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No. RW/34020/1/86/NH(Stds.) *Dated the 12th October, 1987*

To,

1. The Chief Engineers of States and Union Territories Public Works Departments dealing with National Highways and other Centrally Financed Roads.
2. The Director General (Works), Central PWD.
3. The Director General Border Roads.
4. The Chief Engineer, Pamban Bridge Project, Guindy, Madras.

Subject : Specification for new concrete bridges to be constructed in marine environments and susceptible to corrosion

Your kind attention is invited to this Ministry's circular letter No. RW/PL-17(14)/76-Vol. II dated 4.1.82 forwarding "Interim specifications for new concrete bridges to be constructed in marine environments and susceptible to corrosion". A Technical Committee constituted by this Ministry has reviewed the provisions contained in this circular letter on the basis of latest codal provisions/research and accepted sound engineering practice available on the subject matter. Accordingly, modified specifications as contained in the enclosure have been suggested by this Technical Committee for the construction of new concerete bridges in marine environments for inhibiting corrosion and ensuring durability, long term safety and serviceability of the structures.

2. It is also recommended that amongst concrete super structures preference should be given to a fully prestressed concrete structural arrangement. In case of composite construction, the entire deck slab should be cast monolithically over the precast beams and there should be no precast portions in between. Comparatively speaking, easy accessibility of steel structures for inspection and periodic protective painting combined with feasibility of convenient repairs and replacement of members make them for the bridge superstructures and equally viable alternative and in certain locations even a preferable solution. These should also be considered inspite of the initial higher cost of steel structures.

3. It is, however, imperative that for corrosion protection of concrete bridges special attention is paid to the requirements of quality control, ensuring strict compliance of the prescribed standards for materials, concrete production and placement.

4. A complete record should invariably be kept on all important aspects of the work such as specifications of the materials actually used, the field test data for ensuring requisite process control in making good quality concrete and periodic maintenance inspection reports, as already highlighted in this office circular letter No. RW/PL-17(14)/76-VoLII dated March 31, 1981 (currently under review) along with the performance data of the structure.

5. This circular letter, therefore, supersedes the earlier one issued on the subject *vide* Ministry's No. RW/PL-17(14)/76-Vol. II dated January 4, 1982.

Enclosure to letter No. RW/34020/1/86/NH(Stds.) dated 12.10.1987

SPECIFICATIONS FOR NEW CONCRETE BRIDGES TO BE CONSTRUCTED IN MARINE ENVIRONMENTS AND SUSCEPTIBLE TO CORROSION

1. SCOPE

For all new concrete bridge structures located in aggressive environment susceptible to corrosion, the general specifications contained herein should be adopted for evolving detailed specifications on case to case basis depending on the site conditions available.

2. DURABILITY AND ZONES OF EXPOSURE

In order to ensure long term serviceability of the structure, both durability of concrete and immunity against corrosion of embedded reinforcements are the essential requirements and these are achieved by concrete properly proportioned with low-water-cement ratio, low permeability, well laid, compacted and dense with the absence of cracks, joints, adequate curing etc. It has been noticed that the effects of corrosion vary considerably in various zones of exposure which could be delineated for the purpose of applying this specification as under :

(a) **Submerged Zone :** That part of the structure which falls below the splash zone.

In this area, the primary concern is to prevent chemical deterioration of concrete, corrosion of embedded steel and abrasion.

(b) **Splash Zone :** Area of the structure subjected to repeated wetting and drying by sea water, viz. the difference between the highest and the lowest water levels reached by the waves with a statistical return period of 6 months superimposed on the highest and lowest level of spring tides plus one metre above highest tide level.

In this area, attention has to be paid to chemical deterioration of concrete, the adverse effects due to wetting and drying cycles and corrosion of embedded steel. In very cold climate the aspects of freezing and thawing have also to be considered though the same are not generally applicable to India.

(c) **Atmospheric Zone :** That part of the structure above the splash zone exposed to the atmosphere.

In this area, attention has to be paid to the prevenuon of corrosion of embedded steel due to wind action carrying salt/sand particles.

3. SPECIFICATIONS

Apart from the provisons contained in the Specifications for Road and Bridge works, published by this Ministry, the following specifications related to the various zones of exposure shall be followed. It must be ensured that the quality control measures undertaken at site are reliable enough to check that not only the materials as specified therein are upto the proescribed standards, but process control adopted also is of high order so as to achieve good quality of the end product.

3.1 Materials

3.1.1 **Cement :** 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).

3.1.2 **Aggregates :** The coarse and fine aggregates shall conform to the provisions contained in IRC : 21-1987 and IRC : 18-1985. Aggregates should be tested for Alkali-Silica reaction and such reactive aggregates should be avoided.

Aggregates from coastal areas having salts etc. shall not be used in concrete unless they are thoroughly washed in water (as specified in para 3.1.4) to reduce the salt content to acceptable levels (which shall be checked by testing) and to have sufficiently low shale and chloride content.

3.1.3 **Admixtures :** Duly tested admixtures/additives conforming to IS : 6925 and IS : 9103 (without replacement of cement) may be used with the approval of the Engineer-In-charge. Air entraining admixtures or those containing chlorides, nitrates, sulphides, sulphates and any other material liable to affect the steel, concrete and grout should not be permitted.

3.1.4 **Water :** The quality and PH value (not less than 6) of water shall conform to the provisions contained in IRC : 21-1987. However, the permissible limits for solids shall be as follows :

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

All samples of water (including potable water) shall be tested and suitable measures taken where necessary.

3.1.5 **Reinforcement :** Reinforcements shall comply to the provisions contained in IRC : 21-1987.

All reinforcements shall be free from rust, loose mill scale or coats of oil, paint etc. which may destroy bond. The reinforcement may be coated with cement slurry as per anti-corrosive treatement process developed by the Central Electro-chemical Research Institute (CECRI), Karaikudi before embedment. Binding wires shall be galvanised.

3.2 Production of Concrete

3.2.1 **Cement content :** Minimum cement content of 400 and 360 kg/m^3 (for 20mm nominal size of aggregates) shall be used for reinforced/prestressed and plain concrete works respectively. Cement content in excess of 540 kg/m^3 shall not be used due to increased risk of cracking due to shrinkage.

3.2.2 **Water/cement ratio :** To obtain concrete of low permeability, the water/cement ratio should not be more than 0.4 and 0.45 for reinforced/prestresed and plain concrete works respectively. A value less than 0.4 should be preferred subject to attainment of adequate workability.

3.2.3 **Strength of concrete :** Use of controlled concrete with weigh batching shall be adopted in all works. For bottom plug in well foundations, the concrete mix shall be designed in dry conditions and thereafter proper precautions for underwater concreting with termie pipe taken. The following minimum grades of concrete shall be adopted for the components of bridges :

a) Bottom plug	25 MPa
b) Well Steining/PCC Members	30 MPa
c) RCC Members	40 MPa
d) PSC Members	40 MPa

3.2.4 **Placement and compaction of concrete :** Strict attention shall be paid to proper batching, mixing and compaction of concrete, to achieve a homogeneous and dense end product. For adequate compaction, use of form and needle vibrators are essential. For detailed guidelines on the subject, reference may be made to relevant provisions in IRC : 21-1987.

3.2.5 **Curing :** Special attention should be paid to curing of concrete in order to ensure maximum durability and to minimise cracking. Concrete shall be cured with water as specified in para 3.1.4 above and the surface of concrete shall be kept wet by providing proper cover. Sea water shall not come in contact with concrete unless it has attained the desired strength.

3.2.6 **Total chloride content :** Total chloride content (Cl^-) in concrete shall not exceed 0.06% of weight of cement.

3.3 **Prestressed Concrete**

3.3.1 **Prestressing steel and accessories :** The diameter of prestressing wire shall in no case be less than 7 mm. The prestressing steel shall conform to the relevant Indian Standards and shall be used within 3 months from the date of manufacture. Data in respect of modulus of elasticity (tolerance not more than 15%) relaxation loss at 1000 hrs., minimum ultimate tensile strength, stress-strain curve, etc. shall necessarily be called for from the manufacturers.

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. For a typical acceptance standard for prestressing anchorages for post-tensioned construction, reference may be made to BS : 4447 October 1973

3.3.2 **Sheathing :** The thickness of sheathing shall comply to the stipulations given in IRC : 18-1985 for diameters of cable upto 75mm. Beyond this diameter the thickness of sheathing may need to be suitably increased based on past experience, manufacturers recommendations, etc. Special care shall be exercised where the sheathing joins the anchorage. Such junctions should be made waterproof by tightly fitting the sheathing over the protruding trumpet end of the anchorages and thereafter a heat shrink tape applied all around the joint to make it waterproof.

3.3.3 **Protection of tendons during storage :** Water soluable oils of proven specifications, if available, shall be used for coating over prestressed tendons during storage. Instructions contained in Clause 1011.6 of Ministry's Specifications for Road and Bridge Works shall be observed during storage.

3.3.4 **Grouting :** It is suggested that grouting shall be carried out as soon as possible but not later than two weeks after stressing. Wherever, it is necessary to leave one side of formwork of girders open for tying reinforcement or any other purpose, the open side shall be the leeward side. The grout used shall be non-shrink type with ordinary portland cement devoid of admixtures containing chloride, nitrates, sulphides or any other material liable to cause corrosion. The detailed specifications for grouting shall be as per provisions contained in Appendix 2 of IRC : 18-1985 as well as the following additional specifications : —

(i) 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.

(ii) The temperature of the grout after considering the ambient temperature of the structure shall not exceed 30°C.

(iii) All cables should preferably be grouted in one operation and at minimum interval after stressing. However, where this is not possible, it should be ensured that cables or group of cables, proposed to be grouted later should be spaced at distance not less than 300 mm from the group being grouted earlier.

3.3.5 **Anchorages :** Anchorages shall be suitably protected immediately after completing the prestress work by applying dense cement mortar layer of at least 15mm thickness and topped by a coat of epoxy paint to safeguard against corrosion.

3.4 **Other Components**

3.4.1. **Hand rails :** Use of steel sections shall be preferred as the same can be suitably protected by galvanising, painting etc. to prevent corrosion. However, where RCC handrails are used, these shall be pre-fabricated and erected in position.

3.4.2 **Expansion joints :** The exposed metallic components of expansion joints shall preferably be galvanised/aluminized or coated with anti-corrosive paint.

3.4.3 **Bearings :** Corrosion resistant bearings such as elastomeric or PTFE type shall be preferred. However, where metallic bearings are used, adequate safeguards against corrosion such as oil baths etc. shall be adopted.

3.4.4 **Wearing coat :** Asphaltic type wearing coat of approved specifications shall preferably be adopted.

3.4.5 **Construction joints :** Construction joints should be avoided as far as possible by adopting modern slip form methods. No construction joint shall be provided in the splash zone of the sub-structure. However, wherever construction joints become inevitable, properly designed reinforcements shall be provided for transfer of full stress across the joints prior to casting of the next lift. For location, preparation of surface and concreting of construction joints, refer to guidelines contained in Appendix I. In case of segmental construction, continuity of untensioned reinforcement from one segment to the next segment must be ensured.

3.4.6 **Exposed reinforcement :** Exposed reinforcement and permanent fixtures etc. shall be protected from corrosion. The projecting reinforcement, as far as possible, shall not be exposed for a period exceeding 30 days from the date of anti-corrosive treatment.

4. DESIGN & DETAILING

Detailing plays an important part and adds to durability. Some of these aspects are as follows :

4.1 **Sub-structure**

Solid type piers shall be preferred. The minimum thickness of any cellular types of sub-structure shall be 600 mm. PCC cellular and trestle type sub-structure should not be permitted.

4.2 **Diameter of the Reinforcing Bar**

Tensile reinforcement bars exceeding 28mm and shear stirrups exceeding 12 mm shall not be permitted. The minimum diameter of non-tensioned reinforcement bars shall not be less than 8 mm.

4.3 Cover to Reinforcement

Minimum clear cover to reinforcement bar closest to the concrete surface shall be 50 mm. The minimum clear cover for the prestressing cable nearest to the concrete surface shall be 75 mm. In situations, where the sulphate and chloride contents in subsoil or creek water are more than the prescribed codal limits, then for the substructure portion either Ordinary Portland Cement having Tricalcium Aluminate (C_3A) content ranging from 5 to 8% shall be used or in addition to the cover specified above, a sacrificial concrete cover of minimum of 25 mm thickness integrated with the structural concrete shall also be provided. A mild steel mesh reinforcement of 8mm dia @ 175 mm centre to centre both ways shall be provided at the interface of minimum cover and the sacrificial cover.

4.4 Arrangement of Reinforcement

The reinforcement steel shall be so arranged that concrete can be placed and compacted properly. Congestion of reinforcing steel at critical locations shall be avoided.

4.5 Control of Cracking in Concrete

The requirement of crack control at the tensile face of reinforced concrete components under sustained loads shall conform to relevant provisions contained in IRC : 21-1987 except that the diameter of tensile reinforcement shall not exceed 28 mm as stipulated in para 4.2 above.

4.6 Surface Reinforcement

The minimum surface reinforcement irrespective of design requirements shall be 10 mm dia. at 150 mm centre to centre bothways on the exposed surfaces.

4.7 Abrasion

Where severe abrasive action due to pebbles, sand or silt is expected, the coarse aggregates used in the concrete shall be at least as hard as the material causing abrasion and the sand content of the mix kept as low as possible. In very severe conditions, coursed stone masonry jacketting or concrete lining of design strength not less than 35 N/mm^2 shall be used.

5. SPECIAL TECHNIQUES

Special techniques like providing a protective layer to the mild steel reinforcement, surface coatings to the finished concrete surface, special type of steel, cathodic protection etc. may be used only if backed by a research/testing laboratory experimental work. In such cases complete technical data regarding material used, specifications adopted and subsequent performance of the structure shall invariably be kept. High build coatings are to be preferred but in any case single coating shall not be acceptable. Any surface coating material to concrete should be accepted based on proven performance test only in a standard laboratory. Tests, such as, adhesive strength test using Tensometer, electrical resistance measurements on coated concrete and cantilever model slab tests subjected to alternate wetting and drying would form some of the acceptance tests for surface coating. Different zones of exposure (atmosphere, splash, submerged etc.) of concrete structures need specific appropriate coating schemes.

APPENDIX I

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 joint 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 member 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 made, it is essential to ensure that the joint surface is not contaminated with release agents, dust, or during membrane, and that the reinforcement is fixed firmly in position at the correct cover.

1.3 Concreting at Construction Joints

When the formwork 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.

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.

1 This circular withdraw with Circular No RW/NH-34020/1/86-DO II dated 14.11.90