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STRENGTHENING OF GROUND HAVING ADVERSE GEOLOGICAL CONDITIONS OF TAIL RACE TUNNEL'S OUTFALL IN TEHRI PUMPED STORAGE PLANT (1000 MW) -A CASE STUDY.

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Abstract: **- Strengthening of ground in construction area having heavy load is very important. So, we need to do micro pile in this area to strengthen the ground having adverse geological conditions. Micro pilehas been used effectively in many applications of ground improvement to increase the bearing capacity and reduce the settlements particularly in strengthening the existing foundations. Frictional resistance between the surface of pile and rock and the associated group/ network effect of micro pile are consider as the possible mechanism for improvement. This paper deals with a case study in which micro piles of 250mm diameter and 6m to 9m depth on the bases of encountered rock have been used to improve the bearing capacity of foundation. Micro pile has the advantages of flexible pile arrangement, strong applicable to rock, convenient and fast construction etc. It has also been widely used in many fields of Geo-technical engineering in recent years. The actual design for retrofitting assumed that the vertical component of frictional force between the rock and the micro pile resists the additional load coming from the structure over and above the bearing capacity. Based on collection of domestic and foreign literature's, this article makes a more comprehensive summary and introduction of the concept, characteristics, materials, classification, and application development. The work of this article will provide a theoretical basis for the theoretical research and engineering application related to the strengthening of ground in Outlet area of Tehri pumped storage plant.**

Keywords: **- Site specific geology, Purpose of strengthening of Ground surface at TRT outfall, Features and materials of micro pile, Classification of micro piles, Design for micro pile, Reinforcement and concrete pouring used.**

I. INTRODUCTION

Tehri project, a prestigious hydro-power project is the first major attempt to harness vast hydro potential of Bhagirathi River which is fed by Gangotri glacier. The storage project in the Bhagirathi valley in Uttarakhand Himalaya, envisages impounding of surplus monsoon water of the river for utilizing it in regulated manner for hydro-power generation. The 2400mw Tehri Hydro Complex comprises of Tehri Hydro Project (HPP) (1000mw) Stage-I, Koteshwar Hydroelectric Project (400mw) and Tehri Pumped Storage Plant (PSP) (1000mw). Tehri pumped Storage Plant (PSP) is in advance stage of execution and aligned parallel in the same hill as the Tehri HPP underground complex. Major project components are Machine Hall, Upstream Surge Shaft, Butterfly Valve Chamber, Pen-stock Assembly Chamber, and Downstream Surge Shafts, pair of Tail Race Tunnel and Outlet structure. The two Tail Race Tunnels namely TRT-3 (1081m long) and TRT-4 (1174 m long) are connected to outfall/intake structure with sluice gate and trash rack. This outfall structure is an integral part of Tehri Pumped Storage Plant and of utmost importance. Accommodate the hydro mechanical and electro-mechanical components at outlet structure, safe cut slope is require based on rock type and Geo-technical parameters to ensure safety of outfall structure. Detailed Geological / Geo-technical investigation was conducted and suitable methodology for the slope stabilization adopted in different variant of Phyllitic rock, which is emerged as a geological surprise. This paper briefly describes the construction methodology for strengthening of ground based on Geological investigation in TRT outfall structure.

II. SITE SPECIFIC GEOLOGY

The TRT outfall slope is characterized by the presence of PQT+PQM, QP with bands of PQT and SP. However, these litho-units have the appearance of Phyllites, but the Quartz content demarcates the boundary between all the Phyllitic variants. PQM and PQT are the massive varieties with different bed thicknesses. SP is labelled for rock with very weak and sheared phyllite zones. These in general occurs in variable thicknesses in the range from a few cm to 1.5m as observed in exploratory drift (EA-08). Surface geological mapping indicates that the rocks of PQT+PQM are well exposed in the rocky cliff just upstream of TRT-3 portal, i.e. near the start of coffer dam and outcrops extend up to the drift portal. These are limited by SP (phyllites with kinking) at the portal of EA-8 where these two litho-units are in contact with each other. The contact is interpreted to extend towards upstream. The unit PQT+PQM occupies the area towards the hill and SP occupies area towards valley. However, the contact is not clearly discernible upstream of EA-8 portal, but kinking/distressing in SP demarcates the boundary. The rock mass exposed in the slopes is distressed to the depth of about 5-7m. This has been observed in the trench just before the EA-8 portal. The rock exposures are limited at the base of the cliff near the coffer dam. Rock blocks have fallen from the slope at TRT-3 portal due to the foliation orientation being sub-parallel slope. In general, the strata are uniformly dipping at outfall area with kinking particularly in SP occupied stretches, and dips at N185°/50-65° (J1, with dip direction and dip stated) and are dissected by joint sets J2: N350°/35-45°, J3: N130°/60°-75° and J4: N260°/40-50° other than the foliation joint, J1. This foliation joint is represented by smooth and slightly undulating surfaces that are polished, very closely to closely spaced and have persistence along strike of 3-10m. Joint sets J2 and J3 are slightly rough, planar to slightly undulating, closely to widely spaced and have a persistence of generally <10m. Joint set J4 is rough, planar, and discontinuous, with a shorter persistence of <3-4m.

On the NW side of the cutting, several large shear bands within the phyllite are exposed and these can be traced 20-30 m along the slope but appear to not extend as far as the drift portal area. These shears with some kink banding dip 30 degrees into the hill (N090°-150°/30°) and are about 0.5 to 1 m in thickness. Similar trend kink banding is evident in the trench leading to the drift portal and is more obvious within the de-stressed zone of the slope. However, during excavation of the cut slope, these features along with other foliation and jointing require careful mapping and assessment to ensure stability of benches be maintained. Overburden comprises colluvium limits the rock exposure just downstream of the TRT-4 portal area and towards upstream of TRT-3 portal. The overburden is shallow above the PWD road level. The thickness of overburden increases towards downstream and upstream of portal area at higher levels. However, the overburden thickness is expected to be less than 3 meters in both downstream and upstream directions. The present slope is moderately inclined, dipping towards SW direction, i.e. N 225°. The inclination changes from 55° at drift to 45° at TRT-3 portal and 55° at TRT-4 portal. Overall, this slope is concave in disposition. Therefore, the slope is sub-parallel to strike of foliation towards the upstream (near ridge, i.e. 30-40m upstream of EA-8portal) and is oblique at angle of 40°-45° towards the downstream (figure: -1). The lithological types in the Tehri site have been classified during the dam and HPP design and construction by the Geological survey of India (GSI) have been adopted for PSP. The nomenclature has been based on variable proportions and quality of the quartzite and phyllite: they included.

- **Phyllitic Quartzite Massive (PQM):** Megascopic ally Phyllitic quartzite massive (PQM) is more quarzitic (arenaceous) and occasionally argillaceous, micaceous in composition and are coarser in grain size. The rhythmicity of com positional bands is well observed and spacing of these bands are found to be more than 10 cm apart.
- **Phyllitic Quartzite Thinly (PQT):** Phyllitic quartzite thinly bedded (PQT) is also compositionally like PQM i.e., the occurrence of quarzitic (arenaceous) and occasionally micaceous minerals of coarser grain size. The com-positional bands are also well observed and are closely spaced (0.5 cm to 10 cm) with respect to PQM rock mass.
- **Quarzitic Phyllites (QP):** Quarzitic phyllite (QP) is more argillaceous, fine- grained and dark grey colour. The parallel layers of micro flakes of sericite, muscovite and chlorite give a banded appearance t rock.
- **Sheared Phyllites (SP):** It is tectonites variant of three units mentioned above and developed mostly in the vicinity of major shear zones and forms weak zones characterized by mylonite's, phyllonites, talcose, highly fissured rocks with crumpling and intensive schistosity.

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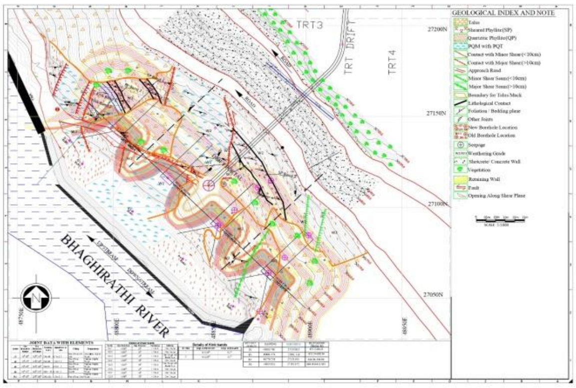

Fig. 1. Geology of TRT Outfall area

Quartzite is medium to dark grey colour composed of quartz but has thin phyllites bands through it that are reported to contain mostly fine mica (sericite) and chloride. The phyllite, where described as SP, has a high proportion of fine quartz, and may be better described as siliceous phyllite; but the term “Quarzitic phyllite” has been adopted. There are also gradations or mixture between these main groups such as PQM/PQT or PQT with SP. Additionally, the rock quality is grouped according to physical and mechanical competency and an isotropic behaviour in relation to their disposition. Some kink bands have been observed in the upstream part of slope which can also be cause of failure along with other joints as shown in figure 2. Swelling/Pinching and destressing in SP zone also observed during geological mapping at several locations of upstream portion and various benches of Outfall slope area as mentioned in figure: -2 (a),(b),(c) and (d) respectively. These structural disturbed locations are stabilized using adequate support system based on approved design drawing.

Fig. 2. Showing various Geological characteristics.(a). kink bands in SP occupied zone (b) Distressing in SP band at surface. (c). Swelling and pinching shear zone filled with clay gauge. (d). Shear zone in PQT+PQM occupied area.

III. PURPOSE OF STRENGTHENING OF GROUND SURFACE AT TRT OUTFALL

Strengthening of ground depends upon the geological condition and structural load on surface. PQT and SP is encountered at the bottom portion of TRT outfall which is having very less UCS <25 to 40 MPA. It is very difficult to construct a such type of heavy structure in TRT outfall. Several discussions were carried out in between design and execution team. Ultimately it was concluded that micro-pile is the best solution to strengthen this area. Micro piles are classified firstly according to design application and concrete method. The design application indicates the function of micro pile while the concrete method defined the concrete/ ground bond capacity. In design application there are two types of application. First type in which micro pile directly loaded either axially or laterally and the pile reinforcement resist the majority of applied load. Micro pile is used to transfer structural loads to deeper, more competent, or stable stratum and may be used to restrict movement of failure plane in slopes. The loads are primarily resisted by the steel reinforcement structurally and by the concrete/ground bond zone Geo technically.

IV. FEATURES AND MATERIALS OF MICRO PILE

On the surface, micro pile is like as soil nails and anchor rods. In fact, micro pile has the following advantages: it has large bearing capacity and has the function of general anti slide pile. If the micro pile is embedded deep enough in the solid rock support layer, a large bearing capacity can obtain. The pile length of the micro pile is easy to adjust. Due to small diameter, when the supporting layer of the pile tip is undulating and uneven, if the length of prepared pile is inappropriate, it can be easily extended or cut short. The length of the pile is easy to adjust, which facilitates the smooth progress of construction. The amount of rock discharged during micro pile driving small. It can be driven in through opening or drilled in advance. Relatively speaking, the cross-sectional area of rock discharge is small and driving efficiency is high. There is no excavation and large open area will be formed. It has little effect on rock disturbance and has no adverse effects on neighbouring structures. It is safe and can be constructed under sites. The micro pile has light weight, not easy to be damaged, and easy to handle and stack. In addition, the micro pile can save engineering cost, has high comprehensive benefits, and is suitable for rapid and large-scale construction. In summary, after years of scientific research and engineering practice, the micro pile technology has obtained many valuable results and engineering application experience. Micro pile reinforcement technology has been widely used in many fields of Geo-technical engineering.

V. CLASSIFICATION OF MICRO PILES: -

According to the several types of reinforcements in the micro-pile, such as steel rails, steel pipes, and steel bars, the micro-pile is often divided into steel rail piles, steel pipe piles etc. in the project. In literature, according to different grouting methods, micro-pile is divided into four types: gravity grouting type, low pressure grouting type, secondary grouting type, and post grouting type. The grouting material of the gravity grouting type micro-pile is cement mortar or net cement slurry. In Tehri PSP gravity type method with M20A20 grade of concrete.

VI. DESIGN FOR MICRO PILE

There is no specific design standard for micro pile design; however, relevant design standards for each design components can be referred to in the design. However, working stress approach is still widely adopted for the pile design in view of compatibility between the structural and the Geo-technical designs. Design steps for micro pile used for structural foundations:

1. Evaluate feasibility of micro pile.
2. Review available information and Geo-technical data.
3. Develop applicable loading combinations.
4. Initial design constructions i.e., spacing, length, cross section, type of micro pile.
5. Final design based on following steps: -

(A) Geo technical strength limit states: bond length design, end bearing, group effect of axial loaded micro piles, uplift resistance of single micro pile, micro pile groups, structural strength limit states, down drag.
(B) Structural strength limit states: axial compression of of cased length lateral resistance of single and group's micro pile, buckling of micro pile.
(C) Other structural consideration: grout to steel bond capacity, ultimate structural capacity, micro pile to footing connection.
(D) Corrosion protection.
(E) Seismic considerations.

6. Develop load testing program and constructionmonitoring requirements.

Fig. 3. Plan of Micro pile in TRT outlet at Tehri PSP

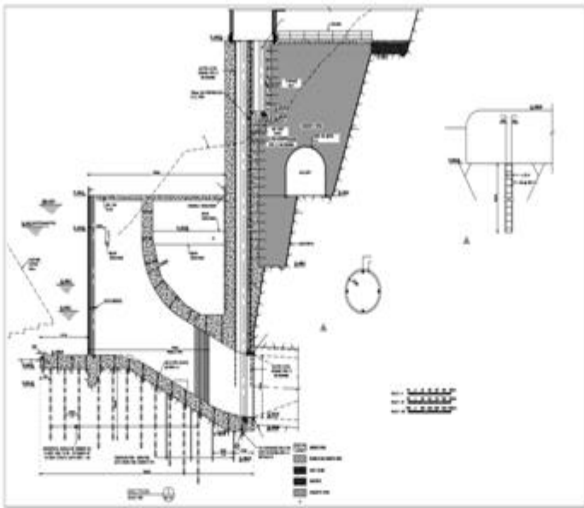

Fig. 4. Drawing of Micro Pile and Reinforcement used in foundation of Tehri PSP outlet area.

VII. REINFORCEMENT AND GRAVITY CONCRETE IN MICRO-PILE

PQT and SP rock encountered in specified location, which is having the tendency to collapse the hole due to very poor nature of rock mass. To protect this casing was provided during drilling for micro piling. Four nos. of 25Ø reinforcement steel used as a main bar which is 8.0 to 9.0m in length based on the encountered rock mass quality and 8.0Ø used a distribution bar in each hole as shown in fig: - 5(a) and (b). Total 560 number of micro piles with a spacing of 3.0m staggered position were installed to strengthen the outlet structure of Tehri PSP having 8 depth Due to poor Geological conditions encountered in some area such as sheared phyllite (SP) the hole depth increased from 8m to 10m on the behalf of interaction of sound rock during measurement of mean time drilling. Diameter of each hole is 250 mm.

Fig. 5. Picture (a) Showing drilling equipment while drilling hole for micro-pile and Picture (b) Showing final micro-pile hole from top of the surface after complete reinforcement & concrete in Tehri PSP outlet foundation area.

VIII. CONCLUSION

Prospect with development of urban construction, more and more complex geological conditions and Geo-technical engineering problems related to rock mass encountered. Under many condition the construction site is limited and the construction schedule is tight. The micro pile reinforcement technology can be used in landslide treatment, slope reinforcement, foundation support and other project to play its unique advantages. With the continuous application of micro pile reinforcement technology, its corresponding technology will develop towards continuous diversification, the design and construction procedures will continue to be standardized and improved, the corresponding reinforcement mechanism will continue to be studied, and the advantages of micro pile technology will also be brought into full play.

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X. REFERENCE

[1]. ISM (International Society of Micropiles), "Micropiles – An Overview'', April (2009). Presentation by Lowa Department of Transportation, AGC (Associated General Contract of low) and FHWA, Presented by: Jim Sheahan, P.E. HDR Engineering, Inc. pp. 5 - 73.

[2]. Barley, A.D. and Woodward, M.A. (1992). "High Loading of long Slender Minipiles", Proceedings, ICE Conference on Piling European Practice and Worldwide Trends, Thomas Telford, London, pp. 131-136.

[3]. Brown, D. A., Morrison, C., and Reese, L. C. (1988). "Lateral Load Behavior of Pile Group in Sand", ASCE Journal ofGeotechnical Engineering, Vol. 114, No. 11, pp. 1261-1276.

[4]. Bruce, D.A., A.F. DiMillio, and I. Juran. (1997). "Micropiles: The State of Practice Part 1: Characteristics, Definitions, and Classifications." Ground Improvement. Thomas Telford, Vol. 1, No. 1, January, pp. 25-35.

[5]. Lizzi F (1988) "The Pali radice (Root piles)" symposium on soil and rock improvement techniques.

[6]. Marek, Muhunthan, B., FHWA supported Structures Research Seismic Behaviour of Micro piles, research report, 2005, Washington State Transportation centre (TRAC), Washington, USA.

[7]. Wetman, A. (1981). "A Review of Micro Pile Types". Ground Engineering, May, pp.43-49.

[8]. Haram Anand Murthy, B.R.S (1993). "Remedial measures to building settlement problem". Proceeding of third international conference on case histories in Geo technical Engineering. St. Louis Missouri, pp. 21-224.

[9]. Venice Charter (1964), IInd international congress of architects and technicians.

[10]. Juran, I., Bruce, D.A., Dimillio, A., and Benslimane, A. (1999). "Micropiles: the state of practice. Part II:

design of single micropiles and groups and networks of micropiles”. Ground Improvement, 3, 89-110.

[11]. Tan, S.A., Luo, S.Q., and Yong, K.Y. (2000). “Simplified models for soil-nail lateral interaction”. Ground Improvement, Vol. 4, No. 4, 141-152.

[12]. Donovan, K., Pariseau, W.G., and Cepak, M. (1984). “Finite element approach to cable bolting in steeply digging VCR slopes”. Geo mechanics application in underground hard rock mining, 65-90.

[13]. Ir. Liew Shong & Fong Chew Chung Gue, Partners SdnBhd, Kuala Lumpur,(2003). "Design & Construction of micro piles", pp. 1-27, 29-33