Analysing the role of Cable Anchor in Hydroelectric project A case study

Abhishek Siwach[1], Monu Rajpoot[2]

[1] M.Tech Transportation Engineering, IIMT University Meerut (U.P.)
[2] Assistant Professor, Civil Department, IIMT University Meerut (U.P.)

Abstract: Purpose of this Scope Cable anchors are tensioned reinforcing elements of higher capacity, consisting of high strength steel tanden fitted with stressing anchorage (fixed length) at inner end, a means permitting force to be transferred, and a head on the rock/Hill surface at the external end. The cable anchors are used for stabilization of steep slopes or slopes consisting of softer soils as well as the enhancement of embankments or to prevent excessive erosion and landslides protection against slope stability failures.

The cable anchor is an advanced reinforcement device used in the integration of passive systems to withstand higher loads. Anchors transfer the tensile stress to the soil to absorb stresses due to effective stress loss. In geotechnical engineering, this is called "pre-tensioned post-tensioned grouted soil anchors". Ground anchors can be made from high quality steel rods using wire or cable anchors. The total length of the rod/wire strip is divided into free length and fixed length. The forces are transmitted to the ground through the bond length/fixed length. The depth of the anchor can be varied to achieve end retention and the desired coefficient of friction to withstand the tensile stress. High performance drilling rigs are used for accurate and stable drilling in dry and wet conditions. Anchors are classified based on the injection technique, the injection method is crucial because it determines the strength of the anchor in the soil and its performance. It is determined by geotechnical engineering survey.

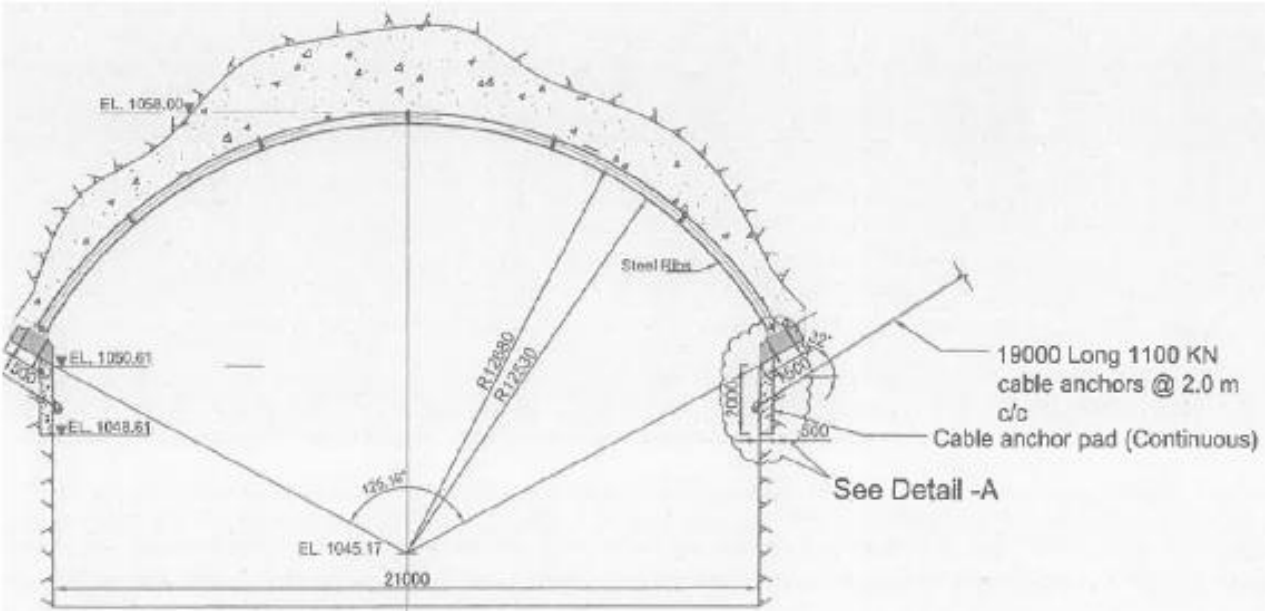
This project involves slope stabilization using a anchor system , Before anchoring work at location , significant soil conditions in the area must be established. The construction and design work of anchoring and grouting is explained as clearly as possible in this project, as well as the difficulties associated with their work..

Keywords: Cable anchor, landslides, tensioned, drilling rigs , Technical specification , Chainage , geotechnical engineering.

I-Introduction.

The stability of slopes and rock surfaces is usually lost due to natural phenomena such as water intrusion, freezing and thawing or erosion. However, in certain cases the stability of slopes is affected by changes in land slopes or loading conditions caused by human activities. Therefore, the slopes have an imbalance due to natural causes and human activities. Mainly, slope imbalances are related to road construction, large buildings or extensions of existing systems. The large structure located in the Himalayan landscape involves the construction of hydropower projects to utilize the existing potential to meet the high electricity needs of the country. Projects for sites with difficult geology are underway or will be built in the near future, as most of the easier sites have been built. Hence stabilization. building slopes to build new hydro projects in the Himalayas is a challenge for engineers.

The hilly terrain in Himalayan Region falls in the category of youngest mountains and needs protection measures, most of the time, whenever some construction is performed for the desired cut in the slopes. These young mountains having fragile geology are still on the verge of their formation and are not stable as compared with southern mountains of India. The construction activities in hilly terrain mostly require cutting or filling in the slopes for the construction of building, road or any other civil structure. After any cutting or filling, slopes shall be examined for stability and protection measures, if necessary, are implemented. The excavated slopes are frequently of considerable extent and in certain circumstances can even affect the stability of adjacent zones and particularly slopes and rock faces situated above them.



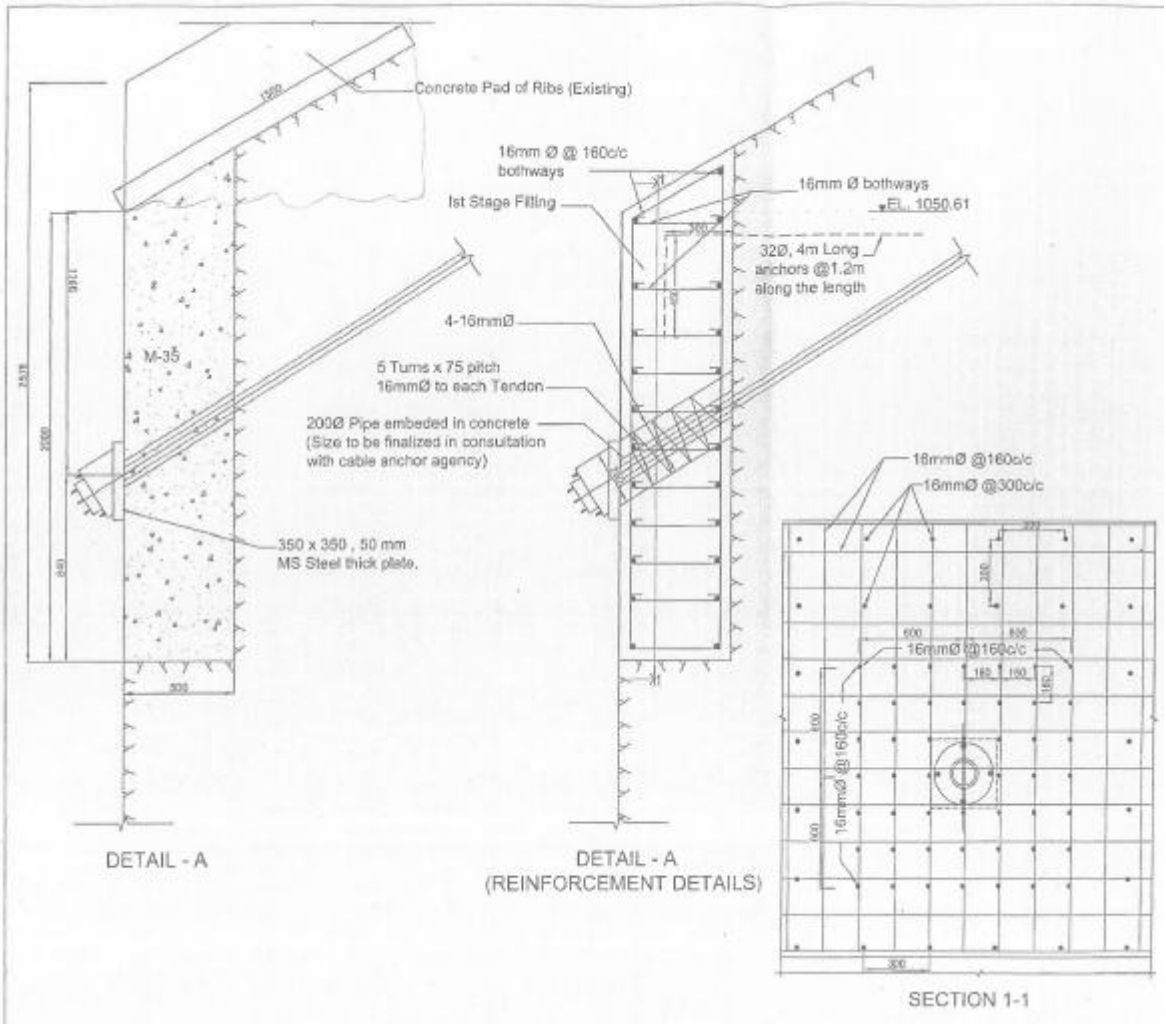
Typical section drawing

Methodology

The powerhouse excavation stages constitute central pilot and side slashing for 8.5m height followed by benching works. During the excavation of powerhouse cavern i.e. Pilot and side slashing works the poor rock conditions is encountered. The cable anchors are proposed to be installed on both sides in poor rock condition encountered stretch. Cable anchors will be installed after consolidation grouting works completion of excavation of niche and casting of cable anchor pad. The excavation will be completed for benching.

The excavation level facilitates positioning of drill machine /jacking assembly for installing cable anchors. Further in order to avoid blasting effect, the bench blast is assumed to be taken up (No mucking till completion of cable anchors works). The excavation of recess/niche shall be completed to start the cable anchor concrete pad works. The excavation shall be done by hydraulic excavator with breaker attachment or manually by rock breakers / Jack hammers. The excavation of niche is described for understanding the construction sequence.

The specialized agency shall be engaged for carrying out cable anchor design and installation works including stressing and testing in all respect. After the suitability /lift off test, the cable anchors 320 upward angle at 2m c/c spacing 19 m long will be installed. The cable anchors fixing which is 1.16m below present concrete beam / rib bottom support level of stage 1a, b. The construction stages to be adopted for cable anchors installation works are detailed as under. The installation and test procedure from specialized agency to be referred during construction stage.



Cable anchor drawing

Anchoring works shall be taken up as under:

a) Preparation of niche

i. The cable anchor works constitutes RCC cable anchor pad 2m height, 0.5m thick with its bottom. The concrete pad is continuous.

ii. The excavation of 500mm niche/ recess 2m height inside rock profile at in vertical side shall be carried out per cycle.

iii. The rock support measures like shotcrete, rock bolt & wire mesh shall be completed progressively during the excavation. The excavation shall be taken up by mechanical earns i.e. Chiselling / by hydraulic excavator with breaker attachment / or manually by rock breakers / Jack hammers.

iv. The vertical side niche/recess of 2m length shall be taken up per cycle. The rock support measures like shotcrete, rock bolt & wire mesh shall be completed progressively.

b) Preparation of concrete pads

i. Niche of size 2m liner length x 0.5m deep x 2m height shall be completed/cycle.

ii. Although the RCC concrete pad is continuous from the construction joint is planned at 20-21m length /pour to facilitate the casting sequence.

iii. Reinforcement binding & shuttering works shall be completed at niche locations. Proper care to be taken to be while fixing of inner/ rock side reinforcement.

iv. The pipe 200mm internal diameter at proper inclination and spacing shall be fixed & keep intact for cable anchor drilling works.

v. Casting for pad will be carried out by use of M35A20 grade concrete. The cable anchor concrete pad casting and start of cable anchor fixing activities shall be planned keeping suitable time period float. Refer methodology sketches attached.

c) Suitability test /Designing of preliminary anchor

i. Suitability test / Lift off test for preliminary anchor shall be designed based on the joint discussions. The various parameters shall be finalized based on the result.

d) Drilling of holes for cable anchors

i. The drilling will be carried out by drilling rig for 150mm diameter hole & 19m length. Compressor of suitable capacity will be used along with drill rig to provide necessary air pressure.

ii. Drilling shall be done by hydraulic rotary or suitable drilling method. The specialized drill bits shall be used. The hole shall be drilled by rotary method with water flush method with air.

iii. Holes shall be drilled with upward inclination as shown in GFC.

iv. Before starting drilling, alignment of drill rig feed will be properly set for carrying out drilling in required angle.

v. Based on strata, there may be possibility of collapse of holes. In such cases, partial drilling of holes, grouting the hole,re-drilling the hole shall be necessary.

vi. If required, water pressure test shall be carried out. If water loss is more than 3 lugeon consolidation grouting shall be carried out as per GFC drawing.

vii. It is assumed during the finalization of methodology that the grouting works as per GFC drawing shall be completed in advance prior to cable anchor works.

e) Fabrication and assembling of anchors

The anchors shall be fabricated over an elevated platform. Strand shall not be laid or dragged on soil or rough surface.

ii. The strand shall be cut by abrasive cutter. Stressing length shall be considered while cutting the strands. Cut strand of the required length as per anchor type

iii. Before applying first coat of epoxy, strands shall be cleaned thoroughly to remove oil, dust etc. if any exist.

The epoxy formulation in required mix proportion shall be applied to the entire length of strand before its setting time.

v. Upon application of epoxy coating the strand shall be allowed for drying.

vi. Second layer shall be applied over first layer and medium quartz or silica sand (as applicable) shall be sprinkled on the strand before setting of epoxy.

vii. Anchor is then assembled properly by using spacers and internal grouting pipe plastic pipe is kept inside bundle of strand from top to bottom of anchor to enable proper grouting inside anchor.

viii. The end cap(shoe) is then fixed at the end of fixed length(bottom of anchor).

ix. The whole assembly will be protected in straight or coiled form as per site convenience until installation of anchors.

f) Installation of cable anchor assembly

i. The cable anchor assembly shall be lifted by suitable lifting device /machinery for placing in the hole.

ii. The cable anchor assembly will be taken to the respective hole & will be placed slowly in the hole. The care should be taken while insertion so that cable anchor assembly including grouting pipe gets fit in to the hole.

g) Grouting of anchors

i. The grouting inside the cable anchor shall be carried out from assembly area.

ii. Mai grout pump shall be used for carrying out grouting.

iii. Grout pressure and water to cement ratio shall be maintained as per specification or as mentioned in GFC drawings or recommendation of agency.

iv. The required tests like flowability, shrinkage, bleeding and compressive strength

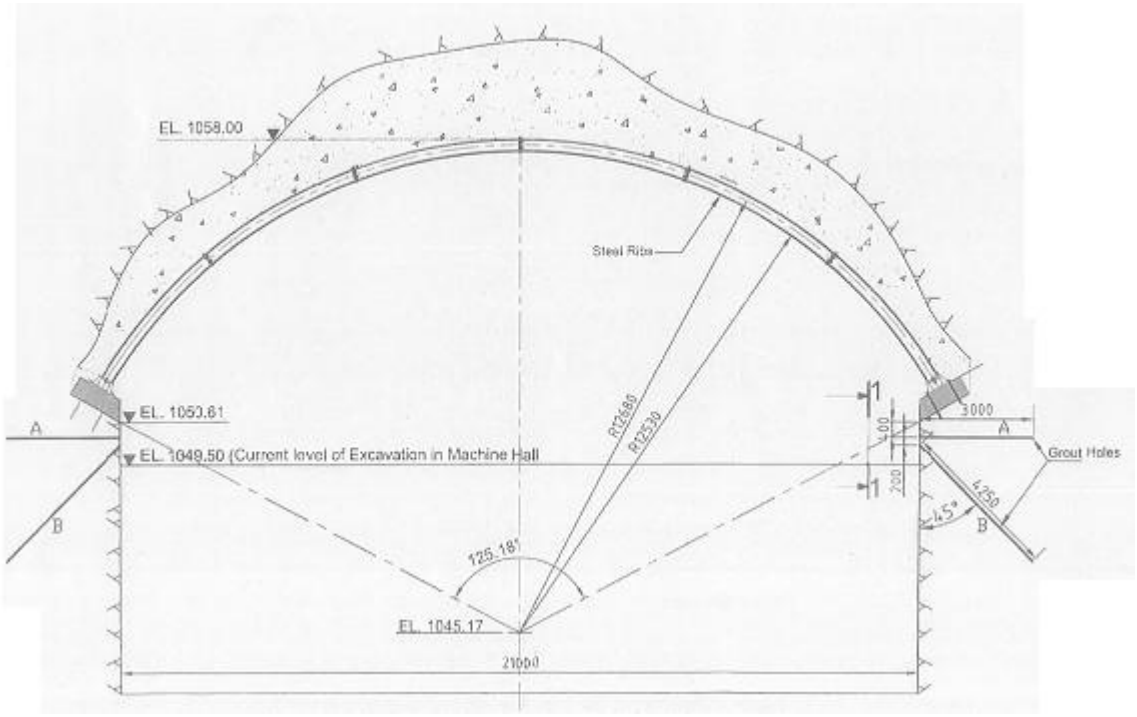
v. Admixture will be used for forming better quality of grout mix.

vi. Outlet of grout pump shall be connected to the internal grouting tube/single wall corrugated pipe.

vii. First stage grouting operation shall be continued till grout start oozing out from the anchor assembly.

viii. After completion of grouting at one anchor assembly area the connections shall be removed and fixed at next assembly anchor grouting tube location. The 2nd stage grouting shall be completed to fill the annular space between single wall corrugated pipe and drilled hole.

ix. To check the grout strength, required number of cubes shall be cast for each day of grouting operation.



Consolidation grouting

h) Mounting of jack

i. Jack of suitable capacity as per design requirement shown in GFC drawing will be used for tensioning of the anchor assembly.

ii. The jacking length of strands will be considered required for suitable jack as per anchorage system.

iii. Extra length of anchor shall be considered for jacking purpose above the face of the anchor head as per GFC drawings/requirement to place jack.

iv. Strands at anchor head area cleaned to remove dust and oil if any.

v. Bearing plates are installed over strand and then pushed so that it touches the thrust plate.

vi. Push segment grips (permanent wedges) as per requirement on each strand shall be fixed in the slots of bearing plate.

vii. The jack will be mounted over strand and rear anchor block shall be fixed to the guide tubes.

viii. The wax to be a applied to master grips and shall be fixed to rear anchor block. The conical hole in the rear anchorage block shall be coated with wax.

ix. Based on requirement necessary platform for the personnel and equipment /tools shall be erected for easy access to the stressing point.

i) Stressing of anchors & acceptance test

i. Stressing operation shall be carried out after achieving required grout as strength mentioned in GFC drawing /Technical specification. The cylinder strength value of 30N/mm2 or 7 days period.

ii. Before starting the activity, it is ensured that hydraulic hoses are well connected to the pump and jack.

iii. Apply pressure to the jack up to designated first pressure interval,mark the reference point on the cable from a fixed reference (rear body of jack). Also, it is recommended to mark 2-3 strands for reference at the same distance. Increase the pressure to the next designated pressure interval and measure the elongation.

iv. The load applied on the anchor will be measured with pressure gauge mounted on the stressing pump.

v. The stressing operation shall be continued in stages till the final pressure and elongation are achieved. Stressing will be done by applying load at intervals and elongation will be recorded for checking as per criteria mentioned in the GFC drawings.

vi. Finally, the cable will be locked, and jack shall be released to first pressure interval and slip will be measured. Further, the jack will be released to 0 kg/cm2 for demounting. The third stage grouting will be completed based on requirement/procedure.

vii. The acceptance test shall be conducted as per GFC/TS condition at specified intervals. The behavior of cable anchor at test load and the deformation shall be observed for period of time in accordance with procedure established during suitability test.

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.

Shrinkage and Bleeding test : Grout mix is poured into a transparent beaker. Shrinkage and bleeding are measured and records maintained.

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.

Expansion = 2- 3 %

Bleeding at 3 hours = Max, 2 %, After 24 hrs – 0 %.

Six nos. of 100mm x 100mm x 100mm cubes shall be taken each working day for compressive strength tests.

Suitability Test:

1 test anchor up to 1.10 Times of working load or as specified your engineering team and followed by LIFT off test at lock off load will be carried out at the beginning of the project.

METHOD OF FILLING THE EMPTY SPACE BELOW THE BEARING PLATE

- After concrete has set. Then Start injecting grout from one of the grout tube. 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.

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.
- As per BS 8081-1989, All Anchors to be stressed for Acceptance test (1 cycle) test and locked at 80% of characteristic strength or 95% of the characteristic 0.1% proof strength stressed and locked with wedges and recorded.

7.3.5 Time cycle activities:

Excavation works

a) Surveying and profile marking

b) Preparation of niche surface for casting of cable anchor concrete pad

c) Excavation of niche portion

d) Rock support system

Cable anchor concrete pad casting works

a) Preparation of surface

b) Reinforcement works

c) Shuttering works

d) Inspection & checking works

e) Cable anchor pad concreting

Cable anchoring works

a) Lift off /suitability test

b) Drilling of hole for cable anchor fixing

c) Assembly of cable anchor at erection location

d) Insertion of cable anchors

e) Grouting through pipes /SWC

f) Jacking /stressing works

g) Grouting & testing works

SAFETY MEASURES:

(Personal Protective Equipment (PPE)

All persons engaged in the dumping area shall be provided with and wear the appropriate Personal Protective Equipment. At all times

- Safety Helmet
- Safety Footwear
- Safety Gloves
- Eye protector when grinding and grouting
- Ear protector when drilling

a) Safety Precautions during Drilling

- Ensure that insertion & extraction of temporary casing pipe are properly supervised by the supervisor.
- While drilling all drillers are required to wear safety helmets, safety shoes, safety goggles & ear protectors.
- Ensure proper connection of joints

b) Safety Precautions during Grouting

- Since any mistake in the operations of grouting can endanger life and limb of persons, only trained and experienced personnel shall be entrusted with carrying out these operations.
- All grout hoses and couplings will have sufficient high-pressure capacity to ensure proper grouting activity.
- Personnel shall wear safety shoes, helmet, and gloves during grouting operations.
- During grouting operations, protective eye goggles should be worn. Check the Snap coupling properly.
- All personnel engaged in operations where the danger of grout spray is present e.g. Mixing Grout should wear protective eyeglasses.
- If the grout enters into the eyes, it should be washed out with clean water and the patient to be taken immediately to an eye Doctor. A First aid kit containing clean water with spray syringe is kept at site.
- Grouting hose connections should be checked before grouting for any signs of damage.

c) Safety Precautions During Stressing

- Ensure all Jacks & Hydraulic connections are leak proof.
- Ensure all pressure gauges & jacks are calibrated properly at regular intervals
- and record available on site.
- No person shall place himself in the line of jacks while stressing.

Proper instruction of stressing with a caution sign is kept at the location of stressing and de-stressing.

8. TIME CYCLE

Sr No	Description	Unit	Value
	Number of cable anchors	nos	92.0
A)	**Cable Anchor**		
i)	Start chainage	m	35.0
ii)	Final chainage	m	125.0
iii)	Liner length	m	90
iv)	Spacing	m	2
v)	Number of rows	nos	1
vi)	Diameter of drilling hole	mm	150
B)	**Cable Anchor pad**		
i)	Length /cycle	m	2.0
ii)	Thickness	m	0.5
iii)	Height	m	2
iv)	Type		RCC
v)	Main reinforcement spacing 16 mm dia.	m c/c	0.16
vi)	Distribution reinforcement spacing 16 mm dia.	m c/c	0.16
vi)	Reinforcement quantity per cycle	kg	158.0
C)	**Grouting details**	m	
i)	Grouting pressure	bar	3 to 5
ii)	Grout type		Consolidation type
iii)	Proportion	W:C	0.36 to 0.6
D)	**Stressing criteria**		
i)	Bearing plate size	mm	350x350 x 50
ii)	Stressing load	KN	1100.0
iii)	Equipment		
iv)	Drilling		Drilling rig
v)	Cable anchor concrete pad		Concrete pump, Transit mixer
vi)	Grouting details		Grout pump assembly
vii)	Cable anchor fixing		Erection platform
viii)	Stressing /jacking		Hydraulic jack assembly

	Time cycle cable anchor pad w orks		
	Pour size		2m x 2m x 0.5m
i)	Preparation of surface	hrs	2
ii)	Reinforcement works	hrs	4
iii)	Shuttering works	hrs	2
iv)	Checking	hrs	2
v)	Concreting works	hrs	0.8
vi)	De-shuttering time	hrs	10
vii)	Total time	hrs	21.0
viii)	Contigency 10%	%	2.1
ix)	Total time	hrs	23.1
x)	Working time/day	hrs	20
xi)	Number of cycles /day	nos	0.87
xii)	Per day progress	m/day	1.73
xiii)	Time cycle for 2 m cable anchor pad casting	hrs	26.69
xiii)	Time cycle for 2 m cable anchor pad casting	hrs	30.84
xiv)	Number of cycles/day	nos	0.65
xvi)	Number of days per month	days	12.00
xvii)	Monthly progress	mtr	15.56
xviii)	Duration required for total casting	months	5.78
xix)	Duration required for total casting-say	months	6.00

Grouting Material and Admixture

The cement to be used for grouting is OPC obtained form approved manufacturer / supplier.

The admixture if required will be used. It is free of Alumina and is a plasticiser and a retarding agent having the following properties.

- Flowability at a given water / cement ratio.
- Reduction of bleeding water.
- Prevention of segregation in grouting.
- Retarding in the setting of grout.
- Expansion of grout.

Summary and final statement

Current research on prestressed anchor cables is mainly focused on the numerical analysis of the interaction mechanism between the anchor cables and the rock and soil masses, as well as the mechanical deformation of the anchor cables. There is little research on anchor cable pre-tension loss. This effect has a significant impact on the quality, safety and integrity of a construction or engineering project. The available methods for determining pre-tension loss in anchor cables are as follows. The first method is based on the use of available monitoring data to summarize the bias voltage law and perform a qualitative analysis of the loss characteristics. Another common method is based on laboratory tests that perform a full life cycle study of prestressed anchor cables. However, this method is subject to many ideal assumptions that are used to reduce the area to be studied when applying internal models. The third method is a process analysis based on the numerical simulation method. This method requires some idealized assumptions, and the analysis of bias loss over time has always been a significant obstacle to effective numerical simulation. To overcome the shortcomings of the aforementioned methods, this work used regression analysis of on-site monitoring data and the results of existing indoor studies to create a mathematical model of the loss of anchor cable pretensions over time based on comprehensive factors. This represents a significant improvement in the modeling of anchor cable pre-tension loss compared to previous work. In addition, this study found that the proposed model has a wide applicability and the basic concept of the model can be extended to other research methods. This statistically based mathematical modeling and optimization approach solves many of the challenges of accurately predicting anchor cable pre-tension loss.

IV-Conclusion.

- A pre-tensioned anchor is the best solution for stabilizing large slopes. To destabilize soil forces, it is not enough to protect parts of the slopes, it is not enough to lay cables or build a retaining wall.

- Coupling efficiency is primarily related to the selected drill hole size. The number of fibers and the density of the steel increases as the hole size increases, increasing these tendon damages.

- Anchor life is directly related to GUTS (Guaranteed Ultimate Tensile Strength) because the working load is determined by GUTS. When investigating the slope stabilization of fiber reinforced polymer anchors and also this type of anchors are most suitable for slope stabilization, no corrosion protection is required.

- Considering various criteria, the anchor type is selected and should be more effective in the future

References

1. Hanna, T.H. (1982), “Foundations in Tension- Ground anchors”, Trans Tech Publications, MCGraw Hili Book Company, USA.

2. CASE STUDY ON CABLE ANCHORING AND GROUTING by Mr.C.Chinnaraj, M.E., M.Naresh kumaar.

3. Design of prestressed cable anchor for stabilization of Himalayan slopes by Sanjeev gupta.

4. Cable anchoring /grouting diaphragm walls by aman thakur.

5. Research on prediaction model of prestressed loss of cable anchor in soil rock dual structure slope by Weiping Tian, Jiachun Li, Hongliang Qi, and Zhipei Zhang

6. IS: 269-1976 Recommended codes for selection of cement .

7. IS: 9457 Code of practice for safety colors and safety signs.

8. IS: 4756-1978 (reaffirmed 2002). Safety code for tunnelling work

9. IS : 7293 Safety code for working with execution machinery.

10. IS: 383-1970 codes for selection of Sand

11. IS: 5878(Part II/Sec 2)-1971 (reaffirmed 1990) code of practice for construction of tunnels.

12. IS: 5878-3 (1972) code of practice for construction of tunnels.

13. RDSO/2012/GE: G-0017 June 2012, Design & construction of tunnels.