PRESTRESSED CABLE ANCHOR

Mr. K.M. MANOJ, M.E.,*[1], P.KARTHICK*[2]

[1*] *Assistant Professor, Department of Civil Engineering, Dr. N.G.P* Institute of Technology, Coimbatore, *Tamil nadu, India.*
[2*] *UG Student, Department of Civil Engineering, Dr.N.G.P.Institute of Technology, Coimbatore, Tamilnadu, India.*

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Abstract - *The slopes are most common sub-aerial landforms on the surface of the earth. Slopes either occur naturally or engineered by humans. The slope stability problems have been faced throughout history when nature or human has disrupted the delicate balance of natural soil slopes. Also, with the increasing demand of cuts or fills of slopes on construction projects has increased the need to understand analytical methods, investigative tools, and stabilization methods to tackle slope stability problems. Further with the advancement of slope stability analysis in geotechnical engineering has followed the development in soil and rock mechanics as a whole. In this project slope stability problem is tackled by prestressed cable anchor.*

Key Words*: *cable anchor, anchorage system, slope failures, stressing, grouting.

1. INTRODUCTION

1.1 General

The stability of slopes and rock faces is normally lost due to natural phenomena such as natural causes and human intervention. Mainly equilibrium disturbances in the slopes are associated with the construction of roads, major structures. Major structure in Tehri terrain covers construction of Hydro-Power Projects to harness the available potential to the demand of electricity in the country. Therefore, the stabilization of slopes for the construction of new Hydro Projects in Tehri dam is a challenge for engineers.

Normally in hilly terrain the protection of slopes is generally achieved by placing Wire crates or constructing retaining walls including proper drainage arrangement, rock bolts, anchors depending upon magnitude and nature of structure. Nowadays, Prestressed Anchors for stabilization of slopes are being used to facilitate the different construction activities in major projects on adverse geological sites.

1.2 Slope failures around hydro projects in India

For the generation of electricity, head (elevation difference) is very important. Therefore, most of the hydro power projects are located in hilly areas and there is a history of slope-failures especially where high relief topography coupled with other adverse factors such as complexly folded, faulted, and jointed rock formations are present. Also, there are evidences that many slope failures in Himalayas have occurred without man's intervention as a natural process. The following Hydro-Electric projects have been affected by mass movement processes (Bhatt and Vipin, 1992).

(i) Loktak Hydel Project slide, Manipur.
(ii) Chineni Hydel Project slides. Distt. Udhampur, J&K.
(iii) Pair and Tanger slides around proposed reservoir of Sawalkot Project, J&K.
(iv) Lower Jhelam Hydro project slide, Distt. Baramullah, J&K.
(v) Baira Siul Hydel Project slide, (H.P.)

1.2 Scope and objective

In this project the construction procedure of prestressed anchors for stabilization of slopes under different geological conditions have been reviewed. Different types of prestressed anchors suitable with site conditions have been described. The important design parameters of anchors related with strength, economics and performance have been discussed. Special emphasizes have been laid upon bond characteristics, corrosion protection requirements and stressing of anchors. Evaluation of important parameters such as fixed and free length of anchors has been discussed.

2. METHODOLOGY

The work was carried out by the following order.

- Site investigation
- Site clearance
- Drilling
- Water penetration test
- Anchor installation
- Anchor grouting
- Stressing
- Final grouting.

3. STRESSING AND ANCHOR SYSTEM

3.1 Principle of stressing

Prestressing is a method of inducing known permanent stresses in a structure or member before the full or live load is applied. These stresses are induced by tensioning the High Tensile Strands, wires or rods, and then anchored to the member being Prestressed, by mechanical means.

The Prestressing counteracts the stresses, produced by subsequent loading on the structures, thereby extending the range of stresses to which a structural member can safely be subjected. This also improves the behavior of the material of which the member or structure is composed. For Example; The Concrete which has relatively a low Tensile strength, shall behave like a member having high tensile strength, after Prestressing.

The High Tensile wires/strands, when bunched together are called Cables. These cables are generally placed inside a cylindrical duct made out of either metallic or HDPE material. The Anchorages, one of the main components of the Prestressing activity, are used to anchor the H.T. Cable after inducing the Load. The whole assembly of the Anchorage and the H.T. Cable is named as 'TENDON'.

3.2 Anchorage system

Prestressing forces of the Tendons are transferred to the concrete structures through Anchorages. Anchorage for the Post Tensioning system normally comprises of a steel plates with a number of conical holes, the conical Grips and the Guide (Trumpet). Trumpet or Guide is used to connect the ducts and provides a flat surface for locating the Bearing Plate on it. As shown in the figure below:

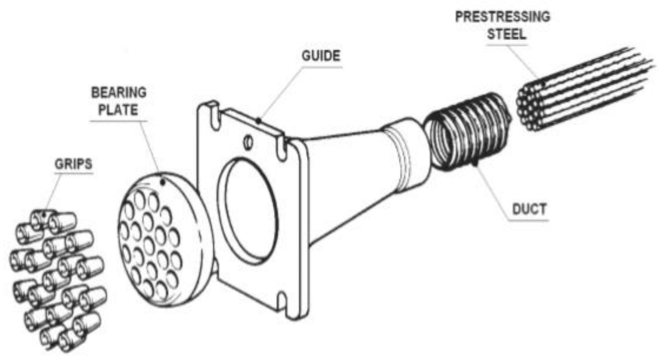

Fig 3.1

4. CONSTRUCTION EQIUPMENTS AND MATERIALS

4.1 Construction Equipment

- Drilling machine and compressor
- Grouting pump machine
- Grout mixer
- Flow cone
- Hydraulic jack and pump

4.2 Materials

- HT Strands
- HPDE Pipes
- Anchor head and wedges
- SWC Pipes
- Spacer
- Binding wires
- Grease
- Epoxy paint
- Bearing plate
- Quartz sand
- Cement
- Admixtures (Cebex 100)
- Endcap

5. DESIGN OF ANCHOR

5.1 General

In order to design the ground anchors, we have to consider some factors as recommended in IS: 10270 and BS 8081. The following data are required for design of anchors as per IS:

- Design load per anchor
- Service life of anchor
- Soil investigation.

The design of ground anchorages requires consideration of the following as per BS:

- Overall stability
- Depth of embedment
- Group effects
- Fixed anchor dimensions.

5.2 Required data

- Anchor capacity or pull-out capacity of the fixed anchor - Tf
- Diameter of the borehole - D
- UCS value from the geological report
- Ultimate bond stress or skin friction – ⍰ult
- Factor of safety – fos.

5.3 Calculation of fixed length

The fixed length of the anchor lies between 3m to 10 m. If the length exceeds 10m, the allowable anchor force will largely be decreased. The anchor power can be increases by enlarging the diameter, not by extending the fixed length.

5.3.1 Fixed anchor design in rock

The designs are based on the assumption of uniform bond distribution (Coates 1970), (Fargeot 1972), (Littlejohn 1972), (Mascardi 1973) and (White 1973). Thus, the pull-out capacity of the fixed anchor Tf, in kN, is estimated from the following equation:

TF = π D L ⍰ult

From this equation the fixed length is calculated,

L(FIXED) = TF x FOS/ π D ⍰ult

Where, T is the anchor capacity
FOS is the factor of safety
D is the diameter of the hole
⍰ult is the ultimate bond stress (10% of UCS)

The ultimate skin friction may be taken as 10 % of the unconfined compressive strength of the rock up to a maximum value ult of 4.0 N/mm2 (Clause 6.2.3.3 of BS 8081)

5.3.2 Calculation of free length

The free length can be calculated by trigonometric function

Free length = DEPTH / sinØ

6. FABRICATION OF TENDONS

Anchors will, according to requirement, be either assembled at site or can be fabricated at fabrication yard nearer to site. The anchor head and other components are stored inside suitable pallets or boxes to protect them against weather and climate. Anchors will not be laid directly on the ground and all necessary measures will be taken to avoid any damage to the anchors.

➢ All materials like HT Strands, Stressing Anchor are tested as per specification and brought to site.

➢ The HT Strands are loaded on to De-coiler with the help of the crane and then only the packing strips are cut. The central strand from the core of the strand bundle is pulled out.

➢ Permanent anchor fabrication process is to be done on an elevated platform at a covered storage area near site.

➢ A cutting bench is set up in a clean area.

➢ Before cutting, the test certificates of the strand bundle are verified and records are kept in the site office.

➢ **Cutting of strands:** Strands 15.24 mm dia from the coil, uncoiled from strands dispensers and rolled out on fabrication platform/ staging made for enough length to accommodate for assembly work.

➢ **Grouping and cleaning:** The cut strands are grouped according to the type of anchor and cleaned with thinner/ patrol for removal of thin oil coatings on strands.

➢ **Free length treatment**: Free length of strands is marked after cleaning, thin layer of grease applied all over free length until the bond breaker spacer provided. After application of the grease PE pipe of 20 mm dia with approx. 1 mm this is pushed over the pipes.

➢ **Securing the strand gripping length**: While treating the strands in free length care is taken to keep 1.5 m free length from greasing and encasing with PE pipes. These lengths later cleaned again before installation of stressing jacks for stressing activities.

➢ **Fixed length treatment**: Fixed length of strands 8 m are applied with 2 coats of epoxy-based resin + hardener (AW 106 + HV 953) or equivalent. During the setting time of second coat quartz sand (or clean sand free from MUD) is sprinkled on epoxy to form the surface of strands get roughened.

➢ **Assembly of strands**: Strands are assembled into the spacers at every 1m and a bond breaker spacer at the junction of free and fixed lengths of the anchor. Two grouting vent pipes one in the middle of spacers and one on external surface of HDPE corrugated pipes are provided to perform the two stage grouting works.

➢ **Anchor assembly**: Once the strands assembly completed in free and fixed with spacers, the whole assembly is inserted into the corrugated SWC HDPE pipe size (OD/ID) 120/103mm and secured with tie wires at specified intervals and bottom cap and spiral with trumpets are assembled and sealed. Centralizers are provided at every 1.5 m distances on outer surface of corrugated HDPE.

7. CONSTRUCTION PROCEDURE

7.1 Designing of preliminary test anchor locations

Choose a location for install a preliminary anchor as close as to the working Anchor area.

7.2 Excavation work

Prepare a safe, stable and flat ground to set up the drilling machine.

7.3 Drilling and flushing of boreholes

➢ Drilling operation will be carried out by crawler mounted drilling machine with casing drilling system if required.

➢ Drill hole of 150 mm will be drilled to the designed length of 15/20m at the specified locations as per drawing given.

➢ Water circulation method will be adopted to remove cutting slam.

➢ Temporary casing will be installed up to hard strata.

➢ Removal of casing will be carried out after the lowering of the Anchors and the completion of the grouting.

➢ After each hole has been drilled to its full length, it shall be thoroughly flushed out with either air or water to remove any loose materials inside.

Phase-1 **Drilling**

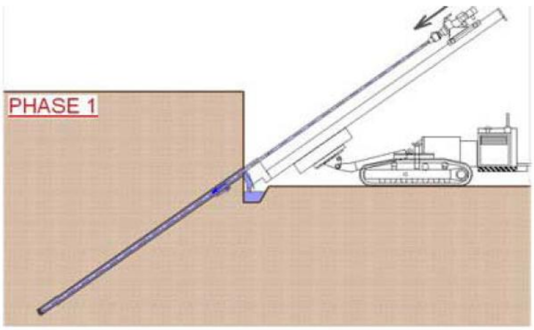

Fig 7.1

Phase-2 **Flusing And Cleaning Of Bore Holes**

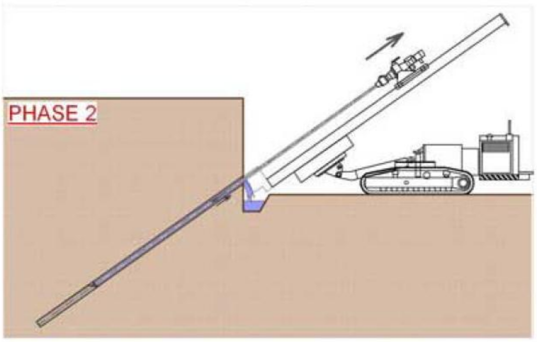

Fig 7.2

7.4 Water penetration test

In the fixed anchor length loss of grout from around the tendon can affect the corrosion resistance of steel along with load transfer efficiencies in the system. Therefore, anchorage length (fixed length) for all permanent anchors has to be tested for water proofing to minimize corrosion effect. In order to ensure that cement is lost in a fissure, the fissure dimension must be greater than 160 microns. Therefore, one fissure of this dimension and under an excess head of one atmosphere will result in a flow of 3.2 liters/min (Littlejohn, 1975), whereas a fissure width of 100 microns gives a flow of 0.6 liters/min/atmosphere. This establishes the variable nature of rocks and therefore it - becomes necessary to interpret the flow rates. The tests should be carried out over the fixed anchor length only with the use of packers. Now situation can arise with two rock types giving the same loss of water, yet one has a large fissure which can permit cement grout loss while the other is uniformly porous and will not permit grout loss.

7.4.1 Procedure

➢ In this test, first step packer installed in the drilled holes and packed as water cannot come outside.

➢There is a pipe in a packer for water to penetrate to the holes.

➢ Water meter is connected at the pipe which is present in packer.

➢ Then water is inlet with constant pressure using centrifugal pump which having pressure gauge.

➢ Note down the water penetration quantity for certain time using watermeter.

➢ Finally find the WPT value using formula.

**WPT VALUE = (WATER QUANTITY X 10)
/ (PRESSURE X TESTED LENGTH X TIME)**

➢ If WPT value is less than 3, then hole is ready anchor installation.

➢ If WPT value is 3 and greater than 3, then hole is not good for anchor installation. Here consolidation grouting is performed to strengthen the holes.

7.5 Installation of tendons

➢ The drilled hole is checked and flushed with compressed air to remove loose materials.

➢ The drilled hole depth is checked.

➢ The manufactured tendon along with central grout pipe is lowered.

➢ Installation of Anchor need 10 labor to lift up and install the tendon.

Phase-3 **Installation of anchor**

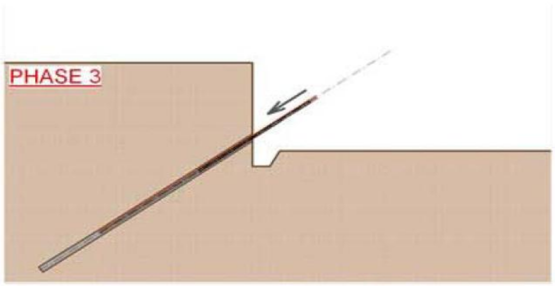

Fig 7.3

7.6 Grouting

7.6.1 Consolidation grouting

➢ This type of grouting is used for tightening the loose soil and fills the interconnected holes with grout. Initially this grouting is starts with ratio of 3:1 and vice versely 2:1, 1:1 and ends with water cement ratio of 0.40.

➢ This grouting is done by using packer.

➢ Pressure should be maintain constantly.

7.6.2 Anchor grouting

The purpose of grouting is to provide permanent bond in the fixed length of the tendon. This also helps in stabilizing drilled holes. Grout also fills up void spaces, expelling the water collection therein, if any.

a) Materials for Grouting
Water: Only clean water to be used.
Cement: Approved Ordinary Portland cement (OPC) Grade 53 will be used.
Admixture: suitable

b) Equipment for Grouting
i) Grout Mixer
➢ Grout mixer and colloidal mixing system which have a tank for the mixing and agitation.

➢ The tank is connected to a pump placed at the bottom of the mixer. The grout flow is distributed to the pump.

➢ Cement and water are mixed in the top tank in the water-cement ratio of 0.36 to 0.40.

➢ The mix is mixed properly in the tanks for about 2-3 minutes till a homogenous grout mix is obtained.

➢ After getting a proper mix this mixture is passed through to the high-pressure pump, pumping this to the anchor duct.

➢ A by-pass valve is fitted between the grout pump and the tendon inlet.

➢ The followings are the specifications of the grout mixer.
Capacity of mixing = 200 kg each time max/ 2 Bag lowest
Delivery of Pump = Approximately 300 L

c) Grout Mix Design – M35 Grade
The grout mix is prepared with on w/c ratio of 0.4 with 20.0 liters of water and 50 kg of Ordinary Portland Cement (OPC). Main parameters of the grout will be as follows:

Minimum strength of grout before stressing operations required is 30 N/mm2

Water cement ratio = 0.36 to 0.40
20.0 liters of water
50 kg of OPC
Non-shrink grout additives (Intraplast N-200 or cebex-100 or equivalent)

Tests Conducted on Grout Mix

Flow ability check: This is done using a Flow Cone Apparatus. The time taken for the flow of pre-measured quantity of grout is noted which shall be in the range of 5 to 30 seconds.

Compressive Strength: Grout cubes of size 100 mm x 100 mm x 100 mm are taken for different W/C ratios and the compressive strength is tested after 7 days & after 28 days. The test results of the grout shall have the following specifications.
Compressive Strength = not less than 27 MPa at 7 days.
Six nos. of 100mm x 100mm x 100mm cubes shall be taken each working day for compressive strength tests.

d) Grouting Operations
Step-1: At first stage grout will be injected to the grout hose inside the SWC pipe. After the required volume of grout pumped, first stage will be completed. Grouting is started with a low pressure. As the grout fills up and flows forward, the pressure increases.

Step-2: Second stage grouting is done by outer grout vent tube. The annular space between the SWC and drill hole will be filled completely with grout.

7.7 Stressing of tendons

➢ Stressing operations will not commence until the grout has attained the required crushing strength of 30 MPa or 7 days after grouting whichever is later.

➢ Place anchor head Plate to Bearing Plate.

➢ Place the anchor head centrally above the bearing plate opening the strands going through the follow.

➢ Place the hollow hydraulic jack, connected to a pump with pressure gauge indicator, centrally above the anchor head.

➢ Centralize the back-anchor block above the jack with back block wedges in place.

➢ Carry out the stressing of the tendon.

➢ The elongations are noted in a stressing format.

➢ After applying the designed force and recording the elongation properly, the strands are locked.

7.8 Prevention coating and final grouting

➢ The anchor blocks, strands, bearing plate and the wedges are applied with one layer of EPOXY coating.

➢ Two Grout tubes are fixed, one in the bearing plate and other in the anchor block. (Ensure whether the grout tube and anchor head protection cap is fully sealed).

Method of filling the empty space below the bearing plate

➢ After concrete has set. Then Start injecting grout from one of the grout tubes. When regular grout outflow appears at the other vents, close vents consecutively in the direction of flow.

➢ Grout must flow the outlet until entrapped air has been removed. When regular grout outflow appears at outlet, lock the grout vent and maintain the working pressure 3-5 Bar for approximately 30 ~ 60 seconds, the pressure should be constant before stopping the operation.

➢ Pressure should be duly controlled so as not to cause segregation of grout or any leakage internally.

8. APPLICATIONS AND ADVANTAGES

8.1 Applications

➢ Slope stabilization (Global Stabilization)
➢ Retaining system rehabilitation
➢ Uplift Resistant
➢ Deep Excavations
➢ Tie down system
➢ Stitching of parallel tunnels
➢ Strengthen and retention of the galleries of tunnels by balancing the forces of the adjoining area
➢ Vertical Prestressed Cable anchors improve dam's rollover resistance.

8.2 Advantages

➢ Control instability of slopes
➢ Suitable for all geological environments
➢ Deformations are minimized
➢ Higher Load capacities
➢ Can be designed for temporary system and be retrieved after work completion
➢ Suitable for all kind of facing systems
➢ Control risk of seismic load.

9. CONCLUSION

In this project, prestressed rock anchor is a high strength steel tendon, fitted with a stressing anchorage at one end and a means permitting force transfer to the grout and rock on the other end. The rock anchor tendon is inserted into a prepared hole of suitable length and diameter, fixed to the rock and prestressed to a specified force. The anchors shall be installed at the required inclination and to the required depth to resist the applied load in an efficient manner so that the tendon material is stressed to permissible levels and the ground in which it is embedded is also realistically stressed. The tendon is usually a high strength steel member (bar, wire or strand) surrounded by cement grout or other fixing agent. The tendon is protected against corrosion effects, otherwise the basic purpose of transferring the tensile force to ground will get defeated. The tensile force introduced through anchor system should maintain necessary equilibrium between the anchor, the structure to which it is attached and the ground in which the anchor is embedded so that the movements of the structure and the surrounding ground are kept to safe and acceptable levels.

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