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STABILISATION OF SLOPES IN GARHWAL HIMALAYA

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ABSTRACT

Application of conventional rigid retaining structures as a measure to improve the stability of slopes in the Garhwal Himalaya was very common inspite of being very expensive and time consuming. The paper highlights two innovative technologies, e.g., reinforced gabion wall and anchored drum diaphragm wall, implemented successfully in the Garhwal Himalaya during eighties to improve the stability of slopes at comparatively lesser cost and time than the conventional retaining wall.

INTRODUCTION

The Himalayas are called the youngest mountain range of the world and that the developmental activities have been started a few million years too early. The normal rainfall, ranging 500-600 cm, spreads over 6-7 months in a year. Cloud bursts resulting in flash floods are also not uncommon. The region is also prone to seismic activity. Super saturation and loss of stability due to high intensity precipitation results in soil mass movement, silting of river beds, floods, toe erosion, erosion of slopes and denuding of vegetation. Indiscriminate deforestation activity in the himalayan region is also largely responsible for the loss of vegetational cover on the slopes. This results into slopes erosion and consequent loss of land in the area. As the population grows, more number of human settlements, dams, water reservoirs, roads etc. would be added. Disturbance of slopes while excavating soil disturbance to the stability of rock mass due to rock cutting and by blasting operations, also creates slides.

Generally measures adopted for improving stability of slopes fall into four categories depending upon the prevailing situation.

1 Installation of appropriate drainage system

2 Reducing slope angle i.e. grading of the slope

3 Injection and grouting of cracks and joints in the fractured rock mass

4 Providing external support to hold back the toe of the slope i.e. restraining structures

Among the above listed stabilization measures, first two are very common. In situations where these two do not suffice, artificial restraining structures, such as, retaining walls, are provided at the toe of the slope to check the downward movement of the rock and debris. Gravity retaining wall has greater resistance to sliding because of its larger weight but is not a cost effective proposition. Moreover, such walls are not very effecive in areas frequently effected by major land slides being rigid structure. Due to paucity of space, paper deals with only two case records of improving the stability of slopes, dealt by the Central Building Research Institute (CBRI) Roorkee, by providing an innovative retaining structure in each case in the Garhwal Himalayan region during eighties.

1. IMPROVING STABILITY OF SLOPE ALONG MUSSOORIE - CHAMBA BYE-PASS

Mussoorie is one of the famous hill stations in north India. It is situated at an altitude varying approximately from 1600 m to 2500 m at a distance of 31 km from Dehradun in the State of Uttar Pradesh. A bye-pass road was built by U.P.P.W.D. in the year 1976-77 connecting Dehradun-Mussoorie road and Mussoorie-Chamba road to bye-pass Mussoorie town and congested Landhour market. In the year 1978-79 a link road was also constructed by U.P.P.W.D. connecting the bye-pass road with Landhour market of Mussoorie town. Both these constructions involved cutting of hill slopes which could be responsible for accelerating instability of the slope in this region. Problem of subsidence of roads by about 60 to 80 cm during rainy season and widening of cracks in a group of buildings, located on the top of slope at km 5 on the bye-pass, was studied by CBRI. This was of great concern as some of the buildings, situated on the slope, had either cracked or even partially damaged due to subsidence and surface movements in the area (Fig. 1 & 2).

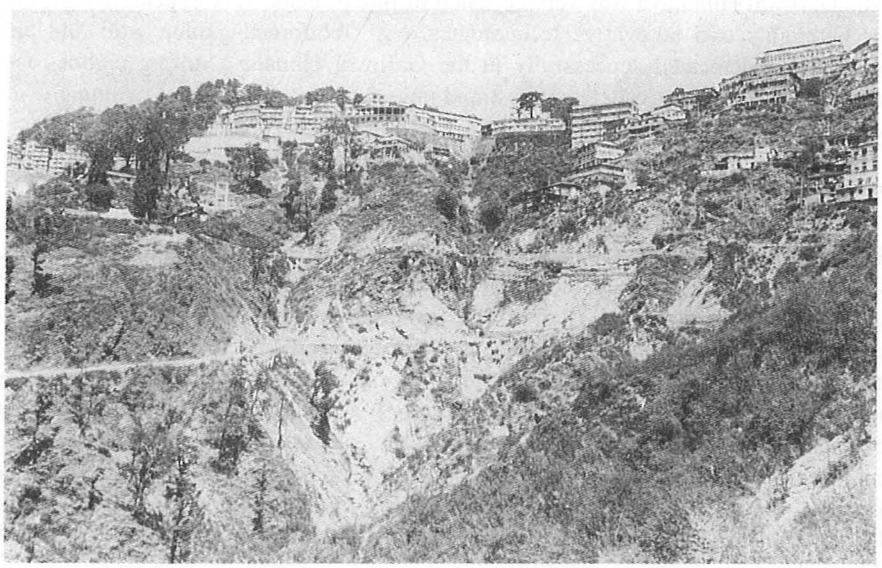

Fig. 1. View of Slope at Km. 5 along Mussoorie Chamba Bye-Pass.

Geology of the Area

Geologically the rocks exposed in and around the slide area belong to Permocarboniferous to Jurassic in age. The main rocks are dolomites and dolomitic limestones. Lithologically the dolomites have been found to vary from greyish black to yellowish grey in colour and show progressive change in degree of weathering resulting into the develoment of moderate to highly plastic clayey soil at the top. The beds dip northwesterly, northerly and north easterly at an angle varying from 20° to 45°. The structural features in this area show the presence of plunging, overturned and recombent folds. As a result the rocks got fractured and pulverised. There appears to be two fault zones in NNW and SSE direction which head towards each other. The bulging in the central region of the slide zone may be the effect of these two high angled fault planes meeting at the toe. In addition, two sets of joint patterns are commonly present in the slide area.

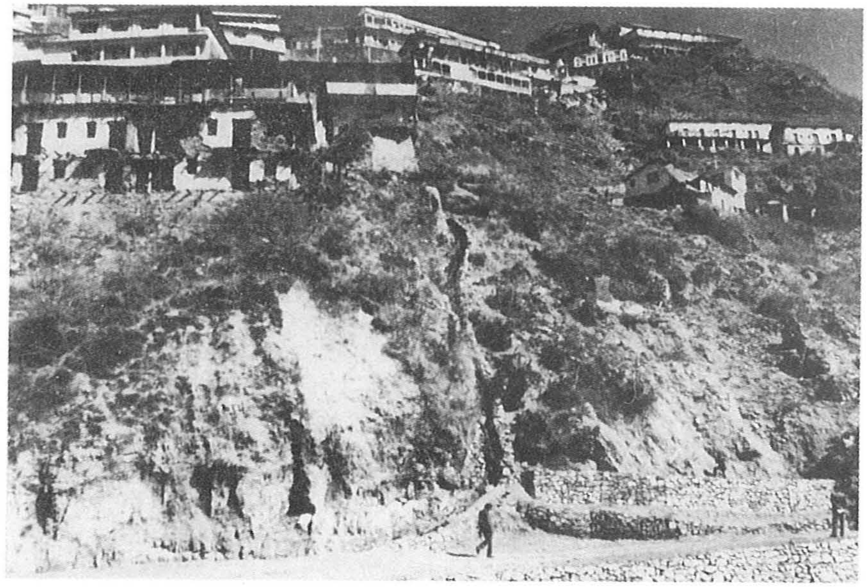

Fig. 2. View of damaged buildings on the slope on Mussoorie-Chamba Bye-pass

Proposed Measure to Improve Stability of Slope

Gabion wall reinforced with geogrid

The conventional practice followed by the U.P.P.W.D. in such a situation is to build either rigid retaining wall or a gravity wall by using stone-crates. The latter was adopted by P.W.D. for this particular site also before the problem was referred to CBRI but this measure had become inoperative due to excessive bulging of the stone crates in a short span of two to three months time after construction. Conventional rigid walls would have worked out very expensive because of their very thick section and still with a chance of failure due to subsidence as such walls can not withstand differential movement. So it was decided to use gabion wall reinforced with geogrids, a technique quite prevalent in developed countries, but its application in this country was new. Design details are available elsewhere (Bhandari & Garg - 1989). Cross-section of the Gabion wall is provided in Fig. 3.

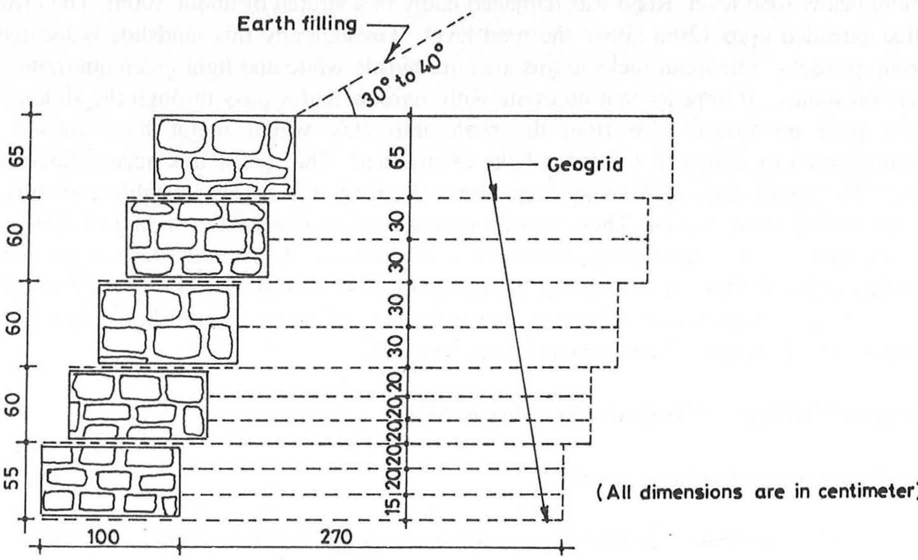

Fig. 3. Cross-Section of geogrid reinforced gabion wall

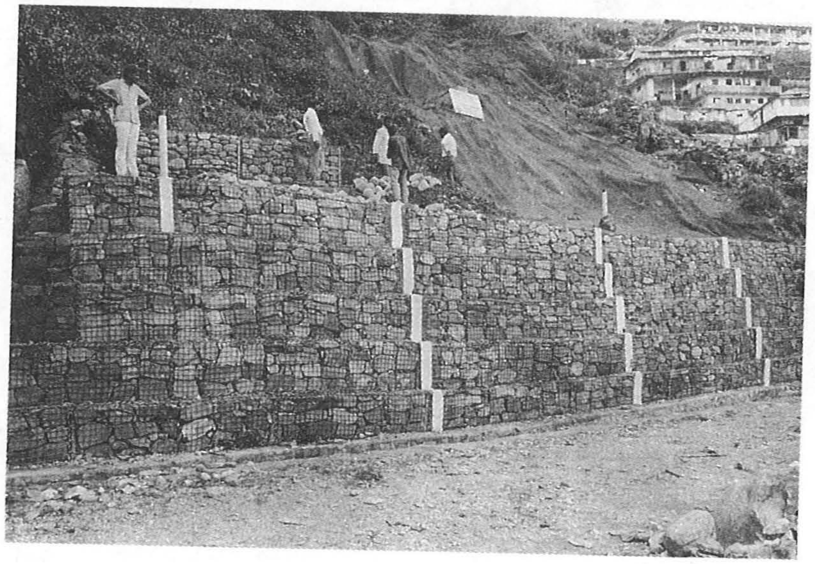

Fig. 4. View of 16m long geogrid reinforced gabion wall

Three grades of geogrids (CE 153 for making boxes, CE 121 for reinforcing backfill and CE 111 for covering hill slope) were used in the construction of wall. Fig. 4 provides a view of the wall under construction. The gabion wall comprised of two stretches of 16m and 12m length, each of 3 m height leaving a stable rock portion in between the two stretches.

The gabion wall was instrumented to monitor its performance. The monitored behaviour of the gabion wall has confirmed its satisfactory performance.

2. IMPROVING STABILITY OF SLOPE AT KALIASAUR LANDSLIDE

This landslide (Fig. 5) is located at km 147 on Hardwar-Badrinath road, 18 km east of Srinagar (Garhwal) and is situated in a sharp bend on left bank of river Alaknanda. Area suffered a major landslide on 19th September 1969 which had blocked 3/4th of the total width of the river flowing about 100m below road level. Road was damaged badly in a stretch of about 300m. The crown portion of the slide extended upto 120m above the road level. Geologically this landslide is located in the Garhwal group of rocks. The main rocks in this area are purple-white and light green quartzites interbedded with maroon shales. It appears that quartzite with maroon shales pass through the slide zone. These rocks have been pulverized converting the shale into clay which might have caused the sliding and accumulation of debris at the foot of the escarpment. The toe of this accumulated debris is near the river. The uphill slope of the slide zone above the road was highly unstable and caused heavy flow of debris during rainy season. There was an urgent need to restrict the sliding of debris. It was with this reason that the idea of making effective use of landslide debris and slope waste was pursued at the CBRI and the technology of drum diaphragm wall was evolved (CBRI - 1988) through design and field trials. Such a construction technology makes the maximum use of landslide debris and costs only about 60 per cent of the cost of conventional retaining wall.

Proposed Measure to Improve Stability of Slope

Anchored drum diaphragm wall

The system of retaining wall consists of empty bitumen drums interconnected vertically and laterally, filled with wasteful debris to achieve gravitational effect and suitably anchored to the slope and at the slope foundation as well. It is basically a dry system of construction. Besides promoting

Fig. 5. View of Slope at Kaliasaur landslide

utilisation of slope waste and enhanced speed of construction in difficult hilly terrains the system eliminates partilally expensive and dangerous excavations for foundations associated with conventional types of retaining walls. It being a self draining system, no excess hydrostatic pressure would be exerted on the wall from behind.

This innovative technology makes use of empty bitumen drums to serve as containers. The top and bottom portions of the drums were removed and only the cylindrical shell was utilised. These drums were arranged in two rows one behind the other. The rear row was of 2½ drums height and front row was 2 drums height. These drums were anchored to their base and also to the backfill with 25mm diameter mild steel bars of suitable length. The drums were also interconnected horizontally and vertically by mild steel flats and bolts. Details are shown in Fig. 6. The rain water that goes inside the drums also drains out through the drum bottom.

Construction of the wall

Location of the wall was marked on the prepared ground. Holes were drilled to a minimum depth of 60cm at predetermined positions 1m apart to accommodate 25cm diameter mild steel rods. The rods were driven into these holes. About 15cm wide and 45cm deep pit was made around these rods. cement slurry was poured into the hole and the pit was filled with 1:3:6 cement concrete. These rods served as vertical anchor at the base and provided additional resistance to sliding. The drums were then assembled and bolted in sequence (Fig. 7) to interconnect them. Alternate vertical rods in the rear row were supported at 1.3m level with the help of 50mm x 6mm mild steel flat which was taken into debris accumulated over the slope. The flats are held in position by two 25mm diameter mild steel bars driven vertically into the debris.

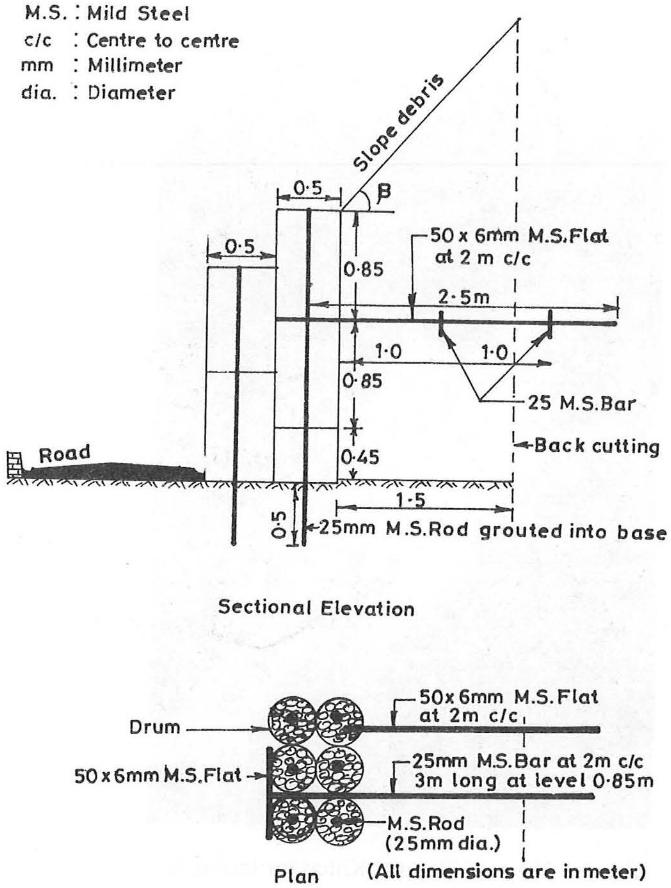

Fig. 6. Anchored drum diaphragm wall - its plan and sectional elevation

This has helped in preventing tilting of the retaining wall. As the construction proceeded, already completed portion of the wall was filled with debris. The space behind the wall was also filled with debris. 50mm x 6mm flat having a 28mm diameter hole at the centre was held against two drums of the front row. An L-shaped 25mm diameter, 3m long mild steel rod was inserted into the hole and driven inside the debris. This system was provided at 2 meters spacing to keep it in proper alignment and to provide additional stability.

About 100m long and 2.5m high wall was constructed at Kaliasaur landslide location during 1986. Alignment of the wall was monitored in those days which did not show any significant change. Fig. 8 provides the view of the wall constructed at the site.

In addition to providing innovative earth retaining structure, some common and site specific measures were also taken at each slope to improve its stability. Common measures include modification of the drainage system, construction of toe wall and breast walls, sealing of cracks and joints, vegetative turfing on the slope etc. Site specific measures consisted of modification of culverts, maintenance of roads, halt on further construction activity in the area and provision of grout columns to improve the stability of upper region of the slope, for the slope along Mussoorie-Chamba Bye-pass whereas construction of series of anchored stone masonry walls and stitching of debris on the slope were recommended for the slope at Kaliasaur landslide.

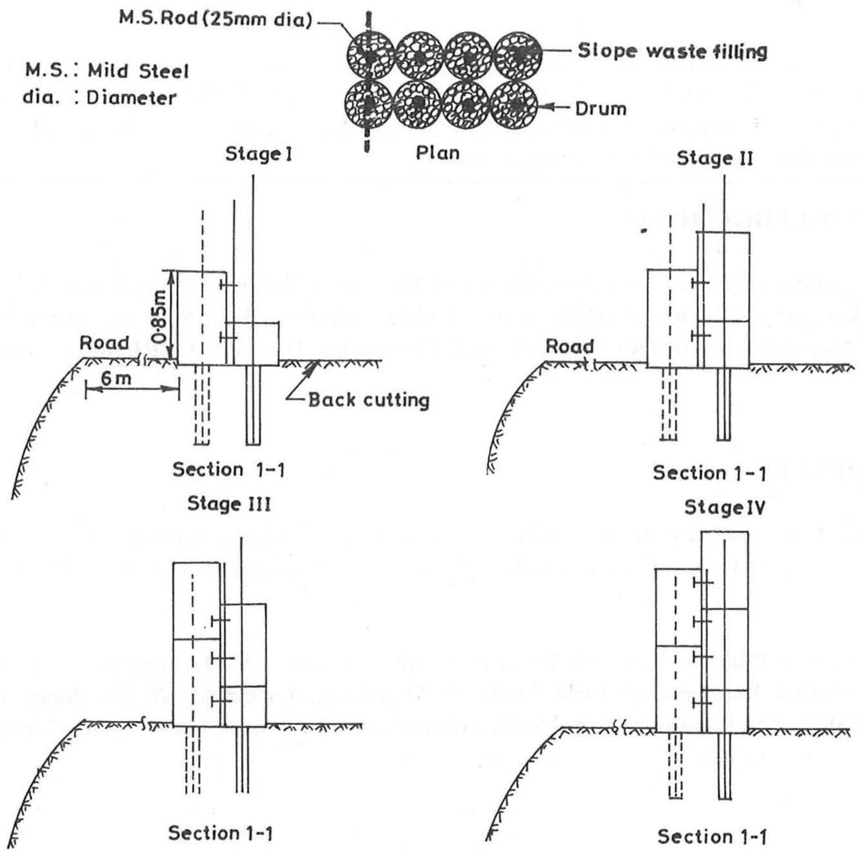

Fig. 7. Sequence of construction of anchored drum diaphragm wall

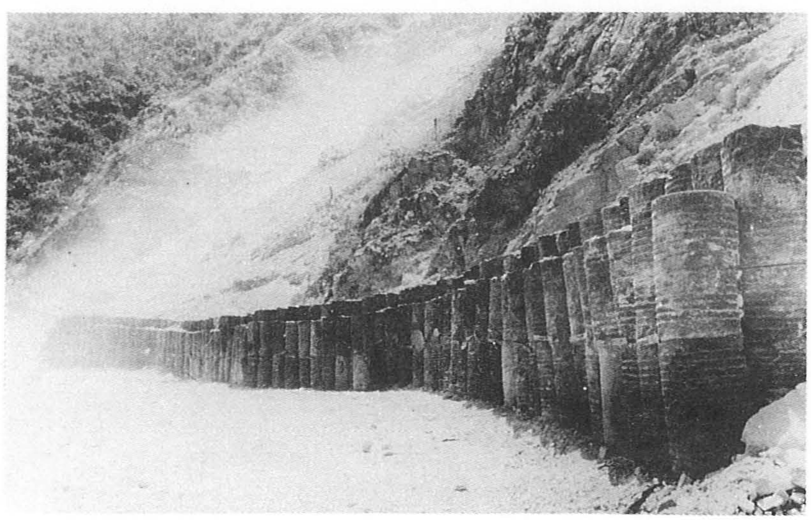

Fig. 8. View of the drum-diaphragm wall built at toe of upper slope

CONCLUSION

It can be stated, based on their performance, that the two innovative technologies were successfully implemented in the field and proved their worth. Both the technologies could safely be recommended elsewhere in the Himalaya as an economical and technically sound substitutes to the conventional masonry gravity retaining walls.

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