately after they were anchored.
- (ii) The strength and age of the test cubes.
- (iii) The minimum age of the concrete at the time the stress was applied to the members.

A copy of all 28-day cube test results relating to the work shall be sent to the S.O. as and when they become available.

Where the S.O. requires additional or independent tests to be carried out, no precast members to which the tests relate shall be delivered to the Site until the tests have been satisfactory completed and accepted by the S.O.

Records shall be kept so that the identity of those who stress the tendons, cast the concrete and transfer the stress, of any member or line of members can be traced.

- (i) Manufacturer of prestressed concrete members shall:
- (ii) Operate based on a quality system certified to the requirements of ISO:9001;
- (iii) establish procedures for manufacture of prestressed concrete members; and
- (iv) have acceptable test and inspection plan (quality assurance and quality control) submitted to the S.O.

Where a new prestressing process is being established, the manufacturer shall submit the procedure for manufacture of the prestressed concrete members to the S.O., giving details of materials, equipment and processes not less than 28 days prior to establishment of the plant.

The manufacturer shall not commence until approval of the new procedure has been obtained from the S.O.

No significant changes to the method of manufacture shall be permitted without the approval of the S.O. A minimum of 14 working days notice shall be given to the S.O of any proposed change.

When a bed is set up to manufacture a new member type, no concrete shall be placed in the members until the formwork, reinforcement and stressing materials have been approved by the S.O.

11.7.6 Launching Of Precast Elements

The Contractor shall inform the S.O. at least one month in advance of each launching operation and submit the following to the S.O. for acceptance:

- (i) Method statement including the launching method, which includes the systems, machineries and equipment used, time taken, traffic closure and safety measures.
- (ii) Method statement for the delivery of units or members including transportation, route, proposal for traffic diversion or closure, as appropriate or as directed by S.O.,
- (iii) Detailed programme of each launching operation.

11.7.6.1 Transportation

The Contractor shall obtain the necessary clearances for the transportation of the prestressed pre-cast elements and movement of the lifting equipment to the launching site. Contractor's method of transportation shall demonstrate that the elements being transported would not be damaged.

A certificate of test of the lifting equipment shall be submitted to the S.O., together with particulars of the operator and details of experiences.

11.7.6.2 Ground Preparation

The ground for the launching area shall be prepared to ensure that it is safe to carry the load during launching operation.

11.7.6.3 Erection

Utmost precautions shall be taken to eliminate any danger to the workers and general public while launching pre-cast elements. All lifting equipment shall be designed such that, if

the primary lifting mechanism fails, a secondary mechanism will ensure that the pre-cast element does not fall.

Upon erection, a fail-safe method shall be used to temporarily secure the pre-cast unit until the permanent fixing arrangements are implemented.

The securing systems, subject to the S.O.'s acceptance, shall include:

- (i) providing chains between beams and supports;
- (ii) connecting adjacent beams by welding protruding bars of the beams; or temporary bracings between the beams;
- (iii) providing wedges or brackets to the beams.

The Contractor shall inform the S.O. and obtain his approval before removing any temporary works but such approval does not, in any way, relieve the Contractor of his responsibilities for the safety of the work.

The Contractor shall:

- (i) ensure that appropriate and sufficient warning signs, lights, barricades and at least one rotating amber light are placed at each point of road closure or diversion in accordance with the latest Arahan Teknik (Jalan) For Temporary Traffic Control.
- (ii) station at least one person in a safe position at each point of road closure, to advise and guide motorists. The person shall be equipped with a torch, reflective vest and walkie-talkie or other means of communications within the launching site.
- (iii) have one person controlling the whole launching operation with a whistle or other means of communications with the lifting equipment operators.
- (iv) ensure that there is sufficient lighting at the launching site.
- (v) ensure that no welding work on the bridge is carried out unless a protective screen is used to prevent sparks and other materials from falling onto the areas below.
- (vi) install 4.5m height restriction signs of standard design immediately after launching of any precast element above the existing carriageway.
- (vii) measure and record the actual height clearance of the bridge at every 2m interval along the span of the bridge above the carriageway.

- (viii) measure and record the location of the smallest clear height between the carriageway and the bridge.
- (ix) submit measurements showing that the height clearance of the bridge satisfies the minimum clearance requirement to the S.O. before opening the road under the bridge to traffic.

11.7.7 Inspection and Testing

The inspection and testing of precast concrete units shall be in accordance with BS EN 1992-2:2005.

The testing of concrete specimens to establish whether the concrete used in the structure complies with the specification for structural materials as described in Section 9 of the Standard Specification for Road Works.

If the quality of the concrete is shown to be inadequate by the results of these check tests, or shows other defects, a loading test may be required by the S.O., and should then be carried out by the Contractor in accordance with 11.7.8 in this section.

11.7.7.1 Types of Tests

(i) Surface Finish

Inspect the surface of the concrete for defects, for conformity with the specification and, where appropriate, for comparison with approved sample finishes. The making good of surface defects may be permitted, but the standard of acceptance should be appropriate to the type and quality of the finish specified and should ensure satisfactory permanence and durability and is subjected to the strength and durability of the concrete being unimpaired. Great care is essential in the selection of the mix proportions to ensure that the final colour of the faced area blends with the parent concrete in the finished structure on permanently exposed surfaces.

(ii) Rebound Hammer Test

If a rebound hammer is used regularly by a trained personnel and if continuously maintained individual charts that show; for a large number of readings, the relation between the readings and the strength of cubes made from the same batch of concrete, are kept, an approximate indication of the strength of the concrete in a structure or element may be obtained by using such charts in conjunction with hammer readings. When used by a trained personnel in these circumstances, the expected degree accuracy is within ± 3 MPa.

When making rebound hammer tests, each result should be the average of at least nine individual readings. Do not take readings within 25 mm of the edge of concrete members. Clearly distinguish readings taken on a trowelled face and those taken on a moulded face. Take special care to firmly bed them against the impact of the hammer, when making the test on precast units.

(iii) Electromagnetic Cover Measuring Devices

Verification of the position of reinforcement or tendons to depths of about 70 mm may be done by an electromagnetic cover measuring device in accordance with the recommendations of BS 4408-1.

(iv) Gamma Radiography

To test concrete up to 450mm thick for the presence of local voids in the concrete and the efficiency of the grouting of ducts in prestressed members, gamma radiography may be used. It may also be used to determine the presence and location of any embedded metal. Special precautions are necessary to avoid contamination from the radioactive source. Carry out the testing in accordance with the recommendations in BS 4408: Part 3.

(v) Coring Test

The drilling and testing of core samples from the concrete must comply to the procedure requirements of BS 1881: Part 4., in circumstances where the compressive strength of the concrete in the structure may need to be assessed. To investigate the presence of voids in the compacted concrete, such cores may also be cut. Whenever possible, reinforcement should be avoided when core cutting.

11.7.8 Load Tests of Structures or Parts of Structures

The tests described in this clause are intended as a check on structures other than those covered by clause 11.7.7.1, where there is doubt regarding serviceability or strength. Test loads are to be applied and removed incrementally.

The test should be carried out as soon as possible after the expiry of 28 days from the time of placing the concrete. When the test is for a reason other than that the quality of the concrete in the structure being in doubt, the test may be carried out earlier provided that the concrete has already reached its specified characteristic strength.

When testing prestressed concrete, allowance should be made for the effect of prestress at the time of testing being above its final value.

The test loads to be applied for the limit states of deflection and local damage are the appropriate design loads, i.e. the characteristic dead and imposed loads. When the ultimate limit state is being considered, the test loads should be equal to the sum of the characteristic dead load plus 1.25 times the characteristic imposed load and should be maintained for a period of 24 h. If any of the final dead load is not in position on the structure, compensating loads should be added as necessary.

During the tests, struts and bracings strong enough to support the whole load should be placed in position, leaving a gap under the members to be tested, and adequate precautions should be taken to safeguard persons in the vicinity of the structure.

Measurements of deflection and crack width should be taken immediately after the application of load. In the case of the 24 h sustained load test, readings should be taken at the end of the 24 h loaded period, after removal of the load and after the 24 h recovery period.

Sufficient measurements should be taken to enable side effects to be taken into account. Temperature and weather conditions should be recorded during the test.