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Anchored earth breast wall for a site in the sub-Himalayan region

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ABSTRACT : The Anchored Earth technique using Semi-Z shaped mild steel anchors has been well established for cohesive soil backfills. An application for a breast wall in the sub-Himalayan region made in a slide-prone area having a backfill with little cohesion was bodily dislocated and damaged due to the slide becoming suddenly active following an abnormally wet six day period during the last monsoons. A conceptualised "Combined System" design for the same structure has now been based on the present experience.

1. INTRODUCTION

The first Indian Anchored Earth structure was constructed in July 1989 as a vertical-faced approach embankment for a small road bridge in Varanasi, and it has performed very competently under field vehicular loading ever since its construction. Recently a 42.5m long vertical-faced anchored earth embankment varying in height from 7m to 2m has been constructed as an approach embankment for the new Varuna Bridge at Varanasi (Singh, et.al., 1995). The designs were based on the theory of resistance mobilised for semi-Z shaped anchors (Singh, 1992a). The designs for the new Varuna Bridge embankment also incorporated the new concept of curtailment of substantial lengths of "dowel" action component of the straight shaft of the anchor reinforcement, effecting savings of approximately 70 per cent of steel over the earlier conventional anchored earth design. Both these applications were for cohesive soil fill, which is essential for the development of three dimensional soil wedges on the arms of the semi-Z anchor during its pulling out of the fill. High holding capacities result due to passive Pressures developing on these wedges.

A 3.5m high and 4m long breast wall was designed and constructed for a slide-prone site in the hilly terrain of the sub-Himalayan region. The Paper presents salient points of design and construction of the breast wall with special emphasis on natural and other conditions, largely unforeseen and beyond control, which resulted in large distress to the structure and its eventual abandonment. A conceptualised "Combined System" design, similar to that already proposed (Singh, 1992b), has now been given for the same structure.

2. THE SITE AND SOIL

The area of application of the Anchored Earth technique lies within a zone of mountains designated as Lesser Himalayas. Meta-sedimentary and meta-volcanic formations ranging from Pre-cambrian to Tertiary in age are met with in the area, and the principal rock types include schists of igneous derivation, quartz-mica schists, chlorites and argillaceous rocks, which have been complexly folded, faulted and thrusted. There is presence of extensive landslide zones due mainly to undercutting by the river flowing by, and planar/wedge failure of slopes along the dip and foliation planes.

The site of the work lies on an strategically important road in the above mentioned slide-prone area, having an elevation of 1800m above the mean sea level. The site as such is not avalanche prone and also has no appreciable snowfall. Its average yearly temperature variations are between 40°C to 4.3°C, with annual yearly rainfall of 95cm. The most infamous slide of the area, viz.; the Kaliasur slide, is not too far from the site as the crow flies. The soil was sandy and gravelly along the hill-side of the road with a very small cohesive component in it (BRO Report, 04.08.95). The soil parameters were :

D_{10}=130 micron; D_{50}=18mm; Plastic limit=30%; Liquid limit=33%, Plasticity Index=3. Proctor Test Optimum Moisture Content=12%. Corresponding maximum dry density=18KN/m^3, specific gravity of soil grain=2.57, Undrained triaxial test cohesion C=20KN/m^2, corresponding angle of internal friction ϕ=20°.

3. THE DESIGN

The design followed the procedure as outlined in the first author's paper published in the proceedings of IS Kyushu '92. Whereas, logarithmic spiral having equation $r=20e^{\theta \tan 20°}$ was the boundary of soil wedge on the inclined arm of the anchor, a simple hemispherical wedge boundary was adequate to be considered for the straight arm since the fill soil was almost fully frictional with only little cohesive component. By considering suitable slices of equal width for both the soil wedges, the total surface area 'A' of the soil wedges for a π rotation was computed. Holding capacities of the semi-Z anchors at different levels in the fill were then

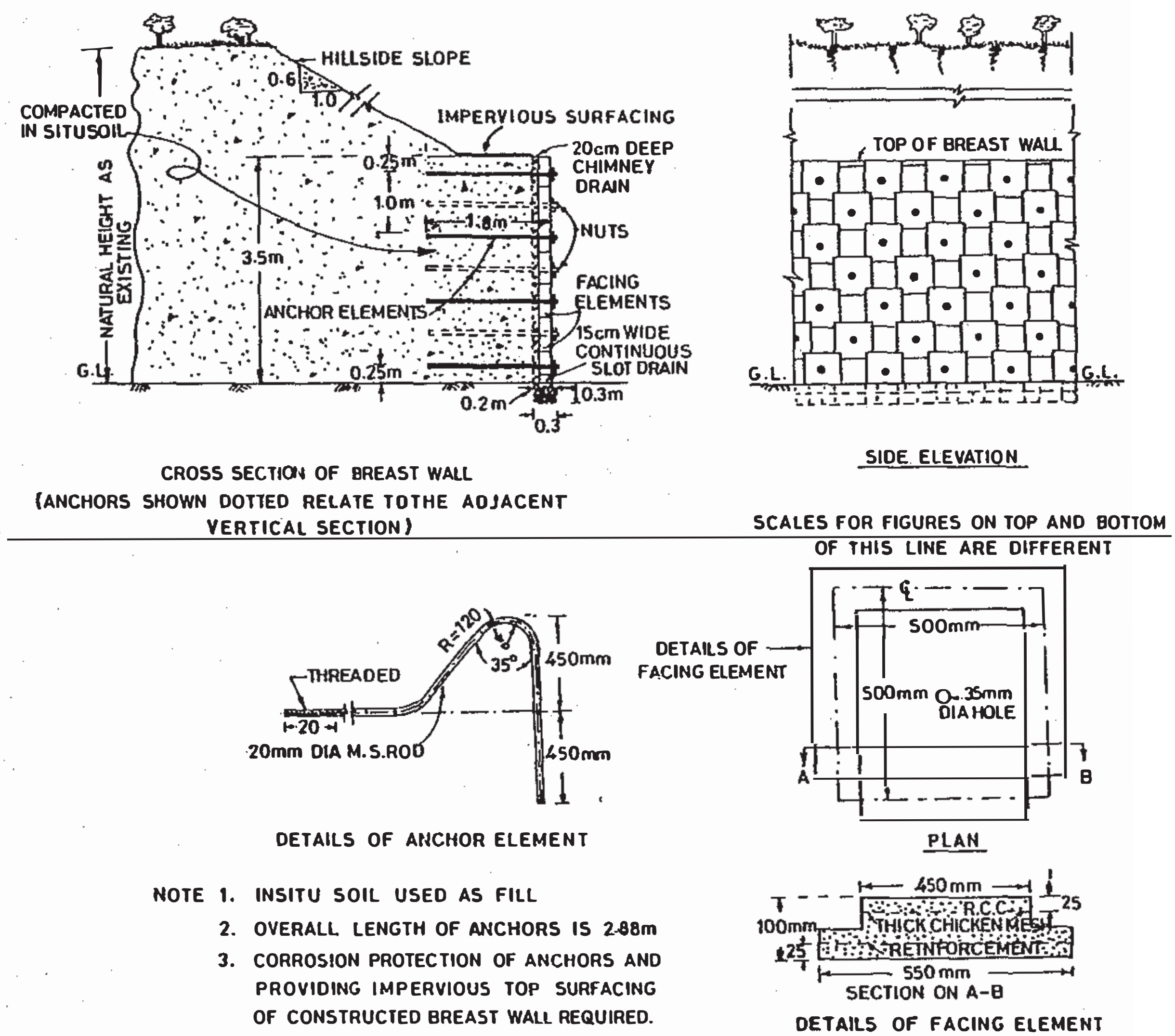

FIGURE 1. Details of Anchored earth breast wall for a site in the sub-Himalayan region.

calculated as the passive resistance mobilised on the fully developed soil wedges. The frictional forces developed along the stem of the anchor were neglected. The salient calculated values for holding resistances for the design of the 3.5m high breast wall are given below :

For the first level of anchors from top; D_1=0.25m, R_1=82.7KN, and the respective values of R for D=0.75m, 1.25m, 1.75m, 2.25m, 2.75m and 3.25m are 107.9KN, 133.1KN, 158.3KN, 183.5KN, 208.7KN, and 233.9KN respectively, where D represents the depth measured from the top of the breast wall and R represents the holding resistance of the anchor.

Assuming that the lateral pressure distribution suggested by Terzaghi and Peck (1969) for a flexible sheet pile wall was the applicable distribution behind the facing elements of the breast wall, the active thrust on one facing element having a size 0.5mx0.5m works out to be 17.5KN. Staggering the anchors as per design shown in Fig.1, where anchors shown dotted related to the adjacent section, each anchor has to hold out against the active thrust on two of the elements, totalling to 35KN. The calculated resistances given in the above paragraph show that a minimum factor of safety of 2.36 is provided for by the first level of anchors, with its value increasing to 6.6 for the lowest level. Hence the design as shown in Fig.1 was considered satisfactory.

4. CONSTRUCTION AND COSTS : SALIENT POINTS

A departure from the previous practice of corrosion protection of anchors using epoxy resin based 3-coat system was attempted, by using hot 80/100 grade bitumen for painting them by dipping to provide three coats of the bitumen. Also, contrasted to the case of earlier structures which were constructed using cohesive backfill soils, where no need for propping of the facing elements arose, propping on ground had to be done during construction in the present case. Compaction was achieved in layers of 15cm using manual rammers.

The overall costt of the wall worked out to Indian rupees 4,561 per m run of the wall (equivalent to US dollars 135 per m). Material costs, including mild steel anchors and concrete for facing elements, was only 20% of the total cost. Likewise, machine usage costs were 22%, and manual labour costs were 36% of the total cost. The remaining 22% of the costs constituted supervision and administrative overhead costs.

5. THE DISTRESS AND POSSIBLE REASONS

Since the site was in a slide-prone area, and no slide mitigation or treatment work had been done, the possibility of the slide becoming active had been lurking. Unfortunately, the year 1995 proved to be a very wet year when wide spread damages to road and other structures in the region were noted. The sudden movement of the landside occurred during the first week of Sept.'95 during the monsoon season following a 6-day period of concentrated precipitation depositing 79.5mm of rain. The slide bodily dislocated and damaged the breast wall. Other possible reasons that are likely to have contributed to the distress of the wall were :

i. Inadequate provision of the chimney and slot drain for the sub-Himalayan region heavy precipitation resulting in the build-up of high pore pressures in the backfill,

ii. Delay, overtaken by the heavy and early monsoons, in surface painting of the top of breast wall to make it impervious.

iii. Marginal suitability of the fully anchored earth structure for the backfill which was only minimally cohesive.

The distressed state of the constructed structure was such that it had to be abandoned.

6. CONCEPTUALISED COMBINED SYSTEM DESIGN

Combined System has been proposed (Singh, 1992b) as a more effective system as compared to the fully anchored system, particularly for soils with little or no cohesion. In the combined system, the semi-Z shaped anchors are alternated with a heavy grade non-woven synthetic permeable geotextile in depth of the fill structure. For cohesive-frictional soils, or soils with low cohesion, a modified combined system using a high density polyethylene mesh geogrid, in stead of the geotextile,

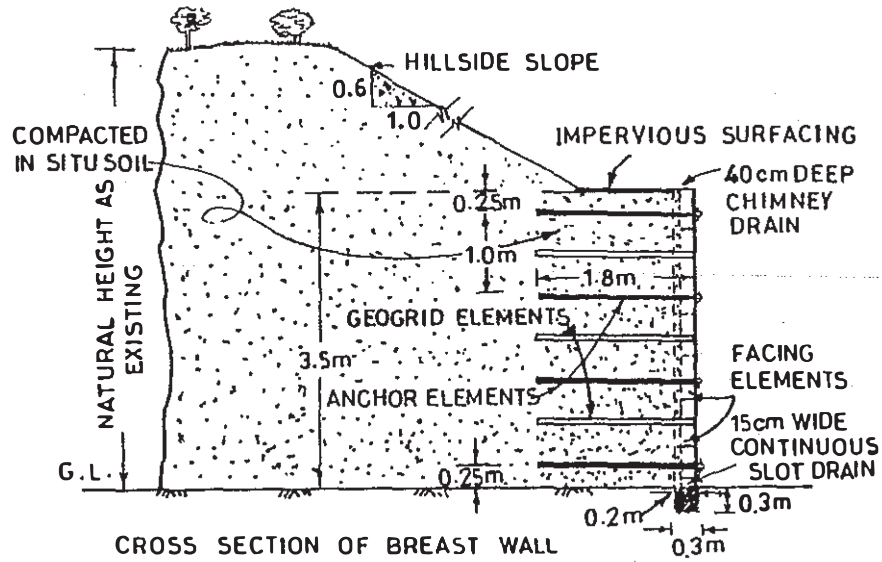

FIGURE 2. Conceptualised Combined System Design.

is better suited. A conceptualised modified combined system design for the same structure is shown in Fig.2.

The design is based on the "Tie-Back Wedge Analysis" method, which is widely reported in literature (e.g., Jenner, 1990). In the composite analysis for the Combined System, the resistance offered by the anchors is considered as previously for the fully anchored structure, and the facing is assumed to rotate about the toe giving active state of stress in the wedge.

7. CONCLUSIONS

Anchored Earth breast wall design and construction in sub-Himalayan regions having fill soils of low cohesive properties should be done using the "Combined System" concept, with generous provision of chimney and slot drains to take care of heavy precipitation.

A fully anchored conventionally designed breast wall constructed at a slide-prone site having sandy and gravelly soil with only a small cohesive component, got dislocated and damaged as the slide became suddenly active following a period of continuous and concentrated rainfall.

8. REFERENCES

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