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Proceedings: Second International Conference on Case Histories in Geotechnical Engineering, June 1-5, 1988, St. Louis, Mo., Paper No. 2.60

# A Novel Low Cost Drum Diaphragm Wall for Landslide Control in the Himalaya

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## SYNOPSIS

Construction of masonry and reinforced cement concrete retaining walls are common as a measure of landslide control in the Himalayan region. They are usually very expensive and call for import of cement, steel, stones, sand and water from long distances. The paper spotlights a novel technology of constructing anchored drum diaphragm retaining walls which make use of slope waste material itself for wall construction, saving to the tune of 40 per cent in cost. Utilisation of slope debris in turn minimises hazards due to debris flow, rockfalls etc and other mass movements.

## INTRODUCTION

Himalayan landslides generate staggering amount of debris most of which are eventually swept away by its mighty river system capable of carrying incredibly large amount of sediment. Satellite pictures taken in 1974 dramatically reveal that eroded debris carried by the Himalayan rivers have indeed created a new land mass about 50,000 sq.km in area extending well beyond 700 km into the sea. With the vast slopes of Nepal, Western Sikkim, Kumaon, Garhwal Kashmir and several other hilly regions getting robbed of their vegetal cover particularly due to indiscriminate deforestation, the gravity of slope erosion and consequent landloss may become even more alarming. As the population grows, more and more of human settlement, dams, tunnels, water reservoirs and roads would be added. The current experience highlights that the network of 40,000 km of hill roads in the Himalaya is already prone to heavy landsliding involving on an average 5,000 tonne of debris and slope waste on every major landslide spot each year. Every kilometre of road when constructed could be expected to generate 1 to 2 lac tonne of debris right at the time of construction. If effective methods of landslide control are to be found, the enormous slope waste material must be put to effective use. By doing so, not only the hazards associated with debris flow and rock falls would reduce but a tremendous economy in building materials and construction costs of control measures would seem possible.

The usual package of landslide control measures for Himalayan landslides inter alia include construction of gravity retaining walls, gabion type walls, timber piling for stitching debris perched on slopes, prestressed anchoring of sliding masses, vegetating of the problematic slopes and provision of surface and subslope drainage systems. The construction of retaining walls normally require large quantities of cement, steel, stones, sand and water to be transported usually from long distances at a very heavy expense. It is for this reason that the idea of making effective use of landslide debris and slope waste was pursued at the Central Building Research Institute and the technology of drum anchored diaphragm walls was evolved through design and field trial. Such a construction technology makes the fullest use of landslide generated debris and costs only 60 per cent of the cost of conventional retaining walls.

## DRUM ANCHORED DIAPHRAGM WALL

A simple to do, low cost technology for construction of retaining wall to stabilise slopes has been developed by the author Bhandari (1987), which promotes extensive use of slope waste and landslide debris. The system of drum anchored diaphragm walling consists of empty bitumen drums interconnected vertically and laterally, filled up with wasteful debris to achieve gravitational effect and suitably anchored at the slope foundation as well as on to the slope retained. It is basically a dry system of construction. Besides promoting utilisation of slope waste and enhanced speed of construction in difficult hilly terrains, the system offers following advantages :

- Effective utilisation of wasteful slope debris, thereby saving scarce building materials and their long distance transportation.

- Partial elimination of expensive and dangerous excavations for foundation associated with conventional types of retaining walls.

- Effective use of wasteful empty bitumen drums available in abundance through road construction agencies.

- Dry construction technology, which does not require water otherwise difficult to get particularly in the hilly areas.

- Self draining system thus relieving excess hydrostatic pressures behind the retaining wall.

- Easy construction that does not require heavy equipment for construction.



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- Speed of construction is usually high and need for skilled personal is generally low.

## SPECIAL FEATURES

The system of retaining wall makes use of empty bitumen drums to serve as containers. The top and bottom portions of drums are removed and only the cylindrical shell is utilised. In an actual construction, these were arranged at Kaliasaur landslide (Fig. 1) in two rows, one behind the other.

*FIG. 1 KALIASAUR LANDSLIDE*

The rear row was of 2 1/2 drums height and the front row was of 2 drums height. The drums were interconnected in both vertical and horizontal direction by m.s. plates and bolts to ensure continuity and were filled with debris to give weight and impart stability. The drum wall was anchored at the base and also to the back-fill to attain further stability against sliding and tilting. Details of the wall are shown in Fig. 2. The contact surface between the two adjoining drums being irregular allows free flow of water, which also flows between the drums and that should relieve the unbalanced hydrostatic pressures on the wall. The rain water that accumulates inside the drums also drains out through the drum bottom.

## DESIGN CONSIDERATIONS

A retaining wall of above description constructed from slope waste can be analysed for its stability by Finite Element Method assuming it as a plane strain problem. A typical drum diaphragm wall is built of slope waste placed into empty bitumen drums which are anchored using 25 mm dia mild steel bars grouted into the foundation to a depth of 0.6 m. The diaphragm is anchored to the slope with the help of 50 x 6 mm m.s. flat at 2 m centres 2.5 m into the slope.

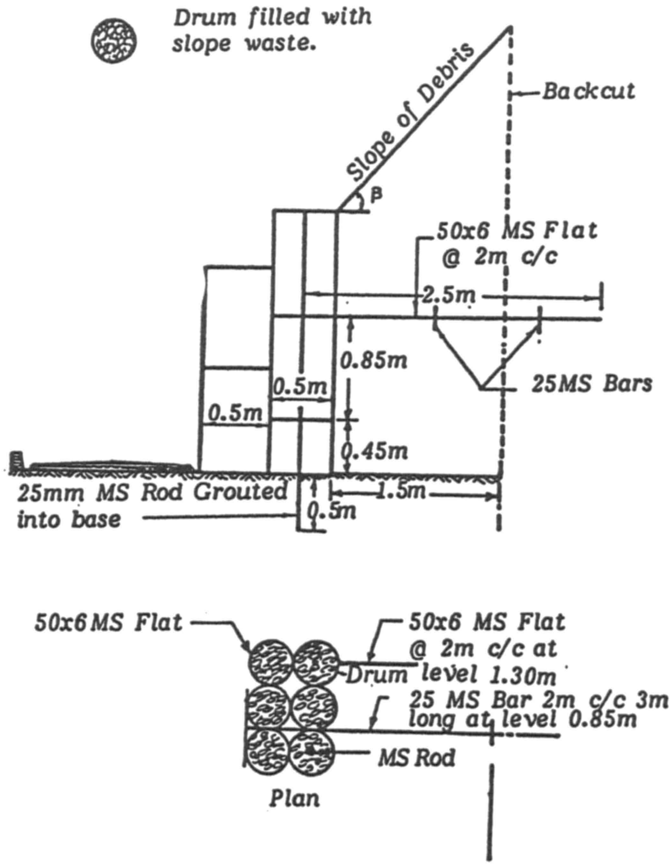


*FIG.2 ANCHORED DRUM DIAPHRAGM WALL BUILT OF SLOPE WASTE AND EMPTY BITUMEN DRUMS*

Tsui and Clough (1974) have examined the validity of assuming the condition of plane strain for the anchored walls. It has been demonstrated that most anchored walls have a tie back spacing that is close enough to justify the assumption of plane strain. They have defined the earth pressure as dimensionless parameter $I_p$ which equals $l_o^2 p/P$, where $l_o$ is the characteristic length of the slab, p the earth pressure, and P the prestress load. The maximum deviation of the plane strain pressure from the three-dimensional pressures works out to be only 15 per cent. In the general case, the deviation of three-dimensional pressures from a plane strain distribution was defined in terms of the soil stiffness, the wall stiffness and the tie back spacing. The results showed that stiffer the wall, the closer the tie back spacing and the softer the soil, the more accurate is the assumption of plane strain condition. In this case the anchors were ordinarily grouted and



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there was no prestress. As such, the assumption of plane strain condition for the drum diaphragm wall appears to be justified.

The analysis of the diaphragm wall with the retained earth has been carried out by discretising the continuum by 8-noded isoparametric element. The continuum has been extended to be 7 m below the diaphragm wall and also on either side of it. The following material properties for the retained disintegrated soft rock mass have been adopted in the analysis.
$E = 250\ kg/cm^2;\ = 0.30;\ = 1800\ kg/m^3;\ Ø' = 30^o$

For the slope wastefill inside the bitumen drum, the following material properties have been taken :

$E = 1500\ kg/cm^2;\ = 0.30;\ = 2000\ kg/m^3;\ Ø' = 35^o$

Fig. 3 shows the distribution of horizontal earth pressure, Fig. 4 the horizontal displacement of the drum diaphragm wall obtained by the finite element analysis and the same has been compared with that obtained by Coulomb's theory. The slope of surcharge of the retained material has been taken as $30^o$.

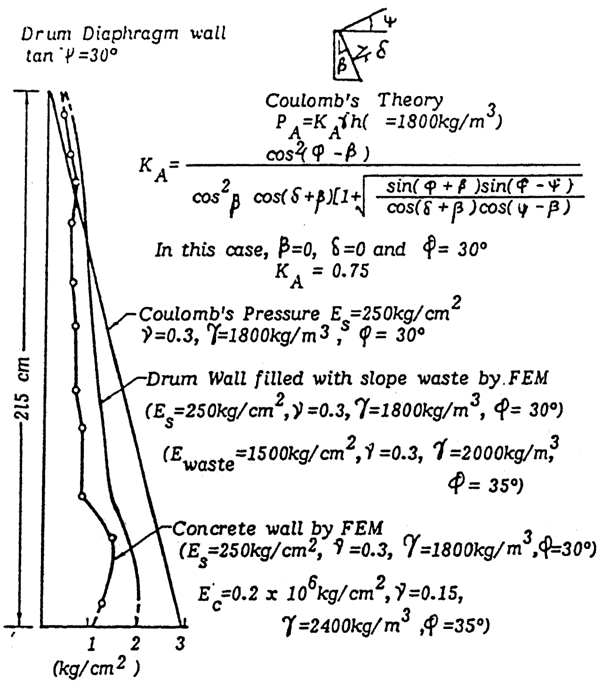


*FIG. 3 EARTH PRESSURE DISTRIBUTION*

## CONSTRUCTION

The alignment of the retaining wall is first marked on a prepared level base on the slope. Holes are drilled using a suitable compressor to a minimum depth of 60 cm at predetermined positions, 1 m apart, to accommodate 25 mm dia m.s. rods. The rods are driven into these holes. About 15 cm wide and 45 cm deep pit is made around these rods and the pit is filled with 1:3:6 cement concrete. The rods serve as vertical anchors at the base and do provide a high degree of resistance against sliding. The drums are then assembled and bolted in the sequence shown in Fig. 5. Alternate vertical rods in the rear row are supported at 1.3 metre level with the help of 50 mm x 6 mm m.s. flat which is taken into debris accumulated over the slope. The flats are held in position by two 25 mm dia m.s. bars driven vertically into the debris; this helps preventing tilting of the retaining wall.

As the construction of drum wall continues, the already completed portion of the wall is filled with debris which provides mass to the wall. The space behind the retaining wall is filled with debris. A 50 mm x 6 mm flat having a 28 mm dia hole at the centre is held against two drums of the front row. An L-shaped 25 mm dia, 3 m long m.s. rod is inserted into the hole and driven into the debris. This system is provided at 2 m centres to keep it in a proper alignment and to provide additional stability.

Based on this technology, about a 100 metre long and 2.15 m high wall has been constructed at Kaliasaur landslide area, 18 km east of Srinagar (Garhwal) on Rishikesh-Badrinath road. A view of the wall after construction in August 1986, at a time when debris flow in the slope cover was at its peak, is shown in Fig. 6. Even when a lot of debris rolled down from the top of the slope and covered the wall, it has stood stable.

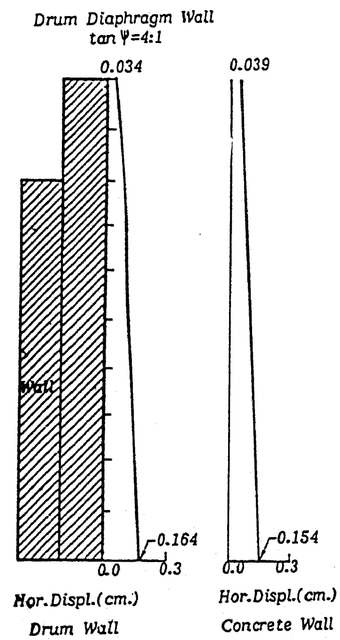


*FIG. 4 HORIZONTAL DISPLACEMENT OF WALL*

The alignment of the wall, monitored so far has not indicated any significant displacements. Observations are continued to monitor the performance of wall. In addition to the drum retaining wall provided at the toe of the slope, other measures like slope drainage and slope vegetation are also being implemented to enhance slope stability.

The materials used for a typical 100 m long wall are given below :

1. Empty bitumen drum - 50 cm dia = 900 Nos.
   (available from Road Construction Deptt. as Waste Material)



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2. 12 mm dia, 7.5 cm long bolts with nuts = 250 kg
3. M.S. flat 50 mm x 6 mm = 3570 kg
4. M.S. rod 25 mm dia = 2770 kg
5. Debris for filling drums (available in plenty at site as waste material) = 160 cu.m

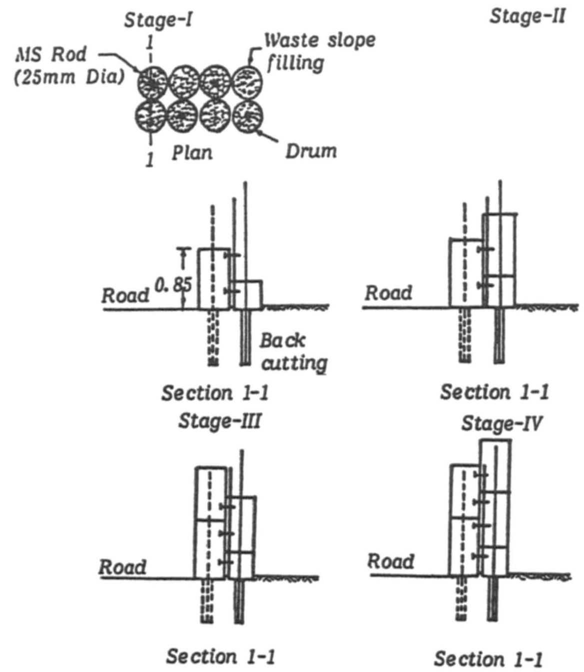


*FIG. 5 SEQUENCE OF CONSTRUCTION OF ANCHORED DRUM DIAPHRAGM WALL*

*FIG. 6 DRUM DIAPHRAGM RETAINING WALL ON KALIASAUR LANDSLIDE*

## FIELD MONITORING

The wall was monitored using EDM surveys and the displacements over a period of 18 months were found to be negligible. Prediction of displacements were made using FEM and the correspondence between the prediction and performance was, so far, found to be satisfactory.

## CONCLUSION

It can be concluded that the drum diaphragm retaining wall built at the Kaliasaur landslide in Garhwal-Himalaya has been successful. The technique could safely be recommended to provide effective and economical substitute for stone masonry or concrete retaining walls elsewhere in the Himalaya. They may ultimately workout to be much cheaper and safer than even the conventional wire-netted sausage walls and gabion walls. The greatest advantage appears to be that the material of construction is available in-situ eliminating need for import.

## ACKNOWLEDGEMENT

The author would like to thank Dr. G.S. Mehrotra and Shri B.K. Jindal for carrying out most of the field work. Thanks are due to Dr. S.C. Chakraborti for assistance in analysis.

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