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"Pictorial Informative Support to Landslide Hazard Management Maps of Uttarakhand, India."

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ABSTRACT: *Garhwal Himalaya is a disaster prone part of the state of Uttarakhand especially known for huge landslides and torrential floods. Many efforts were made so far for landslide hazard zonation mapping along with mitigation plans. NRSC has published landslide zonation maps along with landslide management maps for the state of Uttarakhand and Himachal. But supportive geotechnical data for the same has not been made available. Therefore, in present paper the mitigative recommendations put by National Remote sensing centre (NRSC), Hyderabad is being explained with pictorial examples. This work may be useful for a construction manager handling the vulnerable sites in Garhwal Himalaya.*

Keywords: *Back Analysis, Landslide Hazard Zonation Map, Landslide Hazard Management Map***.**

1. INTRODUCTION

Garhwal Himalaya, belonging to Uttarakhand state, is the part of extra-peninsula that has been compressed 65% and resulted in the orogenesis to form very steep mountain range. The structural disturbances like folding, faulting and shearing are very common in this region. Slopes, deforestation, heavy precipitation and the road construction itself have found to be the main cause of slope instability. This area exhibits varieties of landslide movements. In the present work the attempt has been made to explain the mitigative recommendations suggested in landslide management maps prepared by NRSC, Hyderabad, for Uttarakhand state of North India. Depending on lithological, geostructural, geomorphic conditions the types and extent of landslides greatly vary. Also the physical, social, environmental and economic vulnerabilities vary but the concept of civil engineering mitigative measures have finite ―back analytical aspects and those give the excellent brain storming ideas for designing the cluster of preventive measures for any multicausative landslide event. It has been deciphered in present paper how a Civil engineer reads the hazard management maps. It is essential for understanding the importance of such maps spatially represented, landslide prevention are to be explained with any pictorial example. The effort for the same has been made here for the selected road corridors from Uttarakhand state mapped for landslide hazard and management as shown in figure 1 and 2.

The geospatial data like thematic maps, remote sensing data, geomorphological maps etc have been analyzed for hazard map similarly hazard management maps should be based on back analysis or lab-induced geotechnical data output. Skipping of step of back analysis various mitigative techniques, as suggested in referred maps of Chamoli and Joshimath have been explained in this paper.

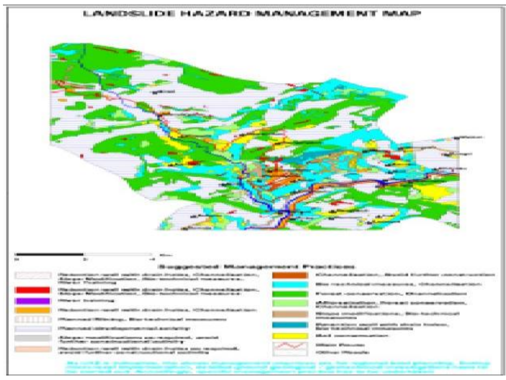

Fig. 1 LHM map of Chamoli

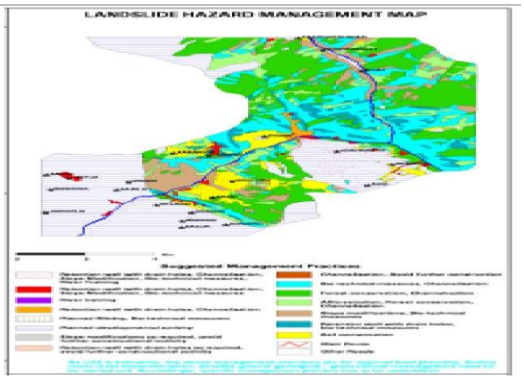

Fig. 2 LHM map of Joshimath.

2. MITIGATIVE RECCOMENDATION AS SUGGESTED IN LANDSLIDE MANAGEMENT MAPS

The mitigative recommendations as suggested and spatially represented in the above LHM maps are being explained here for a ready reference to a construction manager handling vulnerable site in the hilly terrain like Chamoli or Joshimath areas of Uttarakhand

2.1 Slope Modification:

2.1.1 Reducing the height of the slope

Reducing the height of a cut bank reduces the driving force on the failure plane by reducing the weight of the soil mass and commonly involves the creation of an access road above the main road and the forming of a lower slope by excavation. Also, it is possible to excavate deeply and lower the main road surface if the right-of-way crosses the upper part of a landslide. This method is moderately efficient in increasing stability of slope.

Fig. No. 3: Slope reduction by benching

2.1.2 Backfilling with lightweight material

A technique related to height reduction is to excavate the upper soil and replace it with a lightweight backfill material such as woodchips or logging slash. Then, covered with a thin layer of coarse aggregate, the backfilled material can form a foundation for limited-use traffic.

Fig. No. 4: Backfilling lightweight material

2.2. Strengthening Slopes

2.2.1 Plastic mesh reinforcement:

There are numerous synthetic soil reinforcement materials in the market, and one example is a reinforcement material of plastic polymer stretched to form a lightweight, high-tensile-strength grid. The grid acts similarly to reinforcing mesh in concrete, adding strength to the shear strength of the soil.These types of materials have been used to reduce the amount of ballast needed over soft ground by increasing the bearing capacity of the subsoil. These types of grids also have a number of possible applications in slope stabilization, including soil strength reinforcement, soil drainage improvement, and retaining-wall construction.

Fig. No. 5: Plastic mesh reinforcement

2.2.2 Rock-fill buttresses

A simple method to increase slope stability is to increase the weight of the material at the toe, which creates a counterforce that resists failure (Fig. No.6). A berm or buttress of earthfill can be easily dumped onto the toe of a slope. Broken rock or riprap instead of soil is preferable, however, because it has a greater frictional resistance to shear forces and is also free draining, which reduces the problem of impeding ground-water flow.

Fig. No.6: Rock-fill buttresses

2.3 Retaining Walls:

For all types of retaining walls, adequate drainage through the structure is essential because very high ground-water pressure can build up behind any retaining wall, leading to its failure. Drainage can be provided simply with a coarse backfill and foundation material.

2.3.1 Timber crib wall

Timber crib walls are box structures built of interlocking logs and backfilled with coarse aggregate (Fig. No.7). They work by intersecting the critical sliding surface, thus forcing the potential failure surface to a deeper, less critical depth. The structure must be able to withstand: (1) shearing, (2) overturning, and (3) sliding at the base. It must, therefore, be strongly built by burying to sufficient depth and extending beyond the critical failure plane. Crib walls are only effective where the volume of soil to be stabilized is relatively small. They are most efficient where a thin layer of unstable soil overlies a deeper, more stable layer of soil. Crib wall structures should have a volume equal to 10 to 15 percent of the volume of the soil to be stabilized. This relatively small volume provides little counterweight support at the toe; therefore, virtually the entire resistance to failure comes from the strength of the crib.

Fig. No. 7: Timber crib wall

2.3.2 Steel bin wall

A steel bin wall is formed from corrugated galvanized steel components bolted together to form a box and then filled with earth (Fig No. 8). The stability of a gravity wall is due to the weight of the wall itself, perhaps aided by the weight of soil in front of the wall. The bulk of the weight is from the contained soil, not the steel, and this should be kept in mind when the foundation is prepared. Large walls must be individually engineered, with load and foundation requirements calculated. Structural and civil engineering design charts provide stringer (horizontal member) specifications and height-to-width ratios for typical loading conditions. Material behind the wall also should be well drained and moderately compacted.

Photograph No.8: Steel bin wall

2.3.3 Gabion walls

Gabions are wire mesh, boxlike containers filled with cobble-sized rock that are 10 to 20 centimeters (4 to 8 inches) size (Fig No. 9). A gabion retaining wall can also be constructed from stacked gabions. Gabion walls usually are inexpensive and are simple and quick to construct. Due to their flexibility, they can withstand foundation movement, and they do not require elaborate foundation preparation. Because of their coarse fill, they are very permeable and thus provide excellent drainage

Gabion walls work because the friction between the individual gabion rows is very high, as is the friction between the basal row and the soil underneath. When failure occurs, it is almost always in the foundation soil itself. Three-tiered walls up to 2.5 meters (8 feet) high can usually be constructed without consulting any detailed engineering analysis. Higher walls are very heavy by nature of their added bulk and need larger base foundations and possibly counterforts for bracing of the wall. (A counterfort is a buttress bonded to the rear of walls, designed to improve stability.) Gabion walls built on clay soils require counterforts, which can be constructed as gabion headers extending from the front of the wall to beyond the slip circle. The counterforts serve as both structural components and as drains.

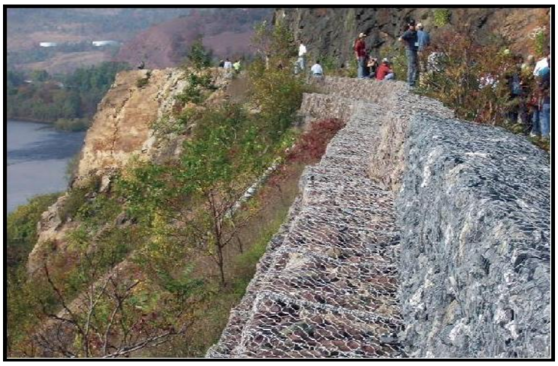

Fig. No.9: Gabion wall

2.3.4 Shear Piles Wall

Large-diameter piles can be placed into the toe of a slope to form a closely spaced vertical pile wall (Fig No.10). Shear Pile walls are normally used as a preexcavation restraint system—the cut slope excavation takes place in front. Whereas large-diameter concrete pile and culvert pile walls have been used successfully on highways, wood or steel piles that are small in diameter have not.

The piles should extend well below the potential failure surface and be firmly driven into firm subsoil. If the depth of placement is not sufficient to allow the piles to act as a cantilever system, then the piles must be tied back with an additional anchor system.

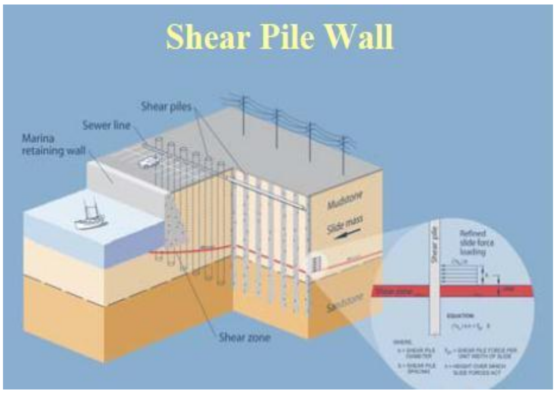

Fig. No. 10: Photograph of Shear pile wall.

2.4 Drainage Techniques:

Ground water probably is the most important single contributor to landslide initiation. Not surprisingly, therefore, adequate drainage of water is the most important element of a slope stabilization scheme, for both existing and potential landslides. Drainage is effective because it increases the stability of the soil and reduces the weight of the sliding mass. Drainage can be either surface or subsurface. Surface drainage measures require minimal design and costs and have substantial stability benefits. They are recommended on any potential or existing slide.

The two objectives of surface drainage are to prevent erosion of the face, reducing the potential for surface slumping, and to prevent infiltration of water into the soil, thereby reducing ground-water pressures. Subsurface drainage also is effective but can be relatively expensive. It is therefore essential that ground water be identified as a cause of the slide before subsurface methods are used.

Fig. No. 11: Subsurface drainage.

2.5. Slope Stabilization Using Vegetation:

Seeding with grasses and legumes reduces surface erosion, which can under certain conditions lead to landslides. Planting with shrubs adds vegetative cover and stronger root systems, which in turn will enhanceslope stability. If not controlled, surface erosion and small, shallow slope failures can lead to larger problems that cannot be controlled. Large-scale erosion requires applied engineering technology to correct and control.The terms ―bioengineering and ―biotechnical slope protection refers to the use of vegetation as slope protection to arrest and prevent slope failure and surface erosion.

A slope made as stable as possible before seeding could be of benefit in making the slope resistant to future erosion and failure. Controlling surface-water drainage, removing cut-bank overhangs, reducing slopeangles, and benching all should be done before seeding begins

Fig. No. 12: Slope stabilization using vegitation

2.6. Stream channel linings

Channel linings are another way of stabilizing a stream or creek channel and the sides of the stream orcreek. The lining is usually slush grouted with high-quality concrete, preferably reinforced by steel fiber mat to resist abrasion. Protruding boulders are set in the concrete to dissipate the energy of water flow.

Channel linings can reduce the incidence and volumes of debris flows .They are also effective in maintaining channel alignment upstream from a bridge and for protecting the abutments. Channel linings are most effective if applied over the entire reach of an unstable channel.

2.7. Check Dams:

Check dams are small, sediment-storage dams built in the channels of steep gullies to stabilize the channel bed. They are commonly used to control channelized debris-flow frequency and volume. A less common use of check dams is to control raveling and shallow slides in the source area of debris slides. Check dams are expensive to construct and therefore are usually built only where important installations or wildlife habitat, such as a camp or unique spawning area, lie down slope. Channelized debris flows are associated with channel gradients over 25 degrees and obtain most of their volume by scouring the channel bed. Check dams serve three purposes when installed in the channels:

1) To mitigate the incidence of failure by reducing the channel gradient in the upper channel.
2) To reduce the volume of channel-stored material by preventing down Cutting of the channel with subsequent gully sidewall destabilization and by providing toe support to the gully slopes.
3) To store debris-flow sediment, when installed in the lower part of the channel.

When installed on debris slides, the dams store raveled material, which eventually creates small terraces on the slide, reducing the surface slope. Check dams can be constructed of reinforced concrete or log cribs (Fig. No.12). Concrete mortared rock dams do not usually exceed 8 m in height, whereas log crib dams must not exceed 2 m (6 feet). The spacing of dams depends on channel gradient and dam height.

Fig. No. 13: Check dams

2.8. Shotcrete and Gunite:

Shotcrete and gunite are types of concrete that are applied by air jet directly onto the surface of an unstable rock face. Shotcrete is an all-inclusive term to describe the spraying of concrete or mortar either by a dry- or a wet-mix process. Gunite refers only to the dry-mix process in which the dry cementitious mixture is blown through a hose to the nozzle, where the water is injected immediately before application. This is a rapid and relatively uncomplicated method commonly used to provide surface reinforcement between blocks of rock and also to reduce weathering and surface scaling. Shotcrete contains aggregate up to 2 cm in size and is more commonly used than gunite, which has smaller aggregate. Both materials can be applied rapidly by air jet so that large areas can be covered in a short time. Fig. No. 14 shows a shotcrete operation on the side of a highway.

Fig. No. 14: Shotcrete operation.

2.9. Anchors, Bolts, and Dowels:

These are tools composed of steel rods or cables that reinforce and tie together a rock face to improve its stability. Anchors are post-tensioned members used to support large blocks of rock, whereas bolts are shorter and support surface rock. Dowels are similar to bolts but are not post-tensioned. Reinforcing a rock slope with steel requires a specialist’s knowledge of rock stability analysis, of grouting techniques, and of testing procedures. The determination of the orientation of the potential failure surfaces is crucial to a successful anchor system and requires a considerable amount of engineering experience. Fig. No. 15 shows rock bolts.

Fig. No. 15: Rock bolting operation

2.10. Debris-flow basins**:**

These catchment basins are commonly built at the base of slopes where debris flows are frequent (Fig. No. 16). They are used especially in areas where the debris must be contained so that soil and debris are stopped from flowing into sensitive ocean or river shorelines areas or where there are structures at the base of the slope that are vulnerable to debris-flow damage. These basins may eventually fill with the debris-flow deposits and must be emptied periodically or they will overflow. Commonly, large pieces of equipment such as dump trucks and power shovels are needed to empty the debris and carry it away. However, small basins can be emptied manually. They should be designed to be able to contain the maximum flow volumes of an area to prevent overtopping during a flow event.

Fig. No. 16: Debris-flow basin

3. CONCLUSION

Though, Geoinformatics is powerful tool for landslide hazard zonation mapping, the landslide hazard management maps need to be supported by proper back analysis of vulnerable areas along with extensive geotechnical investigations. The described mitigative or preventive measures to modify the slopes, the recommendations like reducing the height and backfill with light weight material or to strengthen the slope, recommendations like plastic mesh reinforcement and rock-fill buttresses or to retain the slopes, recommendations like timber crib wall, steel bin wall, gabion wall and shear pile wall or to reduce pore water pressure, recommendations like subsurface and surface drainage techniques or to reduce erosion recommendations like vegetation or to protect the stream slopes, recommendations like stream channel lining or to control channelized debris flow frequency and volume, recommendations like check dam or to reduce weathering and surface scaling, recommendations like shotcrete and guniting or to provide support to large rock block, recommendations like anchors, bolts and dowels or to collect the sliding mass, recommendations like debris flow basins have been suggested are certainly useful if supported by back analysis. The construction manager may refer to get collective information about mitigation practices through this study. Geoinformatical expert has a sufficient scope to use this data to create a meta-data for the spatial representation of geotechnical data outputs.

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