Case Study of Failure of Slopes at Morni Hills

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ABSTRACT

The area of Morni Hills comes under Shivalik hills and is situated at altitudes varying from 1340 m to 1600 m. It has been observed that the area contains lot of problematic locations because of frequent landslides. Problematic areas have been surveyed by traversing along the motorable roads. Through this study, attempt has been made to study the common causes, which can be held responsible for the failure of slopes, and necessary preventive/corrective measures against such failures have been suggested. Stability analysis and design of a rigid retaining wall have been carried out (using computer program developed in FORTRAN language) taking into account the effect of earth-quake. Other remedial measures are also recommended to make the area free from slope failure problems and to develop it as a place of tourist attraction being the lone hill station of Haryana.

***Keywords*:** Morni hills, landslide, slope failure, stability analysis, retaining wall.

1. INTRODUCTION

The area of Morni Hills is situated on the right side of the National Highway No. 22 while going from Ambala to Panchkula in India, the village Morni being at a distance of about 31 kms form the highway on a major district road 40 kms long and going upto village Bidyal. The area lies in Panchkula district located at altitudes varying from 1340 m to 1600 m. It has been noticed that the area contains lot of problematic areas because of reasons, such as, heavy rainfall on unprotected soil, improper surface drainage facilities, tension cracks on slopes and toe-cutting for making road, etc. These reasons lead to frequent landslides in the area, especially during monsoons (B.Tech Project, 1991).

The scope of the paper includes study of the problematic areas along motorable roads, investigation of causes behind them and accordingly remedial measures for the individual area are recommended with their design, if any, on the basis of the data available. A computer program in FORTRAN language has been developed for the design of rigid retaining wall taking into account the effect of earthquake.

2. STUDY AREA

The area of Morni Hills comes under Shivalik hills, which form parallel ridges along the foot to the Himalays and show highly dissected land topography. When viewed from the plains, the Shivalik appear to be dwarfed by the Himalayan ranges, which occur behind them. The area has pockets of dense forest but unfortunately, inspite of these forests, the area is almost denuded because of improper surface drainage facilities, tension cracks on slopes, heavy rainfall on unprotected soils and toe – cutting for making road , etc. So the area has been investigated along motorable roads.

3. CAUSES OF SLOPE FAILURE

Common causes, which can be held responsible for the failure of slopes at Morni hills, are as under:

3.1 Improper Drainage

In the absence of adequate and proper drainage facility, the rain water formed preferential flow channels, eroding the slope (Fig. 1). Percolation of rain water into the soil caused an increase in pore water pressure. The process of saturation lead to the instability. Although the influence of increase of unit weight on the stability of slope was marginal, the effect of increase in pore water pressure lowered the shear strength of the soil by reducing the value of effective normal stress and resulted in instability.

3.2 Un-protected Soil

Loose unprotected soil on granular slope, acted upon by turbulence of running water offered little resistance to erosion while moving over unprotected soil. Water detached and carried the fine soil particles by eroding them and the exposed areas allowed greater amount of infiltration into the soil mass resulting in building up of excess hydrostatic pore water pressure.

3.3 Toe-Cutting

Excavation close to the toe of a slope caused the same effect as that of loading of slope. The removal of the lateral supports particularly the removal of the toe of slope for construction of highway was responsible for the slide (Fig. 2).

Fig. 1 – Rain water flowing on the road in the absence of drainage facility. A breast wall is there on hill side

Fig. 2 – Slope failure because of toe-cutting for construction of highway

Here, the normal pressure on the potential slip surfaces decreased and the tensile and shearing stress in the unsupported earth or rock mass increased resulting in a slope failure.

Other causes of slope failure can be development of tension cracks, unpaved ditches or stone quarrying.

4. STABILITY ANALYSIS

4.1 Basis of Analysis

The soil mass must be safe against slope failure on any conceivable surface across the slope. Although the methods using the theory of elasticity or plasticity are also being increasingly used, the most common methods are based on limiting equilibrium. The methods of limiting equilibrium are statically indeterminate. As the stress-strain relationships along the assumed surface are not known, it is necessary to make assumptions so that the system becomes statically determinate and it can be analyzed easily using the equation of equilibrium.

In the analysis, the resultant of all the actuating forces trying to cause the failure is determined. An estimate is also made of the available shear strength. The factor of safety of the slope is determined from the available resisting forces and the actuating forces.

4.2 Proposed Design Structure

The stability of retaining wall should be thoroughly analyzed since its failure may lead to loss of human life as well as colossal economic loss. The retaining walls fall mainly due to instability of the hill slopes and settlement of the walls in monsoon season because of loose soil below the foundation. Retaining walls also fail if the backfill is not a free draining material.

Various theories (Coulomb, Rankine and Terzaghi) for the calculation of the earth pressure exist, but the most accurate theory is Coulomb's theory. According to this theory, the equilibrium of the whole of the material supported by a retaining wall when it is on the verge of moving slightly away from the backfill is considered and the earth pressure on the wall is calculated. This pressure on the wall is, in fact, a force of reaction, which it has to exert to keep the sliding wedge in equilibrium. Further, standard design assumptions have been considered.

5. ANALYSIS AND DESIGN OF RETAINING WALLS

The plan view of the problematic area including Panchkula – Morni road, various villages on the route and other features are shown in Fig. 3. Three important cross-section of slope involving the problematic areas are presented in Fig. 4 where landslides are a regular feature, especially during monsoons. Further, there are practically no drainage measures adopted in the area except a little bit at Mountain Quail. The entire area, though heavily vegetated, still contains patches of denuded soil, which needs to be attended to.

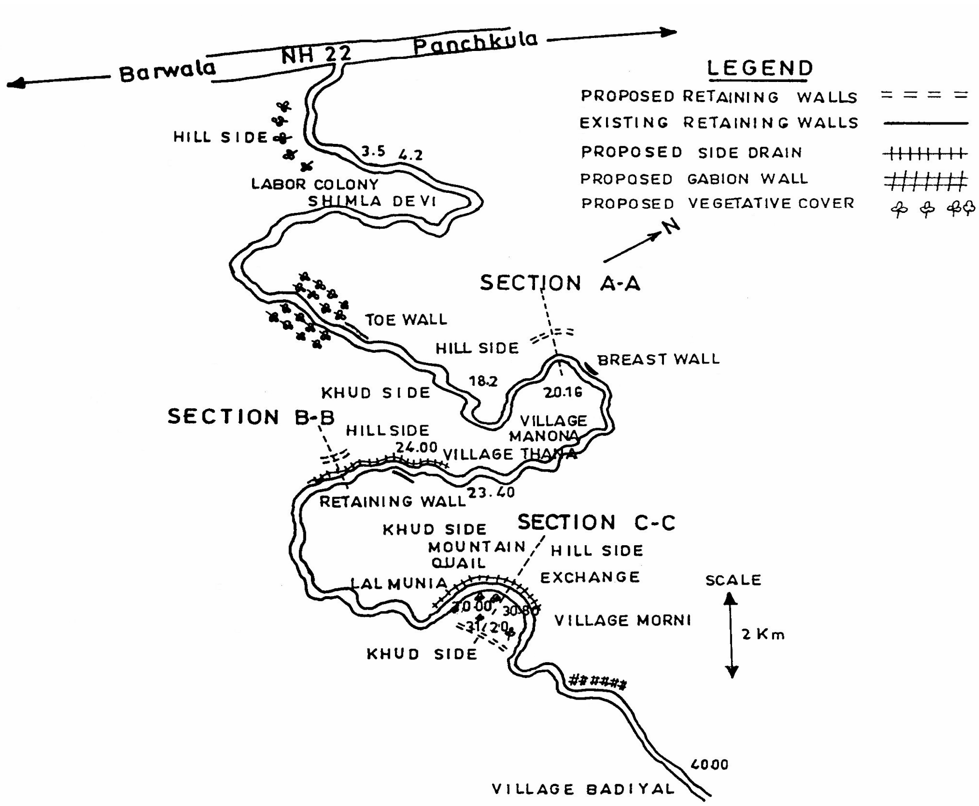


Fig. 3 – Plan of the problematic area

5.1 Stability Analysis for Problematic Slopes

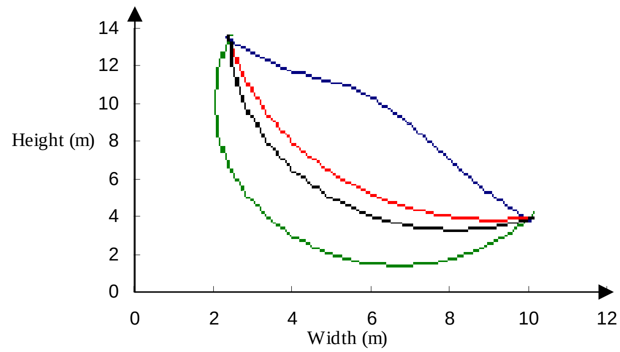
After identifying location of the problematic slopes as shown in Fig. 4 the areas were investigated for back-analysing the values of cohesion ‘c’, angle of internal Friction ‘ϕ’ and unit weight of the slope material ‘γ’. The values obtained for three sections are given in Table 1 assuming factor of safety (FOS) of 1.0 for failed slopes.

Table 1 - Material properties from three cross sections

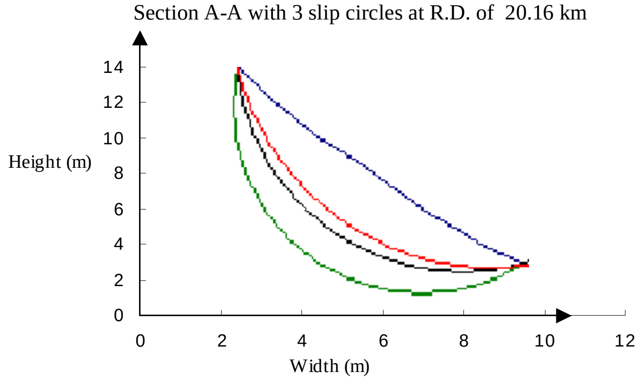
Section –AA	Section –BB	Section –CC
c = 1.5 t/m^2	c = 2.5 t/m^2	c = 1.5 t/m^2
ϕ = 24°	ϕ = 24°	ϕ = 28°
γ = 2.0 t/m^3	γ = 2.3 t/m^3	γ = 2.1 t/m^3
FOS = 1.0	FOS = 1.0	FOS = 1.0

The three sections were analyzed from the stability point of view by method of slices (c-ϕ method).

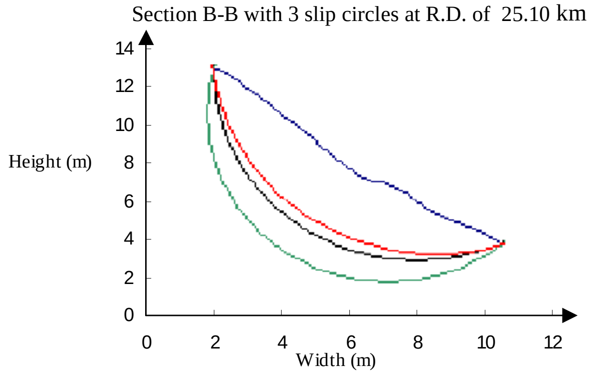
For each section, three trials were made as in Fig. 4 for the assumed slip surfaces and factor of safety for each was calculated.



Section A-A with 3 slip circles at R.D. of 20.16 km



Section B-B with 3 slip circles at R.D. of 25.10 km



Section C-C with 3 slip circles at R.D. of 30.60 km

Fig. 4 – Slip circles at three critical sections A-A, B-B & C-C marked in Fig. 3

5.2 Design of Retaining Walls

After the location of the three most critical slip surfaces corresponding to the three sections i.e. AA, BB and CC, the location of the retaining wall was decided, the wall being kept penetrating the critical slip surface for safety. To increase walls stability, the walls were tilted at an angle of 10° and the minimum depth of penetration for each was kept as H/10 + 30 cms, where H is the height of the wall. As the area falls in Zone-IV of the seismic zones of India, the values of α_h and α_v were obtained as 0.05 and 0.025 respectively. A computer program was developed in FORTRAN language for the design of retaining walls. Using the computer program, trials were made with different wall dimensions, till all design criteria was satisfied. In this way, the final wall section was arrived at. The design was done for both static conditions (i.e.

without seismic effect) as well as dynamic conditions for both upward and downward effect of the vertical component of earthquake force till prescribed factor of safety against overturning, sliding etc. were obtained.

The recommended locations of retaining walls to be built are marked in Fig. 3 having cross-sections as obtained in Table 2 after the design. These sections may call for minor changes to suit actual or changed site conditions. A typical cross section of retaining wall is shown in Fig. 5.

Table 2 - Proposed retaining walls

Reduced Distance (m)	Length (m)	Height (m)	Remarks
20,160.00	20.0	8.0	For section A-A
25,100.00	15.0	8.2	For section B-B
30,600.00	25.0	9.0	For section C-C

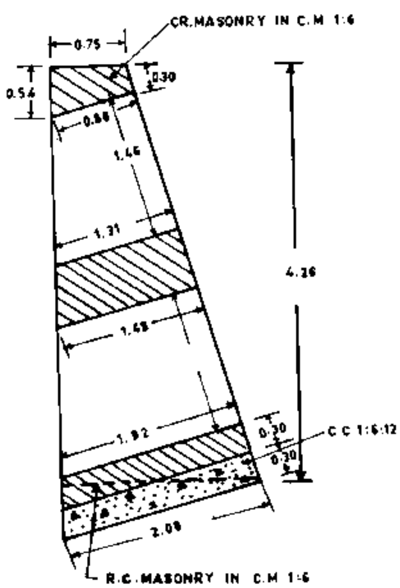


Fig. 5 - Typical cross-section of retaining wall (Dimensions in mm)

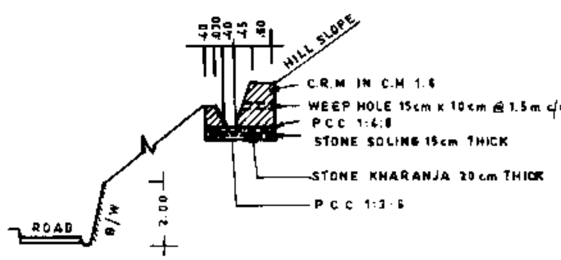


Fig. 6a – Typical cross-section of catch water drain

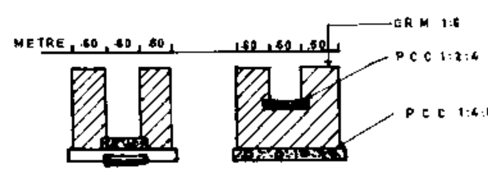


Fig. 6b –Typical cross-section of catch water drain and chute

6. OTHER REMEDIAL MEASURES

6.1 Drainage Measure

Poor drainage facilities very often lead to state of slope instability and deserve serious consideration in the context of the present problem. Morni experiences peak rainfall between June and August every year. Bulk of the rainwater infiltrates into the slopes.

For improving overall drainage system, it is considered desirable to (a) provide impervious carpeting on the associated areas through which infiltration is suspected (b) repair existing drains, if any and (c) provide additional drains.

The drains should be constructed according to the scheme presented in Fig. 3. The recommended cross–sections of the drainage structures can be as shown in Fig. 6 (a & b). These cross-sections are based on past-experience and may call for some minor modifications. Figure 7 shows a view of the recently constructed side drain at R.D. 24000 near village Thana.

Fig. 7 – A view of the recently constructed side drain at the proposed location (RD 24000m)

6.2 Proposal on Erosion Control

The existing vegetative cover on the slopes down the Mountain Quail building comprises of local annual and perennial species of mixed order. The roots of this vegetative cover are hardly 0.5m deep. The sward is also not uniformly spread and gaps of considerable extents are left uncovered rendering the area susceptible to erosion and water percolation during rains.

It is recommended that the slopes be vegetated by deep rooted species of KUDZU-VINE, ROBINIA RSEUDOACACIA and ERITHRINA INDICA cuttings. These vegetative materials are easily available at forest soil conservation centers.

Success of erosion control by vegetation largely depends on the care exercised in the initial stages of vegetative growth. The area should be guarded by providing barded wire fencing or such convenient means to arrest grazing by cattle at least for one season. Thereafter, there would be no need for maintenance.

7. CONCLUSIONS

Slope failure is a common feature in the area of Morni Hills. In the analysis of slope failure, the element of probability surpasses the element of certainty. Further, it is difficult to forecast a slide, unless there is a definite evidence of a horizontal motion of sloping grounds, such as cracking or relative motion of some points with respect of others.

The damages in the Morni area were mainly due to slope movements. Poor drainage facilities led to the development of excess hydrostatic pressure thereby resulting in lowering of the effective shearing resistance of the ground. In order to counter the forces, which may impair stability as well as for obtaining additional measures of safety, some retaining structures should be provided. Rock at some places in the region was fractured and disintegrated necessitating the construction of Gabion Walls. The foremost step towards the stabilization and strengthening of the hill slope would be the provisions of an efficient surface drainage system. Paved drains should be constructed. A spray of the asphalt mulch will make the slope impervious and plantation of vegetation will bind the soil to the slope and thus help in the retention.

The above measures, if adopted on a large scale, will convert the almost barren, deeply scarred area into no problem area with stable slopes, luxuriant forests, greenery and beauty all around. Further, they will convert the area under consideration into a place of tourists' attraction.

Acknowledgements

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References

B.Tech. Project (1991). Slope Failures at Morni Hills and Recommendations Concerning Corrective Measures, R.E.C., Kurukshetra.

Bhandari, R.K. and Mehrotra, G.S. (1985). Hill Roads and Himalayan Landslides, Proceedings – IRC Seminar on Construction of Roads in Hill Areas, Nainital.

Mehra, S.R. and Natarajan, T.K. (1966). Hand Book on Landslide Analysis and Corrections, CRRI, New Delhi.

Singh, A., Malhotra, B.R. and Tolia, D.S. (1982). Drainage of Roads and Slopes in Simla – A Case Study, IRC Seminar on Maintenance and Drainage Aspects of Road Pavements, Bangalore.