

PROTECTION AND STRENGTHENING OF ROCK SURFACES

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Protection and strengthening of rock surfaces within optimum time, cost and with adequate reliability is among the challenges on the projects. This article shares TCE's experience in protecting and strengthening of rock surfaces in deep excavation, valley and hilly terrain.

TCE have developed expertise in the design of protecting and strengthening the deep excavated/exposed rock surfaces. Some of the area of importance is rock filled reservoir, underground tunnels, caverns and structures like wagon tippler, pump house, basements and hilly terrain etc.

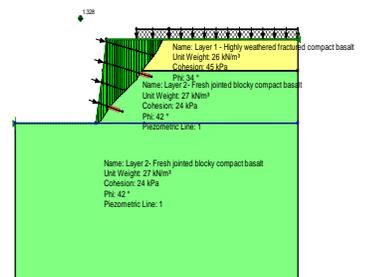
TCE have design protection and strengthening of rock surfaces in many projects. This article briefly covers the design procedure of protection and strengthening of rock surfaces adopted with some photos showing the same.

(a) Geotechnical investigation

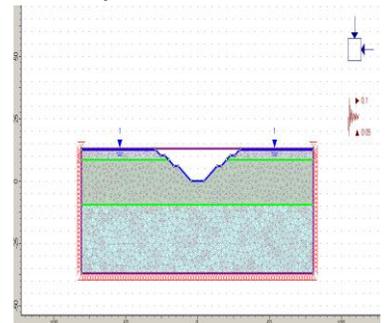
The purpose of investigation is to collect the parameters required for designing the strata to be protected and strengthen that is Rock Quality designation (RQD), Core Recovery (CR), Unconfined compression strength(UCS), water absorption and porosity, Modulus of sub grade reaction poisson ratio and petrography (on selected samples). In addition to this surface geological mapping through a geologist expert is required to capture geological features like joint set number, orientation of joints, joint roughness, joint alteration, filling of joints, sizes of joint , dip & strike direction, water seepage, faults, fissures , fractures as can be seen from surface . Other, General site information such as ground water table, seismic zone, annual rainfall data, presence of any water bodies nearby type/condition of strata at deeper depth, strength of strata etc are to be captured in the investigation.



Installing rock anchors



Analysis in Geostudio



Analysis in Phase2

(b) Preliminary designs based on the performed Geotechnical investigation

Preliminary design is carried out using the design parameters obtained from geotechnical investigation.

Preliminary design is carried out by using Barton theory. Based on the rock mass quality Q obtained as per IS 13365, the suitable type of support treatment in the form of rock bolts/anchors, fibercrete, spot bolting, shotcreting etc with the required spacing of bolts/anchors and required thickness of lining are determined.

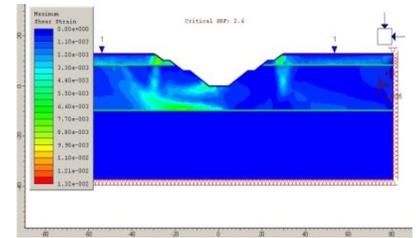
(c) Detailed design

In rock surfaces with large expected variation in the strata, the preliminary design is revised/updated based on the expert geologist report/ mapping prepared on inspecting real time subsurface strata actually exposed during/on completion of excavation.

In rock substrata expert Geologist carries out geological mapping of substrata covering the geological features as discussed above. Geological mapping is prepared based on physical observations of the strata, interpretations based on experience and with the use of geological tools like Geological hammer.

The geometry of the excavation (or exposed surface) and the properties of the strata are used along with other site conditions in the stability analysis. Global stability of the rock profile is carried-out using Geostudio 2007 slope/w module or Phase2 software for different loading condition as specified in IS 7894.

In rock slopes where plane wedge failures are anticipated, the adequacy of the strengthening is verified using the method provided in IS 14448.



Analysis using Phase 2



Slope stabilisation with prestressed anchors

Strengthening of Rock strata may require provision of rock anchors/bolts. The length of rock anchors/bolts is determined considering plane wedge and global stability analysis. Various factors like strength of grout, rock- grout bond strength, strength of rock, area of failure cone are considered in calculating the per meter capacity rock anchors or rock bolt .The capacity of rock anchors is validated by carrying out pullout test and minimum among the two is considered for the design analysis.

Maximum length and minimum spacing of rock bolt/anchor as obtained from plane wedge and global stability analysis is adopted. Additionally spot anchors are provided after reexamining the area appearing weaker from appearance but not properly captured in mapping.

(d) Facia elements

Excavated surface strengthened with or without rock anchors/bolt (based on analysis) is protected against weathering action by wire mesh/fiber and shotcreting or only shotcreting (depending on existing of weathering condition of strata).

Shotcrete is used as facia element in combination with rock anchor/bolt in strengthening the wedges in the closely jointed rock surfaces. It is used as additional support for the wedges in blocky ground. Good bond between shotcrete and rock surface has to be ensured for good performance. The thickness and compressive strength of the shotcrete layer is determined by carrying out punching shear analysis as per the guidelines provided in FHWA-NHI-14-007 manual.

Thickness of shotcreting and requirement of providing wire-mesh is govern by degree of weathering, orientation of joints, dip of discontinuities and strength of parent material.



Anchoring in Tunnel



Stone pitching

List of reference:

- 1) IS 14448: 1987: Code of practice for reinforcement of rock slopes with plane wedge failure.
- 2) Stability modeling with SLOPE/W- Geostudio Design manual
- 3) Phase 2 Design manual
- 4) Rock engineering course notes by Evert Hoek
- 5) IS 13365(Part 3):1997. Quantitative classification systems of rock mass – guidelines :determination of slope mass rating
- 6) IRC 75: Guideline for the design of high embankment.
- 7) FHWA-NHI-14-007: geotechnical engineering circular no. 7 -Soil nail walls - reference manual