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Landslides in Sahyadri Mountains: A threat to Transport in Palghar District, Maharashtra.

Suchitra Pardeshi,
Annasaheb Magar College,
Hadapsar, Pune, India

Abstract - Landslide is the most common geomorphic hazard in many parts of the world. In Maharashtra the landslide are very much common in Sahyadri Mountains along the western slopes, of which high proportion is anthropogenic. Western Nasik and Palghar district are some of the most frequently affected areas of landslide hazards. Total 31 slope failures were identified were studied and grouped on the basis of the material movement. Steep slope, heavy rains and are the principal natural factors, which generate landslides in the study region. Even single event along the road causes hazardous effects. Landslides has effected not only the natural environment but also the man made environment i.e. it has disturbed and has caused geomorphic damage to hill slopes, vegetation cover, road breakage and blockades, settlements. Present study is an attempt to identify such effects of landslides in this area. Major effect of these slides is blockade of this road because of that commuter and several trucks cannot move on this road. Around 10 major and minor villages and village population is directly affected. As a result, it puts pressure on the economy of the State. Every year at least a million rupees are spent by the government on landslide mitigation. Hence, to overcome the economic losses, immediate remedial measures have to be taken to stabilize these slides in order to revitalize the geo-ecology of the area.

Keywords - Sahyadri Mountains, Landslide, Slope failure, Economic losses, Hazard mitigation.

I. Introduction

Landslide is a geological phenomenon which includes a wide range of ground movement, such as rock falls, deep failure of slopes and shallow debris flows. Although gravity acting on an over steepened slope is the primary reason for a landslide, there are other contributing factors affecting the original slope stability. (Wikipedia, 2006). Landslides are one of the major forms of geomorphic hazards, which cost economic losses in the form of infrastructural damages and many deaths every year in the world. Landslides are of different scales from a few meters to several kilometres in dimensions and at varying rates of few meters per year to several meters per second. Human activities have triggered a number of disastrous landslides that have caused great damage and loss of life.

Landslides are very common in many parts of the world. Rockslide in Montana in 1959 killed 27 people and caused damming the gorge (De, 2003). In Indian subcontinent Himalayan ranges and Northeastern regions and Western Ghats in the South are the major regions of landslide threat. In Sahyadri Mountains along the western slopes, landslides are very common phenomena of which high proportion is induced by human activity. Landslides pose serious threat to various human activities such as transportation, and other similar economic activities.

Palghar district is one of the districts in Konkan region of Maharashtra. Eastern part of the district is the most frequently affected areas of landslide hazards. Landslides are very common in Eastern Palghar district mainly along the ghat roads. Vada-Khodala road (State Highway no. 34) is one of those.

Present study was carried out with objectives to know how the landslide events cause effects on human environment. What was the severity of landslide as a hazard? To identify the 'landslide prone stretches' and 'potential stretches'. To know whether occurrences of landslides is related to human activities?

Field surveys were carried out to find out dimensions of landslide debris. Interviews of local people were conducted to realize the severity and the consequences of landslide as a hazard. Data regarding the hazard mitigation activities were collected from the office of the Executive Engineer, Public Works Department Javhar sub-division, district Palghar. The data collected and field observations were analyzed and it was found that landslide occur on general slopes of 15^0 to 35^0 angle. Debris samples were collected for textural analysis. By using simple dry sieving technique, the sediment sizes were recognized. The average sediment size is 1.5 to 3.0 in millimeters. According to Wentworth's scale, the material of the debris is of very fine granule to very coarse sand type. After field survey, 'landslide hazard map' is prepared. The hazard map depicts landslides prone and landslide potential areas in the study area.

Causes of landslides in this area are identified such as, steeper slope angles, heavy rainfall, coarser material, and thick waste mantle etc. Even a single event along the road causes hazardous effects and can block the road and may paralyze the to and fro movement of the vehicles. Economic and other losses caused by such events are significant. The losses may be in terms of wastage of time, Use of extra fuel for long distance travels via alternate route. Landslide also causes reduction in market supplies, reduction in working hours, mental fatigue and many other effects. Major effect of these slides is blockage of road and consequences of it. After a slide event around 700 to 750 commuters and several trucks per day cannot travel by this road. Around 10 major and minor villages and about 8500 people are directly affected. During the field visits it was also noticed that, landslides have caused damages to both the natural and human environment such as disturbance and geomorphic damages to hill slope systems and vegetation cover, A detailed enquiry related to a geomorphic damages and preparation of geomorphic damage map will provide useful information for the planners, foresters and for landslide hazard evaluation and mitigation. Hazard evaluation may be quantitative and qualitative. Qualitative landslide hazard evaluation includes geomorphologic mapping and heuristic or index based approaches. (Beguería, et. al. 2003)

Every year average 0.4 million rupees are spent by the government on landslide mitigation work. Some measures such as plantation of rock holding plants are suggested to minimize the severity of the hazard.

II. Study Area

The study area is a stretch of eight kilometres along Vada-Khodala road. It is located in Mokhada Tahsil of Palghar District of coastal Maharashtra. The study area is in the south of 'Suryamal surface' along Vada-Khodala road lies between Latitudes of 19^0 26' 15" North to 19^0 27' 45" North and Longitudes between 73^0 11' 30" East to 73^0 13' 42" East. It is part of northern slopes of Rakhadi river basin at an average altitude of 500 meter from mean sea level.

1. **Geology:** The entire study area is covered by Deccan basalts of Cretaceous –Eocene age. Deccan basalt is arranged in several strata. The lowermost Megacryst lava flow horizon (M1) of 60 meters thickness is observed near Suryamal at about 400 meters above sea level. The rocks are fine to medium grained. There are number of fracture joints. In the area frequency of alkaline dykes is more. The area is in the north of monoclonal Panvel flexures. In the Bhatsa- Khardi area, which is only 25 to 30 kilometres in the north of study area where some seismic activity has been reported. Around Khardi numerous NW-SE faults/ linears have been reported. (G.S.I., 1995). It is also referred as 'fault set' where a group of parallel or near parallel faults are associated. (Lapidus, 1987) Average slopes in the study area range between 20^o to 40^o.

2. **Climate:** The climate is of tropical monsoon type with an average temperature of 25^o C. The average rainfall is 2000 to 2200 mm with most of rainfall is concentrated during southwestern monsoon period that is in the months of June to September.

Landslide: Occurrences in study area

In the study area more than 40 recent landslides are noted, out of that 31 landslides are observed in the stretch of 8 Km. distances along the Vada-Khodala road. Every year average six to eight landslides occur during monsoon and post monsoon periods. There at least one landslide is observed for every 200 meters of distance

Various characteristics of Landslides

To understand the severity of landslide hazard and blockage of road, the volume and spread of landslide debris should be known to the rescue and hazard mitigation team. In the study area most of the landslides, the debris material along the roads forms cone of colluviums against steep cut slopes. With the help of cone geometry, and 'sin rule' slope angles and volumes of cone are calculated. Slope angles are measured in the field and by using **'sine rule'** method.

1. **Debris Slope angles:** To quantify the debris volume, angle of debris slope were surveyed and the extents of debris were also measured in the field. It was difficult to get an angle made by the debris material at the base of scar. Assuming the horizontal surface at the base of debris and with the help of 'Sin rule' formula, angles of general slope (made at scar base) and height of debris cone were calculated and the volume of cone can be estimated. Before estimation, angles of debris slope and general slopes are calculated.

2. **Debris volume estimation:** To estimate the volumes of debris is calculated. Volume of debris is half of the volume of cone therefore total volume of cone is halved. Landslide volumes are estimated for all the slides. The details are given in Table No. 1

Landslide No.	Type of Movement	Potential to Failure #	Debris Volume (m^3)@
LS1	Boulder fall	Yes	24.14
LS 2	Boulder fall	Yes	2.625
LS 3	Boulder fall	No	17.76
LS 4	Boulder fall	Yes	22.5
LS 5	Boulder fall	Yes	27
LS 6	Boulder slide	No	22.77
LS 7	Boulder slide	No	47.6
LS 8	Boulder fall	No	32.675
LS 9	Boulder fall	Yes	49.1
LS 10	Slump	No	79.9
LS 11	Boulder slide	No	6.635
LS 12	Boulder fall	Yes	758
LS 13	Slump	No	810
LS 14	Boulder slide	No	17.945
LS 15	Boulder slide	No	147.5
LS 16	Slump	No	22.945
LS 17	Debris slide	Yes	392.79
LS 18	Debris slide	Yes	347.78
LS 19	Debris slide	No	47.29
LS 20	Debris slide	No	77.275
LS 21	Boulder fall	Yes	*
LS 22	Boulder fall	Yes	*
LS 23	Boulder fall	Yes	*
LS 24	Boulder fall	Yes	*
LS 25	Boulder fall	Yes	*
LS 26	Debris slide	No	229.83
LS 27	Boulder slide	No	2828.125
LS 28	Boulder slide	No	328.325
LS 29	Debris slide	No	430.18
LS 30	Debris slide	No	2353.01
LS 31	Debris fall	No	19

Table No.: 1 Volume and details of debris material

* Observation sr. nos. LS 21 to LS 25 are potential landslides to fall; hence no debris is observed.

Causes of landslide in the study area:

In the study area we have tried to identify some natural processes responsible for the landslides.

1. **Steep slope:** General slopes angle along the Vada-Khodala road calculated by using Wentworth's method are between 15 to 35 degrees. Based on categories of slopes angles suggested by Young (1972) the slope angles are in the category of 'moderately steep', 'steep' and 'very steep'. The weathered mantle becomes very susceptible when the slope angle is greater than 48 degree. (Selbey, et. al 1996). In the study area at some places slopes are cut that increased the steepness of the slope.

2. **Rainfall:** The average annual rainfall of study area is 2000-2200mm. Saturation of the weathered mantle due to supply of water from rainfall can increase debris mass on slope thereby the balance of slope is not maintained. Areas that are affected by landslides

commonly have either cliffs or steep colluvial deposits, gentler slopes of unstable geology, and prolonged or intense rainfall. (Anonymous, 2004)

3. **Deforestation:** In many cases deforestation is one of the causes of landslides but in this particular area deforestation is not significant cause of landslide. Dense forest cover is observed in most of the area. Problem of deforestation is due to damage to vegetation cover, which is a major environmental effect of landslides in the study area.

4. **Stream density:** The Density of first and second order stream in the study region is predominant with 65 % and 70 % respectively. These also promote the surface water movement and reduce seepage. On the terminating slopes the streams or rills follow the surface of underlying rock. Where, saturation of slope material takes place, which promotes the movement of material in down slope direction. (Anonymous, 2004) Water play an important role in mass wasting by over steepening slopes through surface erosion at their bases and by generating seepage forces through groundwater flow' (Bloom, 1978).

5. **Soil and slope:** The soil in the study area has predominantly of very coarse sandy in nature. The coarse material and moderately steeper and steep slopes as suggested by Young, (1972) is the two major factors leading to the slope failure.

6. **Human activities:** For the road construction in hilly areas, slope-cutting activity is obvious. Slope cutting is observed in the study area. It is directly affecting on slope steepness. The increased steepness is noticed due to slope cutting, at many locations, which will promote landslide in near future.

Landslide as a hazard:

Many scholars define the term hazard in different ways' Landslide is a hazardous event that causes unacceptably large number of fatalities and overwhelming property damage is a natural disaster. (The OFM/CRED international disaster database)

Possibly the largest landslide on land occurred some 10,000 years ago in southwestern Iran called the Saidmarred landslide, (Selbey, et. Al. 1996).

Worldwide average death toll in landslide may be about 600 per year. (David, 1993)

Landslides are the example of geomorphic hazards. Where the landslide occurs, it affects to the various aspects of physical and cultural environment.

Physical environment includes: failure of slope, damage to slope surface, damage to vegetation by scar development or by debris deposition, geomorphic damages by scouring the material and by deposition.

Cultural environment: blockage of roads, damage to communication, water supply and electricity lines along the roads. If landslides occur in the inhabited areas the damage is more severe. Settlements and population are always under threat in landslide prone areas.

In the study area the event of landslide becomes hazardous when they affect transpassing of commuters on Vada-Khodala road. There are 09 villages, which are having connectivity with Parali, Khodala and Vada towns.

The road from Khodala to Vada via Parali remains closed after landslide events. This means due to single landslide event, around 200 private and public transport vehicles cannot run on this road. Almost all 09 villages cannot use this road. If people want to travel from Khodala to Vada via Parali, (the shortest route) they follow the Vada-Khodala road of 35 Kms. distances. During road blockage they have to travel Vada via Javhar the distance is about 80 Kms. For weekly market and to avail the medical facilities at Khodala, Vada and Mokhada for administrative work; they have to travel to Parali and Mokhada.

The events of landslide damages to vegetation cover; road surface and protective walls etc. and stops transportation, indirect effects of landslides are disturbance in communication, expensive alternate long distance travel, shortage of essential goods due to road blockages of the surface etc.

Hazard mitigation:

David A., (1993) suggests that, 'internationalization of scientific study of landslides will lead to more countries adopting an active policy of systematic landslide mitigation'. Worldwide several methods are suggested to mitigate the landslide hazards. Among these some methods are pre hazard or precautionary measures. Many of these methods are aimed to maintain appropriate physico-mechanical properties of rock and soils at the sliding surface. These are inefficient, laborious, costly, and feasibility of these methods also raised the question. Most of these methods or techniques are costly and laborious affairs to adopt in Indian circumstances.

To minimize the effects of landslide hazard following measures can be suggested:

1. **Brick plantation:** In which bricks can be laid down on the slopes to minimize the surface runoff as well as the movement of material on the slopes. (Gupta, 2004)

2. **Check walls:** constructions of the check walls resist the movement of material on the slopes along the roads. 'Check wall' construction can also be supported by 'retain wall' and 'breast wall'.

3. **Geo-grids:** A mesh of steel wire can be laid down on the slopes that are potential to boulder fall.

4. **Plantation:** Plantation of rock/ soil holding plants, covering the slopes is suggested to minimize the frequency of slope failure and the severity of the hazard.

    1) Further disturbance or under cutting of slopes along the road should be avoided.

    2) Plantation of rock holding and soil holding plants should be done to hold the weathered mantle. Details of such plants are given table no. 4

Major Findings:

In the study area human activities are responsible for most of the slope failures. The most significant activity is slope-cutting activity for road construction. It makes the slopes steeper and

unstable. More rainfall, steeper, unstable slopes and weathered mantle are the causes of landslides along the Vada-Khodala road.

Occurrence of landslide is more frequent in monsoon and late monsoon period.

In the study area most of the landslides fall in categories of boulder fall, boulder slide, debris slide and slump.

1. Sites of potential landslides are also observed in the field. With the help of slope analysis and field studies, areas of potential landslide are also marked.

2. Deforestation is another important effect of landslides in this area. Vegetation cover is damaged due to debris movement along the slopes. Average 4 to 5 big trees and numbers of small trees and shrubs are uprooted due to single landslides.

3. Since the number of occurrence of landslide is more, geomorphic damages are also more. Geomorphic damages caused by landslides are mainly due to scouring or scar development and debris deposition.

Besides Geomorphic damages, following effects are also observed

1. Blockage of roads: restricts road transportation and disrupts communication.
2. Every year average Rs.3.5 Lakhs are spent for road clearing, construction of protective walls and other related works.
3. Soil erosion is promoted due to easily erodible loose debris.

III. Suggestions

After doing literature survey, analysis of data it can be suggested that for further study of landslides and for landslide hazard management data related to landslide hazard should be recorded, maintained and made available to the researches by the concerned authorities. Many scholars like Rigon, R., Cozzini and others (www.cosis.net/abstracts/EGS02/04956) claimed that the traditional procedure and modern techniques could be successfully used in landslide hazard management. Hence it can be further said that Not only the data but also the detailed field studies of the landslide prone areas and application of new techniques like Geographical Information System and Remote Sensing will definitely help to understand the problems of landslides and hazard mitigation work.

IV. Conclusions

With the help of slope analysis and field studies, analysis of landslide parameters it can be concluded that, the landslides along Vada-Khodala road have occurred between distances from 3 to 13 kilometers from Khodala. There are 31 landslides observed in this stretch. Out of that 5 to 6 sites are of potential landslides. Most of the landslides fall in categories of boulder fall, boulder slide, debris slide and slump. The landslides are caused by human activities mainly due to slope cutting.

These landslides cause road blockage and restricts road transportation and disrupts communication. About 8500 people from 10 villages are directly affected by the landslide event/s. From 2001to 2005 almost 1 million rupees are spent for road clearing, construction of protective walls and other related works.

A landslide damages the vegetation cover. Soil erosion is promoted due to easily erodible loose debris brought down by landslides.

For landslide hazard management and to mitigate the hazardous conditions detailed studies of this area and such other areas are necessary. Use of advance techniques such as remote sensing and GIS can be used.

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