No. RW/NHVI-50(3)/83-Vol. II *Dated the 31st August, 1987*

To

Chief Engineers of State Public Works Departments and Union Territories dealing with National Highways and other Centrally Financed Schemes; Director General (Works); C.P.W.D.; Director General Border Roads

Subject: Supplemental Measures for design, detailing and durability of important bridge structures.

This Ministry has been deeply concerned over the inadequate performance in service of some major bridges on National Highways and set up a Special Committee under the aegis of Indian Roads Congress of bridge experts to recommend measures for ensuring greater professionalism in construction practice and security of major bridges. The Committee in its report has recommended supplemental measures for safety, serviceability and durability of the important bridge structures. Specific supplemental recommendations of the Special Committee for important bridges regarding design, detailing and durability measures needing immediate application as contained in the Report submitted to this Ministry and appended herewith have been considered by the Ministry and it has been decided that the same should be adopted for immediate compliance.

2. These specific recommendations shall apply to important bridge structures, which shall be graded important essentially on the basis of the seriousness of the consequences of failure and the extent of remedial measures. In general the following bridges may be classified as important:

(i) Major bridges.

(ii) Bridges with large individual span length.

(iii) Bridges built with innovative design/construction/material.

(iv) Bridges carrying large volume of traffic.

(v) Bridges on a critical location with no neighbouring crossing to provide alternative route.

3. While the current Specifications, Guidelines, Practices as defined in various publications of Indian Roads Congress including Codes, Guidelines, Special Publications or those of this Ministry including Specifications for Road and Bridge Works, Pocket Books, Standard Plans, Technical Circulars and relevant Indian Standards will continue to be adopted vigorously in planning, design, construction, maintenance and repair of the bridges, the supplemental measures recommended herein are to be scrupulously followed for ensuring higher quality in construction of important bridges. These supplemental recommendations shall, therefore, be read alongwith the current specifications and practices and shall take precedence and supersede existing codal/other provisions wherever these are at variance for all important bridge structures.

4. It is also suggested that these supplemental recommendations/specifications should be suitably incorporated in all the future tender documents for important bridges.

5. In the case of existing important bridges under construction, the same may be adopted to the maximum extent, as found technically feasible.

6. The receipt of this communication may please be acknowledged.

Enclosure to letter No. RW/NHVI-50 (3)/83-Vol. II dated 31/8/87

SUPPLEMENTAL MEASURES FOR DESIGN, DETAILING AND DURABILITY OF IMPORTANT BRIDGE STRUCTURES

1. Design

1.1 The following design parameters shall be clearly specified for each case over and above those required as per Codes and Specifications:

(1) All climatic data including the temperature differential to be accounted for in the design of superstructure.

(2) Earthquake forces, barge impact forces (in case of bridges with navigational requirements), where necessary drag and lift forces based on wind tunnel studies, cyclic loading for fatigue and dynamic analysis to account for vibration effects, alongwith the acceptance criteria.

(3) Values of expected differential settlement to be accounted for in design.

1.2 Superstructure

1.2.1 The design of post-tensioned prestressed concrete members shall comply with the 'no tension' criteria for all conditions stipulated in the Codes of Practices, except for the case including the combination of loads with differential temperature gradient effects. Under this condition the thermal stresses shall be taken care of by providing adequately designed non-

tensioned steel, subject to the crack width limitations stipulated in IRC:21-1987.

1.2.2 The maximum permissible jacking force (inclusive of any over stressing) shall not exceed 70 per cent of the minimum ultimate tensile strength (UTS).

1.2.3 The thousand hour relaxation loss value shall be obtained from the manufacturer of prestressing steel. This date shall be independently cross checked to ascertain its varacity. The independently checked date shall be adopted for extrapolating the final relaxation loss value occurring at about 0.5 x 10^6 hours which shall be taken as 2.5 times the 1000 hr. value. The above value shall be for initial stress level of 0.7 UTS reducing to 0 at 0.5 UTS. The intermediate values may be interpolated linearly.

1.2.4 The characteristic values for assessment of prestress losses based on the factors given in IRC:18-1985 (relaxation loss being modified as per clause 1.2.3 above) shall be modified by a factor (indicated below) and designs be based on the effective prestress obtained from the following two limits.

P_{eff} Max. = P_0 - 0.8 ($\Delta P_0 + \Delta Pt$)

P_{eff} Min. = P_0 - 1.2 ($\Delta P_0 + \Delta Pt$)

Where ΔP_0 = represents total immediate losses at time t = o

ΔPt = represents the total time dependent losses at any period 't'.

1.2.5 The minimum radius of curvature, spacing and cover for curved tendons shall be specified to ensure that bursting of the side cover both perpendicular to the plane of curvature and in the plane of curvature of the ducts does not take place. Guidance in this regard may be taken from BS:5400: Part 4:1984 (Appendix D) subject to spacing and cover stipulations given in clause 1.2.7 and 3.2.6 respectively.

1.2.6 The locationing of prestressed cables shall be such as to facilitate easy placement and vibration of concrete in between the tendons. Grouping of cables shall be avoided. However, in exceptional circumstances where two or more rows of cables have to be used, the cables shall be vertically in line with adequate space to enable insertion of internal needle vibrators. Form vibrators shall continue to be used in addition to internal vibrators.

1.2.7 The number of stages of prestressing shall be reduced to the minimum preferably not more than 2. Wherever 2 stage prestressing is contemplated, at the location of the 2nd stage cables in the sheathing already provided, a preformed dummy core (inflatable type may be used) shall be provided and pulled out after the 1st stage prestressing and grouting is over.

Thereafter, the cables for the 2nd stage shall be threaded by a threading machine. In such situations, it shall be ensured that cables or group of cables proposed to be grouted later are spaced at a distance not less than 100 mm from the group being grouted earlier.

However in segmental construction, where it may be necessary to adopt multi-stage prestressing and not possible to provide dummy cores, the spacing between the 1st stage and subsequent stage group of cables shall be kept a minimum of 300 mm.

Anchorage of cables in the deck slab shall be avoided as far as possible. All anchorages shall be properly sealed after prestressing and grouting operations.

1.2.8 All falsework shall be properly designed in accordance with IRC:87-1984.

2. Detailing

2.1 Foundations :

Foundations supporting the super-structure located in deep water channels shall comprise of liberally dimensioned caissons, preferably having a single dredge hole. The outer diameter shall be large and preferably not less than 8-metres with the minimum thickness of the caisson wall as one metre.

For long span cable stayed bridges adopting large size monoliths as foundations, the size of dredge hole shall be decided as to facilitate ease of construction, inspection of foundation, etc. in consultation with the Engineer-in-charge.

No caisson shall be permitted to be placed in a pre-dredged hole.

For caissons resting on rock proper square seating must be ensured and plugging done under dry conditions, wherever practicable.

For checking the efficacy of bottom plug, the possibility of dewatering the well/caisson after plugging shall be considered in the design of well and bottom plug.

The bottom plug concreting shall be done by tremie only.

Pile foundations shall not be accepted within the flood zone of the river.

2.2 Piers, Abutments and Returns:

2.2.1 Piers and Abutments shall be of solid type, as far as possible. If, however, cellular type is to be adopted, the minimum thickness of the walls shall be 60 cms. P.C.C. Cellular type piers shall not be permitted.

Construction joints shall be kept to the minimum and modern slip form methods shall be adopted. No construction joints shall be provided in the splash zone.

2.2.2 Trestle type frames for sub-structures shall not be allowed.

2.2.3 To account for barge impact, a suitably designed fender system capable of protecting the main sub-structure from such large impacts should be preferred. Further, in such situations only solid type piers shall be accepted.

2.3 Superstructure

2.3.1 Multi-span deck continuity may be encouraged unless soil conditions dictate otherwise e.g. deltaic regions, areas with soft founding strata, etc. where it may not be suitable.

Drop in spans with halved joints (articulations) shall not be permitted. The thickness of deck slabs and webs of beams shall not be less than 220 mm and 300 mm respectively.

In case of segmental construction for bridges located in marine environment, continuity of untensioned reinforcement from one segment to the next must be ensured.

For cantilever construction preference be given to box type cross section with diaphragms provided at supports. Sudden change in depth of superstructure should not be permitted.

In case of multi-beam arrangement the number of diaphragms shall at least be three.

For long span wide bridges having beam and slab type of superstructure, the number of longitudinals shall not be less than 3. The depth of the end cross diaphragms shall be suitably adjusted to allow access for proper inspection of bearings and to facilitate positioning of jacks for future lifting up of the superstructure.

2.3.2 The diameter of untensioned steel shall conform to one of the following: 8, 10, 12, 16, 20, 25, 28 and 32 mm.

2.3.3 The minimum diameter of un-tensioned reinforcement shall not be less than 8 mm.

2.3.4 Welding of HYSD bars shall be prohibited, and instead mechanical splices of proven quality should be used.

2.3.5 The detailing of reinforcement in all components shall be such as to ensure that satisfactory placement and compaction of good concrete all around in the components, with due consideration being given to the construction techniques adopted.

2.3.6 The number of expansion joints and bearings shall be kept to the minimum.

2.3.7 A complete drainage system for the entire deck shall be provided to ensure that the drainage water gets collected and disposed off quickly from the deck to a safe location. For bridges level in the longitudinal profile, the cross slope in the deck shall be kept as 2.5%.

2.3.8 Large capacity bearings such as pot bearings, PTFE bearings, specially surface treated bearings may be preferred. Mild steel bearings may not be suitable. Forged steel bearings are better than cast steel bearings. The basic aim shall be to obtain products from prequalified manufacturers and to adopt a design which permits easy replaceability of the bearings at a future date and facilitates inspection and proper drainage.

2.3.9 Instead of conventional sliding plate and open type joints, sealed joints with elastomer seal may be preferred. In cases where large expansion gaps have to be catered for and an open joint becomes necessary, adequately designed joints with proper arrangement for drainage must be catered for.

2.3.10 As far as possible, construction joints shall be kept to the minimum by adopting proper construction techniques. In case construction joints become inevitable their locationing and construction specifications shall comply with the provisions given at *Annexure-1* and properly designed reinforcements shall be provided for transfer of full tensile stress across the joints prior to casting of the next lift.

3. Durability

3.1 Construction Materials

1. Aggregates: All coarse and fine aggregates shall continue to be tested to conform to IS:383 and the relevant provisions contained in IRC:18-1985.

   Aggregates shall also be tested to ascertain alkali-silice reaction and such aggregates must not be used.

2. Water: The quality of water must conform to the provisions contained in IRC:21-1987. The permissible limits for solids must satisfy the following:

	Permissible limits (max.)
Organic	200 mg/lit
Inorganic	3000 mg/lit
Sulphates (SO_4)	500 mg/lit
Chlorides	250 mg/lit
Suspended matter	2000 mg/lit

   The pH value, shall be not less than 6.

3. Comment: High Strength Ordinary Portland Cement conforming to IS:8112 and Ordinary Portland Cement conforming to IS: 269, capable of achieving the required design concrete strength shall only be used. (guidance may be taken from IS:SP:23 'Handbook on Concrete Mixes' for ascertaining the minimum 7 days strength of cement required to match with the design concrete strength).

4. Admixture: To improve the workability of concrete and cement grout, admixtures conforming to IS:6925 and IS:9103 could be permitted, subject to satisfactory proven use, Admixtures generating hydrogen, nitrogen, etc., should not be used.

5. Prestressing Steel and Accessories: The Prestressing Steel shall conform to the relevant Indian Standards. All prestressing steel, sheathing, anchorages and sleeves or couplings must be protected during transportation, handling and storage. For wires upto 5 mm dia, coils of about 1.5 mm dia and for wires above 5 mm dia, coils of about 2 m dia without breaks and joints shall be obtained from the manufacturer. The Prestressing steel, sheathing and other accessories must be stored under cover from rain or ground damp and protected from the ambient atmosphere if it is likely to be aggressive. Storage at site must be kept to the absolute minimum. All prestressing steel must be provided with temporary protection during storage such as coating of soluble oils, silicagel or vapour phase inhibiting materials of proven specifications.

   Data in respect of modulus of elasticity, relaxation loss at 1000 hrs minimum ultimate tensile strength, stress-strain curve, etc. shall necessarily be obtained from the manufacturers. The modulus of elasticity

value as per tests shall conform to the design value which shall be within a range not more than 5% between the maximum and minimum. Prestressing accessories like jacks, anchorages, wedges, block plates, etc. being patented items shall be obtained from authorised manufacturers only. The Prestressing Steel and the prestressing accessories shall be subjected to an acceptance test prior to their actual use on the works (guidance may be taken from BS:4447).

6. Untensioned reinforcement: The reinforcement bars bent and fixed in position shall be free from rust or scales, chloride contamination and other corrosion products. Effective methods of cleaning such as sand blasting must be made mandatory.

7. Sheathing: The specifications for sheathing shall comply with the provisions contained in IRC:18 and the sheathings must be clean and free from rust. The thickness of sheathing for dia-meters of cables exceeding 75 mm shall be suitably increased beyond 0.3 mm based on manufacturers recommendations/expert literature and satisfactory past experience. The joints of all sheathings shall be water-tight and conform to the provisions contained in Annexure-2. Special attention must be paid to the junction at the anchorages and, where the sheathing must tightly fit on to the protruding trumpet end of anchorages and thereafter sealed with the heat shrink tape to make it waterproof.

8. Storage of Materials: Materials shall be stored in accordance with the provisions contained in clause 1011 of Ministry of Shipping & Transport Specifications for road and bridge works. All efforts must be made to store the Materials in proper places so as to prevent their deterioration or intrusion by foreign matter and to ensure their satisfactory quality and fitness for the work. The storage space must also permit easy inspection, removal and re-storage of the materials. All such materials even though stored in approved godowns must be subjected to acceptance test prior to their immediate use.

3.2 Cement Concrete:

3.2.1 Grades of concrete for different structural components

All concretes used in major and important bridges shall be design mix concrete based on the prescribed target mean strength (also designated as grade of concrete). The minimum grades of concrete for different structural component shall be as follows:

(i) For bottom plug, the concrete mix shall be designed (in dry condition) to attain a concrete strength of M 25, thereafter the considerations required for under-water concreting taken. The entire concrete shall be laid by tramie pipe conforming to the prescribed specifications.

(ii)

	Member	Conditions of Exposure	
		Normal	Severe/Marine
a)	Well Steining/PCC Members	25 MPa	30 MPa
b)	R.C.C. Members	35 MPa	40 MPa
c)	PSC Members	35 MPa	40 MPa

3.2.2 From durability considerations strict control on the cement content and water cement ratio and in the process of concrete making, laying, compaction and curing must be exercised. The aim being to achieve a dense and impermeable concrete. The following limits in respect of cement content and water cement ratios shall be maintained:

Structural Member		Min. cement content for all exposure conditions (for 20 mm nominal size of aggregate)	Maximum water cement ratio exposure conditions	
			Normal	Severe/Marine
(a)	PCC Members	360	0.45	0.45
(b)	RCC Members	400	0.45	0.40
(c)	PSC Members	400	0.40	0.40

3.2.3 The cement content shall be as low as possible but not less than the quantities specified in clause 3.2.2 but in no case shall exceed 540 kg/m^3 of concrete.

3.2.4 The total water soluble sulphate (SO_3) content of the concrete mix expressed as SO_3, shall not exceed 4% by mass of cement used in the mix.

3.2.5 Total chloride content in concrete expressed as chloride-ion shall not exceed 0.06% of the mass of cement used.

3.2.6 The minimum clear cover to the reinforcement bar closest to the concrete surface shall be 50 mm. Wherever, the prestressing cable is nearest to the concrete surface, the minimum clear cover shall be 75 mm.

Cladding or any other supplementary protective measures shall be adopted as considered adequate.

3.3 Construction

3.3.1 Installation of cables, prestressing operation and grouting shall be entrusted to only-specially trained and qualified personnel. All prestressing accessories must be procured from authorised manufacturers with in-house testing facilities, who should also be entrusted with the total service contract for fabrication of cables, protection of cables during concreting, prestressing and grouting. Necessary certificates shall also be accorded by such specialised agencies that the work has been carried out in accordance with prescribed specifications. In exceptional cases where the Central/State P.W.Ds are convinced that the contractor of the bridge itself is well experienced and has the qualified personnel and sufficient track record to substantiate his performance in the particular system of prestressing being adopted the prestressing and grouting operations could be entrusted to such a contractor.

3.3.2 The following additional specifications for grouting shall be enforced over and above those contained in IRC:18-1985.

(a) The mixing of the grout must be done in a colloidal mixer such that the grout mix is maintained in a homogeneous colloidal state during the entire grouting process.

(b) The temperature of the grout after accounting for the ambient temperature of the structure shall not exceed 30°C.

3.3.3 **Railings and wearing coat.** The finishing items in bridge construction are not receiving the attention they deserve with the result that they show early signs of deterioration. All care must therefore be exercised to see that adequate quality control is exercised in the execution of such works. The concrete cover to reinforcements during casting of railing shall be strictly enforced. During the concreting operation of wearing coat, not only the thickness as per drawing shall be maintained but the concrete properly vibrated to ensure a dense and homogeneous mix.

Annexure I

SPECIFICATIONS FOR CONSTRUCTION JOINTS

1. CONSTRUCTION JOINTS

1.1 The Position of Construction Joints

Construction joints should be positioned to minimise the effects of the discontinuity on the durability, structural integrity, and appearance of the structure.

As far as possible, joints should be positioned in non-aggressive zones, but if aggressive zones cannot be avoided, joints should be sealed.

Joints should be positioned where they are readily accessible for preparation and concreting. The preparation of the joints is more likely to be satisfactory where the cross-section is relatively small, and where reinforcement is not congested.

As far as possible, joints for fair-faced concrete should be located where they conform with the architectural features of the construction. Unless they are masked in this way, the positions of the joints are always obvious, even when the concrete is given a textured finish.

If substantial changes in the cross-section of a member are necessary, the joints should be formed where they minimise stresses caused by temperature gradients and shrinkage.

Joints should be located away from regions of maximum stress caused by loading, particularly where shear and bond stresses are high. In beams and slabs, therefore, joints should not generally be near the supports. Construction joints between slabs and ribs in composite beams should be avoided.

1.2 Preparing the Surface of the Joint

The minimum number of joints should be used, and their construction should be simple. They should be either horizontal or vertical, because concreting sloping surfaces is usually unsatisfactory.

Where concrete is placed in vertical members e.g. walls, columns and the like, the lifts of concrete shall finish level or in sloping members, at right angles to the axis of the member, the joint lines matching the features of the finished work. Concreting shall be carried out continuously upto the construction joints.

Laitance, both on the horizontal and vertical surfaces of the concrete, should be removed before fresh concrete is cast. The surface should be roughened to promote good adhesion. Various methods for removal can be used, but they should not dislodge the coarse aggregate particles. Concrete may be brushed with a stiff brush soon after casting while the concrete is still fresh, and while it has only slightly stiffened.

If the concrete has partially hardened, it may be treated by wire brushing, or with a high-pressure water jet, followed by drying with an air jet, immediately before the new concrete is placed.

Fully-hardened concrete should be treated with mechanical hand tools or grit blasting, taking care not to split or crack soft aggregate particles.

The best time for treating the joints is a matter of judgement because it depends on the rate of setting and hardening (which is itself dependent on the temperature of the concrete). Before further concrete is cast, the surface should be thoroughly cleaned to remove debris and accumulated rubbish, one effective method being by air jet.

Where there is likely to be even a short delay before placing the next concrete lift, protruding reinforcement should be protected. Before the next lift is placed, rust loose mortar, or other contamination should be removed from the bars and, where conditions are particularly aggressive and there has been a substantial delay between lifts, the concrete should be cut back to expose the bars for a length of about 50 mm to ensure that contaminated concrete is removed.

In all cases, when construction joints are mode, it is essential to ensure that the joint surface is not contaminated with release agents, dust or curing membrane, and that the reinforcement is fixed firmly in position at the correct cover.

1.3 Concreting at Construction Joints

When the form work is fixed for the next lift, it should be inspected to ensure that no leakage can occur from the fresh concrete.

The practice of first placing a layer of mortar or grout when concreting joints is not recommended. The old surface should be soaked with water, without leaving puddles immediately before starting concreting, then the new concrete should be thoroughly compacted against it.

Annexure II

SPECIFICATION FOR SHEATHING DUCT JOINTS

The sheathing ducts shall be of the spiral corrugated type. For major projects, the sheathing ducts shall preferably be manufactured at the project site utilising appropriate machines. With such an arrangement, long lengths of sheathing ducts may be used with consequent reduction in the number of joints and couplers.

Where sheathing duct joints are unavoidable, such joints shall be made mortar-tight by the use of corrugated threaded sleeve couplers which can be tightly screwed on to the outer side of the sheathing ducts. A heat-shrink coupler could also be used if suitable.

Typical details of a sleeve coupler is shown in Fig. 1. The length of the coupler should not be less than 150 mm but should be increased up to 200 mm wherever practicable. The joints between the ends of the coupler and the duct shall be sealed with adhesive sealing tape to prevent penetration of cement slurry during concreting. The couplers of adjacent ducts should be staggered wherever practicable. As far as possible couplers should not be located in curved zones. The corrugated sleeve couplers are being conveniently manufactured using the sheath making machine with the next higher size of die set.

The heat-shrink coupler (Fig. 2) is supplied in the form of bandage rolls which can be used for all diameters of sheathing ducts. The bandage is coated on the underside with a heat sensitive adhesive so that after heating, the bandage material shrinks on to the sheathing duct and ensures formation of a leak proof joint, without the need for extra taping or support in the form of corrugated sleeve couplers. The heating is effected by means of a soft gas flame.

When fresh concrete is cast against existing mature concrete or masonry, the older surfaces should be thoroughly cleaned and soaked to prevent the absorption of water from the new concrete. Standing water should be removed shortly before the new concrete is placed, and the new concrete should be thoroughly vibrated in the region of the joint.