Study of Bunga Landslide - A Case Study from Garhwal Himalaya, Uttaranchal, India

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Abstract

In order to understand the causative factors and the mechanism of sliding, the geological and geomorphological studies of the Bunga landslide were carried out. The sliding process was monitored with the help of measuring pedestals, in order to identify the unstable areas. The slide was monitored from July 2002 to July 2004 and the clay mineralogy and the chemical analysis of major oxides of the slide zone was also carried out for identification of montmorillonite, which aides in slope failures. The investigation shows that the main causative factor was heavy precipitation, construction of road, supplemented by toe erosion and presence of subsurface seepage. The main mechanism of sliding was rotational with debris flow in upper part and mudflow in lower part. Various remedial measures are suggested to minimize the damage to the road and settlements and cultivated fields in the affected area.

Introduction

The Bunga landslide, located at a distance of 23.75 km from Karnaprayag along Karnaprayag - Bareth - Nauti highway in the Garhwal Himalaya, was taken up for detailed geological and geomorphological studies in order to delineate the causative factors and the mechanism of sliding. This slide creates problems particularly during the monsoon period but according to local people the movement of material from the landslide zone is a continuous process throughout the year. The movement of the slide was monitored during July 2002 - July 2004, with the help of measuring pedestals, in order to identify the unstable areas. For finding out the presence of montmorillonite, which causes slope failures, and various oxides were collected on grid pattern. The investigation shows that the main causative factor was the heavy precipitation. The sliding took place due to loss in shear parameters as a result of percolation of water into the slope forming material. Disturbance in the equilibrium state of the slope facet during the construction of road is another factor for sliding to occur.

Causes/ history of landslides

The landslide first occurred in 1984 when a large chunk of cultivated terraces slided down following heavy precipitation (cloudbursts). Other causes reported were the road construction and toe cutting of slope by Bangri stream.

Initial disturbance of the area is attributed to neotectonic movement along the North Almora Thrust (NAT) and the slide was reactivated due to March 1999 Chamoli Earthquake (6.8 M; Naithani *et al.* 2004). The earthquake and its after-shocks triggered hundreds of large and smaller landslides. This valley experienced a number of rock dislodgements and ground fissures. Earthquake shocks particularly those of shorter duration, accelerated ground motion and tilted the slope. Usually a failure of rock mass is the result of slow deterioration of its cohesive properties during repeated intervals of high saturation with rising ground water table or a repeated seismic activity leading to liquefaction.

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Since 80's, the sliding activity has become more pronounced, larger in size and more problematic. A retaining wall, constructed by state PWD, has not been found useful to check the flow of debris during monsoon, causing blockades of road, and disruption of traffic. About 170 meters length of the road has been badly affected by this slide that has also led to loss of cultivated fields.

Geology and site conditions

Geologically, the rocks in and around the Bunga slide zone belong to Garhwal Group (Late Pre-Cambrian/ Lower Palaeozoic). The rocks of this area are mainly low to medium grade metamorphic and deformed repeatedly. The main rock type is metabasics with quartz veins. The metabasics is generally deformed and weathered. The central portion of the slide zone is mainly covered with debris containing moderate to highly weathered rock fragments. The metabasics are highly jointed, fractured and slight to moderately weathered in nature and traversed by closely spaced fractures. The rock foliation generally dips towards southwest at an angle of 26°-38°. Three sets of joints are present which are generally open. The discontinuities in these rocks including joints and foliations have a great influence on the stability of slopes in relation to their inclinations.

It is observed that a number of cracks are present in upper portion of the slide with their trends almost parallel to the slide boundaries and inclination towards the slide. The presence of the cracks near the top of the slide zone indicates that the upper region of the slide area is highly unstable. The rocks are highly weathered in that part with the unstable clayey soil. The convex central portion has formed due to the accumulation of slided debris from above. A number of rivulets pass through the slide area. Wherever the angle of repose of this material exceeds the critical angle, the material slides down. The slide area had scanty vegetation whereas, the surrounded areas were moderately to densely vegetated.

Geochemical analysis

For geochemical analysis, five unaltered samples were collected from the margin of slide area while five samples were collected from the landslide zone. The chemical analysis includes percentage analysis of major oxides. The overall SiO_2 percentage of the slide zone area varies from 51.76 to 54.12%. The content of Al_2O_3 varies from 11.51 to 14.95%, whereas the content of Fe_2O_3 varies from 0.42 to 6.72. The reason of higher values of Al_2O_3 in comparison with Fe_2O_3 may be due to the breakdown of aluminium silicate by biological and geochemical weathering leading to release of different compounds into the soil. Unlike aluminium, much of the iron is lost in the soil solution especially during monsoon when temperature and precipitation is high enough for removal of iron from soil. Manganese and titanium show great variations while K_2O content ranges between 1.46 and 3.01.

Clay mineral identification

Samples of landslide debris and soil sample were collected for the identification of clay minerals, using X-ray diffraction. This slide zone shows the dominance of montmorillonite (2.2 A°) and kaolinite (3.7 A°, 2.7 A°, 2.1 A°). Other dominant minerals of this zone are chlorite (3.5 A°, 2.5 A°, 2.4 A°, 2.0 A°, 2.0 A°, 1.5 A°), illite (10.0 A°, 4.2 A°, 3.6 A°, 3.3 A°, 3.1 A°) and little amounts of vermiculite (4.7 A°), and sepiolite (3.3 A°). Quartz (1.5 A°), feldspar (3.2 A°), dictite (3.3 A°), micas (3.2 A°) are other minerals present in this zone.

Landslide monitoring

As a prelude to the planning of landslide control measures, monitoring of the landslide has been done to decipher its surface movement behaviour. A grid pattern has been taken up for the placement of pedestals to effectively follow the movement vectors. To facilitate the measurement of displacements, 20 pedestals have been fixed on the slopes of Bunga slide area. Two benchmarks for the study consisted of 2 m long iron rods, cemented in concrete below a depth of 1.5 m and surrounded by coarse sand and gravel. In Bunga slide area, monitoring of surface movements has been initiated in July 2002. The trends of movement of each pedestals was recorded, which has been found to vary from 7 mm to 210 mm. The analysis of the data procured from field observations has indicated the extent and direction of movement of slope material.

Conclusions

Studies indicate that the main causative factors of Bunga landslide are the reduction in shear parameters of slope forming material due to percolation of water during rains and toe removal during the construction of road. The displaced segments of soils as well as rock debris in the vicinity of the crown of the landslide are gradually converting the agricultural land into a wasteland. In the landslide area the presence of openings in the debris material and bedrocks allow percolation of water into the ground leading to frequent occurrences of debris fall during and after heavy or prolonged spells of rain. Cultivated fields and dense vegetation at the top of the cut slope also promote build up of ground water flow within the landslide zone, often leading to the erosion or piping along the flow path. The presence of ground water may lead to formation of crack and erosion through piping. The cracks are generally present above the crown of the slide. It has been observed that during monsoon, some new cracks are formed and some of the existing ones show widening. This indicates unstable condition along the slope. A number of surface channels pass through the slide area. During monsoon a lot of slope material moves down through these drains and gets accumulated in the middle portion of the slide zone. Wherever, the angle of repose of this material exceeds the critical angle, material slides down. The mechanism of land-sliding is mainly rotational sliding, with debris flow in the upper part and mudflow in the middle and lower parts. Various control measures such as construction of toe wall, installation of drum walls, diversion of drainage away from the slide zone and construction of benches above the road have been suggested to minimize the damage to the road, settlements and cultivated fields in the sled affected area.