

C4.1 Post- Tensioning

Prestressing steel may be tensioned by means of hydraulic or mechanical jacks. Devices attached to the tensioning apparatus for measuring the applied force shall be such that they do not introduce errors exceeding 5 percent. Jacking Force normally should not exceed 76.5% of the Breaking Load.

Before commencement of prestressing, it should be ensured that all the Cables/Ducts are free of any clogs and that the structure–members are free to accommodate the horizontal and vertical movements due to application of prestress, and that there is enough space for the movement of the jack piston.

Prestressing cables shall be protected against any unacceptable rusting, damage due to 'pitting', and any greasing. The strands must be thoroughly cleaned with petrol at locations where Stressing Jacks and Wedges have to grip them.

Each Cable shall be stressed from both its ends simultaneously, equally and gradually, and the extensions recorded at each suitable increment of Jacking Force. Any slack in the prestressing tendon shall first be taken up by applying a small initial tension. The initial tension required to remove slackness shall be taken as the starting point for measuring elongation. Further increase of tension shall be carried out in suitable steps and corresponding elongations noted. The 'force-elongation' relationship shall be recorded in tabular and/or graphical form. The magnitude of initial effective elongation corresponding to initial tension applied to remove slackness shall be obtained from the recorded and linearized portion of measured tension elongation relationship and added to the measured elongation to give the total elongation.

Alternatively, the same correction can be carried out graphically as shown in Fig. 4.1.

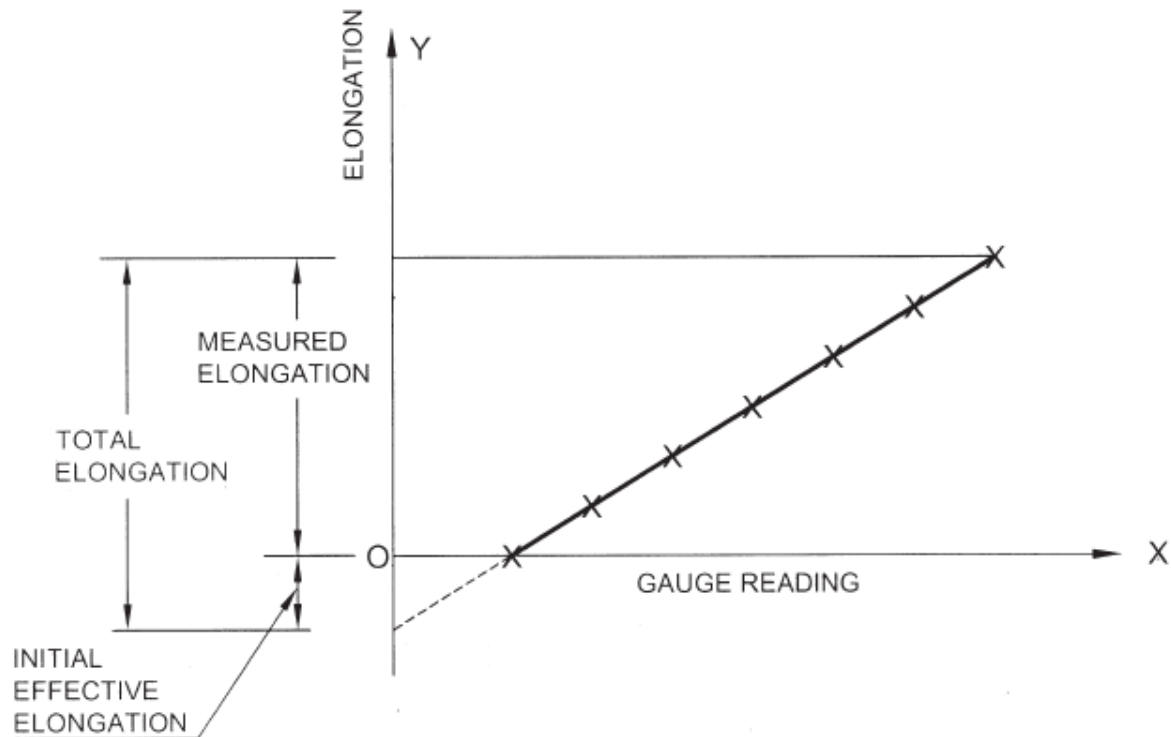


Figure 4.1 Determination of Actual Elongation

In practice, the force and elongation of tendon may not exactly match with the expected values given in stressing schedule. In such cases either the force (or the elongation) will be achieved first and the other value lag behind. In such cases the force (or elongation) shall be further increased, but not exceeding 5 percent of the design value till the elongation (or force), which had lagged behind reaches the design value. If, even after reaching 5 percent extra value of the force (or elongation), the other lagged quantity does not reach the design value, reference should be made to the designer for review and corrective action.

When two or more prestressing wires or strands are to be tensioned simultaneously by the same tensioning apparatus, care shall be taken to ensure that all such tendons are of the same length from grip to grip.

Guideline for Quality Management for Concrete Bridges

The placement of tendons and the order of stressing and grouting shall be so arranged that the prestressing steel, when tensioned and grouted, does not adversely affect the adjoining ducts.

The Cable Elongations at their Jacking-Points, mentioned in the drawing, are based on the assumption that the Modulus of Elasticity of Cable-steel, E_{sd} , (generally 1.95×10^5 MPa (i.e. 1.988×10^6 kg/cm²)). However, if E_{sd} of the actually supplied Cable-steel at site is slightly different, then the required Elongations at each end shall be re-worked out at site by multiplying the specified values by the ratio of (assumed E_{sd} / actual E_s), and these shall then be the 'correct' specified extensions.

Tensioning of Prestressing Cables:

Normally, the specified required extensions shall be achieved at the specified Jacking Forces at stressing ends.

Check the correct functioning of the jack, pump and leads.

The difference between calculated and observed tension and elongated during pre-stressing operations shall be regulated as follows:

- a) If the calculated elongation is reached before the specified gauge pressure is obtained, continue tensioning till attaining the specified gauge pressure, provided the elongation does not exceed 1.05 times the calculated elongation. If 1.05 times the calculated elongation is reached before the specified gauge pressure is attained, stop stressing and inform the Engineer.
- b) If the calculated elongation has not been reached at the specified gauge pressure, continue tensioning by intervals of 5 kg/sq. cm. until the calculated elongation is reached provided the gauge pressure does not exceed 1.05 times the specified gauge pressure.
- c) If the elongation at 1.05 times the specified gauge pressure is less than 0.95 times the calculated elongation, the following measures must be taken, in succession, to determine the cause of this lack of discrepancy:
 - (i) De- tension the cable. Slide it in its duct to check that it is not blocked by mortar which has through holes in the sheath. Re- tension the cable if free.
 - (ii) Re-establish the modulus of elasticity of steel for the particular lot from an approved laboratory.

If the required elongation is still not obtained, further finishing operations such as cutting or sealing, should not be undertaken without the approval of the Engineer.

When stressing from one end only, the slip at the end remote from the jack shall be accurately measured and an appropriate allowance made in the measured extension at jacking end. Extensions should also be checked 24 hours after anchoring the cables to guard against the possibility of 'slow slipping', if any. If the average observed 'slow slip' at anchorages of a cable exceeds 3mm, the matter should be reported to the Designer for any further instructions.

All cables which satisfy the above provisions shall be grouted, taking care that the cables not yet stressed do not get accidentally blocked due any internal grout leak.

The number of stages of pre-stressing and grouting shall be reduced to a minimum, 2 in the case of simply supported girders.

The Sequence of Stressing of Cables shall be as indicated in the attached relevant Prestressing Drawing and the prestressing shall be accomplished accordingly. First Stage Cables i.e. PS-I cables shall be stressed in their indicated sequence when the last cubic meter of concrete in the deck-slab has attained a work's cube crushing compressive strength of at least 40 N/mm² and is more than 10 days old (after the day of its casting).

Cables of PS-II shall be stressed in their indicated sequence when concrete in the deck slab has attained a works cube crushing compressive strength of higher of least 45N/mm^2 or designed concrete strength and is at least 28 days old (after the day of its casting).

After completion of stressing and anchoring a cable, the Jack Force shall be released in such a way so as to avoid shock to the anchorage and the cable.

A complete record of pre-stressing operations along with elongation and jack pressure data shall be maintained in the approved format.

An appropriately experienced Technical representative of the Supplier of Prestressing system shall carry out and supervise all Prestressing and Grouting Operations at site and ensure, monitor and certify their correctness.

C4.2 Grouting the Ducts of Successfully Tensioned Cables

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.

Prestressing steel shall be bonded by the Grout to the concrete by filling the void space between the duct and the tendon with cement grout.

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°C . Prior to commencement of grout, care must be taken to ensure that the duct is completely free of frost/ice by flushing with warm water, but not with steam.

When the ambient temperature during the day is likely to exceed 40°C , grouting should be done in the early morning or late evening hours.

When the cables are threaded after concreting, the duct must be temporarily protected during concreting by inserting a stiff rod or a rigid PVC pipe or any other suitable method.

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 the above requirements.

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.

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

In case of stage prestressing, cables tensioned in the first stage should not remain ungrouted till all cables are stressed. It is a good practice, while grouting any duct in stage prestressing, to keep all the remaining ducts filled up with water containing 1% 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.

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.

For this purpose each cable shall normally be Grouted within 5 days of completion of its successful tensioning unless specific requirements require delaying it till certain other cables are first successfully stressed. Grouting shall be carried out as early as possible but not later than 2 weeks of stressing a tendon.

The Grout shall consist of Ordinary Portland Cement, Water, and an Expansive Admixture(approved by the Engineer. All grout shall pass through a screen with 2 mm maximum clear openings prior to being introduced into the grout-pump. No admixtures containing chlorides and nitrates shall be used.

The Grout shall be mixed in mechanical mixing equipment of a type that will produce uniform and thoroughly mixed colloidal grout. The water content shall not be more than 24 litres per 50 kg sack of cement. Retempering of grout shall not be permitted. Grout shall be continuously kept agitated until it is pumped in.

Grouting Equipment shall be furnished with a pressure gauge having a full-scale reading of upto 20 Kg/cm² (2 MPa) and it shall be capable of grouting at a pressure of at least 10 Kg/cm² (1 MPa).

If the expansive Admixture (other than Aluminium compound) is used to expand the Grout, it shall be added strictly as per Manufacturer's instructions. The ducts shall be completely filled, from the low end, with grout, under NOT MORE THAN 7 kg/cm² pressure. Grout shall be pumped through the duct and continuously wasted at the outlet until no visible slugs of water or air are seen. All vents shall then be closed, and the grouting pressure at the injection–end raised to 10 kg/cm² and held for a minimum of 10 seconds before closing the hole in the cable–anchorage at the injection–end.

If some delays in Grouting are unavoidable (e.g. due to sequence of construction planned), temporary protection against corrosion shall be provided by ventilating the Ducts with dry/hot air, since any humid conditions contribute considerably to acceleration of corrosion of cable–steel.