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DISTRESS IN A HILL AND REMEDIAL MEASURES

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SYNOPSIS: The paper presents a case study of a hill which developed signs of distress in 1979-80. Retaining and breast walls provided at many locations on the hill had been damaged and laterally shifted, indicating some movement in the hill. The distress in the hill were attributed to poor drainage of hill water, weaker sections of walls, dumping of loose lateritic material on the slopes, formation of erosion gullies etc. The hill was stabilized by removing these signs of distress with suitable remedial measures which are functioning satisfactorily over last 5-6 years. Systematic photographic presentation of different portions/features of the hill which showed signs of distress and then of different remedial measures which proved satisfactory makes the case study very interesting.

INTRODUCTION

It is a case of a 50m high hill having two water tanks constructed at its top. The site is situated about 5 km away from Dharampur on way from Kalka to Simla in Himalayas (India). The tanks store water brought from distant springs through pipes and it is then pumped to higher level localities. So the complex on the hill consists of two big tanks and a large pumping station.

Alarming signs of distress were observed in the hill in 1979-80. They were of two types. Firstly, some of the retaining/breast walls of the approach road had cracked, bulged out and laterally shifted. Secondly, some part of the hill was constantly being eroded by rain water leading to formation of deep gullies.

All these created anxiety because the hill was supporting tanks on it. So factors contributing to distress in the hill were investigated and certain remedial measures were adopted in 1981. Since then there is no difficulties with the slopes and walls on the hill.

The paper reports details of signs of distress, their analysis and suggested remedial measures which have proved to be satisfactory.

STUDY OF DAMAGES

Damaged Walls

A breast wall constructed at the foot of the hill on the main Simla road was damaged as shown in Fig.1. The damages were in the form of bulging out of the wall in the middle of its height and stones coming out of it at many locations. These signs indicated development of heavy earth pressures which might be partly due to lateral outward movement of the hill and partly due to accumulation of hill water in the backfill.

Fig.1: Damaged Wall at the foot of the Hill.

The complex with water tanks located at top of the hill was approachable through a Jeepable road. Certain portion of this approach road was damaged as shown in Fig.2. Originally the road

Fig.2: Sinking Side of Approach Road.
on curve was provided with outer edge at a higher level than the inner edge. But the figure shows sinking of the outer edge below the inner edge by more than 30 cm and cracking of the road surface. This happened since the retaining wall supporting the outer side of the road had experienced large outward shifting and rotation. It also resulted in movement of soil in certain lower portions of the hill. The breast wall reported in Fig.1 was in the lower portion of the hill.

The breast wall seen by the side of the road in Fig 2 had also cracked. A close-view of the damaged wall is seen in Fig.3. The cracks were so wide that in certain patches the wall had become almost ineffective.

The worst damage to the breast wall is seen in Fig.4. The wall had failed, rubbles had rushed out and a big opening was formed in the wall.

Fig.3: Cracked Breast Wall.

Fig.4: Completely Failed Wall.

Causes of Damages:

The damages to the wall shown in Fig.1 to 4 were on account of the following three main reasons:

1. In certain portions, the strength of the wall was not adequate, viz. either the wall was relatively thin in section or the quality of mortar used was poor. The bulging of wall along its height shown in Fig.1 is partly due to inadequate thickness of the wall. The cracking and opening out of the joints shown in the wall of Fig.3 is partly due to poor quality of mortar.

2. The portion of the hill below the approach road shown in Fig.2 had relatively steeper slope. Stability analysis of the slope gave a factor of safety of 1.03 which indicates state of critical equilibrium. Probably this resulted in the lateral shift of the wall supporting the approach road and cracking of the road surface.

3. There were two small natural streams of water in the hill. Their free flow was hindered by the transverse walls. Collection of water in the backfill increased the earth pressure and damaged the wall. The wall in Fig.4 is broken open by the water collected at its back. The rubbles carried by the gushing water were deposited in the front of the wall. Fig.1 also shows collection of such water which had seeped through the damaged wall. This poor drainage of hill water was another major cause of damages to the walls.

Erosion Gullies

Another cause of anxiety was the constant erosion of the soil in the eastern part of the hill. It resulted into deeper and wider erosion gullies as shown in Fig.5. One of the water tanks is also seen on the left side in the backg round of the figure. The soil excavated during the construction of this partly under ground tank was deposited on the slopes of the hill with an idea that it would increase stability. But the soil so deposited did not support any plant-life and constant erosion of it under rain water led to formation of erosion gullies. Another close view of it is shown in Fig.6.
Causes of Erosion

The hill was made of lateritic soil. Grain size analysis of the freshly excavated soil revealed that it was a well-graded mixture of 40% gravel-sand, 47% silt and 13% clay which if compacted in proper wet condition could form a stable slope. But the soil when left loose and subjected to weathering, got converted into stiff angular grained material which with dry sieve analysis was classified as gravelly coarse sand.

The soil excavated out during construction of the partly underground tank was deposited on the hill. And on weathering, it had changed into gravelly coarse sand like material as shown in Fig.7. The grains of the deposit had become stiff, angular in shape. The material was non-cohesive and its grains used to roll down the slope even with scanty rain fall. So it resulted in as low an angle of repose as 35° as seen in Fig.8.

Remedial Measures

As reported earlier, in the portion between the foot of the hill and the approach road, the slope was in critical condition. Hence the slope was regraded, the approach road was realigned and the section of the foot wall was improved. The measures stabilised the slope and the reconstructed foot wall showed no sign of distress over last 5-6 years. A recent picture of the wall is shown in Fig.9. Its comparison with Fig.1 speaks of satisfactory functioning of the remedial measures.

The damaged breast wall reported in Fig.3 and 4 was also reconstructed with wider section after adopting necessary measures for proper drainage of the hill water. It is also functioning very satisfactorily now.
The other important remedial measure which effectively arrested the signs of distress was the wall planned scheme of drainage of seepage water from all parts of the hill. Along the main erosion gulley formed on the hill which was shown in Fig. 6, a drain was constructed as shown in Fig. 10. It was of adequate section to carry the maximum rain water discharge and had adequate longitudinal slope to allow uninterrupted flow of water in all seasons. Also for matching the bed level of the drain with the natural topography of the hill, falls of heights of 1 to 2.5 m were constructed at suitable intervals along its length. Also the rain water of the areas adjoining to the drain was made to flow towards the drain by suitable landscaping with construction of transverse walls as shown in Fig. 11. These walls form part of the fall-structure and also support the ground above them. The soil in between these walls was protected from erosion either by properly compacting it and then growing grass on it or by covering the surface with a bituminous premix carpet. Fig. 12 shows one such transverse wall with a premix carpet cover in the front of it and vegetation cover on the surface of the slope at the back of it.

CONCLUSIONS

Generally instability of an embankment is studied by considering equilibrium of an earth mass over an assumed potential slip surface and under action of disturbing and restoring forces. But this approach is not suitable for natural hills of Himalayas which are made of non-homogeneous and heterogeneous materials and since the approach cannot consider the role of different agencies causing distress at different parts of the hill (Bhandari, R.K., 1986). Some of the agencies found active in the present case study were (i) presence of inorganic deposit on the hill which did not promote growth of protective vegetation cover, (ii) presence of lateritic material which on weathering changed into easily erodable loose granular material, (iii) inefficient drainage of natural hill water causing development of excessive earth pressures on retaining walls and (iv) development of critical equilibrium state in certain slopes subjected to constant erosion.

The remedial measures which proved successful in removing the distress from the hill were (i) regrading of the slopes which were in critical equilibrium state, (ii) compacting loose earth masses of the hill, (iii) preparing vegetation cover on barren surfaces with special measures like introducing manure, watering it and protecting it manually or by using geogrids, (iv) covering erosion-susceptible surfaces with bituminous premix carpets, (v) providing suitable retaining and breast walls, (vi) providing longitudinal and transverse drains with suitable cross-falls etc.

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References: