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No. RW/PL-17 (14)/76-Vol. II

Dated the 31st March, 1981

To

All the Chief Engineers/Addl. Chief Engineers of littoral States, Union Territories PWDs dealing with Highways

Sub : Guidelines for maintenance repair of existing concrete bridges susceptible to being affected by corrosion

Your kind attention had already been drawn in this Ministry's circular letter No. PL-67 (29)/76-NHVI dated 22.9.78 to the need for conducting periodic inspection of highway structures on National Highways, in accordance with the provisions contained in I.R.C. Special Publication No. 18—"Manual for Highway Bridge Maintenance Inspection."

2. The problem of corrosion and corrosion protection of concrete bridges exposed to marine environment has been engaging since some time the attention of this Ministry which has launched a research on this subject. Until findings of research are available, it has been decided that the maintenance and repairs to the concrete highway bridges/structures located in coastal areas and affected by corrosion, shall be carried out in accordance with the provisions in the enclosed guidelines.

3. In order to ensure the safety and efficient functioning of the bridge structures, the Chief Engineers are requested to attach utmost importance to such inspections for "preventive" maintenance of these structures and to bring it to the notice of their officers and staff the above guidelines to be followed.

4. Suggestions to improve/augment the above guidelines based on experiences are welcome.

Enclosure to letter No. RW/PL-17 (14)/76-Vol. II dt. 31.3.81

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

Concrete bridges mainly in the coastal areas are vulnerable to corrosion due to the aggressiveness of the environment. 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 upto—date history of structure right from construction stage with a mention of any special anti-corrosive treatments adopted at the time of design and construction stage itself.

3. Inspection

3.1. All bridges shall be inspected once a year to ascertain if there are any signs of distress such as appearance of strains, cracks, spalling etc. and action taken to remedy such defects. Such bridges be kept under constant observation by resorting to frequent inspections and further remedial measures undertaken as considered necessary.

3.2. The inspection report should cover the items listed in the proforma—Annexure-A. The items requiring special attention during inspection are briefly elucidated in notes at the end of Annexure-A.

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 remedial measures 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 delimited for the purpose of applying these specifications 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 super-imposed 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.

4.2. The causes leading to corrosion of reinforcement and/or damage of concrete such as inadequate cover, poor concrete quality, type and quality of aggregates and cement used, quality of water used, etc. shall be investigated to ascertain, whether they have been responsible

for the deterioration of concrete and steel.

4.3. For bridges more than 5 years old and exposed to adverse atmospheric conditions detailed inspection using techniques mentioned in para 6 may be undertaken.

5. Remedial Measures :

5.1. 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 :

i) **Inadequate cover :** For components having inadequate cover, surface treatment by way of providing additional good quality dense concrete cover with 20 mm size of aggregates, so as to have a minimum cover of 50 mm shall be considered.

ii) **Repairs to cracks :** Where corrosion has just set in and cracks appear but spalling has not started, it is felt that it may be adequate to seal the narrow cracks against ingress of moisture etc. For this purpose where rigid type sealant is required, it may be sufficient to cement grout or gunite or inject into the cracks epoxy mortar with adequate bonding and tensile strength. For flexible sealants a chase should be cut along the line of crack and then sealed with an elastic material such as poly-sulphide rubber or by the insertion of a prepared neoprene or rubber bitumen sealing strip. Even after such a treatment, it will be necessary to keep a constant watch on its performance, so as to undertake further steps as and when required.

(iii) *Repairs to damaged/spalled concrete* : For repairs to damaged/spalled concrete, where extensive damage has already occurred due to corrosion, the defective concrete should be cut out to the full depth but not less than 50 mm beyond the loose concrete layer and all loose materials removed. The exposed reinforcement should be thoroughly cleaned up to the root of the rust with brushes, sand blasting, chemical solution, etc. If felt necessary the bar could also be removed and replaced by another new bar duly welded in position. On the replaced as well as remaining steel surface either a thin coat of neat cement grout or epoxy coating as per specifications enclosed (Annexure-B) with adequate bonding and tensile strengths should be applied before any further treatment. The repairs can either be done by reconcreting with smaller chips of 20 mm size preferably and good quality dense concrete, or guniting with cement mortar or epoxy mortar. The guniting for cement mortar shall satisfy the following specifications :

(a) Water cement ratio 0.35 to 0.50 by weight wet enough to reduce rebound.

(b) Mortar mix of 1 part of cement: 3 to 4 parts of sand.

(c) Drying shrinkages 0.06 to 0.1 per cent.

(d) Cement used shall be with inhibitors such as calcium nitrite of approved specifications.

(e) Thickness of guniting 50 to 65 mm.

(f) Test panels should be gunned under field conditions to check or reduce rebound.

(g) Conventional 150/300 mm cylinder moulds shot-creted shall give strength of about M 300 at 28 days.

Where epoxy mortar guniting is to be preferred, the specifications in respect of the same will have to be drawn in consultation with experts in the field as this is a specialised job. However, not much experience has been gained to draw the specifications and report on performance of such treatment for bridges in this country.

(iv) For exposed components of expansion joints, the same shall be protected by a suitable covering of proven specification.

6. The performance of the remedial measures undertaken shall be carefully watched and monitored. For monitoring use of copper sulphate half cell for measuring the potential difference over a time period in the affected portion and comparing such values with previous records, use of non-destructive tests such as SCHMIDT Hammer, Ultrasonic Pulse Transmission Techniques etc. could be considered.

ANNEXURE A

PROFORMA FOR INSPECTION

A. HISTORY OF BRIDGE

1. Name of Bridge
2. Location of Bridge (with map showing predominant direction of wind)
3. Age of Bridge on the date of inspection.
4. Approximate distance from sea. Whether located in back waters.
5. Whether any chemical industry is nearby or harmful affluent passing in the river.
6. Type of bridge along with GAD-R.C.C. Prestressed.
7. Grade of concrete with cement content
8. W/C ratio used (if available).
9. Chemical analysis of all the materials (if available).
10. Minimum cover to steel reinforcement used.
11. Whether any anti-corrosive treatment adopted at the time of construction.
12. Position of Construction Joints (if available).

B. INSPECTION REPORT

I Bridge component affected
i). Superstructure
ii). Substructure
iii). Foundations

iv) Bearings
v) Any other

2. NATURE OF DISTRESS OBSERVED
i) Rusting or staining of concrete

ii) Bulging and/or cracking of concrete
iii) Spalling of concrete
iv) Rusting of metallic bearings
3. Extent of increase in deterioration since previous inspection

4. Repair measures proposed to be taken.

C. ANY OTHER OBSERVATION

NOTE: The items of inspection, as listed in proforma (item B I) are briefly elucidated here.

1. **Bearings:** While inspecting the bearings, following shall be kept in mind:

i) The general condition like cleanliness, rusting and greasing of metallic/plate bearings.

ii) Condition of rubber bearings, deterioration due to oxidation, flattening, bulging & splitting.
iii) Condition of grease/oil (if provided) in case of metallic bearings.
iv) Whether any structural cracks in supporting members like abutment cap, pier cap, pedestal, etc.

2. **Superstructure:** The inspection officer shall inspect the superstructure and report in respect of the following:

(i) **Reinforced concrete members:** The following aspects shall specially be looked for spotting (rusting), cracking, leaching, spalling and other signs of deterioration in critical areas of the structure viz., splash zone, water line at low tide level and portions exposed to atmospheric attack on the windward side. For the latter the web of concrete girder and box girder, articulations, under-side of decks, etc., shall particularly be inspected.

(ii) **Prestressed Concrete Members:** For prestressed concrete members aspects like loss of camber, excessive deflection, cracking, deterioration in concrete viz., spalling etc. shall be looked for. The critical areas being end anchorage zones, junction of diaphragms, under-side at the centre of span for longitudinal cracking etc.

3. **Expansion Joints:** Besides inspection for proper functioning of the expansion joint, any deterioration in the material such as rusting etc., shall be looked for along with remedial measures required.

4. **Wearing Coat:** The surface condition i.e. whether there are any cracks, spalling of concrete, disintegration etc. need to be reported along with remedial measures.

5. **Hand rails and Footpaths:** Hand rails, being slender members, are susceptible to corrosive distress. Appearance of rust stains, cracks, scaling deterioration in concrete, spalling etc. need to be reported along with remedial measures.

ANNEXURE B

CONCRETE CLASSES PSD, PSG, AND XYP

Concrete classes PSD, PSG, and XYP shall meet all of the requirements of concrete Class AX except the materials shall be proportioned to produce a concrete which shall have a minimum compressive strength of not less than 5000, 7000 and 6500 pounds per square inch, respectively, at the age of 28 days.

The Contractor shall design a mix that meets the specified strength requirements in conformance with ASTM C 685. A coefficient of variation of 20 per cent shall be assumed unless the supplier can demonstrate a record of sufficient tests to justify the use of a lower coefficient in conformance with ASTM C 685.

The mix shall be reviewed by the Engineer and verified by tests of cylinders made from the mix prior to commencing work on the portion of the bridge using this concrete. The use of calcium chloride as an admixture to the concrete will not be allowed.

EPOXY-COATED STEEL REINFORCING BAR

This item of work shall consist of furnishing, fabricating, coating and placing epoxy-coated steel reinforcing bars in accordance with the plans, the standard specifications and these special provisions. The coating material shall be applied by the electrostatic spray method or the electrostatic fludized-bed method.

COATING MATERIAL

The coating material shall be one of the following or an approval equal:

(a) SCOTCHKOTE 202 by the Minnesota Mining and Manufacturing Company, Inc.
(b) FLINTFLEX 531-6080 by the E.I. Dupont de Nemours Company, Inc.
(c) EPOXY POWDER 720-A-009 by the Cook Paint and Varnish Company.
(d) CORVEL ECA-1440-J-Green-2779 by the Polymer Corporation.
(e) EPOXIPLATE-346, 347, 348 and 349 by the Armstrong Products Company.
(f) MOBILOX 1004-R-2 by Mobil Chemical Company.
(g) SCOTCHKOTE 213 by the Minnesota Mining and Manufacturing Company Inc.
(h) NAP-GARD 7-2000 by the Napco Corporation.
(i) OXY-PLAST EL-704-P-9 by the Fuller-O'Brien Corporation.
(j) SCOTCHKOTE 214 by the Minnesota Mining and Manufacturing Compnay Inc.
(k) HYSOL DK 23-0602 by the Dexter Corporation.

Manufacturer's information on the proper use and application requirements of the resin to be used shall be submitted to the Engineer by the Contractor.

The Contractor shall furnish a written certification that the material furnished for the coating of the reinforcing steel is the same formulation as previously approved by the National Bureau of Standards, or the Materials Laboratory of the Washington State Department of Transportation. The Contractor shall supply to the Engineer a representative sample of 8 ounces of the powdered epoxy resin used to coat each given lot of bars. The sample shall be packaged in an airtight container with identification by lot numbers.

SURFACE PREPARATION

The surface of the steel reinforcing bars which are to be coated shall be blasted to near white metal in accordance with the steel structure Painting Council Surface Preparation Specification SSPC-SPIO-63T, amended January I, 1971.

All traces of grit and dust from the blasting shall be removed. The surface shall be clean and free of any oil, grease, or other surface contaminants at time of coating.

The coating shall be applied to the cleaned surface as soon as possible after blast cleaning. The time between blast cleaning and coating of the bars shall not be more than approximately eight hours without specific approval of the Engineer.

COATING PROCESS

Bars shall be coated in accordance with the resin manufacturer's recommendations and these specifications. The coated bars shall meet the requirements specified and may be inspected for approval at the coating plant. Samples of coated bars of each size for testing shall be submitted to the Engineer for plant and process approval. A certification statement stating that all bars have been coated in accordance with the resin manufacturer's recommendations and these specifications shall be furnished with each shipment. This certification shall include for each bar size the preheat temperatures, cure times, thickness checks, holidays detected and bend test results. Two copies of these certifications shall be forwarded to the Engineer.

The coating applicator shall submit certifications of compliance with the above requirements. In addition, the Contractor shall submit to the Engineer six samples of each size of epoxy coated bars shown in the plans. The samples shall be four feet long and the Contractor shall ensure that samples for this testing shall not short the bar lengths specified in the project plans.

HANDLING

To protect the coated reinforcement from damage, the Contractor shall use padded or nonmetallic slings and padded straps. Bundled bars shall be handled in a manner which will prevent excessive sagging of bars which will damage the coating. The bundled bars shall not be dropped or dragged and must be stored on wooden cribbing. If, in the opinion of the Engineer, the coated bars have been extensively damaged, the material will be rejected. The Contractor may propose, for approval of the Engineer, alternate precautionary measures.

FABRICATION AND PLACEMENT

The bars shall be fabricated as specified in section 9-07 of the standard specifications before or after applying the epoxy coating.

Metal chairs and supports shall be coated with an epoxy or other inert coating approved by the Engineer. The Contractor may propose the use of other devices for approval of the Engineer. Plastic-coated tie wires approved by the Engineer shall be used to protect the coated bars from physical damage during placement.

The bars shall be accurately placed in the position shown in the plans and firmly held in place during placing and setting of the concrete. All epoxy-coated bars in the top mat of the roadway slab shall be tied at all intersections. All other epoxy-coated bars shall be tied at all intersections except where the spacing is less than I foot 0 inches in either direction, in which case alternate intersections shall be tied.

After placement of the coated bars and before pouring the bridge deck concrete, the coated bars will be inspected and, at the Engineer's direction, the Contractor shall patch damaged areas as specified elsewhere in this specification.

COATING THICKNESS

A film with a thickness after curing of 8 mils ± 2 mils shall be applied in a uniform, smooth coat. Thickness of the film will be measured on a representative number of bars from each production lot by the same method as outlined in ASTM Designation B 499, Non-magnetic Coatings on Magnetic Basis Metals.

CONTINUITY OF COATING

The coating shall be checked after cure at the coating plant for continuity of coating and shall be free from holes, voids contamination, cracks, and damaged areas. In addition, there shall not be more than two holidays (pinholes not visually discernible) in each linear foot of coated bar. A holiday detector shall be used in accordance with the manufacturer's instructions to check the coating for holidays. A 67-1/2 volt, A.C. powered, on-line, holiday detector shall be used.

FLEXIBILITY AND BONDING OF COATING

The coated reinforcing bars shall be capable of being bent 120 degrees over a mandrel of the following diameter without and visible evidence of cracking or disbonding of the coating. The diameter of the mandrel for number 4, 5, 6, 7, 8, 9, 10 and 11 bars shall be 4, 5, 6, 7, 8, 9, 10 and 11 inches, respectively. The rate of bending shall be one minute plus or minus 15 seconds. The coating applicator shall test one sample of each bar size as prescribed above for each day's processing. If there is any evidence of cracking or disbonding of the coating, two additional test samples from different bars shall be secured and tested from the bars previously coated that day. Any evidence of cracking or disbonding will be considered cause for rejection of the coated bars represented by these samples.

PATCHING MATERIAL

Patching or repair material, compatible with the coating and inert in concrete, shall be supplied by the epoxy resin manufacturer and shall have approval of the Engineer. The material shall be suitable for repairs of areas of coating that have been damaged.

PATCHING

Patching material shall be applied to damaged areas at the points of occurrence, such as at the initial application, fabrication, destination or installation points.

Areas to be patched shall be clean and free of surface contaiminants. They shall be promptly treated in accordance with the resin manufacturer's recommendations and before detrimental oxidation occurs.

Unless otherwise shown in the plans, all bars shall be epoxy-coated.

All costs for furnishing and installing epoxy-coated reinforcing bars shall be incidental to and included in the unit contract prices of the various contract items containing epoxy-coated reinforcing steel.