Landslides Management in Rural Roads in Regions of Kotdwar in Pauri District (Uttarakhand): Challenges & Opportunities

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Abstract

Landslides are one of major geohazards in mountainous regions, often leading to severe damage to life & property, state of Uttarakhand is no exception. Causes associated are both, natural as well as anthropogenic. Under normal climatic conditions, a majority of the hill & valley slopes are in the state of geomorphic equilibrium. Rain normally triggers the landslide by raising the water table and pore water pressure, which ultimately leads to slope failures, often get accelerated due to on-going road constructions activities. An effective management of aforementioned Geohazard along rural roads around Kotdwar tehsil in Pauri district or elsewhere requires understanding of spatial & temporal aspects related with the hazard scenario across the road networks. Assessment, Quantification of landslides, Mapping, Hazard Zonation, Development of adequate institutional capacities along road networks are main challenges due to in-adequately documented inventories & mapping about the spatial probability of hazard (susceptibility), temporal probability, and magnitude-frequency analysis The study area consist of sub-projects i.e. total number of 4 roads for a total length of 48.20 Km. The entire project is located in Pauri District which is administratively divided into six tehsils, viz., Pauri, Lansdown, Kotdwar, Thalisain, Dhumakot & Srinagar, and fifteen developmental blocks, of which eleven blocks are coming under the project area viz. Pauri, Pabo,Thalisain,Bironkhal, Dwarikhal, Dugadda, Jaihrikhal, Ekeshwer, Rikhnikhal, Nainidanda & Khirsu The proposed improvement roads project encompasses an area of 5440 sq. km and situated between 29 45' to 30 15' N Latitude and 78 24' to 79 23' E Longitude and at 1650 meters above the Mean Sea Level. Highly significant numbers of landslides, approximately 25 in each ten kilometers of several roads have been observed. Treatments of all such slides depend upon the severity. Majority of these slides belong to severe to moderate categories. Slope geometry correction, providing protection to the toe of slope by retaining structures, management of the surface and sub-surface water drainage to reduce the development of pore pressures, nailing, bolting, anchoring, micro piling, application of geo-grids and geo-textiles and afforestation, constitute powerful elements of most geotechnical packages commonly used for improving the stability of problematic slopes and landslide sites in India. The present paper intends to briefly describe, analyze & review the causes of ten major landslides and mitigation measures implemented so far in four rural roads around Kotdwar town of Pauri district, while identifying challenges & opportunities associated with required institutional capacities in assessing slope failure

possibilities, hazard zonation & mapping along with innovative approaches to be followed regarding the management of landslides in the same region.

1. Introduction:

Construction and maintenance of rural hill roads in the entire Himalayan regions is always beset with lot of challenges as well as vast opportunities not only for the engineers, environmentalists, geologists but also for administration & local communities. Rural roads around Kotdwar town as well as other regions of Pauri district get blocked due to landslides in almost every monsoon season, sometimes for days at different stretches. There are limited numbers of alternative roads as a result of which public & private transport as well as transport of essential commodities get stranded on the road during such natural calamities. Often people cross the trouble spots on foot with their essential commodities at the risk of their own lives. A review of literature suggests that significant number of studies have been carried out regarding detailed geological investigations & management of landslides in Garhwal & Kumaon Himalayas. However, most of them have been confined so far beyond Pauri district & Siwalik foothills.

2. The Study Area:

The study area is located in foothills of Siwaliks and comprises of four roads of total length of 48.20 Km (Table 1 & Figure 1). A number of 10 landslides were studied at different chainages with major emphasis on slope conditions, causes, treatments implemented to control & prevent frequent occurrences of slides.

Table 1
Landslides & Management Measures Implemented in Rural Roads around Kotdwar Town (Pauri-District-Uttarakhand)

S. No.	Road	Length	Chainage of Landslide Occurrence	Mitigation Measures Taken	Photograph No
1.	Kandakhal-Chailusain	15.00 km	10 + 650	Wire crate	1
			6 + 730	Breast wall	2
2.	Matyali-Dwarikhal	17.20 km	14 + 600	Wire crate	3
			8 + 400	Wire crate	4
			6 + 900		5
3.	Chailusain-Devikhet	10 km	1 + 950	Wire crate / Retaining Wall	6
			3 + 000	Breast wall	7
4.	Hanumanti-Fatehpur	6.00 km	0 + 650	Breast wall	8
			1 + 250	Retaining Wall	9
			2 + 050	Breast wall	10

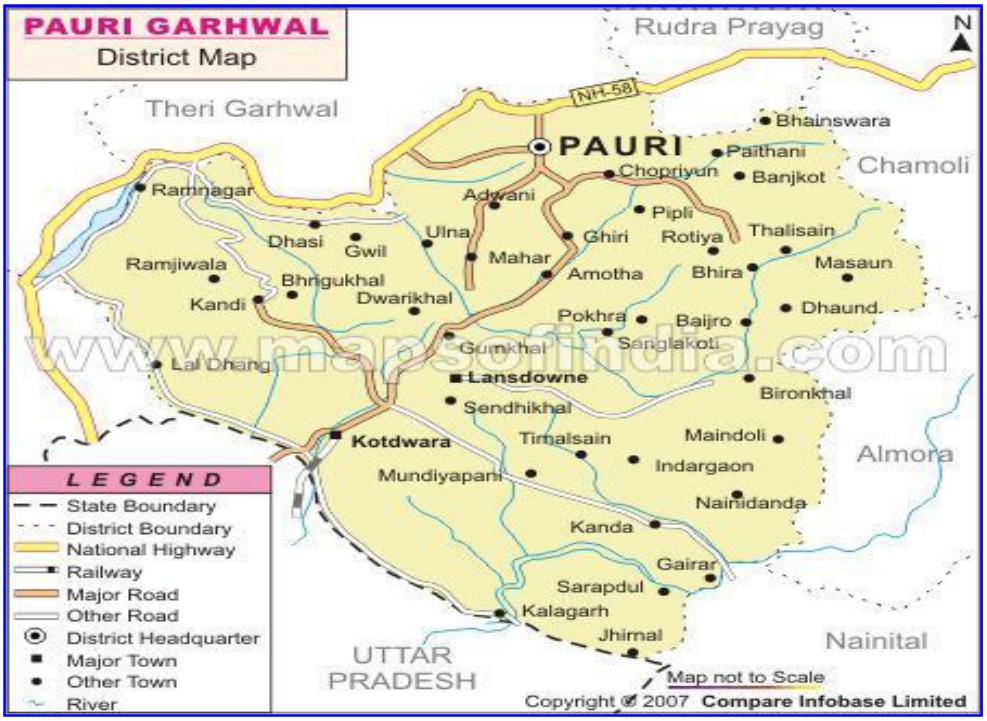


Figure 1 Location of the Subprojects Roads around Kotdwar Town (Pauri District Uttarakhand)

2.1.1. Geology (Based on Krishnan & Wadia):

All project roads under construction are located in Siwalik foothills. The Siwalik hills with its rugged topography are very recent in origin, being only 18.5 million years old compared to Himalayas (40 million years old), Vindhyachal (1,000 million years old) and Eastern Ghats (2,500 million –3.5 billion years old).. The sedimentation of Siwaliks (Tertiary rocks) took place broadly in three cycles i.e. (i) Lower Siwalik during Early Pliocene (ii) Middle Siwaliks during Mid Pliocene and (iii) Upper Siwalik during Early and Middle Pleistocene during Himalayan tectonic upheavals. The Siwalik system is a 5,000 meters thick detrital stratified mass of sandstone, sand rocks, mudstone, and conglomerates. The southernmost zone is the Siwalik Foothills fault that is all along the foot of the Siwalik Hills. This is not a single fault extending throughout but a series of overlapping and sometime interlacing faults across which the land mass has moved significantly. The relative movement between the plains and the Siwaliks should be seen from the perspective of the hundreds of meters of alluvial material that has accumulated with a thickness of over 500 meters and the heights of nearly 1600 meters attained by these hills. This continual upheaval and burial has brought about a unique physiographic situation in the region south of the Siwaliks. As far as rock types are concerned, these uplifted ridges & valley system comprises primarily of sandstone, clay, gneiss and quartzite. The sedimentary nature of the mountains makes them prone to erosion and thus during the south-west monsoon the several ephemeral streams that originate in this region bring down large quantities of coarse material comprising chiefly of boulders, clay and

coarse alluvium. Sandstone is the predominant rock type in & around Kotdwar region of Siwalik foothills are essentially sandstones with subordinate shales, siltstones and clays.

2.2. Slope Conditions:

Highly unstable & steep slope conditions have been observed across roads mentioned in the table 1. Angle of slope is usually higher than 30 degree in all hills along roads.

3. Causes of Landslides:

Hill roads in the study area are characterized by highly steep and rugged slopes with frequent landslides. Most of the studies conducted in such types of Himalayan regions include construction and GIS overlaying of thematic maps that correspond to contributing causative factors, and are interpreted either manually (e.g. Anbalagan; Pachauri and Pant; Gupta *et.al*.; Sarkar et.al.; Mehrotra *et al.*) or by GIS-based techniques (Gupta and Joshi ; Nagarajan *et al.*; Kanungo *et al.*), thus lead to the identification of vulnerable or landslide susceptibility zones along hill roads .Main factors identified as responsible for the frequent landslides in these regions are steep slopes, toe erosion by rivers, heavy rainfall, melting of snow at high altitude, loss of vegetation (deforestation & tree losses due to hill cuttings required for the construction of roads), earthquake, mining and unplanned urbanization. However, less number of location & site-specific studies have been conducted regarding ground truth verification due to highly difficult terrain beyond foothills of Siwaliks Both natural & anthropogenic factors are responsible the occurrences of landslides\slips in the study area. A brief description of all such factors is given in the foregoing paragraphs:

3.1. Natural Factors:

3.1.1. Monsoon Rainfall:

Entire road network in Pauri district have witnessed extensive damage in the near & remote past and continuing with the similar fate on a lesser extent due to mitigation measures being taken and alertness of district administration in times of calamities. The entire road network is still prone to landslides\slips, subsidence, lateral mass movements & toe erosion. The region experiences heavy rainfall almost every year. Saturation of rock & soil strata on steep slopes during monsoon period lead to building of high pore water pressure in lack of appropriate & adequate drainage across the steep slopes, leads to slope failures which further leads to the frequent occurrences of landslides\slips across these hill roads.

3.1.2. Geology:

Lithology (rock types) & structural characteristics (Mechanical properties of joints, faults, folds, bedding planes. All roads comprises of highly fragmented rocks along with aforementioned structural features which due to heavy rainfall generates disequibrillum in stress-strain relation on steep slopes accompanied by heavy pore water pressure, due to

lack of appropriate & adequate drainage facilities , lead to slope failures and slides on & around roads**.**

3.1.3. High Slope Gradients:

It has been mentioned earlier that roads have been and being constructed along steep slopes with highly fragmented & weathered lithologies & structural features. Moreover, these slopes are devoid of soil holding vegetation in most locations, thus saturation of rock/soil strata on these steep slopes during monsoon period lead to frequent occurrences of landslide\slips**.**

3.1.4. In-situ Chemical Weathering and lack of Appropriate & Adequate Drainage Systems:

In-situ chemical weathering over geological periods have converted hard rock lithologies on steep slopes into fragmented rocks and even soil also which after getting saturated with rainwater during monsoon periods slides/slips due to build up of heavy pore water pressures due to the lack of appropriate drainage systems on & around slopes .

3.1.4. Neotectonic Activities & Earthquakes:

The entire Himalayas are highly tectonically active and experiences a lot of earthquakes as revealed by earthquake & landslides history..However, adequate attention has been paid by geologists in foothills of Siwaliks where roads under study are located, thus, seismicity & tectonics induced landslides /slips have been least reported from this region unlike other parts of Himalayas**.**

3.2. Anthropogenic Factors:

3.2.1. Deforestation on Slopes

Deforestation across the steep slopes leads to lessening of strengthening of rocky/soil materials with roots of trees, thus, steep hill slopes lose their resistances to failures and occurrences of landslides/slips take place**.**

3.2.2. Grazing on Hill Slopes:

Indiscriminate grazing without appropriate & adequate arrangements for social fencing lessens the cohesive strength of soil materials on slopes, and occurrences of landslides/slips take place due to speedy saturation of soil strata on hill slopes.

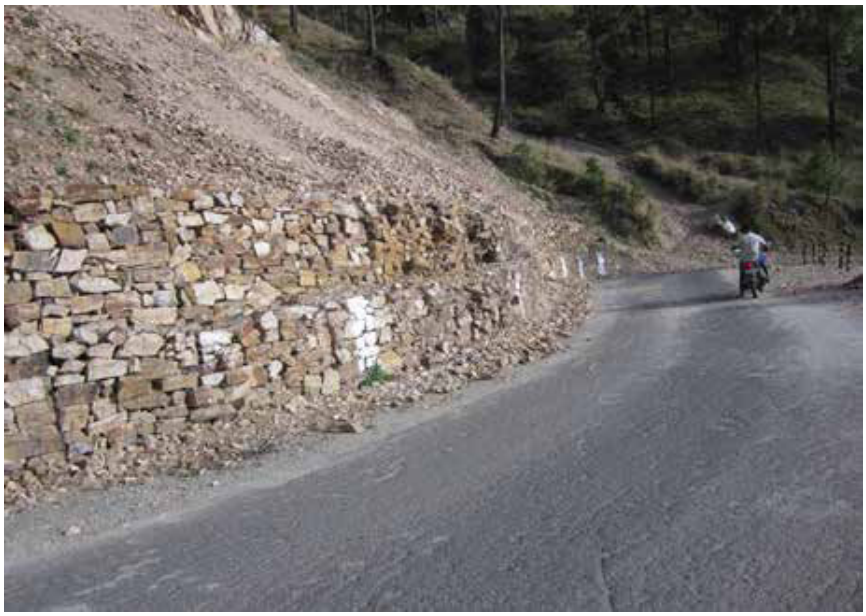
3.2.3. Road Construction Activities:

Road construction activities, especially hill cutting& blasting activities, if not planned & executed as per IRC standards & Specifications, may lead to deforestation and reduction of mechanical strength of rock & soil strata along hill slopes and ultimately lead to landslides/slips.

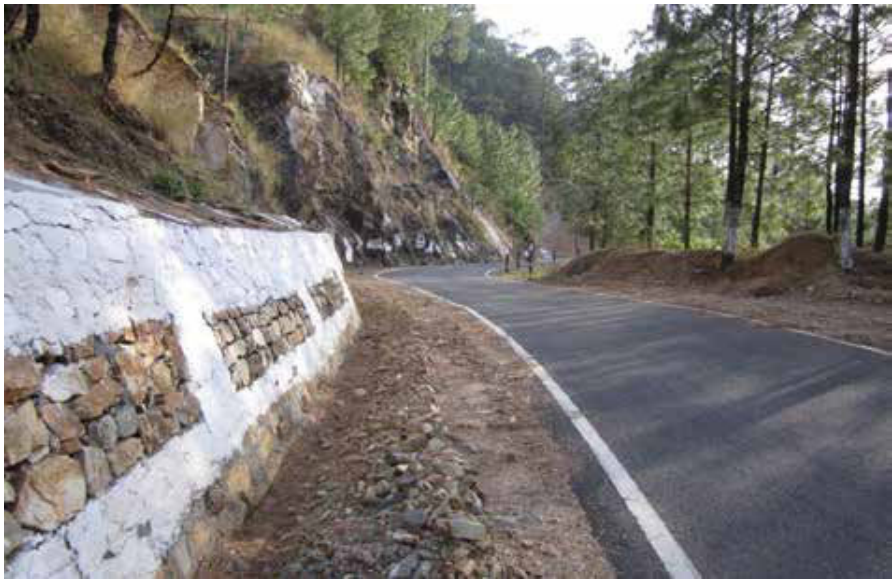
4. Landslides Management (Treatments) Implemented So far:

4.1. Civil Engineering Measures:

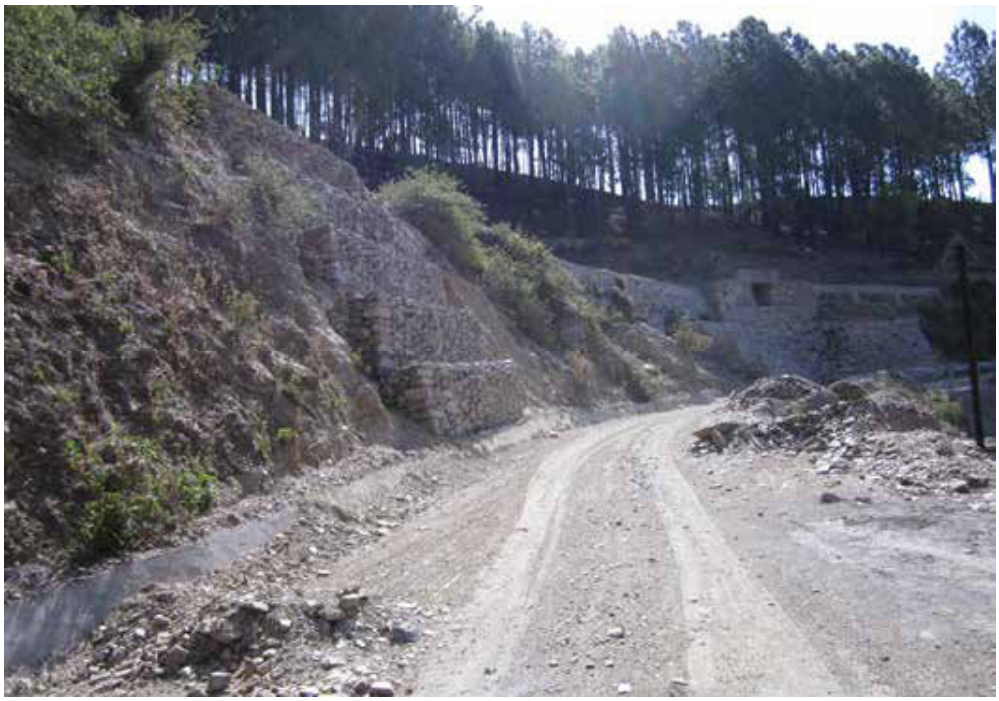
So far only civil engineering measures have implemented, though there is a need for applying combination of civil & bioengineering measures. Majority of civil engineering measures are Bresatwalls, Check walls, Wire-Crete and retaining walls (Pictures 1 to 10).



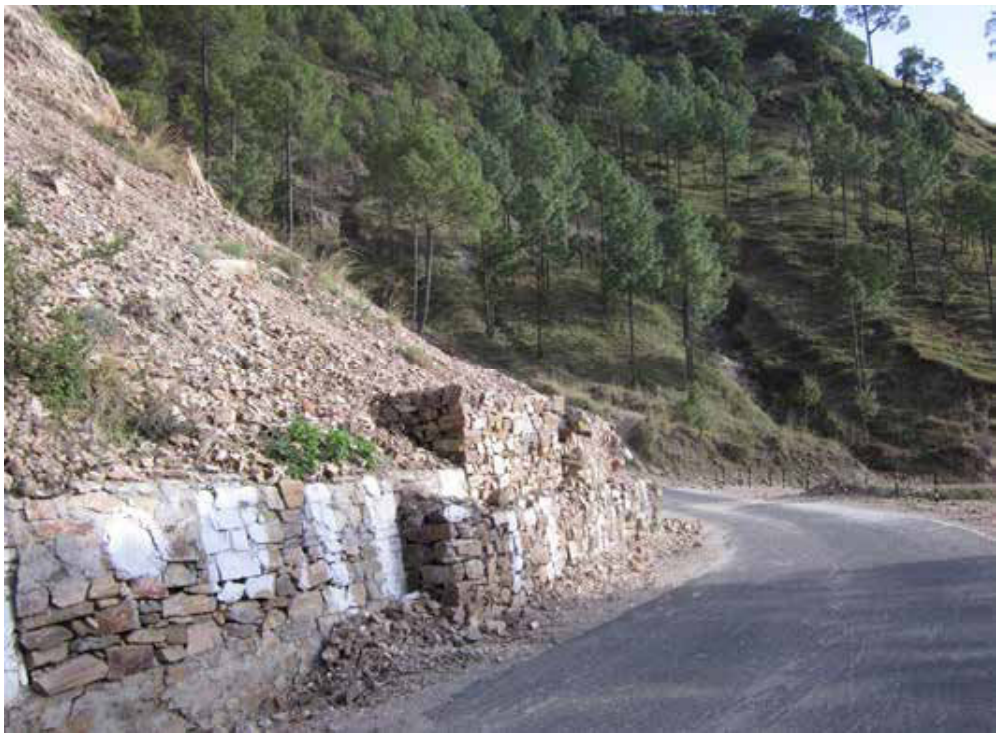
Picture 1: Wire-Crete under construction along the chainage 10 + 650Km on Kandakhal-Chailusain road



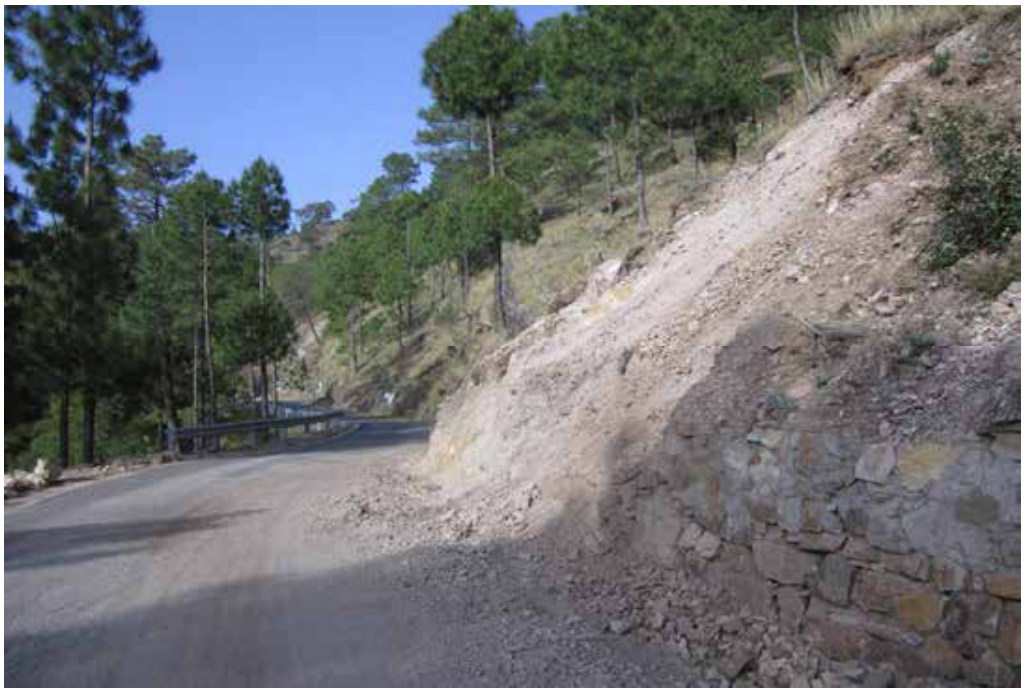
Picture 2 Breast wall constructed along the chainage 6 + 730 Km on Kandakhal-Chailusain road



Picture 3 Wire-Crete constructed along the chainage 14 + 600Km on Matiyali-Dwarikhal road

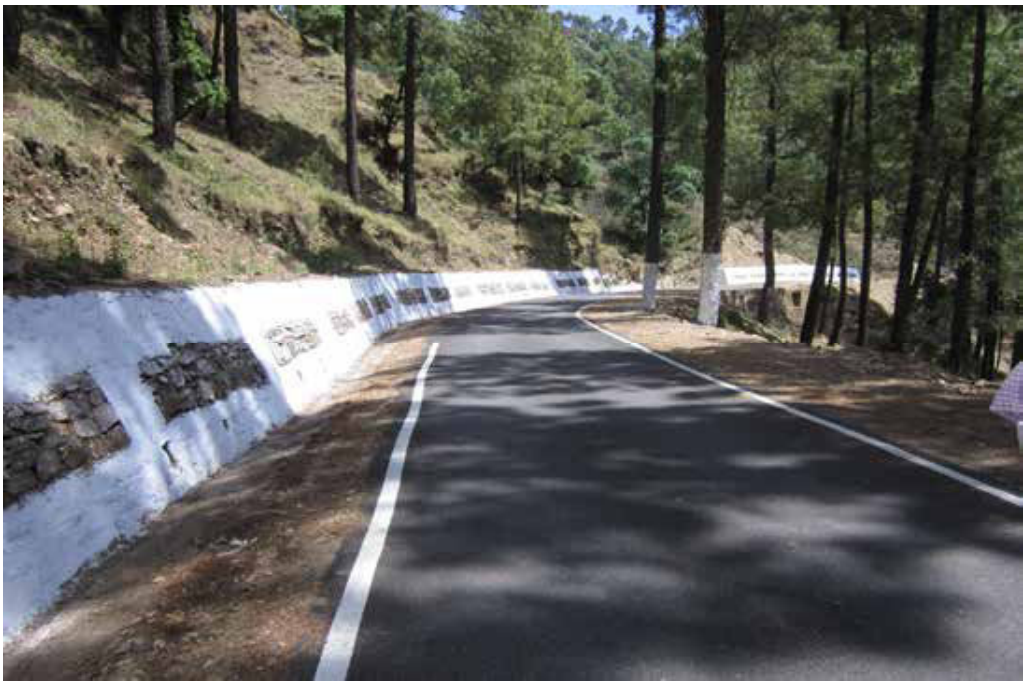


Picture 4 Wire-Crete constructed along the chainage 8+400 Km on Matiyali-Dwarikhal road.

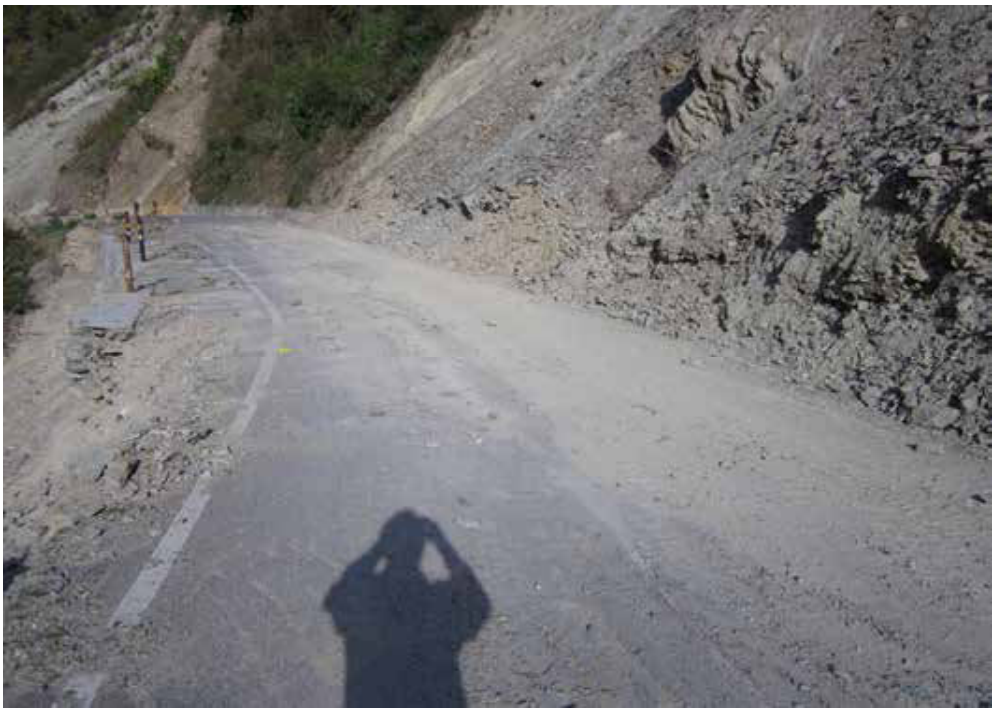


Picture 5 Breast wall constructed along the chainage 6 + 900Km on Matiyali-Dwarikhal road.

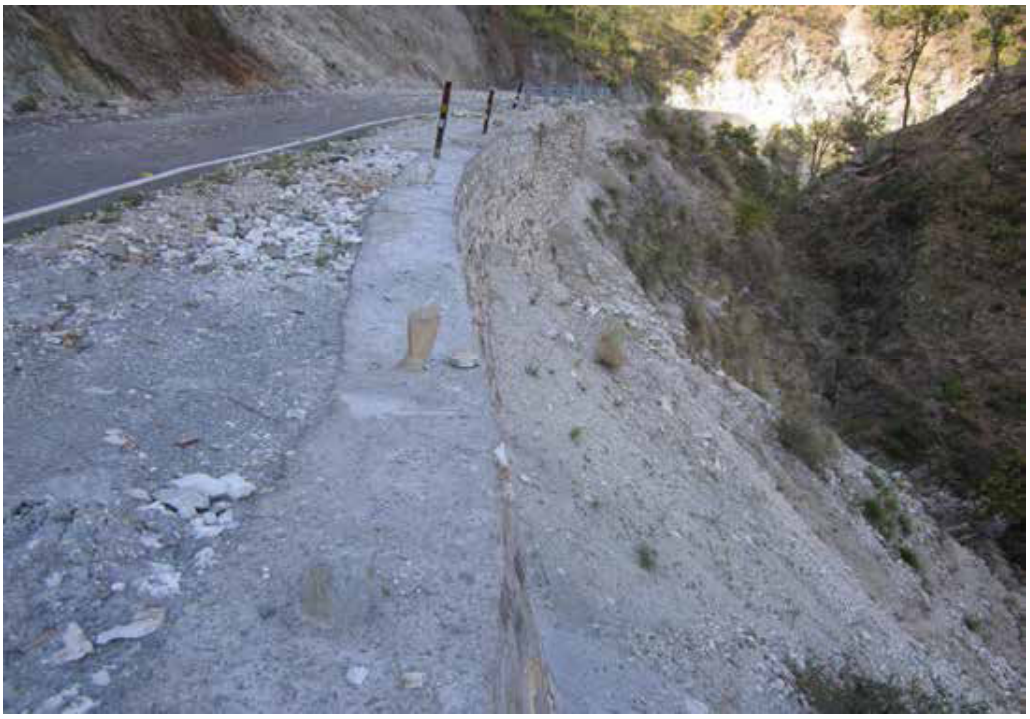
Picture 6 Wire-Crete & Retaining wall constructed along the chainage 1 + 950 Km on Chailusain-Devikhet road.



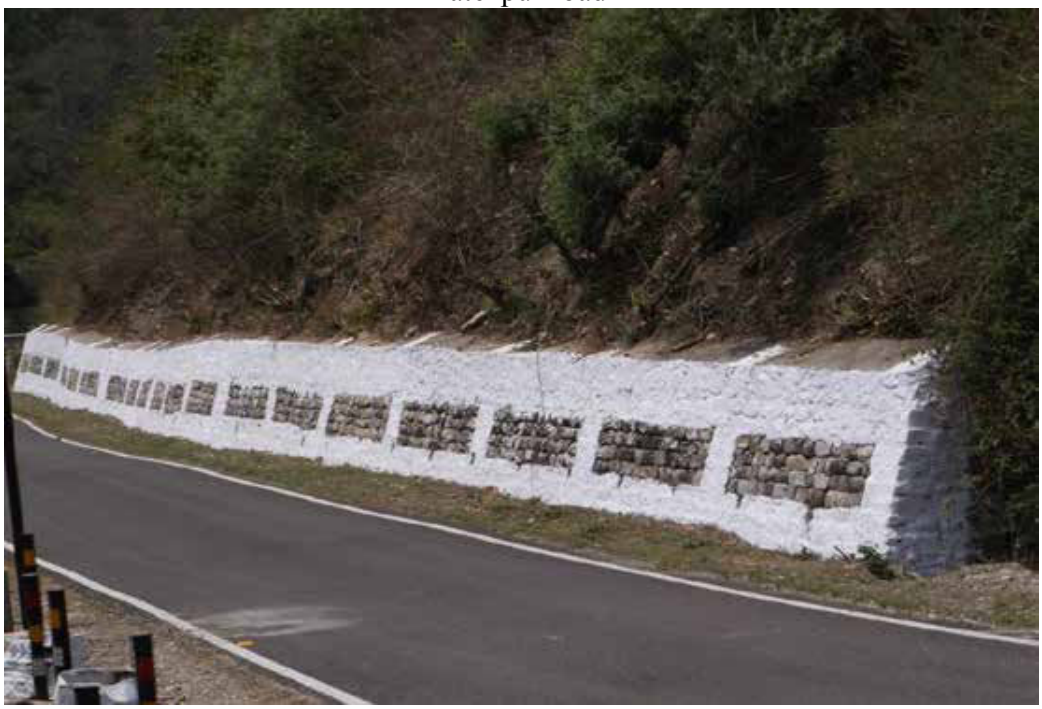
Picture 7 Breast wall constructed along the chainage 3 + 000Km on Chailusain-Devikhet road



Picture 8: Breast wall constructed along the chainage 3 + 000Km on Hanumanti-Fatehpur road



Picture 9: Retaining wall constructed along the chainage 3 + 000Km on Hanumanti-Fatehpur road



Picture 10: Breast wall constructed along the chainage 13 + 400Km on Hanumanti-Fatehpur road

Other Civil engineering measures adopted & suggested along with aforementioned ones are as follows:

Removal of unstable materials from slopes.
Shifting of road alignments.
Improvement of surface water drainage to avoid & prevent excess pore water pressure.
Benching of slopes by dividing long slopes into smaller segments.
Geotextile with nails.

4.2. Bio-Engineering Measures:

Civil engineering Measures along bio-engineering measures have been advised, in fact , found very effective in the management of landslides & slips in hill roads [(Howell , Sandhu, Vyas, Seikh & Rana (2008)) & HESCO-2005]. Aforementioned mix treatments have positive impacts on calamity affected regions by strengthening conservation of soil & water on hill slopes, thus, enhancing mechanical strength of bedrock in a manner similar to steel road strengthening of concrete. A successful Implementation of the mix of civil & bio-engineering measures requires seasonally sound planning as been proposed & being implemented in other regions of Himalayas by HSECO in the following manner, by selecting appropriate species of indigenous grasses, shrubs, seedlings & trees:

Construction of required civil engineering measures – May-June
Plantation of grasses/Agave– Nov-Dec
Seed broad cast – July/Aug
Cutting plantation – Nov-Feb

4.3. Other Institutional Measures:

Besides civil & bio-engineering measures to control & minimize the damage to life & property due to the occurrences of landslides/slips, other institutional measures such as Disaster Management Cells/ Units are functioning in the entire Pauri district for managing the emergencies associated with the disaster. Signage for contact details of authorities to be contacted in the event of calamities have been displayed along all roads prone to landslides/slips. Their distances are to be less, say at every three kilometer may be less and more machinery along with increased trained manpower need to be deployed for more effective management of calamity.

5. Challenges & Opportunities:

Landslides/slips management in project roads is full of significant challenges & opportunities. Main challenges comprising opportunities are as follows:

5.1. Inadequate inventories & mapping:

Uttarakhand Space Application Centre (USAC) in association with other departments should work towards generating a scientific database on spatial and temporal changes in the terrain characteristics. This information may not only prevent, but also of significant help in devising methodologies by the concerned departments in order to minimize the severity of landslides in future

5.2. Inadequate geological investigations & Landslides Hazard Zonation:

Detailed geological & geotechnical investigative studies need to be carried out on the basis of available inventories of the landslides for different roads in Pauri roads. There is need for landslide hazard mapping & zonation based upon Landslide Hazard Rating (LHR, carried out by DST in 1993) in all roads of Pauri district, for reduction in damages which may be caused.

5.3. Inadequate Implementation of highly advanced mitigation techniques:

Recent advances in risk analysis and risk assessment are beginning to provide systematic and rigorous processes to enhance slope management. In recent years, risk analysis and assessment has become an important tool in addressing uncertainty inherent in landslide hazards. This article reviews recent advances in landslide risk assessment and management, and discusses the applicability of a variety of approaches to assessing landslide risk.

5.4. Inadequate Implementation of NDMA Guidelines:

National Disaster Management Guidelines- Management of Landslides and Snow Avalanches by the National Disaster Management Authority (NDMA).should be implemented by the central ministries/departments and the states/union territories in formulating effective & decentralized Landslide and Avalanche Management Plans that will lead to holistic and effective management of these geohazards in the future., adopting a participatory approach involving all the stakeholders, in order to take forward the task of operationalizing the National Vision of securing proactive and pre-disaster preparedness, and emphasizing a mitigation-centric approach. Strict implementation of NDMA guidelines will be having help in overcoming following challenges being faced for effective management of landslide geohazards in hill roads:

i. Inadequate trained manpower for implementing National Disaster Management Guidelines—Management of Landslides and Snow Avalanches by the National Disaster Management Authority (NDMA).
ii. Inadequate awareness & public participation in disaster management processes
iii. Inadequate coordination among agencies involved in landslides management

6. Conclusions:

Rural as well as state & national highways and all other types of roads around Kotdwar region has suffered extensive damage in the past and still prone to landslides, subsidence, lateral mass movements & toe erosion. Heavy monsoonal rains are among the main factors triggering landslides/slips in these roads. Sheet & gully erosion are main impacts leading to severe loss in agricultural productivity, besides other damages to life & property. Most of the slides observed belong to very severe to severe category. Majority of Landslides are Debris fall , Mudslides and Rock falls Lithologies of slides are not very different; vary from weathered sedimentary & metamorphic rocks getting converted to clay due to years & years ex-situ & in-situ weathering. The management of slope stability & landslide\slips in hill roads is really full of several challenges. Which are, in fact opportunities for administration, research & development sector, agencies involved in road construction, local communities & other stakeholders to bring required institutional capabilities & excellence for minimizing the life & property damages..There is a pressing need for the scientific planning & implementation of the mix of civil & bio-engineering measures. The implementation of NDMA guidelines for the management of landslides by adopting a public participation at each & every aspects involved, as emphasized in these guidelines itself, will certainly bring desired results for the sustainable development .i.e. design, construction, operation & maintenance of road networks in Siwalik foothills & elsewhere

References:

1. Anbalagan, R. (1992). Landslide Hazard Evaluation and Zonation Mapping in Mountainous Terrain, *Engineering Geology*, Vol. 32, pp. 269-277.
2. Gupta V., Sah M.P., Virdi N.S., and Bartarya S.K. (1993). Landslide Hazard Zonation in the Upper Sutlej Valley, District Kinnaur, Himachal Pradesh, *J. Himalayan Geol.*, Vol. 4, pp. 81-93.
3. Sarkar S., Kanungo D.P., and Mehrotra G.S. (1995). Landslide Hazard Zonation: a Case Study in Garhwal Himalaya, India, *Mountain Research and Development*, Vol. 15, pp. 301-309.
4. Himalayan Environmental Studies & Conservation Organization **(**HESCO-2005), Landslides, Village: Shuklapur, P.O. Ambiwala, Via: Prem Nagar, Dehradun, Uttarakhand,
5. Gupta R.P., and Joshi B.C.(1990). Landslide Hazard Zoning Using the GIS Approach- A Case Study From the Ramganga Catchment, Himalaya, *Engineering Geology*, Vol. 28, pp. 119-131.
6. J. H. Howell, Bio-engineering Consultant, The World Bank, S. C. Sandhu, Senior Environmental Specialist, The World Bank , N. Vyas, Environmental Consultant, The World Bank , R. Sheikh and S.S. Rana, Assistant Engineers, HPPWD(2008) "Introducing Bio-engineering to the Road Network of Himachal Pradesh"
7. Kanungo D.P., Arora M.K., Sarkar S., and Gupta R.P.(2006). Comparative Study of Conventional ANN Black Box, Fuzzy and Combined Neural and Fuzzy Weighting Procedure for Landslide Susceptibility Zonation in Darjeeling Himalayas, *Engineering Geology*, Vol. 85, 2006, pp. 347-366

8. Krishnan, M.S. (1968). *Geology of India & Burma*, CBS Publishers Ltd, New Delhi.
9. NRDMS (Department of Science and Technology) Landslide Risk Management in India, Road Map For the consideration of Expert Committee for Research on Geohazards (Landslides and Tsunami etc.)
10. Mehrotra G.S., Sarkar S., Kanungo D.P., and Mahadevaiah K.(1996). Terrain Analysis and Spatial Assessment of Landslide Hazards in Parts of Sikkim Himalaya, *J. Geological Society of India*, Vol. 47, pp. 491-498.
11. National Disaster Management Guidelines (2009) - Management of Landslides and Snow Avalanches by the National Disaster Management Authority (NDMA)
12. Nagarajan R., Mukherjee A., Roy A., and Khire M.V. (1998). Temporal Remote Sensing Data and GIS Application in Landslide Hazard Zonation of Part of Western Ghat, India, *Int. J. Remote Sensing*. Vol. 19, pp. 573-585.
13. Pachauri A.K., and Pant M.(1992). Landslide Hazards Mapping Based on Geological Attributes, *Engineering Geology*, Vol. 32, pp. 81-100.
14. Thakur, V.C (1996), Landslide Hazards Management & Control in India, International Center for the Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.
15. Wadia, D.N. (1919): Geology of India, Macmillan Publishers India Pvt.Ltd, Delhi.