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No. RW/PL-17 (14)/76-Vol. II *Dated the 4th January, 1982*

To

All the C.Es/Addl. C. Es of Littoral States, Union Territories, PWDs dealing with Highways

Sub : Interim specifications 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 of even number dated the 31st March, 1981 forwarding "Guidelines for maintenance and repairs of existing concrete bridges susceptible to/being affected by corrosion". It is equally important that specifications adopted for the construction of new concrete bridges in such environments are adequate for inhibiting corrosion, so as to ensure durability and long term safety, and serviceability of our bridge structure. The Ministry has undertaken a research programme in which a detailed study of the problems of corrosion has been sponsored in the Central Electro Chemical Institute at Karaikudi, with a view to drawing up suitable specifications for concrete bridges to be constructed in marine environments susceptible to corrosion. However, till such time final results of this study are made available, it has been decided that for all centrally financed new concrete bridges located in marine environment susceptible to corrosion the interim specifications, herewith enclosed, may be adopted.

2. It is also recommended that amongst concrete superstructures preference should be given to a structural arrangement which is fully prestressed both longitudinally and cross-wise. A system with gap slabs should be avoided as not only the joints permit ingress of moisture into cable ducts however effectively sealed and promote chances of corrosion but also holes in some cases are not in the same vertical and horizontal alignments causing difficulties for threading cables. Comparatively speaking easy accessibility of steel structures for inspection and periodic protective painting, combined with feasibility of convenient repairs and replacement of members made them for the bridge superstructures an equallv viable alternative and in certain locations even a preferable solution. These must also be considered in spite of the initial higher cost of steel structures. Conventional normal practice of using fully galvanised sections and painting with special anti-corrosive paints should be continued at regular intervals for protection against corrosion.

3. It is, however, imperative that 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 laid down in the "Specifications for Road and Bridge Works" and the enclosed interim specifications, the latter superseding the former, wherever conflict occurs.

4. A complete record should invariably be kept on all important aspects of the work such as specificauons 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 of even number dated March 31, 1981 along with the performance data of the structure.

Enclosure to letter No. RW/PL-17 (14)/76-Vol. II dt 4.1.82

Interim specifications for new concrete bridges to be constructed in marine environments and susceptible to corrosion

1. **Scope :**

Till such time the final results of the detailed condition survey of concrete bridge structures located in marine environment, susceptible to corrosion, and findings of research undertaken by the Ministry, are available, the interim specifications contained herein should be adopted.

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 and 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 de-limited 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 and corrosion of embedded steel. In very cold climate the aspect of freezing and thawing has also to be considered though the same is 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 prevention of corrosion of embedded steel due to wind action carrying salt/sand particles.

3. **Detailed specifications** : Apart from the provisions contained in the specifications for Road and Bridge works, published by this Ministry, the following interim 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 prescribed 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 : The cement used shall invariably be any of the following types with the prior approval of Engineer-in-charge and tested to comply with the relevant standards.

i) Ordinary Portland cement conforming to IS:269.
ii) Rapid Hardening Portland cement conforming to IS:8041.
iii) High Strength Ordinary Portland cement conforming to IS:8112.
iv) Supersulphated cement conforming to IS:6909.

In submerged as also less exposed atmospheric zones, ordinary portland cement will normally prove satisfactory. In the splash and more exposed atmospheric zones, concrete made with Portland cement having a Tri-calcium aluminate (C_3A) content ranging between six to nine per cent will give satisfactory long term performance. To improve resistance to sea water, supersulphated cement will be better or additions of specified Pozzolanic material may be made to Ordinary Portland cement having C_3A content greater than eight per cent, with the proviso that the total chloride content in the cement shall be such that the overall chloride content including that from water is less than 500 PPM.

3.1.2. **Aggregates** : The aggregates shall conform to the provisions contained in Cl. 302.2 of IRC-21:1972 (Bridge Code Sec. III). The max. size of aggregates shall neither exceed the value of concrete over nor 20 mm. In well foundations with concrete steining the maximum size of aggregates shall not exceed 40 mm.

Aggregates from coastal areas having salts etc. shall not be used in concrete unless they are thoroughly washed in fresh water to reduce the salt content to acceptable levels and to have sufficiently low shale and chloride content.

3.1.3. **Admixtures** :Admixture may be used with the approval of the Engineer-incharge. Calcium chloride or admixtures containing calcium chloride shall not be permitted.

3.1.4. **Water** : Water used for mixing concrete shall comply with Cl. 302.4 of IRC:21-1972. The sub-soil water shall be tested for its chloride and sulphate content and suitable measures taken where necessary.

3.1.5. **Reinforcement** : Reinforcements shall comply with clause 302.5 of Section III IRC Bridge Code IRC:21-1972.

All reinforcement shall be free from rust, loose will scale or coats of oil, paint etc. which may destroy bond. The reinforcement may be coated with cement slurry before embedment.

Binding wires shall be of stainless steel or galvanised wire. Use of polythene binding strings and galvanised bar grips may be made after making sure that they have no adverse effect on the concrete.

3.2. **Production of concrete**

3.2.1. **Cement content** : Minimum cement content of 400 kg/m^3, not considering the quantity of Pozzolana material, shall be used for concrete in the splash zone. In other zones, the minimum cement content in reinforced concrete work shall be 360 kg/m^3 cement content in excess of 540 kg/m^3 shall not be used unless special consideration has been given to the increased risk of cracking due to shrinkage. For well steining in zones other than splash zone the minimum cement content shall be 300 kg/m^3.

3.2.2. **Water/cement ratio** : To obtain concrete of low permeability, the water/cement ratio should be kept as low as possible, the value should normally be less than 0.45. A value less than 0.40 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 reinforced concrete work in the submerged zone the minimum characteristics compressive strength at 28 days shall not be less than 20N/mm^2, for other zones it shall not be less than 35N/mm^2.

3.2.4. **Placement of concrete** : Strict attention shall be paid to proper batching, mixing and compaction of concrete, to achieve a homogenous and dense end product. For adequate compaction use of form and needle vibrators are essential.

3.2.5. **Curing** : Special attention should be paid to curing of concrete in order to ensure maximum durability and to minimize cracking. Concrete shall be cured with fresh water 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.

3.3. **Prestressed concrete** :

3.3.1. **Cement** : Ordinary Portland cement, high strength ordinary portland cement shall only be permitted for prestressed concrete work.

3.3.2. **Prestressing steel** : The diameter of prestressed tendons shall in no case be less than 5 m.

3.3.3. **Sheathing** : Metal sheathing to be used for prestressed concrete work shall be of galvanised type. For semi rigid type of metallic sheathing, the thickness of sheathing shall not be less than 0.6 m. Vents shall be provided at any changes of section and at high and low points of the duct for the sheathing.

3.3.4. **Protection of tendons during storage :** Water soluable oils of proven specifications, if available, shall be used for coating over pre-stressed tendons during storage.

3.3.5. **Grouting :** It is suggested that grouting should be carried out as soon as possible 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 of 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 Annexure I.

3.3.6. **Anchorages :** Anchorages shall be suitably protected immediately after completing the prestress work by applying dense cement mortar layer of at least 15 mm thickness 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 R.C.C. handrails are used, these shall be shop fabricated and brought to site and erected in position. It is preferable to adopt steel reinforcements duly protected by a suitable protective layer, e.g. epoxy mortar, cement slurry coating with inhibitor of proven performance etc.

3.4.2. **Expansion joints :** The exposed metallic components of expansion joints shall be galvanised.

3.4.3. **Bearings :** Corrosion resistant bearing 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.

4. **Design & Detailing :**

In RCC work, detailing plays an important part and good detailing adds to durability. Some of the aspects are as follows :

4.1. Thickness of member : In the submerged and splash zone the minimum thickness of the members shall not be kept less than 450 mm.

4.2. **Diameter of the reinforcing bar :** Tensile reinforcement bars exceeding 28 mm and shear stirrups exceeding 12 mm shall not be permitted. The diameter of reinforcing bars shall be kept as small as permissible to effect close spacing with reduced resulting cracking.

4.3. **Cover to reinforcement :** The concrete cover to reinforcement shall satisfy the following requirements :

a) 2 times the nominal maximum size of aggregate is or 1.5 times maximum diameter of bar whichever/greater but not less than those specified below.

b) Minimum concrete cover to any reinforcement shall not be less than 35 mm nor more than 50 mm for R.C.C. and 60 mm for pre-stressed concrete.

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. **Crack with limitation :** The crack width for mild steel and HYSD bars at the tensile face of the concrete under the worst combination of dead and live load shall not exceed 0.15 mm for members of concrete bridge structure located in the splash zone and 0.3 mm for other zones. The evaluation of the crack width shall be based on any rational formula. For this purpose, the formula given in CEB-FIP is acceptable with the dominantly occurring live load being taken as 0.5 times I.R.C. Class A wheel loads.

For solid slab bridges the check of the crack width shall deem to be satisfied, if the spacing of the longitudinal main reinforcement bars does not exceed 150 mm nor that of the transverse bars 300 mm.

4.6. **Surface reinforcement :** For mass concrete structures surface reinforcement shall continue to be provided in accordance with clause 306.4 of IRC:21 (Bridge Code Section III.)

4.7. **Abrasion :** Where severe abrasive action due to pebbles, sand or silt is expected, the coarse aggregate 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, stone masonry jacketting or concrete lining of design strength not less than 35 N/mm^2 shall be used.

5. **Special techniques :** Adoption of special techniques like providing a protective layer to the mild steel reinforcement, surface coatings to the finished concrete surface, special type of steel, cathodic treatment etc., are still to be tried on large scale in this country and their performance data is lacking.

As such any special technique 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.

Encl Annexure I

Annexure I

SUMMARY OF INTERNATIONAL (FIP) RECOMMENDATIONS FOR GROUT AND GROUTING

(quoted from ref. 71)

Preamble

In accordance with the general instructions of the Executive Committee of FIP, the Commission has refrained from going into details of giving figures which would not be applicable in all cases and in all countries in the belief that these remain the responsibility of

the Member Groups and the bodies responsible for supervision of works.

It is believed that what has resulted will form an adequate basis whose principles are applicable in all cases, and which should meet the aims of achieving durability, and the complete effectiveness of one of the basic components of the structure.

Summary

(1) Objectives of grouting: There are two principle objectives in grouting post-tensioned concrete members;

(a) to prevent corrosion of the prestressing steel;

(b) to provide an efficient bond between the prestressing steel and the concrete.

(2) Ducts: Vents should be provided at any changes of section and at high and low points of the ducts.

(3) Properties of the grout (a) where a cement-based grout is used, the water/cement ratio should be as low as possible consistent with adequate workability.

It is recommended that the fluidity of the grout should be measured on the site as a method of control.

(b) The bleeding of the grout at 20°C should not exceed the following:

2 per cent of the volume 3 hours after mixing; a maximum of 4 per cent.

In addition, the separated water must be adsorbed after 24 hours.

Bleeding should be measured in a metal or cylinder with an internal diameter of approximately 100 mm with a height of grout approximately 100 mm. During the test, the container should be covered to prevent evaporation.

(c) The compressive strength of the hardened grout after 28 days at a temperature of 20°C and relative humidity of approximately 70 per cent should not be less than 300 kg/cm^2, the method of measurement being that laid down by RILEM/Cembureau.

(d) Products other than cement-based grouts may be used following acceptable agreement tests.

(4) Materials for grout: (a) Cement normally used should be portland cement. The use of other cement may be authorised following agreement tests.

(b) If aggregates are used, they should consist of siliceous fine aggregate, finely-ground limestones, trass or fine sand.

(c) Acceptable admixtures may be used if tests have shown that their use improves the properties of the grout, e.g. by increasing workability, reducing bleeding, enteraining air or expanding the grout. Admixtures must be free from any product liable to damage the steel or the grout itself, such as chlorides, nitrates, sulphides, sulphites, etc.

(5) Mixing grout: (a) The cement (and aggregates if used) should be measured by weight.

(b) The mixing equipment should be of a type capable of producing grout of uniform, and if possible, colloidal consistence.

(c) Mixing time depends on the type of mixer.

(d) Mixing by hand should be prohibited.

(e) After being mixed, the grout should be kept in continuous movement, it is essential that the grout should be free from lumps.

(6) Injecting grout: (a) Injection should be carried out with as little delay as possible after tensioning of the steel. If for structural reasons, it has to be put off, protection of the steel by methods or products which will not prevent the ultimate adherence of the injected grout, should be ensured.

(b) The method of injecting should ensure complete filling of the ducts and complete surrounding of the steel. To check this, it is advisable to compare the volume of the spaces to be filled by the injected grout with the quantity of grout actually injected.

Equipment for this check should be installed at the entry and exit points of the grout.

(c) Injection by compressed air should be forbidden.

(d) The pump should be fitted with an effective control against build-up of excessive pressure.

(e) In all cases, the ducts should be cleaned out by compressed air. Before injecting grout in unlined ducts, it is advisable to flush the duct with water to wet the concrete, except in cold weather. After flushing, excess water should be removed by suitable means.

(f) The connection between the nozzle of the injection pipe and the ducts should be hermetic so that air cannot be sucked in.

(g) Injection must be continuous and should not be interrupted. It should be slow enough to avoid producing segregation of the grout.

(h) In cold weather, and especially in frosts, special precautions should be taken when injecting. If the temperature is not likely to hinder setting, grouting may continue using a frost-proof grout, containing a certain proportion of entrained air, generally 6 to 10 per cent.

(i) Injection must be continued until the consistence of the grout flowing from the free end and vent openings is equal to that of the injected grout.

(j) After a certain time, it is recommended that further injections should be carried out to fill any possible cavities.

(7) Precautions to be taken after grouting :

(a) In cold weather, or if there is a danger of the temperature falling below 2°C within 48 hours of injection, the work should be protected to avoid frost effects.

(b) In all cases, after final injection, openings and vents should be hermetically sealed, so as to avoid the ingress of water, de-icing materials and other corrosive agents.