16TH JULY, 2013 LANDSLIDE OCCURRED IN VILLAGE KOTI GAAD IN TEHRI GARHWAL, INDIA- AN ASSESSMENT OF LANDSLIDE CONSEQUENCES

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Abstract: On 16th July 2013, Uttarakhand faced devastating experience of massive landslide and debris flow because of heavy rainfall and cloudburst. This study is about the landslide occurred in Village "Koti gaad" of Tehsil Kandi Saur in district Tehri Garhwal. This village is situated along NH 94 and 200-300 m road was destroyed, and it was realigned by the authorities. In a similar event of cloudburst here, in July-Aug 2009, a heavy loss to property including agriculture land were occurred even though there were no reports of man missing. Similar types of disasters occur every year and this study aims at assessment of their consequences. For conducting this study, details were collected from local people and past records from Public Works Department, Chamba. Satellite Imagery technique was also used in this study.

Keywords: Debris flow, Cloudburst, Agriculture, Geotechnical Properties, Satellite Imagery.

Introduction: Landslides are geological hazards that cause damage to infrastructure, loss of human life and create disturbance and other problems related to transport, ranging from minor trouble to social and economic catastrophe. The frequency of landslide events and the extent of damage resulting from slope failure are expected to be increased due to increased precipitation in landslide vulnerable areas arising from changing patterns of global climate which may be attributed to urbanization and development. Generally, landslides can be triggered by a variety of external stimulus, such as intense rainfall, earthquake shaking, water level change, storm waves, or rapid stream erosion that cause a rapid increase in shear stress or decrease in shear strength of slope-forming materials. Among the all causative factors, rainfall is the most common triggering agent. Both high intensities and short-duration rainfall as well as prolonged rainfall can trigger landslides. Landslide damages are often reported as a result of a triggering event like an earthquake or an excessive rainfall episode, which can be represented by purely economic costs. The overall cost of landslides includes both direct and indirect costs. Direct costs typically include property damage and restoration cost specifically associated with the physical impacts of landslide events, while indirect cost are those incurred through the expenses resulting from driving longer distances and increased travel times. However, an accurate accounting of these costs is often difficult and not visible to a majority of the population. The indirect costs from landslides can be as large, and in some cases, significantly more than the commonly reported direct damage figures, if they were realistically determined. Generally, damage output data become available from several months to some years after the landslide occurrence, so that the data gathering turns to a complicated and long process. Consequently, so far, the estimation of the landslides monetary losses is not systematically or comprehensively investigated. The past estimates have been, in general, very qualitative and not well documented. In the region of great Himalayan mountain ranges, one of the main causes of land degradation is landslides, and it is annually recurring phenomenon along the major communication routes. The occurrence of landslides is particularly common in geo-dynamically sensitive belts, i.e. zones and areas repeatedly rocked by earthquakes and affected by the neo-tectonic activities. The long sweep of Himalaya consists 30 percent of world's landslide in which Garhwal region is an essential and well known for its rapid altitudinal variation, varied topography and climatic extremes resulting a much varied and complex physical characteristics. Scientific studies about Garhwal Himalaya clearly reveal that there is an average of two landslides per sq. km. The National Highways, especially NH 94, have been damaged every year at several locations. Consequently, the monetary losses through the landslides have become a serious matter. Thus, it is necessary to investigate landslides in a proper manner and suggest the ways for estimating losses either direct or indirect, associated with landslides. Koti Gaad landslide is a complex slope failure problem and one of the major landslides in India, which has consistently damaged the NH 94 for last 5 years. The landslide is located at 115 km on NH 94, 68 km ahead of New Tehri town, in Tehri Garhwal district of Uttarakhand. On September, 2010, a major slide occurred which have completely damaged 300 m length of highway and blocked the National Highway. The rate of the landslide is heavy, which has caused disruption of traffic. This paper aims at highlighting the indirect and some of the direct losses associated with the slide, the hardships in reaching the destinations through other long and difficult alternative routes and estimates of the impact of landslide on socioeconomic situation of the region.

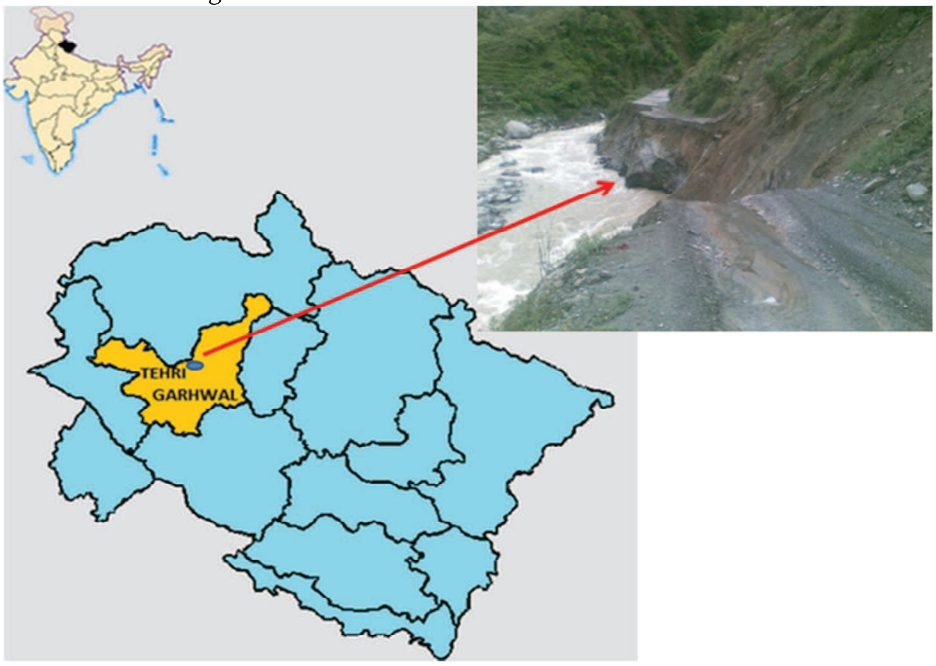

Figure 1 Location map of Koti Gaad landslide

Study Area: Koti Gaad landslide is located on the catchment Bhagirathi River about 115 km upstream of Rishikesh Township on NH 94. Spatially, the landslide is positioned at latitude: 30°28'40" and longitude: 78°21'10". The study area belongs to Lesser Himalayan division, the rocks of which come under Bhatwari-Ramgarh Formation of Garhwal Group, ranging in age from Paleoproterozoic to Mesoproterozoic. Lithologically, the landslide area mainly consists of metamorphic rocks namely Uttyasu Quartzite and Dharasu Thrust, which have been highly fractured due to tectonic activities in the past geological time .The crown portion has low vegetation and existence of cracks near to periphery of the main slide. The main sliding body has extended vertically about 300 m all along the road. The lower portion just above the highway acts as zone of the debris flow. The debris mainly consists of fragments of quartzite, metavolcanics, and gauge material of particles ranging from clay to boulder of 0.5 m diameter. The main scarp houses both rocks: quartzite and metavolcanic. Main scarp of landslide has irregular surfaces because of the numerous gullies of 5-6 m deep and 6-7 m wide sizes developed during last 2 year. The landslide area receives maximum precipitation in July, August, and September with an average of 260 mm rainfall. All along the highway, the vertical cut slopes are vulnerable because of moderate to highly jointed rock mass, intercalation of weaker strata, frequent minor faulting and continuous erosion and weathering of unprotected rock exposures. A masonry gabion wall of 6 m high constructed in 2011, all through the length of the highway along the valley in the slide portion has helped in retaining the debris to some extent, but the reactivation of slide in 2012-2013 has completely covered a stretch of 200 m of the highway. NH 94 links the Uttarakhand state with rest of the country and is one of the busiest highways during May to October each year. This is because, the networks of its subsidiaries are connected the four holiest shrines of India (Badrinath, Kedarnath, Gangotri, and Yamunotri called as "Char Dham") and various other tourist places. To visit these places, millions of people travel from all over the country and world on this highway. The unit cost estimation method involves average daily traffic (ADT) data that help to estimate the number of commuters forced to detour through the alternative routes in the event of closure of the highway. On the basis of a traffic survey in that area, it was examined that around of 1,200 vehicles of various types would have crossed the highway at this point, had the landslide not affected it.

Highway Closure Consequences: National Highway 94 is an important and the only major lifeline of Uttarakhand, which connects the surrounding region with rest of the country and therefore linked with the socioeconomic progress of the region. These highways are preferred to be always maintained without traffic disruption, being one of the major tourist and pilgrimage hubs of the country. However, in certain critical locations, the highways are often disrupted due to frequent landsliding. Although Koti Gaad landslide has been occurring since long, and similar events of like magnitude have been experienced earlier, no economic impact analysis was carried out. Due to cumulative effect of heavy rainfall during July–August, the slide has activated in the month of September 2010, and it has intensified after the rains stopped in the month of October 2010. From July to October 2010, the highway was reportedly blocked completely for 20 days. As the highway remained busy most of the times because of the movement of tourists and pilgrims from all over the country, traffic disruption for such long time has created unrest among the visitors because of limited time on their schedules and excessive money for their stay and hardships, sometimes, beyond their tolerable limits. There are other serious socioeconomic consequences of the blockage of highway as the circumstances of unrest have forced few people to break the prohibitory restriction to cross the highway while taking risk to their life. The trading of basic amenities, fruit, vegetable, other eatables, etc. got affected, and the cost of these gone higher by multifold making unaffordable for most of the local public. This also created class inequality tension among the rich, middle class, and poor as the sky high rise cost of amenities could not be afforded by the poor people not only the local people but also the visiting tourists as well.

Figure 2 Trapped a vehicle while crossing landslide zone. [A]and Full Road flows with debris.[B]

Figure 3 Blockade of Highway due to large volume of debris generated. [C] and Fall of stone from uphill.[D]

Genral Geology, Geomorphology, And Physiography: Tehri Garhwal exhibits characteristic rugged topography of the Lesser Himalayan terrain. The ground elevations generally vary between 1050 to 2000 meters above MSL. The hill slopes in the area are generally observed to comprise of rocky outcrops, rocky cliffs and mantle of colluviums. The hill slopes in the area is generally moderately steep (25°- 35°) to steep (36°- 45°) while few escarpments or cliffs (> 50°) are also present. The slide area is represented by rugged and undulatory topography of Lesser Himalaya. This slide is located on a fairly steep slope adjoining Bhagirathi river on its left bank. The village Koti Gaad (EL ± 1200 m) is located close to slide zone. Tehri Garhwal district is located in the Lesser Himalayan geotectonic block and it is bound by two major Thrust fault i.e. Main Centre Thrust (MCT) and Srinagar Thrust (ST). The MCT can be traced to the northeast of Uttarkashi while the Srinagar Thrust lies in the southwest. Phyllite, metabasic and quartzite of

Garhwal Group are exposed around the area. The geological setup of area is as given below. The study area in the Bhagirathi valley is mainly covered by the rocks of the Garhwal Group. The low grade sedimentaries of inner Lesser Himalaya lying between the Main Central Thrust (MCT) and North Almora Thrust (Dharasu Thrust) in the area is represented by two main sedimentary facies, i.e. calcareous and arenacous (quartztic) formations with intrusive of acid and basic rocks and are referred variously by different workers: Garhwal Group and Duda Toli Group, Bhatwari-Ramgarh Formation, Berinag Formation (Valdiya,1980,1988) and autochthonous-para autochthonous sedimentary belt and Chail nappe I, II, III (Fuchs and Sinha 1978). The lithology of the underlying zone is mainly of the sedimentary sequence (Garhwal Group) and comprise of quartzite, metavolcanics, limestone and phyllites. Below the Vaikrita thrust (Valdiya 1980) lies a thick sucession of imbricate thrust sheets evolved in a piggyback structure (Schuppen Zone) referred to as MCT zone (Bist and Sinha 1990). The high strained major shear zone is best developed in the area between the Mandakini and Bhagirathi Valley (Valdiya 1980, 1988., Saklani and Bahuguna, 1986). East of the present area is mainly responsible for the splitting, shearing, shattering and crushing of the rocks together with seismic and high rainfall conditions which form a most vulnerable zone for the mass movements in the region.

Observations At Sites :

The following observations are noted at sites:

• The slope materials involved in the landslide are debris consisting of unsorted, angular weathered fragmental material with partially-cohesive lime rich soil matrix.

• The fracture zones, well split along road cut slope and slightly deepened forming fracture controlled streams. The bedrock along the roads is fragmented into angular boulders.

• The blocks are dislodged from the slopes and toppled down and slided down along road causing the rock-fall and rockslide.

• Rock fall is associated with rapid down slope movement of angular fragmental colluvial material and upper soil layer causing the huge rock avalanching at several places.

• Debris flows are along the road. Some live debris flows have been observed during the visiting the area.

Note On Cause Of Slope Instability :

The following factors together have caused the present landslides:

1. Water is the most important factor. After percolation it reduces cohesion of the loose ground and makes it prone to slide has been observed here that the rain water, while percolating down, carries with it fine clay and silty material which may form a thin band at the interface of loose debris and underlying hard and structurally folded, faulted/sheared limestone. In the presence of water this clayey base, becomes very plastic and provides slippery base for a loose overburden to slip downwards. The presence of water also has increased the weight of the colluviums increasing the influence of gravity, and the slope is also above the angle of repose (more than 35°).

2. The rocks are Limestones and Phyllites. Limestones have the organochemical origin and have the non plastic fine texture. Phyllites are the products of low grade dynamo thermal metamorphism of argillaceous sediments. Both these rocks are highly fractured.

3. Unfortunately, there is a very severe deforestation that is observed especially around Dharasu to Uttarkashi that have initiated considerable sliding movements. In future they may be converted into huge vulnerable zones and may interrupt the traffic rather transportation in the area.

4. The area lies in seismic zone IV during all other favorable conditions to landslide. The minute, feeble to slight seismisity may have acted as a triggering factor.

Remedial Measures : The failure of the slope is mainly dominated by the phenomenon of saturation of slope material due to intensive rainfall and permeability of soil. With the view of the above discussions following remedial measures are being suggested:

a) Gabion wall may be constructed against the slope along the down slope roadside.

b) A network of surface drains is to be provided in the uphill side of the road for efficient and quick drainage. A roadside deep trench drain with lining near the road is proposed in the uphill side.

c) Unsorted, loose, colluvial debris or the glaciofluvial material resting along the angle of repose may be removed wherever possible.

d) The affected cross drainage or culverts can be suggested to be in proper place so that water can pass through culvert and the water coming during rainfall may be discharged without percolation.

e) The foundation of retaining wall may be sealed by using proper grouting techniques.

Figure 4 Pre- (left) and post- (right) landslides images shwoing damaged of road during rainfall.

Figure 5 Old alignment as a road itself and new alignment in yellow line.

Conclusion: Being the major lifeline of Uttarakhand, any destruction caused in National Highway 94 can affect tourism as well as the local public life. It is situated in the seismic zone IV, which is highly vulnerable to landslides, as a minute seismicity can act as a triggering factor. Moreover, severe deforestation observed also adds to the cause. The rocks found in the region are Limestones and Phyllites, which are highly fractured. Water is an important factor affecting the slope instability. Construction of Gabion walls, surface drain network in uphill side and cross drainage works at proper places may be used as remedial measures. The foundation of retaining wall may be sealed by using proper grouting techniques and unsorted, loose, colluvial debris or the glaciofluvial material resting along the angle of repose may be removed wherever possible.

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