Slope Failure and Highway Management in Hilly Areas

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Abstract— **Slope failures in the form of variety of mass wasting processes including landslides on/along the highways are usual phenomena. However, their frequency and magnitude depends on the variety of natural as well as manmade factors. One of the most important factors is the management strategy of the highway and its slopes beyond construction. Generally, there is a set methodology followed for maintenance of the highways, post construction, but, there is no set practice to maintain the highway slopes. The frequent disruption/damage of highways in hilly areas mostly occurs due to landslides and failure of slopes and not due to the failure of highways. Therefore, highway slope maintenance should be made an integral part of the highway maintenance so that both the highways and their slopes are maintained together to avoid frequent damage to the highways. This article highlights the need, advantages and disadvantages of such management strategy.**

Keywords: Himalayas, Highways, Landslides, Management

I. INTRODUCTION

Indian highways in hilly and mountainous terrain suffer due to frequent slope failures. It is generally noticed that the slope failure once initiated becomes the phenomena of repeated nature. The repeated onslaught of monsoon with recurring landslides invites an emergency like situation when the restoration of highways becomes the priority leaving aside the short term as well as long-term remedial measures for prevention of landslides. These incidences which occur at several tens or hundreds of places not only rank very high in risk but also result in huge revenue loss on just restoration of the highways which mostly surpasses the budget of the maintenance earmarked for the whole year. Moreover, such slopes remain unattended/partially attended or overlooked for longer time helping aggravate the situation further. This repeated aggravation makes the task of the concerned agencies, mainly the Border Roads Organization and Public Works Departments more difficult to save/restore/maintain the highways to their minimum standards. As experienced and reported, all the hill roads/highways suffer from recurring landslides of varying intensity, type and frequency depending upon the various geo environmental characteristics/conditions and other factors of the terrain. The geo environmental setting of the hill and mountain slopes may vary due to their varying terrain composition and characteristics and, therefore, when cut for highway construction/widening and exposed to the act of external triggering factors like rain, earthquake etc. they behave differently. For that reason, not all the slopes behave identical and experience failure. This is precisely the reason for which we should understand the terrain and its geo environmental characteristics so that to identify/classify the slopes based on their degree of potentiality to develop landslides of varying sizes, shapes, type and intensity as well as the intricacies of geo environmental factors on the slopes. The slope failure management system which encompasses the highway as well as the highway slope should be practiced as an undividable part of highway developmental planning, construction and maintenance. This article highlight, in brief the need, objectives, the advantages of such a system and disadvantages of not practicing it.

II. HIGHWAY SLOPES

The highway slopes mean the slopes through which the highway has been constructed which includes both the downhill as well as the uphill slopes. These also include the highway cut and fill slopes. The highway slopes in the context of this paper limits up to a nearest ridge, uphill side and up to nearest toe, downhill side of the highway. The slope composition involving its topography, morphology including drainage, geological setup, plant, biological and other environment are inseparable. These slope components are connected with each other in the formation and stability of the slopes. Imbalance on any one of the components may impact the other and the chain as a whole. Therefore, before cutting the hill slopes for road construction, the whole geo environmental setup of the slopes should be taken into consideration for long term stability. That means before construction it is essential to, a reasonable level, understand the terrain/slopes through which the roads are being cut. In case the new road construction is planned, the concerned agencies should be interested in early consultation with the engineering geologist and geotechnical engineers for assessment of the slope conditions prior to the selection of the final road alignment. When planning a new road, the alignments of the route should be carefully determined considering the probability of landslides during and after the construction. However, in view of the repeated landslide incidences and consequent loss of lives and property, it is not difficult to

assume that a serious consideration for the probability of such problems have not been fully considered while selecting the highway alignment. The slope failure and highway management system when developed can be used as a multi-purpose management system, an integral part of roadway slope mitigation and management which, not only evaluate the landslide hazard but overall hazard the slope may experience during and after the construction of the highway

III. Understanding Landslides

Landslides, when occurred without human interference, can be considered as normal processes of landscape forming as a part of continuous evolutionary earth processes. They are the manifestation of geo morphological changes occurred over the year. Landslide is a generic term which includes a wide variety of mass movements in a wide range of earth materials (rock, debris, earth/soil) with a variety of failure mechanisms (rock fall and rock topples, debris flow and earth slide etc.) and a great variety of shapes and sizes (very large to very small) and speed (imperceptible to a very rapid, catastrophic rate). They can be single events of slope instability, or they can be complex in nature with multiple events at the one site (Gangopadhyay et.al 2009). They can be classified in number of ways, each having some usefulness in emphasizing features pertinent to recognition, avoidance, control, correction or other purpose of classification (IRC: SP: 106-2015). There are several attributes that have been used as different discriminating factors and criteria for identification and classification of landslides. Although they can occur everywhere, depending upon the site conditions and material characteristics, most of them are noticed in hilly areas on highways/roads and other developed/developing areas due to human interference and not solely for natural reasons.

IV. Landslide on Highways

The erroneous constructional/slope developmental practices can either reactivate old slides or convert a largely stable slope into an unstable one. A large number of landslides which have occurred in the past on various highways of the region have been recurring every time the rain falls. Starting from a small patch of slip or erosional scarp or vertical road cut, these have grown to a gigantic size. Most of these landslides repeatedly create problems during every monsoon rain. Additionally, numbers of more landslides also occur every year (Kumar et.al 2013). Though there is a huge list of the landslides on the highways a few of the examples are: In 2009, heavy rains triggered landslides in Darjeeling and took 81lives. 41,000 affected people were sheltered in 109 relief camps. August 1998 in Madhmaheswar valley, in Okhimath District of Uttarakhand state witnessed a devastating landslide affecting 9000 plus people of 29 villages. More than 100 fatalities were reported. A cloudburst followed by heavy landslide had completely wiped out three hamlets in Munsiyari sub-division of Pithoragarh district, Uttarakhand, killing 43 people and more than 100 cattle on 8th August 2009. 16th – 18th June 2013 an unprecedented rainfall followed by flash flood in different part of hilly areas of the country caused havoc. Though many such disasters have been experienced before, it was the first of its kind in respect of coverage and magnitude of destruction and loss of life. Over 2000 landslides have been reported and over 5000 people have been killed & property over worth 488 million dollars has been reportedly destroyed. It would take many years to fill the wide gap left after the disaster in the socio-economical, environmental & cultural harmony of the region. It has put a bright penetrating light on the wide crevasses on the disaster management platform of the area specific & country as a whole (Kumar at.al 2013).The Malpa rock avalanche tragedy of 18 August 1998 which instantly killed 220 people and wiped-out the entire village of Malpa on the right bank of river Kali with the tracking route, in the Kumaun Himalaya of the state of Uttarakhand. The same have recurred on 14 August, 2017 killing 8 people and 16 went missing.

V. Slope Failure and Highway Management

It is important to ensure that the highways, which have strong bearing on Socio – Economic development, environment and strategic needs of the region operate uninterruptedly. This is possible only when a system, through which the health of the highways and highway slopes continuously monitored and rectified, put in place, for example as proposed, a slope failure and highway management system. The slope failure and highway management system is an important management system to maintain the highways as well as their slopes together. Usually practiced procedure excludes the highway slopes from highway maintenance. However, in hilly areas, particularly in Himalaya, including North Eastern region, the highways get damaged mostly due to frequent slope failures or causes related to slopes and less due to embankment or pavements. Therefore the maintenance system only mandating to maintain highways without involving the highway slopes is not a correct procedure and requires changes in it. The highway slope management involves the right assessment of slope based on its various interactive geo environmental factors/characteristics/ conditions. This helps in classifying the slopes in different categories of vulnerability based on which the desirable action can be initiated to avoid any damage to highway due to the slope failure etc.

VI. Components of Slope Failure and Highway Management System

The entire slope failure and highway management system can be divided into following main components (Kumar et.al 2014).

1. Inventory and Database of Highway Network & slope/ landslides
2. Slope failure and highway Information System
3. Slope failure/Landslides Hazard Monitoring & Forecasting and prevention

The first component starts with the collection, management and updating of the digital inventory of the highway network, highway slopes, slope failure/

landslides. The database and inventory prior to any mitigation and management planning and construction of any highway infrastructure are prerequisite (Kumar et. al 2014). The database will help to get useful indicators for probable slope failure/landslide hazard assessment or/and type, size, frequency, run out distance, velocity etc of the landslides. Therefore the first step of the management plan is to prepare an inventory of the landslides along with the network of the highways. This will help to identify the locations on the highway and the slopes which are required to be addressed based on the priority.

Slope failure and highway information system would help to provide all necessary details about the characteristics and properties of slope and road cuttings if already carried during construction of Highway. In the already constructed highways, cuts made during construction if left untreated even requiring of preventive measures may generate slides during rains, destabilize hill or strata. A small patch of erosion or a miner landslide may become a chronic large landslide due to repeated negligence. All such chronic landslide areas become threat to the road and the life of the people. To maintain the highways, therefore classification of the cuts based on their vulnerability is required so that to prevent further development of slides for uninterrupted functioning of the highway. The safety of the roads therefore cannot be insured until the information about the cuts and associated feature of the slope, particularly in critical areas are known.

Real time monitoring of the recurring slope failure/landslides and forecasting of any type of danger according to their behaviour on the slope is an important aspect. Such recurring slope failure/landslides cause huge amount of revenue loss every year on account of restoration and repair works and in certain cases, detouring of the traffic during the landslide events of long hours. It is to be considered mandatory to scientifically study such failures, particularly the large ones, as pace setter examples and state of the art work involving every step right from reconnaissance survey, large scale mapping, geotechnical, geo morphological, geological investigations, instrumented monitoring, risk analysis, forecasting and remedial actions (Kumar et al 2014). The information about forecasting would be disseminated on line through web based system so that anyone can have forehand information to avoid the risk and danger and possible damage.

VII. CONCLUSIONS

The establishment of the slope failure and highway management system for landslide hazard should be consistent with the geological environment, the increasing degree of landslide hazard and economic development of the study area. When planning a new road, the alignments of the route should be carefully determined considering the probability of slope failures during and after the construction. The slope failure Management System when developed can be used as an integral part of roadway slope mitigation to work as a multi-purpose management system for evaluation of geo hazard on the highways, their monitoring, forecasting and mitigation without interrupting the operability of the highway or with minimum interruption and nil loss of life and property as incurred today.

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