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No. RW/34020/1/86/NH-Stds. *Dated the 15th March, 1988*

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.

Subject : Guidelines for :

(1) Maintenance repairs of existing concrete bridges susceptible to being affected by corrosion.

(2) Repair and rehabilitation of existing concrete bridges suffering from distress due to corrosion.

Your kind attention is invited to this Ministry's circular letter No. RW/PL-17(14)/76-Vol. II dated 31.3.81 forwarding "Guidelines for Maintenance repairs of existing concrete bridges suseptible to being affected by corrosion". A Technical Committee constituted by this Ministry has reviewed these guidelines and accordingly recommended separate modified guidelines for "maintenance repairs" and "repair & rehabilitation" of concrete bridges as cited under subject and the same are enclosed herewith as Annexures I & II for necessary compliance.

2. In this Ministry's circular letter No. RW/NHIII/P/2/79 dated 18.11.86, it was emphasised that regular inspection of bridges on National Highways and under other Centrally Financed Schemes should be carried out in accordance with the provisions contained in various circular letters (cited therein) issued by this Ministry and as per IRC Special Publication No. 18 — "Manual for Highway Bridge Maintenance Inspection"

3. The problem of "Corrosion and Corrosion protection of concrete bridges in marine environments" had been engaging the attention of this Ministry and accordingly a research scheme was undertaken by the Central Electro-Chemical Research Institute, Karaikudi under the sponsorship of this Ministry. The findings of this research scheme are that the major factors contributing to the accelerated reinforcement corrosion are the atmospheric salinity prevailing at the site irrespective of the distance from sea, inadequate concrete cover and loss of alkalinity at the reinforcement.

4. (a) For ensuring serviceability of bridge structures at a level well adapted to traffic needs through appropriate management, preventive maintenance should aim to :

(i) Avoid injury to third parties or failure of a structure liable to entail tragic consequences involving responsibility of the Departments Incharge.

(ii) Ensure flow of traffic under the most favourable conditions possible.

(iii) Protect the national stock of bridges while striving for overall optimisation, especially from the economic point of view.

(b) Whereas, failure to repair and rehabilitate any structure at the appropriate time could involve increased traffic hazard and may constitute a missed opportunity to make investment, thereby necessitating makeshift emergency repairs at a cost completely unrelated to benefits obtained.

5. In order to ensure the safety and efficient functioning of the bridge structures, the Chief Engineers are requested to attach utmost importance to inspections for "maintenance repairs" and "repair & rehabilitation" of these structures and to bring to the notice of field formations under their control the above guidelines to be followed.

6. This circular letter, therefore, supersedes the earlier one issued on the subject *vide* Ministry's letter No. RW/PL-17(14)/76-Vol. II dated 31.3.81.

7. Suggestions to improve/augment, the above guidelines based on experience are most welcome.

ANNEXURE I

Enclosure to letter No. RW/34020/I/86/NH-Std. dated 15th March 1988

GUIDELINES FOR MAINTENANCE REPAIRS OF EXISTING CONCRETE BRIDGES SUSCEPTIBLE TO BEING AFFECTED BY CORROSION

1. Concrete bridges mainly in the coastal areas and in adverse environments due to chemical factories etc. are vulnerable to corrosion. Repairs to the affected structures have to be made as soon as deterioration is noticed, and this requires a regular and timely inspection of the existing bridges by a competent engineer.

2. It is essential that records are maintained to provide a complete uptodate history of the structure right from construction stage with a mention of any distress or any special anti-corrosive treatment adopted at the time of design and construction stage itself. Special efforts should be made to make available the 'as constructed drawings' which are also known as the completion drawings.

3. Inspection

3.1 All bridges shall be inspected twice a year (once before the floods and then after the floods) to ascertain if there are any signs of distress such as appearance of stains, cracks, spalling etc. and action taken to remedy such defects. Such bridges should be kept under constant observation by resorting to frequent inspections and further remedial measures undertaken, as considered necessary. Special arrangements should be made for a closer inspection of all the components of the bridge.

3.2 Proforma for detailed bridge inspection report has already been circulted *vide* Ministry's letter No. RW/33037/1/87/NH (Stds) dated 23rd September, 1987. The inspection report should cover items listed therein as well as additional aspects elucidated in Annexure-A enclosed.

3.3 The reports shall be compared with previous reports to get an idea of the rate of deterioration. If the rate of deterioration is alarming, further detailed investigations to ascertain causes of deterioration etc. shall be undertaken. Thereafter the desired adequate measures will be suggested.

4. Identification of Corrosion and Damage of Concrete

4.1 The durability of the structure varies considerably in various zones of exposure which could be delineated as under :

(a) Submerged zone: that part of the structure which falls below the splash zone and is permanently under water.

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 lower water level 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 consisdered 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 prevention of corrosion of embedded steel due to wind action carrying salt/sand particles apart from the atmospheric pollution.

4.2 The causes leading to corrosion of reinforcement and/or damage of concrete such as inadequate cover, poor concrete quality and workmanship, type and quality of aggregates and cement used, quality of water used etc. shall be investigated to ascertain whether these have been responsible for the deterioration of concrete and steel. Some of the methods which could be used for investigation are as under :

(a) Electro-chemical techniques such as surface potential measurements on concrete surface and measurement of open circuit potential of embedded rebar (if electrical connection is available).

(b) Measurement of electrical resistance of concrete and coating over it, if any.

(c) Non-destructive tests such as SCHMIDT Hammer, Ultrasonic pulse transmission technique, pull-out tests etc.

(d) Chemical tests for chlorides, sulphates, PH etc.

5. **Remedial Measures**

Based on the detailed inspection and after identification of the causes leading to the defects in the structure, the remedial measures could be classified as follows :

(a) **Inadequate cover**

For components having inadequate cover, suitable surface treatment shall be adopted. For any treatment, it is essential to remove all loose concrete and expose corroded reinforcement with a clear gap of 20 mm behind the reinforcement by adopting due safety precautions. The surface shall be sand blasted to remove all rust. Wherever necessary, welding of new reinforcement shall be done.

5.2 **Repairs to Damaged/Spalled Concrete**

(a) For repairs to damaged/spalled concrete, where extensive damage has already occurred due to corrosion, in addition to reinforcement to be exposed all defective concrete should be completely removed to its full depth but not less than 20 mm beyond the level of reinforcement by adopting due safety precautions. For removal of concrete, the methods other than manual chiselling such as pneumatic hammers, hydrodemolition, rotary saw cutting, sand blasting & shot blasting and abrasive (including grinding) processes can be used depending upon the relative precision (ability to remove only the material intended) and selectivity (ability to remove defective material selectively) afforded by a particular process for the situation to be tackled. Care should be taken to prevent contamination of concrete surfaces by oils and lubricants from construction machinery during the process of concrete removal. If the removal involves both large and deep areas, it will be necessary to verify by calculations the statics of the structure and take suitable measures, if necessary (e.g. shoring).

(b) After the removal of the bulk of the deteriorated material and before undertaking repair & rehabilitation, it should be ensured that all the necessary material has been removed and the quality of the remaining concrete and the condition of the reinforcement is good. The surface of the concrete should be clean, free from dust, dirt, oil and grease, without obvious cracks and free from loose concrete fragments. The exposed reinforcement should be thoroughly cleaned upto the root of the rust with sand blasting, non-acidic chemical solution etc. If felt necessary the bar could also be removed and replaced by another new bar duly welded in position (if feasible) or otherwise positioned by drilling holes into sound concrete with the ends secured by grouting. On the replaced as well as the remaining steel surface, anti-corrosive treatment developed by Central Electro-Chemical Research Institute, Karaikudi should be applied.

(c) The repairs can either be done by reconcreting with smaller size chips not greater than 20 mm size and good quality dense concrete, or with epoxy mortar/concrete or guniting with cement mortar. Over the exposed concrete surface having a massive, compact appearance, and being sound, dry, hard and uniform with the bond and crushing strengths not below admissible values, the procedure applied is generally as follows :

(i) cleaning the surface by sand blasting followed by washing.

(ii) grouting of all cavities and rough areas.

(iii) application of a suitable bonding layer.

The shotcreting (guniting) with cement mortar shall satisfy the specifications given in this Ministry's circular No. RW/PL-17(14)/74-Vol.II dated 15.6.83.

As a rule, the required strength of the new mortar or concrete should be higher than that of the parent concrete. Fibre-reinforced concrete is useful in zones adjacent to expansion joints etc., where dynamic action is extremely severe.

5.3 **Prestressed Bridge Decks**

Compared to reinforced concrete slabs, repair work on prestressed bridge decks appears to be far more delicate, requiring specific procedures for each individual case as well as special attention to static problems.

(a) **Repairs of the concrete section of prestressed decks**

Preparation of the surface and the execution of the repair are generally the same as applicable for reinforced concrete. However, when carrying out repairs to the surface of prestressed members, the prestressed section should not be significantly reduced, in order to avoid excessive redistribution of static forces within the section.

(b) **Application of additional prestress**

Additional prestressing needs to be imparted with care to avoid overstressing certain parts of a structure and the existing level of prestressing should be known before any such work is undertaken. It is also essential to inject all cracks caused by bending and/or shear before or after additional prestressing is applied. Additional tendons can basically be applied in two ways :

(i) as vertical or inclined tendons.

(ii) as straight or curved tendons in beams.

Vertical or inclined tendons are normally used to strengthen resistance in shear, whereas, longitudinal tendons in beams are for strengthening resistance in bending.

(c) **Methods of checking and approval**

During the entire repair work, the material to be used should be checked continuously. Proper bending between the old and the new concrete has to be achieved. Further more, the compatibility of the new materials and the old concrete has to be investigated. The technical and working instructions of the manufacturer have to be observed.

6. With the rapid technological developments in bridge design, construction methods and systems as well as materials, there appears to be a growing need for application of more advanced techniques for assessment of the distress to the structure. However, in order to gain reliable knowledge as regards safety and serviceability of bridges, validated assessment techniques have to be used. At the present state of technology the following techniques suit the need of a bridge structure :

(a) Electro-chemical techniques such as surface potential measurements on concrete surface and measurement of open circuit potential of embedded rebar (if electrical connection is available).

(b) Measurement of electrical resistance of concrete and coating over it, if any.

(c) Non-destructive tests such as SCHMIDT Hammer, ultrasonic pulse transmission technique, pullout tests etc.

(d) Chemical tests for chlorides, sulphates, PH etc.

The performance of the remedial measures undertaken shall be carefully watched and monitored. Measurements should be made periodically in the affected portion, recorded and the data compared. Arrangements should be made for taking down deflections.

ANNEXURE A

PROFORMA OF ADDITIONAL ASPECTS FOR INSPECTION OF RCC/PRESTRESSED CONCRETE BRIDGES SUFFERING FROM DISTRESS DUE TO CORROSION

HISTORY OF BRIDGE

(i) Approximate distance (km.) from the sea coast

(ii) Whether located in backwaters

(iii) Whether any chemical industry is located nearby or harmful affluent passing in the river (Report in detail the bridge components exposed to industrial smoke/sewage)

(iv) Grade of concrete used for different components

(v) Minimum cement content used for the concrete in components mentioned in (iv) above

(vi) Water cement ratio used for the components mentioned in (iv) above

(vii) Chemical analysis of all the materials (if available)

(viii) Minimum clear concrete cover to steel reinforcement and prestressing cable used for the components mentioned in (iv) above

(ix) Whether any anti-corrosive treatment adopted at the time of construction. If so, give details

(x) Position of construction joints (if available)

(xi) Initial camber

B. INSPECTION REPORT

1. Condition of bridge components affected by corrosion :

(i) Hand rail, road kerb and footpath (if any)

(ii) Wearing coat

(iii) Deck slab

(iv) Main girders

(v) Cross girders/diaphragms

(vi) Soffit slab in case of hollow box

(vii) RCC pier

(viii) RCC abutment

(ix) RCC return walls

(x) RCC pier & abutment caps

(xi) Bearings

(xii) Any other component (please specify)

2. Nature of distress observed (Supported by photographs and detailed sketches)

(i) Rust or staining on the concrete surface

(ii) Bulging and/or cracking of concrete (Note the type and pattern of cracking alongwith approximate width of cracks. The extremities of the major cracks should be marked and dated with paint).

(iii) Spalling (depression resulting from separation and removal of the surface concrete) of concrete, and exposure of rusting reinforcement

(iv) Loss of camber

(v) Excessive deflection

(vi) Snapping of wire of cables due to corrosion (for prestressed concrete members).

(vii) Structural cracks, if any.

(viii) Any other type of distress.

Note : Where the effects of corrosion due to marine conditions are very serious, a detailed descriptive note on the damages to different components of such a bridge should be enclosed.

3. When was the above distress first observed ?

4. Extent of increase in deterioration since previous inspection

5. Repair measures proposed to be taken.

6. Corrective measures taken in the past and their behaviour.

C. ANY OTHER OBSERVATION

ANNEXURE II

Enclosure to letter No. RW/34020/1/86/NH(Stds.) dated the 15th March, 1988.

GUIDELINES FOR REPAIR AND REHABILITATION OF EXISTING CONCRETE BRIDGES SUFFERING FROM DISTRESS DUE TO CORROSION

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Special attention should be paid to the following locations, whcih are predominantly vulnerable for deterioration :

(a) Foundations.
(b) Under the water.
(c) Inside the box.
(d) near expansion joints.
(e) footpaths.
(f) kerbs
(g) wearing coat discontinuities.
(h) under wheel tracks
(i) hogging zones (Negative bending moment sections).
(j) prestressed concrete ducts & anchorages
(k) splashing zones
(l) parapet beams

5. Remedial Measures

5.1 Wherever possible, root causes should be identified before repair is undertaken. Repair and rehabilitation operations should be mechanically and chemically compatible with the original material properties of concrete and steel and also with the basic structural concept. Based on the detailed inspection and design analysis and after identification of the causes leading to the defects in the structure, the remedial measures could be taken as under.

The following are recommended surface treatments :

(i) Additional concrete with suitable reinforcement (jacketting).

(ii) Shotcrete/guniting — The concrete surface shall be saturated with water sometime before shotcrete/guniting to prevent absorption of water from gunite by dry concrete.

(iii) Painting with suitable paint.

(b) Repairs to Cracks

Concrete is low in tensile strength. Further heat of hydration has a tendency to induce shrinkage cracks especially in the absence of proper easing. Minor surface cracks thinner than 0.1mm normally are of no structural imporiance. However, exposure to moisture on account of any cracks in concrete may create conditions favourable to corrosion of steel. Such minor cracks can effectively be sealed by use of suitable flexible paint.

Structural cracks can be either (1) Passive or (2) Active. In case of passive cracks, suitable protection measures should be taken as detailed below :

(i) Flexible sealants such as polysulphide, liquid rubber etc.

(ii) Epoxy injection after sealing the crack surface with epoxy mortar.

Active cracks are cracks which have a tendency to show changes in crack width or length. In such case, unless remedial measures to prevent recurrence is taken, the crack may re-appear either at the same location or at another location. However, to prevent possible corrosion of steel, it is advisable to seal such cracks as soon as they are noticed even as a temporary measure before structural assessment of the problem is made. For this purpose, a "V" groove cut along the crack can be filled with polysulphide, bitumen etc. It is also possible to provide a sealing strip across the cracks by use of this neoprene sheet. It must be remembered that this is only an immediate temporary measure and the cause of the crack must be analysed and rectified for long term satisfactory performance. If necessary, the load may also have to be reduced.

Whenever injection of epoxy resin is done, proper equipment to ensure continuous injection without stoppage must be insisted upon. In case of stoppage of injection, it is possible that only the front portion of the crack gets filled with epoxy resin but not the full depth of the crack. It is also essential to use viscosity resins depending on the crack width. It is advisable to draw specifications for such work in consultation with experts in this field.

Even after various treatment outlined above for repair of cracks, it will be necessary to keep a constant watch on the performance of the structure so as to undertake further steps as an when required.

(c) **Repairs to damaged/spalled concrete**

For repairs to damaged/spalled concrete, guidelines on "Repair and rehabilitation of existing concrete bridges suffering from distress due to corrosion" may be referred to.