Appendix - 1800/III

SPECIFICATIONS FOR GROUTING OF POST-TENSIONED CABLES IN PRESTRESSED CONCRETE

1. GENERAL

1.1. The recommendations cover the cement grouting of post-tensioned tendons of prestressed concrete members of bridges. This also covers some of the essential protective measures to be adopted for minimising corrosion in PSC bridges.

1.2. The purpose of grouting is to provide permanent protection to the post-tensioned steel against corrosion and to develop bond between the prestressing steel and the surrounding structural concrete. The grout ensures encasement of steel in an alkaline environment for corrosion protection and by filling the duct space, it prevents water collection and freezing.

2. MATERIALS

2.1. Water

Only clean potable water free from impurities conforming to section 1000 shall be permitted. No sea or creek water is to be used at all.

2.2. Cement

Ordinary Portland cement should be used for preparation of the grout. It should be as fresh as possible and free of any lumps. Pozzolana cement shall not be used.

2.3. Sand

It is not recommended to use sand for grouting of prestressing tendons. In case the internal diameter of the ducts exceeds 150 mm, use of sand may be considered. Sand, used, shall conform to IS:383 and shall pass through IS Sieve No. 150. The weight of sand in the grout shall not be more than 10 per cent of the weight of cement, unless proper workability can be ensured by addition of suitable plasticizers.

2.4. Admixtures

Acceptable admixtures conforming to IS:9102 may be used if tests have shown that their use improves the properties of grout, i.e. increasing fluidity, reducing bleeding, entraining air or expanding the grout. Admixtures must not contain chlorides, nitrates, sulphides, sulphites or any other products which are likely to damage the steel or grout. When an expanding agent is used, the total unrestrained expansion should

not exceed 10 per cent. Aluminum powder as an expanding agent is not recommended for grouting because its long term effects are not free from doubt.

2.5. Sheathing

2.5.1. For specifications of sheathing, section 1800 may be referred

2.5.2. Grout openings or vents

a) All ducts should have grout openings at both ends. For this purpose special openings should be provided where such openings are not available at end anchorages. For draped (curved) cables vents shall be provided at all crown and valley points. It is a good practice to provide additional air vents at suitable intervals not exceeding 20 m. All grout openings or vents should include provisions for preventing grout leakage.

b) Standard details of fixing couplers, inlets, outlets and air vents to the duct/anchorage shall be followed as recommended by the supplier of the prestressing system.

2.5.3. Ducts should be securely fastened at close intervals. All unintended holes or openings in the duct must be repaired prior to concrete placing. The joints of the couplers and the sheathing should be made water proof by use of adhesive tape or similar suitable system capable of giving leak proof joints. Grout openings and vents must be securely anchored to the duct and to either the forms or to reinforcing steel to prevent displacement during concreting operations due to weight, buoyancy and vibrations.

2.5.4. Ducts require very careful handling as, being of thin metal, they are susceptible to leakage due to corrosion in transit or storage, by tearing/ripping in handling particularly when placed adjoining to reinforcing steel, by pulling apart at joints while inserting tendons prior to concreting, or by accidental puncturing while drilling for form ties/inserts. Ducts are also liable to damage by rough use of internal vibrator and sparks from welding being done close by.

3. EQUIPMENT

3.1. Grout Mixer and Agitator

It is essential that the grout is maintained in a homogeneous state and of uniform consistency so that there is no separation of cement. Use of grout mixers to obtain a colloidal grout is essential. The mixer should have an additional storage device with an agitator to keep the grout moving continuously before it is pumped in the duct. Positive reciprocating type grout pumps should be used.

3.2. Grout Pump

The pump should be a positive displacement type and should be capable of ejecting the grout in a continuous operation and not by way of pulses. The grout pump must be fitted with a pressure gauge to enable pressure of injection to be controlled. The minimum pressure at which grout should be pumped shall be 0.3 MPa and the grout pump must have a relief arrangement for bypass of the grout in case of build up of pressure beyond 1 MPa. The capacity of the grout pump should be such as to achieve forward speed of grout of around 5 to 10 metres per minute. The slower rates are referable as they reduce the possibility of occurrence of voids. If the capacity of the pump is large, it is usual to grout two or more cables simultaneously through a common manifold.

Use of hand pumps for grouting, is not recommended. Use of compressed air operated equipment for injection is prohibited, as it is likely that there will be some air trapped in grout.

3.3. Water Pump

Before commencement of grouting, a stand by direct feed high pressure water pump should be available at site for an emergency. In case of any problem in grouting the ducts, such pump shall immediately be connected to the duct and all grout flushed by use of high pressure water flushing. It is, therefore, necessary to have adequate storage of clean potable water for operation of the water pump for such emergencies.

3.4. Grout Screen

The grouting equipment should contain a screen having a mesh size of 106 micron size of 150 microns if sand is used). Prior to introduction into the grout pump, the grout should be passed through such screen. This screen should be easily accessible for inspection and cleaning.

3.5. Connections and Air Vents

Standard details of fixing inlets, outlets and air vents to the sheathing and/ or anchorage should be followed as recommended by specialist supplier of the system of prestressing. In general, all connections are to be of the "Quick couple" type and at change of diameters suitable reducers are to be provided.

4. PROPERTIES OF THE GROUT

4.1. Water/cement ratio should be as low as possible, consistent with workability. This ratio should not normally exceed 0.45.

4.2. Before grouting, the properties of the grout mix should be tested in a laboratory depending on the facilities available. Tests should be conducted for each job periodically. The recommended test is described below.

4.3. Compressive Strength: The compressive strength of 100 mm cubes of the grout shall not be less than 17 MPa at 7 days. Cubes shall be cured in a moist atmosphere for the first 24 hours and subsequently in water. These tests shall be conducted in advance to ascertain the suitability of the grout mix.

5. MIXING OF GROUT

5.1. Proportions of materials should be based on field trials made on the grout before commencement of grouting, but subject to the limits specified above. The materials should be measured by weight.

5.2. Water should be added to the mixer, first, followed by Portland cement and sand, if used. Admixture if any, may be added as recommended by the manufacturer.

5.3. Mixing time depends upon the type of the mixer, but will normally be between 2 and 3 minutes. However, mixing should be for such a duration as to obtain uniform and thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixtures. The grout should be continuously agitated until it is injected.

5.4. Once mixed, no water shall be added to the grout to increase its fluidity.

5.5. Hand mixing is not permitted.

6. GROUTING OPERATIONS

6.1. General

a) Grouting shall be carried out as early as possible but not later than 2 weeks of stressing a tendon. Whenever this stipulation cannot be complied with for unavoidable reasons, adequate temporary protection of the steel against corrosion by methods or products which will not impair the ultimate adherence of the injected grout should be ensured till grouting. The sealing of the anchorage ends after concreting is considered to be a good practice to prevent ingress of water. For structures in aggressive environment, sealing of the anchorage ends is mandatory.

Notes :

i) Application of some patented water soluble oils for coating of steel/VPI powder injection/ sending in of hot, dry, oil-free compressed air through the vents at frequent intervals have shown some good results.

ii) Some of the methods recommended for sealing of anchorages are to seal the openings with bitumen impregnated gunny bag or water proof paper or by building a brick pedestal plastered on all faces enclosing the exposed wires outside the anchorages.

iii) Any traces of oil if applied to steel for preventing corrosion should be removed before grouting operation.

iv) Ducts shall be flushed with water for cleaning as well as for wetting the surfaces of the duct walls. Water used for flushing should be of same quality as used for grouting. It may, however, contain about 1 per cent of slaked lime or quick lime. All water should be drained thorough the lowest vent pipe or by blowing compressed air through the duct.

v) The water in the duct should be blown out with oil free compressed air.

Blowing out water from duct for cables longer than 50 m draped up at both ends by compressed air is not effective, outlet/ vent provided at or near the lowest point shall be used to drain out water from duct.

vi) The connection between the nozzle of the injection pipe and duct should be such that air cannot be sucked in.

vii) All outlet points including vent openings should be kept open prior to commencement of injection grout.

viii) Before grouting, all air in the pump and hose should be expelled. The suction circuit of the pump should be air-tight.

6.2. Injection of Grout

a) After mixing the grout should be kept in continuous movement.

b) Injection of grout must be continuous and should not be interrupted.

c) For vertical cable or cables inclined more than 60 degrees to the horizontal, injection should be effected from the lowest anchorage or vent of the duct.

d) The method of injection should ensure complete filling of the ducts. To verify this, it is advisable to compare the volume of the space to be filled by the injected grout with the quantity of grout actually injected.

e) Grouting should be commenced initially with a low pressure of injection of upto 0.3 MPa increasing it until the grout comes out at the other end. The grout should be allowed to flow freely from the other end until the consistency of the grout at this end is the same as that of the grout at the injection end. When the grout flows at the other end, it should be closed off and building up of pressure commenced. Full injection pressure at about 0.5 MPa shall be maintained for at least one minute before closing the injection pipe. It is recommended practice to provide a stand pipe at the highest point of the tendon profile to hold all water displaced by sedimentation or bleeding. If there is a built up of pressure much in excess of 1 MPa without flow of grout coming at the other end, the grouting operation should be discontinued and the entire duct flushed with high pressure water. Also, the bypass system indicated in para 3.2 above is essential for further safety.

f) In the case of cables draped downwards e.g. in cantilever construction simultaneous injection from both ends may be adopted Fig. 1800/III-1.

g) Grout not used within 30 minutes of mixing should be rejected.

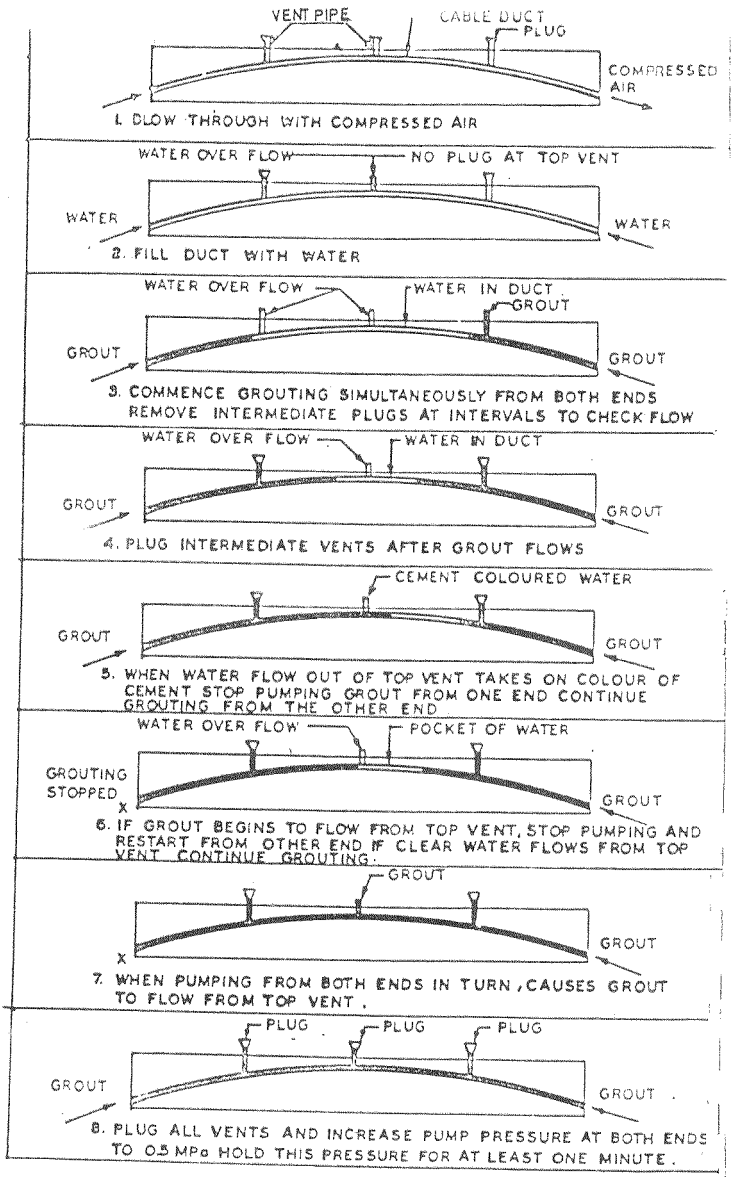

Fig. 1800/III-1 : Procedure for Grouting of Cables Draped Downwards

GROUTING RECORD

Job Name: _____

Span No. _____ Cable No: _____

Date of Cable Installation: _____ Date of Grouting: _____

Type of Cement: OPC/HSOPC

Week and Year of Manufacture of OPC/HSOPC

W/C Ratio:

Name and amount of admixture used, if any _____

Temperature: Mixing water _____ ; Grout _____

Time: Start _____ ; Finish _____

Equipment: Grout mixer _____ ; Grout pump _____

Cable duct: Diameter _____ ; Length _____

Volume of grout in litres _____ ; Regrouting _____

Grouting pressure _____ :

Cement consumption: Theoretical _____ ; Actual _____

Pre-grouting checks:

Free of blockage: Inlet: Yes/No ; Outlet : Yes/No

Vents: Yes/No ; Cable duct : Yes/No

Leakage observed: Yes/No ; Sealed : Yes/No

If cable duct blocked: Remedial Measures _____

Grouting observations:

Passage of grout through vents : Yes/No

Passage of grout through outlet : Yes/No

Any equipment failure : _____

Post grouting checks :

Probbing by stiff wire : _____

Remarks : _____

Signatures of officers present during grouting:

Client Contractor System Supplier

h) Disconnection is facilitated if a short length of flexible tube connects the duct and injection pipe. This can be squeezed and cut off after the grout has hardened.

7. PRECAUTIONS AND RECOMMENDATIONS FOR EFFECTIVE GROUTING

a) In cold and frosty weather, injection should be postponed, unless special precautions are taken. If frost is likely to occur within 48 hours after injection, heat must be applied to the member and maintained for at least 48 hours after injection so that the temperature of the grout does not fall below 5 degrees Celsius. Prior to commencement of grouting, care must be taken to ensure that the duct is completely free of frost/ice by flushing with warm water, but not with steam.

b) The temperature of the grout shall not exceed 25 degrees Celsius. For increasing the workability of grout, its temperature may be lowered by use of chilled water or by putting ice outside the grout storage container.

c) When the cables are threaded after concreting, the duct must be temporarily stiffened during concreting by inserting bunch of strands, wires or reinforcement or a rigid PVC pipe or any other suitable method.

d) During concreting, care shall be taken to ensure that the sheathing is not damaged. Needle vibrators shall be used with extreme care by well experienced staff only, to ensure against such damage.

e) It is a good practice to move the cables in both directions during the concreting operations. This can easily be done by light hammering the ends of the wires/ strands during concreting. It is also advisable that 3 to 4 hours after concreting the cable should be moved both ways through a distance of about 20 cms. With such movement, any leakage of mortar which has taken place in spite of all precautions, loses bond with the cables, thus reducing the chance of blockages. This operation can also be done by fixing prestressing jacks, at one end pulling the entire cable and then repeating the operation by fixing the jack at the other end.

f) The cables to be grouted should be separated by as much distance as possible.

g) In case of stage prestressing, cables tensioned in the first stage should not remain ungrouted till all cables are stressed. It is good practice, while grouting any duct in stage prestressing, to keep all the remaining ducts filled up with water containing 1 per cent lime or by running water through such ducts till the grout has set. After grouting the particular cable, the water in the other cables should be drained and removed with compressed air to prevent corrosion.

h) Care should be taken to avoid leaks from one duct to another at joints of precast members in particular.

i) End faces where anchorages are located are vulnerable points of entry of water. They have to be necessarily protected with an effective barrier. Recesses should be packed with mortar concrete and should preferably be painted with water proof paint.

j) After grouting is completed, the projecting portion of the vents should be cut off and the face protected to prevent corrosion.