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LANDSLIDES OVER TWO PLACES OF UTTARAKHAND; AN OBSERVATION

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Abstract— **Wazri landslide took place on 12 September, 2017 in Yamuna valley while another rock slide activity is reported to have started to the upslope of the Kunwari village on 10 March, 2018 in Pinder valley. The 106 houses and around 400 persons were affected in Kunwari landslide while around 250 meters road got blocked in Wazri landslide. Being tectonically active zones, these areas are controlled by structural elements like thrusts and faults. Seismicity creates disturbance in these tectonic features and eventually causes landslide within their vicinity. Additionally, slope aspect, slope angle, high relief, low cohesion and friction of slope materials and seepage are some considerable causative factors for the slope instability in the areas. Construction of houses beside drainage network, unplanned agricultural practices and excavation for road construction over steep slopes further enhanced the susceptibility of landslides. Because of the presence of thick debris materials and ground cracks on the slopes, these sites are still in danger. The purpose of this study was to highlights factors contributing to landslides and recommendations for ensuring safety of human being.**

Keywords— **NH 134; Kunwari village, Contributing factors, Recommendations, Yamunotri**

I. INTRODUCTION

Occurrence of landslides is frequent phenomenon in geodynamically and seismically sensitive belts like Himalaya. Fragility of the terrain together with loose debris materials over steep slope also enhances the potentiality of landslides. Every year these may lead to loss of human lives, property, infrastructure and natural resources. Over the past two decades, a number of major landslides events were frequently reported in Indian state of Uttarakhand. These including Malpa rockfall in 1998 "Pant and Luirei (1999); Paul et al. (2000)", Okhimath landslide in 1998 "Sah and Bist (1998)", Amiya landslide in 2005 "Pant and Luirei (2005)", Phata Byung landslide in 2001 "Naithani et al. (2002)", Budha Kedar landslide in 2002 "Sah et al. (2003)", Varunawat landslide in 2003 "Gupta and Bist (2004)", Agastyamuni landslide in 2005 "Rautela and Pande (2005)", landslide in Alaknanda valley "Joshi and Kumar (2006)", landslide in Pithoragarh district in 2009 "Sarkar and Kanungo (2010)", landslide in Asi Ganga in 2012 "DMMC Report (2012); Gupta et al. (2013)", landslide in Okhimath in 2012 "DMMC Report (2012); Martha and Kumar (2013)", landslide in Rudraprayag district in 2013 "Khanduri et al. (2018)", and Bastari, Naulra, Didihat landslides in 2016 "Khanduri, S. (2017)", slope instability in Dharchula tehsil "Khanduri et. al. (2018)" are adversely affected the state.

According to local people, Wazri landslide was initiated in the year 2007 further activated in 2013, 2016 and in September, 2017 while Kunwari village had been affected by slope instability previously in 2007, further landslide triggered in 2013 and in March 2018. Investigations of these two slide zones were carried out on the aftermath of the incidences and traverses were taken around the affected areas to identify the causes and effects of landsliding.

II. STUDY AREA

Wazri landslide (N 30° 54' 22.87" and E 78° 20' 46.87") took place on 12th September, 2017 along Yamnotri national highway (NH-134) just before Saina Chatti and falls in Survey of India toposheet number 53 J/5. Yamunotri shrine (3,291m above mean sea level) is situated at a distance of 20 kilometers form Saina chatti till Janki chatti by road. From Janki Chatti one has to travel on foot for 5 kilometers to reach Yamunotri temple. It is also one of the four sites of Char Dham pilgrimage.

Another, Kunwari landslide (30° 04' 58" N and 79° 48' 00" E) is located at an altitude of 2,350 meters on the right bank of Baura gad tributary of Pinder river in the Kapkot Tahsil of Bageshwar district and falls in Survey of India toposheet number 53 N/16. Enroute to treking around Sundardhunga and Pindari glaciers in this region are main attractions. Kunwari village also marks the boundary between Bageshwar and Chamoli district of Uttarakhand. The area can be approached by road till Badiyakot village that is located at a distance of 48 kilometers from Kapkot. From Badiyakot one has to travel on foot for around 15 kilometers to reach Kunwari village (Fig. 1).

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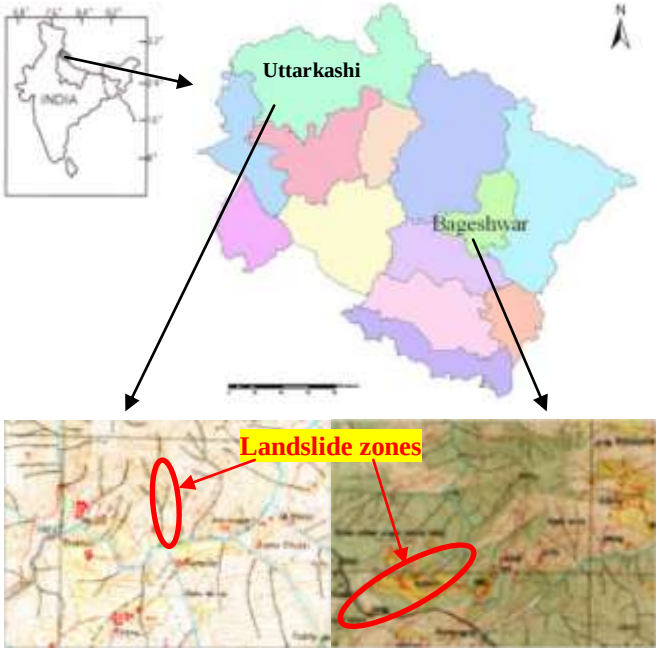

Fig. 1. Study area

III. MATERIALS AND MATHODS

Geological traverses during the course of the investigations were taken around the questioned sites to examine the slope instability on the basis of Survey of India toposheet numbers 53 J/12 and 53 N/16 on 1:50,000 scale. Lithology and structural data were collected and assessment was made to categorize the landslides. Locals were contacted to get the history of the slides in the affected areas. An attempt was also made to suggest recommendations to reduce the risk in the areas.

IV. GEOMORPHOLOGY AND GEOLOGY

The Pinder river is the major drainage system of the Kunwari area while the Yamuna river in Wazri area that generally flows in southwestwardly directions. The ground elevations in the area around Kunwari village generally vary from about 2500 meters to 1500 meters above mean sea level (msl) whereas highest 3000 meters and lowest 1600 meters in Wazri area.

The hill slopes in the areas are generally observed to comprise of rocky outcrops, rocky cliffs and mantle of colluviums. These areas are observed to be prone to rock falls and debris slides that are attributed to structural configuration of the rocks, high relief, presence of overburden and high seasonal precipitation. Steep rocky cliffs at places show indications of small scale instability. The areas under investigations are located in the Higher Himalayan and Lesser Himalayan geotectonic blocks.

Kunwari village is situated on mid slope over thick colluviums. The evidences of creep movement in the same are observed in the form of subsidence and vertical cracks on the walls of the house. Another, Wazri landslide lies to the contact zone of Main Central Thrust (MCT) which activated the same.

The rocks of Central Crystallines thrusts over the rocks of Lesser Himalaya which is marked as Main Central Thrust (MCT). Wazri landslide is located within the contact zone of MCT while Kunwari village within the Lesser Himalayan tectonic block “Auden (1937); Heim and Gansser (1939); Valdiya (1980)”. Main Central Thrust (MCT) passes through the Wazri area in Yamuna valley where it separates the gneisses/schists of Central Crystallines from quartzites of Garhwal Group. Lesser Himalayan Kapkot Formation is observed to be exposed in the area around Kunwari village in Pinder valley.

The Higher Himalayan Central Crystalline Group of gneiss is exposed just upstream side to Wazri slide zone is generally observed to strike N-S and dip towards east at angle 25°. The joint sets are observed to dip towards SSW (70º /250º) and NNW (40º/ 340º).

Kunwari village is situated on the thick colluviums with scarce exposures of Lesser Himalayan phyllites/slates are observed along the drainage flowing towards northeast present beside north of Kunwari village. General trend of the rocks is observed to be NW– SE and these exhibit steep dips towards NE at angle 45°. The rocks are observed to be traversed by numerous joints. The important joint sets are observed to dip towards NE and SE (80º / 50º and 73° / 140°).

V. FACTORS CONTRIBUTING TO LANDSLIDES

Heavy rainfall during monsoon season have reduced shear strength of slope mass though the landslides was took place at that time when there was no rain. Abundance of overburden and weathered/shattered nature of rocks are observed over the slope that leading to consequent failure in the affected areas. There are many factors that contribute to landslides are as follows:

- Low rock mass strength due to structural disturbances as Main Central Thrust (MCT) and other associated faults and shear zones.
- Shattered, sheared, folded and heavily jointed rocks.
- As the areas lie in high seismic zones IV and V.
- High relief, slope aspect, steep slope, seepage and heavy precipitation.
- Low cohesion and friction of slope forming materials.
- Predominance of thick overburden deposits.
- Severe climatic conditions leading to rapid weathering.

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- Large proportion of the area around Kunwari village falls under cataclinal slope.
- Constructions beside drainage network.
- Unplanned agricultural practices and toe erosion by streams.
- Disturbances in the rock strata by blasting during road construction.

VI. CASE HISTORIES

Around Kunwari village constructions on thick colluviums, beside drainage network and unplanned agricultural practices are observed during the field investigation. Another Wazri landslide is observed to be in close proximity of major tectonically active zone as Main Central Thrust (MCT). Details of landslide incidences are described in the sections below.

6.1 Kunwari landslide

On 10 March 2018, SW side of Kunwari village experienced massive rock slide (L2) triggered on the hills which continued for next fifteen to twenty days (Fig. 2b). Crown of the slide is located in the forest land and a number of trees are observed to have been uprooted by the same. Crown portion of the slide extends along NW-SE trending Man Singh Dhar ridge. Especially on this slide zone fractured and jointed phyllites/slates are observed and slope of the same is observed to have steep gradient (~55º). The slide mass has accumulated in cultivated terraces and poses threat to few houses located its run out zone (Figs. 2a and 2b).

Another, debris cum rock slide (L1) is located just downslope of village on the right bank of Baura gad. Slope of the same in the crown and toe portions are observed to have very steep gradient (~60º) with affected face towards northeast. In the downslope of village is also affected by the toe erosion by Baura gad and seasonal drainage located in the close proximity of Kunwari village. Landslide is observed to occur over almost entire stretch of the seasonal drainage which extends up to the Baura gad. Shattered, sheared, folded and heavily jointed phyllites are observed along this drainage. These are dipping towards valley side that is observed to facilitate movement of huge slope mass below the village, causing instability. The ground fissures are observed in the failure slope in the area and vertical cracks are also observed on the walls of the house located just above crown portion (Figs. 2a and 2c). Signatures of lake formation are also observed on Baura gad which is attributed to damming of the same by the huge slide debris (Fig. 2d).

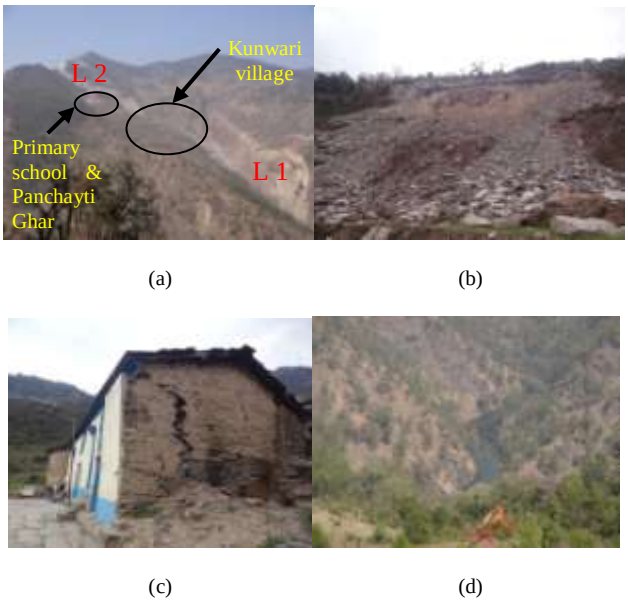

Fig. 2. (a) Kunwari village between landsliding zones (b) rock slide (L2) upslope of village (c) wide cracks in the house wall indicating active slope movement (d) lake formation on Baura Gad below Kunwari village due to landslide

Recommendation

Kunwari village is bounded by Massive rock slide (L2) and debris cum rock slide (L1) which are creating risk to the villagers and their property. L2 poses threat to few houses located its run out zone while L1 is creating creep movement for the whole village. In view of the landslides threat local population is advised to stay away from rock slide and subsidence zones. It is therefore recommended that the population residing in the surrounding area needs to be shifted to alternate safe locations.

6.2 Wazri landslide

Wazri landslide is rock cum debris slide located just upstream to Wazri village along Yamunotri national highway (NH 134) on the right bank of Yamuna river. It is an old landslide and is reactivated on 12 September, 2017 which continued intermittently for a month. Due to this, huge amount of debris and boulders thus came down and got accumulated on the Yamunotri national highway and around 250 meters stretch of road got blocked. Pilgrim, tourist and local people are forced to achieve 2.5 kilometers distance by on foot from Wazri to Saina Chatti. Thus total 7.5 kilometers distance by on foot has to achieve by the people to reach Yamunotri temple, earlier it was just 5 kilometers from Janki Chatti.

The landslide area is observed to be occupied by well exposed rock with loose debris on crown part. The sliding material was

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observed to comprise of rock mass, hill wash, and debris that consists of fragments of rock.

Slope of the landslide zone in the mid part is observed to have very steep gradient (~70º) and in the crown part it is relatively less steep (~60º) with affected face towards southwest. It was observed during field investigation that mid part in between two chutes of the landslide is stable and consists of well exposed sound rock.

As noticed, slide consists of mainly two chutes and these are merged towards each other on the crown part (Figs. 3a to 3c). Chute 1 shows highly fractured, jointed and sheared rock whereas chute 2 shows ground fissures in loose debris (Fig. 3d). Falling rock slabs can cause risks for the vehicles and passengers.

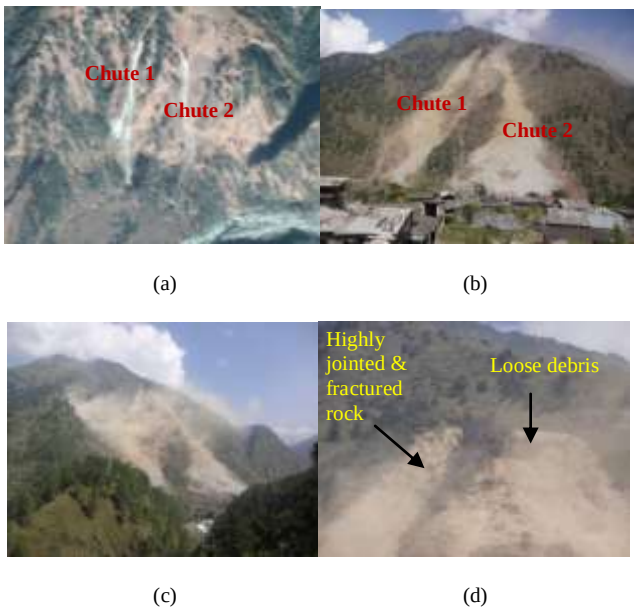

Fig. 3. (a) Google Image of Wazri slide zone of November 2016 (b) Wazri landslide in September 2017 (c) dusty clouds around the slide due to continuous fall of slope forming materials (d) loose debris on crown part of slide

Recommendation

The situation could well be serious in case of violent seismic shaking and heavy precipitation. It is therefore recommended that realignment of Yamunotri highway near Wazri needs to be given, for this Kunsala and Kupra road of Pradhan Mantri Gramin Sarak Yojana (PMGSY), should be strengthened and to be attached with national highway (NH-134) by bridge.

VII. CONCLUSIONS

Geodinamically and seismically active nature of the region and severe climatic conditions leading to rapid weathering are significantly responsible for the landsliding. Being located in tectonically active zone, instability of the rocks in the areas are largely controlled by structural elements that include thrusts and faults together with various geomorphic factors like slope aspect, high relief, steep slope and low cohesion and friction of slope forming materials. Among these are held responsible for landsliding in the areas.

Upslope of the Kunwari village is infested with rock slide (L2) and downslope is also by debris cum rock slide (L1). Due to rock slide which were present on the upslope became a constant threat to the some houses located its run out zone while debris cum rock slide facilitated due to severe toe erosion by local drainage and Baura gad.

Tectonically active Main Central Thrust (MCT) is crossing Yamuna river near Wazri in the close vicinity of landslide which activated the same and disturbances in the rock strata by blasting during road construction further aggravated the problem.

Furthermore, construction of houses beside natural drainage, unplanned agricultural practices and excavation for road construction over steep slopes enhanced vulnerability of the affected areas.

As discussed in the previous sections the areas have a history of mass instability and interplay of many processes has rendered the areas highly vulnerable. However the possibility of these being reactivated by extreme precipitation events and high intensity seismic tremors cannot be ruled out.

It is therefore important to adopt fine blend of relocation, mitigation, capacity building and awareness. These studies could also help the local administration to take necessary step for safety of inhabitant and other people.

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