Some Challenging Geotechnical Projects

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Abstract: This note a couple of very challenging geotechnical projects illustrating the varied nature of the issues involved. In both the cases, geotechnical data is scanty due to the location of the projects. Only the damage or consequence of both natural and human induced actions are known. It became necessary to conjure and diagnose the causes and arrive at relatively conservative solutions. In the first project of stabilization of a steep slope in Lower Himalayas, access to the site itself was difficult if not impossible. In the second project involving serious coastal erosion that was progressing at an alarming rate, it became imperative to develop a quick fix solution that had to be implemented in tidal waters.

1. Stabilization of Steep Slope in Lower Himalayas

An Industrial Unit is located on high ground about 100 m above the mean flow level adjacent to a fast flowing river in Sikkim. (Fig. 1). The lean season flow width of the river is 50 m and expands to 100 m in the peak rainy season with maximum flood level reaching 15 m above the mean flow level. The original slope of the cliff is 65^0 to 85^0 from the bed of the river. The layout of the industrial unit can be seen in Fig. 2. The boundary of the industrial unit is about 50 m from the river bank. The profiles and vegetation along the four locations along the slope were examined following collapse of the compound wall and part of the industrial area adjacent to the wall (Fig. 3). Vegetation was washed away following slope failure.

Fig. 1 Aerial View of the Site

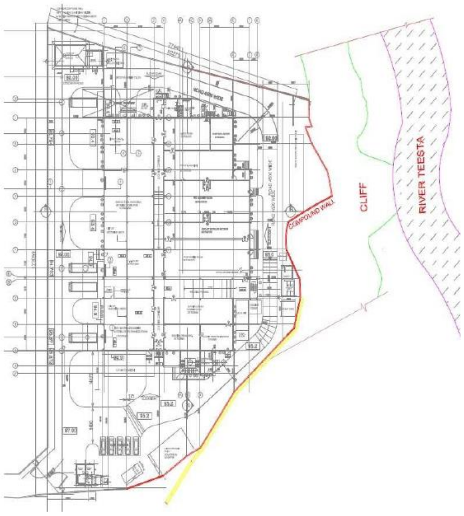


Fig. 2 Layout of the Industrial Unit

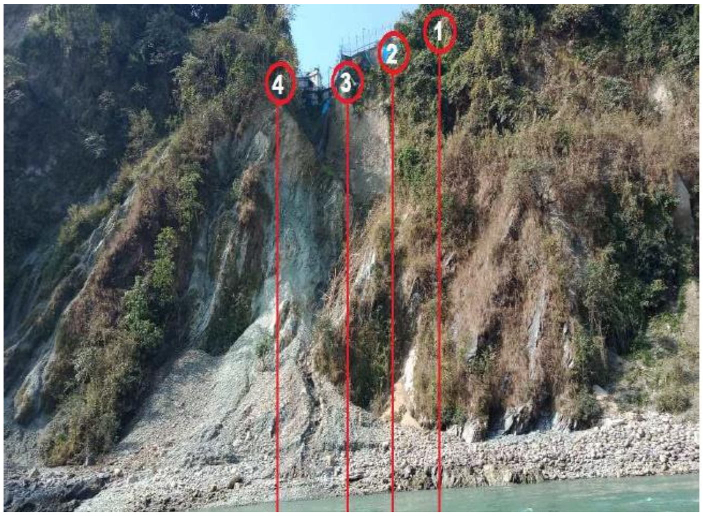


Fig. 3 Slope Failure leading to Collapse of part of the Compound Wall

Normal geotechnical investigations were not possible because of the terrain, steep slopes and inaccessibility. Drone was used for detailed visual inspection. The strata appeared to be high to partially weathered flaky rock typical of lower Himalayas. Drone was used for detailed visual inspection. Table 1 lists the observations and estimates of the slope angles made. Loose surface samples were collected from few places (Fig.4) and tested and the engineering geology of the site in particular and of the region in general studied.

Table 1. Slope Angles and Vegetation at Select Locations along the Slope

Reference Point	Slope	Vegetation
1	65^o - 75^o	Fully covered with bamboo vegetation
2	75^o - 85^o	Partially covered with vegetation on crown. Vegetation which was below crown got washed away.
3	85^o - 90^o	No vegetation found. Vegetation washed away.
4	85^o - 90^o	No vegetation found. Vegetation washed away.

Fig. 4 Points for Sample Collection

The soils collected indicated silty soil with boulders at Point 1, weathered disintegrated flaky rock and silty soil at Points 2 and 3 and powdered rock with silty soil with boulders at Point 4. Causes of failure of the upper part of cliff are surmised as possibly due to erosion of soil near the toe of the fast flowing river, intense rainfall during the months of May to September and a storm water drain outlet.

Two alternate design solutions, viz., reinforced earth wall supported by plum concrete anchored to rock slope and rock/soil anchors were considered. However a combination of both (Fig. 5) was implemented.

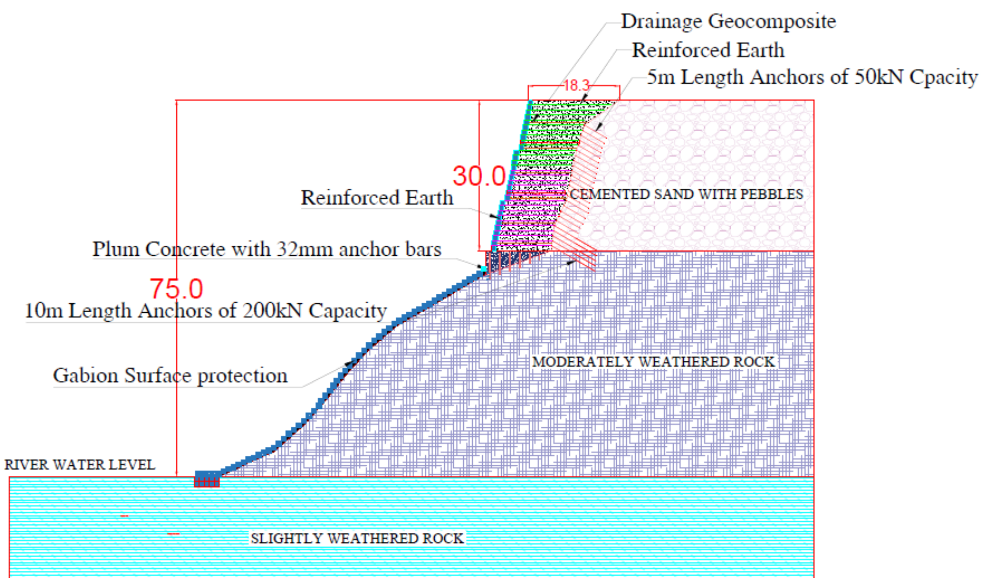


Fig. 5 Slope Stabilization Adopted

2. Coastal Erosion and Protection

Extreme coastal erosion was taking place in the Gulf of Khambat (Cambay) (Fig. 6) for years due to both natural changes and human intervention to the coastline. The tide was reported to be 5.5m to 6.0 m high and water velocity of the order of 5 m/s. It was reported that coastline was moving inwards (Fig. 7) at the rate of 10 to 20 m per year and damaging the boatyard (Fig. 8) and even some of the installations of ONGC a little farther inland. Attempts to prevent or control the rapid erosion with piles/sheet piles were unsuccessful.

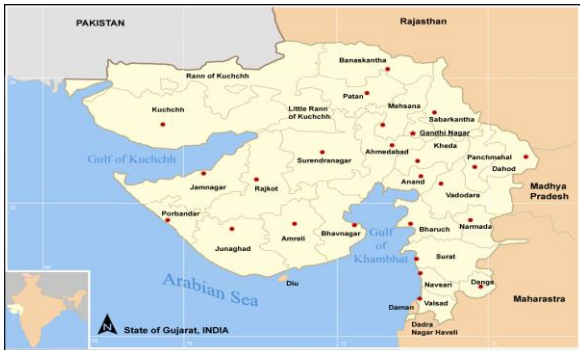
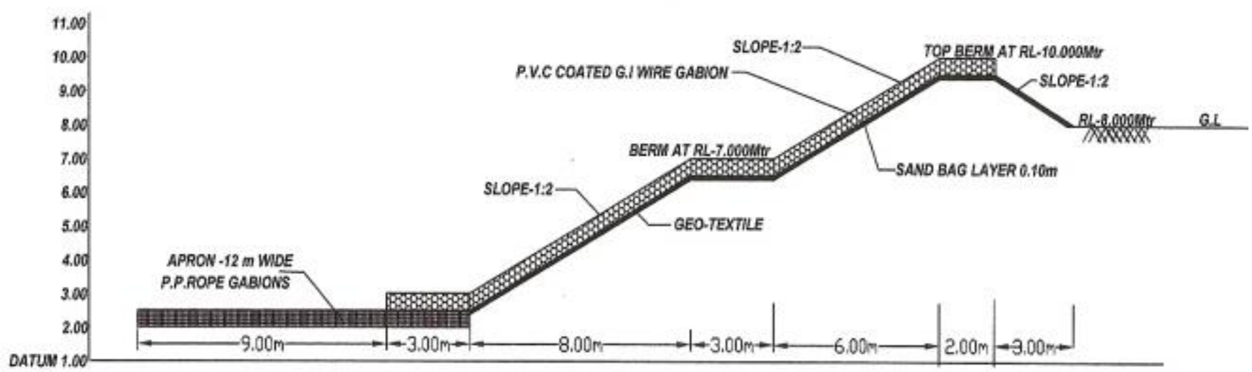


Fig. 6 Gulf of Khambat

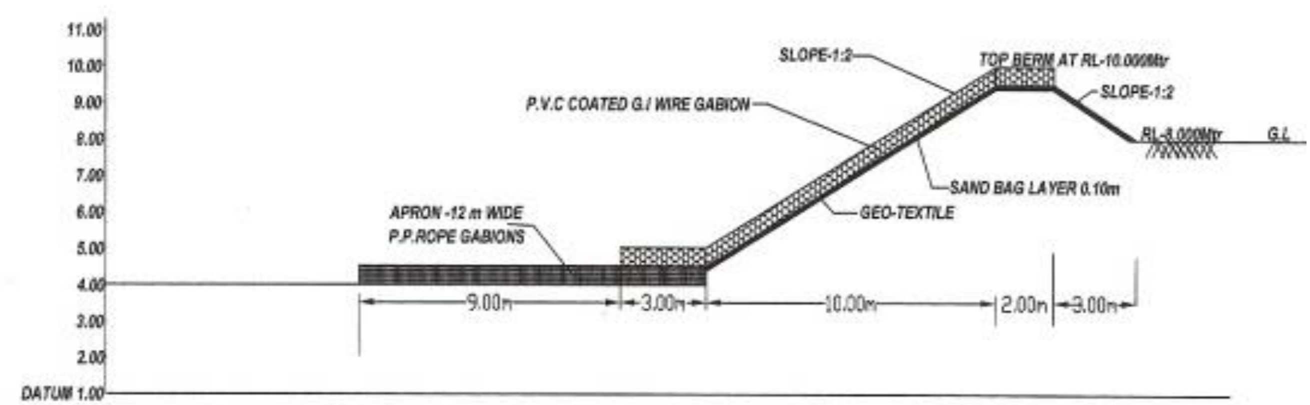
Fig. 7 Example of Coastal Erosion

Fig. 8 Critical State of Erosion- Note State of Earlier Control Measures

The soil at the site was silty sand/sandy silty which is easily erodible. The problem needed an out of the box approach. The solution suggested and implemented consisted of using gabions and geosynthetics. Fig. 9 presents the design for relatively high, 10.0 m and normal 6.0 m high slopes. The slopes were graded to 2H:1V, a non-woven geotextile laid, over which geobags placed. PVC coated gabions were then placed on the geobags and anchored. More importantly gabion mattress or apron of 12.0 m long was placed along the base with an overlap of 3.0 m with gabions protecting the slope. If indeed erosion was initiated, the apron would arrest the same and prevent further damage.



(a)



(b)

Fig. 9 Erosion Protection for (a) 10 m and (b) 6 m High Slopes

(a) (b) (c)

Fig. 10 The Solution (a) Immediately after Installation, April 6, and on (b) May 16 and (c) Aug. 4, 2007

Fig. 10 illustrates the solution soon after installation in early April 2007 and over the next four months, in May and August 2007. Needless to state the work had to be carried out in flowing water with pre-filled gabions launched from barges and with divers tying them under water. It has reported that the erosion has been controlled successfully. Some accretion of fines can be noticed at low tide.