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No. RW/NH/34020/1/90-DO II *Dated the 26th September, 1990*

To

The Chief Engineers of State PWDs/Union Territories dealing with NHs and other centrally sponsored projects; Director General (Works) CPWD; Director General Border Roads; Chairman, National Highway Authority.

Subject: Important considerations in the design, construction and maintenance of prestressed concrete bridge works on National Highways and under other centrally sponsored schemes - Recommendations of High Level Technical Committee therefor.

The High Level Technical Committee set up to examine the technical issues arising out of the recommendations of the Inquiry Commission on the collapse of the Mandovi Bridge has submitted its report, which has been accepted by this Ministry. The recommendations of the High Level Technical Committee in respect of some important considerations in the design, construction and maintenance and monitoring of prestressed concrete bridges are enclosed as Annexure-I to III respectively.

It is requested that the same may be brought to the notice of all Officers in your Department dealing with NHs and other centrally sponsored schemes for strict compliance.

Annexure-I

SOME IMPORTANT DESIGN CONSIDERATIONS FOR PRESTRESSED CONCRETE BRIDGES AS RECOMMENDED BY HIGH LEVEL TECHNICAL COMMITTEE

1. The decision whether to adopt a non-conventional/innovative type of structure for a bridge is required to be taken before inviting tenders. Complete design and drawings of such non-conventional/innovative structures should as far as practicable be finalised and thereafter tenders

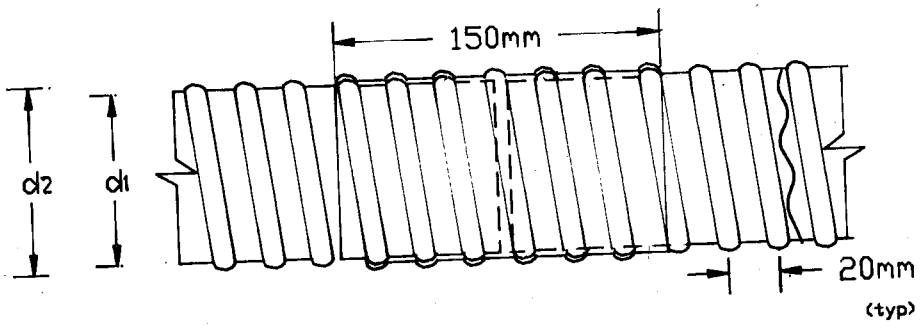

FIG.1

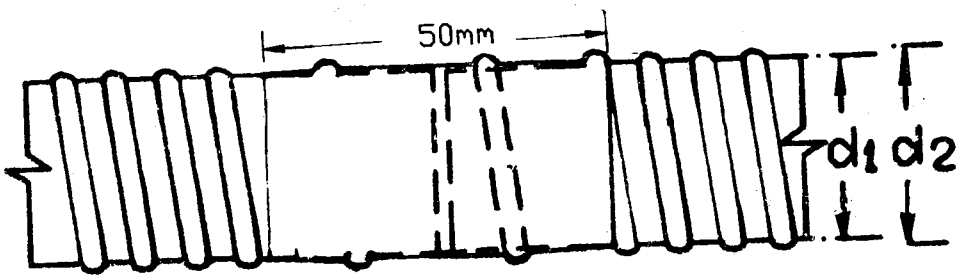

FIG.2

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Attach locality map showing geographical features of the area, indicating, inter-alia, the alignment of the project, beginning and end points of project location of the contract packages and brief details etc. The scale of the map should be such that project length is shown clearly within the prescribed size of the report.

(Sample copy of the locality map is enclosed)

invited for execution in accordance with these finalised drawings. If necessary, experienced consultants may be engaged for preparation of designs and drawings of such types of structures.

2. Innovative bridge designs should be got checked in detail by an independent agency, identified by the department.

3. Important parameters like deflection, support movements, crack widths etc., for monitoring of structural behaviour of the bridge should be identified and worked out at the design stage. These data should be made available for monitoring to the Maintenance Organisation when the work is completed.

4. For structures located in aggressive environment, unforeseen loss of prestress during service life should also be accounted for in design in addition to losses stipulated in Bridge Codes. The design and detailing should, however, provide for imparting additional prestressing force to the extent of about 20% of the design prestress either in the form of internal or external prestressing at a later date.

Annexure-II

SOME IMPORTANT CONSIDERATIONS IN CONSTRUCTION OF PRESTRESSED CONCRETE BRIDGES AS RECOMMENDED BY HIGH LEVEL TECHNICAL COMMITTEE

The following provisions (some of which may be already existing in the current Codes of Practices and Specifications), are important for ensuring durability and are being highlighted for strict compliance

1. Materials

(i) Ordinary Portland Cement conforming to IS:269, High Strength Ordinary Portland Cement conforming to IS:8112 or IS:12269 must not contain chloride (as Cl^-) ions more than 0.05 per cent.

(ii) Water for mixing and curing of concrete should conform to the requirements of IRC:SP:33-1989 including the specified limits of sulphates and chlorides.

(iii) Coarse and fine aggregates from natural sources should conform to the requirements of IS:383 and should not contain harmful dosages of chlorides and sulphates. Fine aggregates quarried in coastal areas must be tested for strict compliance to the above.

(iv) The total chlorides (as Cl^-) and sulphates (as SO_3) in fresh concrete should not exceed 0.06 per cent and 4 per cent respectively, by weight of cement.

(v) For bridges located in severe environment, the maximum water cement ratio in concrete production shall not exceed 0.40 and the minimum cement content shall be 400 kg/m^3 of concrete.

(vi) 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 to the same shall be 75 mm.

(vii) Due care should be taken in the storage of materials at the work site in marine environment to prevent contamination of materials with the salt laden water, spray or breeze and to prevent corrosion of steel reinforcement, HT wires, sheathings and other metallic fixtures.

(viii) Concrete admixtures and super-plasticizers should only be used after proper evaluation of their performance in the concrete mixes with regard to materials and mix proportions to be used on the work. Admixtures and super-plasticizers must not contain harmful constituents like chloride ions, etc., in such amounts which may affect durability.

2. False Work

2.1 The form work should be robust and strong and the joints should be leak-proof. The staging, scaffolding and shuttering are required to be properly designed so that their erection as well as striking can be conveniently done. The design should also ensure that at the time of striking, the concrete does not get disturbed and the forms are conveniently removed. For this, wooden or other type of packing should be designed and placed in position for easy removal of the form work. Use of bamboo staging shall be prohibited.

2.2 Where 'ballie' staging is used, the joints shall be properly spliced. Such staging shall be checked for its soundness and shall be properly braced to make it rigid and strong.

2.3 Where centering trusses are adopted for casting of super-structure, the joints of the centering trusses, whether/rivetted or bolted should be thoroughly checked before proceeding with the concreting. Also, various members of the centering trusses should be examined for proper alignment and unintended deformation before proceeding with the concreting.

2.4 The locations where fixing of reinforcement and placing of concrete are being done, should be accessible to the inspecting officers at all stages of the construction.

3. Concrete Production

3.1 The aggregates, cement, admixtures, etc., should be continuously tested according to a prepared schedule and the results noted before using them in the actual construction.

3.2 In order to ensure uniformity and good quality of concrete, concrete ingredients should be mixed in a concrete mixer with integrated weigh batching facility & automatic water measuring and dispensing device or in a concrete batching and mixing plant and should be transported by transit mixers or properly designed concrete buckets.

3.3 After placing, concrete must be vibrated using needle vibrators and form vibrators. Proper fixtures should be provided in the form work to fix form vibrators. Before start of concreting operations, form vibrators should be fixed in position and tested.

3.4 Proper curing of concrete must be ensured, for which perforated type pipes or proven curing compounds may be adopted as convenient.

4. Precast Concrete Construction

4.1 Following points are required to be specially taken care of in precast concrete construction.

(a) Length and sizes of the precast members.

(b) **Their handling** in the casting yard.

(c) **Proper curing** of the precast members in the casting yard.

(d) **Their transportation** upto the site of construction.

(e) **Launching, hosting and lifting** the precast members in position.

(f) **The joining** of the precast members wherever required and the sealing of the joints with epoxy mortar to avoid ingress of moisture through the joint upto reinforcement bars.

(g) **The equipment** required for launching, hoisting and lifting of these members.

4.2 If the precast elements are to be partially/fully supported during assembly, before prestressing/jointing them together, proper construction scheme should be prepared in detail before start of precasting operations.

5. Prestressing Operations

5.1 Various requirements of concrete strength as given in Bridge Codes must be ensured both by design and field staff.

5.2 At the design stage, the number of cables must be worked out in such a way that they can be properly placed in position. Spacing, cover around cables and grouping of cables where permitted, shall be as per codal requirements. The drawings should clearly indicate all these aspects for the convenience of the field staff.

5.3 Forming of Cables

5.3.1 Wires/strands should be staightened to remove twist amongst themselves. Where profilers are permitted, the wires/strands should be assembled with the help of profilers.

5.3.2 The wires/strands should be bought from the manufacturers in proper spools and the cables should be formed in such a way that the wires/strands do not come in contact with the ground soil. For this, a suitable arrangement like mounting the spool on a cross frame with a pivot in the centre and making bench for the entire length of the cable may be adopted so that while decoiling and making of cables the wires/strands may rest on the bench and do not touch the ground below. The cables thus formed should be tied with binding wire at suitable intervals in order to keep them in position.

5.4 Sheathing

5.4.1 Sheathing should conform to the following:

(a) Provisions of IRC:18-1985 with the proviso that the same sample should be subjected to the various tests stipulated therein. However, the thickness of sheathing for diameters exceeding 75 mm shall be suitably increased beyond 0.3 mm, based on manufacturer's recommendations/expert literature and satisfactory past performance.

(b) Should be clean and free from rust.

(c) Should be flexible enough to take the shape of the cable profile.

(d) Should not get punctured/broken during handling, placing/threading of cables in position and vibrating of the concrete.

(e) Should have rigid joints which do not open out during handling of the cables.

(f) Should be of proper metallic composition, to be specified in case of severe environment.

(g) Should be available in suitable lengths, joined together with the help of couplers, made of same material as the sheathing & with slightly larger diameter. The joints of the sheathing where the couplers are fixed should be made leak-proof by the use of PVC tape.

5.4.2 A sheath making machine should be kept at the site of work so that sheathing can be prepared as and when it is required for construction.

5.4.3 In severe environment, plastic sheathing may be considered for use, which should conform to the general specifications given in Appendix 'A'.

5.4.4 Placement of cables: Sheathing should be placed in correct position and profile, by providing suitable ladders and spacers. Such ladders may be provided at intervals of 1 to 1.5 metre. Sheathing should be tied rigidly with such spacer bars so that they do not get disturbed during concreting.

5.4.5 In order that the angles of the cable at the ends are maintained as per design, the tube anchorage should be temporarily bolted to the end plate of shuttering plate, which should be fabricated very precisely. In order to thread the cables in the sheathing after the concreting has been done, it should be ensured that the duct holes do not get choked due to inlet of slurry from possible leakages in the sheathing. For this, cables alongwith sheathing are first placed in position and are kept under to and from movement during concreting as well as for a period of about 3 to 4 hours after the concreting is over. These cables are thereafter taken out leaving the sheathing in position. Subsequently, when a particular cable is scheduled to be prestressed, the cable is threaded inside the preformed hole in this section, with the help of a cable threading machine. Alternatively, an inflatable tube which should be strong enough to keep its size and shape, duly inflated, is left in position during concreting and after the concrete gets hardened, this tube is deflated and the whole tube is then extracted out.

5.4.6 Before prestressing of cables, the ducts should be thoroughly cleaned with water and air jets, so that the high tensile steel becomes free from all deleterious matter. Also the ends of the cables should be protected with suitable devices to prevent ingress of water, to keep them free from rusting & other harmful chemical effects during the period of concreting and prestressing of the cables.

5.5 Prestressing and Grouting

(a) Engineers engaged in design and construction of prestressed concrete works should be highly qualified, and well conversant with all aspects of prestressed concrete construction, the do's and dont's, and about the harmful effects if proper precautions are not taken.

Senior Level Management should ensure that only trained and qualified personnel are deployed for the work. The training should include the following:

(1) Different systems of prestressing (a good source would be illustrative literature from manufacturers of various systems).

(2) The equipment used in each system.

(3) The importance of slips (designed and actually observed).

(4) Implications of prestressing from one end or from both ends.

(5) Observations of wedge set at the dead end in case of prestressing from one end, for single wire/strand or multiple wire/strand prestressing.

(6) Advantages and disadvantages of single/multiple prestressing system.

(7) Sequence of prestressing of individual wires/strands, in case of single stressing system.

(8) Precautions to be taken before actually prestressing such as cleaning of wires/strands, where the wedges are going to finally grip the wire/strand, cleaning of wedges, equal setting of wedges.

(9) Proper calibration of prestressing gauges giving pressure.

(10) Effect of increasing pressures in case elongations are not met or vice-versa; increasing the elongations when jack pressures are not achieved.

(11) The percentage increases in jack pressures or elongations which are permissible or which can be permitted.

(12) The importance of proper testing of high tensile steel, method of testing and effect of possible variation in value of 'E', percentage elongation, etc.

(13) The chemical composition of high tensile steel, MS & HYSD bars, their permissible and ultimate tensile stress.

(14) The stress/strain curves of HTS, MS & HYSD bars and their permissible and ultimate/proof tensile stresses: and

(15) On job training.

5.6 **Grouting of Cables**

5.6.1 Cables should be grouted immediately after tensioning the high tensile wires/strands especially in case of severe environment.

5.6.2 The mix of the grout, its consistency, the rate at which the grout should be injected and other precautions to be taken to inject the grout so that it fills the entire duct should conform to the Codes and Specifications. The temperature of the grout should preferably be kept about 20° to 25° Celsius which may be achieved in warm climate, by putting ice outside the grout.

5.6.3 Utmost care should be taken about proper grouting of the prestressing cables. Efficacy of the grout mix and the grouting operations should be ensured by carrying out trials before actual operation.

6. **Quality Assurance**

Quality assurance should be carried out in a systematic manner at various stages of construction. A check list should be prepared for different items of work and the field staff should tick each item, to ensure that each and every item, has been checked and found to be in order. The field staff should also fill in a prescribed format, the details of prestressing operations.

7. Specialised agencies of different prestressing system should be deployed for prestressing operations to ensure quality and reliability of the construction.

8. Type of equipment to be used should be spelt out clearly in the Specification and contracts which should be scrupulously followed.

9. There should be close interaction between design engineers/consultants and the field engineers at each stage of construction.

10. An extended defect liability period should be provided particularly for bridges located in severe environment.

11. A water proofing layer should be provided over the bridge deck as an intervening layer between the deck and the wearing coat. Where bituminous wearing coat is provided, markers may be installed on kerbs so as to control the increase in the thickness of the wearing coat after repeated applications of bituminous layers during service.

Appendix 'A'

GENERAL SPECIFICATIONS FOR PLASTIC SHEATHING

1. The plastic material from which the sheathing is made should not react with cement, grease or steel.

2. It should be durable and resistant to damage and abrasion. It should remain stable and flexible during handling, storage at site and in service during the entire range of temperatures which are likely to be experienced.

3. The plastic material should be resistant to aging due to exposure to ultra-violet light.

4. While abrasion and splitting of the plastic sheathing can be repaired at site before concrete is poured, it may not be possible to discover all the damages and consequently the plastic sheathing should be of a type which is resistant to damage of any kind.

5. Deviations in profile cause the tendon to exert constant pressure on the sheathing, which may cause the plastic to flow and to become thinner along the line of contact. The plastic should, therefore, have relatively low creep properties.

6. The plastic material should be either high density polyethylene or polypropylene. Both materials are tough, durable and non-reactive. High density polyethylene is more flexible and less liable to embrittlement at extremely low temperatures, while polypropylene is more stable at high temperatures. Both materials have high resistance to abrasion and creep, although polypropylene is slightly superior in these aspects.

7. While PVC and low density polyethylene have been extensively used as sheathing, they are less able to satisfy all the above requirements than higher density materials. The use of PVC is not recommended since it is known that chloride ions can be released under certain conditions.

Annexure-III

IMPORTANT MAINTENANCE AND MONITORING CONSIDERATIONS AS RECOMMENDED BY HIGH LEVEL TECHNICAL COMMITTEE

1. The levels of inspection, requiring different scale and frequency of examination of bridge structures should be as follows:

   (a) General
   (b) Detailed
   (c) Special

   (a) The general inspection should be carried out every year. It will be primarily a visual inspection for the purpose of assessing the overall integrity of a bridge. A written report should be made on the condition of the bridge and its various components. This record should include exact location and extent of the damage and defects found at the time of inspection giving sketches and elucidating with photographs if necessary. In case of observation of cracks, the ends of cracks may be marked with 'tell-tales'. In addition, observation should be made as regards excessive deformations, deflections, spalling, etc.

   (b) The first detailed inspections should be carried out before the end of the Defect Liability Period of a bridge contract or earlier, if any distress is observed. Thereafter, the interval between detailed inspections should be about three years. the detailed inspection should be intensive and should require close examination of all elements of the structure. It should also include assessment of concrete properties and other physical tests, if necessary, including testing of condition of reinforcement, monitoring of deflection, etc.

   A full report containing sketches and drawings should be prepared in case there are any defects observed during this inspection.

   (c) Special inspection may be carried out in the following cases:

      (i) After unusual floods/cyclone/strong earthquake which might have damaged or adversely affected the condition of the bridge.

      (ii) When there are signs of weakness in the bridge as may be revealed in the detailed inspection.

      (iii) When bridges having similar design and constructed more or less during the same period are showing same signs of distress.

      (iv) In case cracks appear and persist in the wearing coat proper investigations must be carried out to find the cause of cracking so as to exclude the possibility of structural inadequacies.

      (v) For long span bridges proper guidelines regarding maintenance of hinges should also be given in the maintenance manual for the bridges wherever applicable.

      (vi) For long span prestressed concrete bridges necessary provisions may be made for instrumentation to be provided at the construction stage for proper monitoring of the bridge behaviour during service life. The measurements to be regularly made may include among other things concrete strains at critical points, temperature effects, deflections, movement of hinges, etc. Based on this data, decision at the appropriate moment may then be taken as to whether loss of prestress is taking place, particularly in case of prestressed concrete bridges located in severe environment, so that corrective measures including additional prestress for imparting of which built-in provisions have been made in the structure, are taken in time.

2. Proper maintenance cells with specially trained personnel should be set up by PWDs.