Landslide risk management in Malaysia

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Abstract

Malaysia is located in a tropical region where rainfall is abundant. Due to this condition, Malaysia experiences frequent flooding and landslides. The Slope Engineering Branch of the Public Works Department of Malaysia is given the task by the Malaysian Government to monitor and enhance slope safety. Losses due to landslides in Malaysia are estimated to be more than USD 1 billion since 1973. One of the first thing carried out by the Slope Engineering Branch after its establishment in 2004 is the drafting of a National Slope Master Plan (NSMP) to pave the way for enhancement of slope management. The goal of the NSMP is to reduce risks and losses due to landslides. There are ten components in the NSMP. The NSMP laid out strategies and action plans required to better manage the slopes in Malaysia. Some of the action plans that have been translated to practice include but not limited to the following activities: inventorizing slopes; producing hazard and risk maps; carrying out public awareness and education programs; and forming committees among agencies to formulate effective slope mitigation policies and cooperation. The paper describes the actions taken by the Public Works Department to mitigate landslides in Malaysia.
Keywords: slope master plan, risks, losses, action plans, landslide, mitigation.

1 Introduction

Malaysia has been experiencing rapid economic development since the early 1990s. As a result, more hilly terrain areas have opened up for development. From 1973 to 2011, there have been a number of major landslides in Malaysia with a total loss of lives amounting to more than 600. Figure 1 shows the number of landslide events and fatalities from 1973 to 2011. It is estimated that economic losses due to landslides since 1973 is more than USD 1 billion. Faced with landslides that seemed to increase annually, the Malaysian Government took steps to come up with mitigation measures. In 2004, the Slope Engineering

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Branch was established within the Public Works Department Malaysia (PWD). In the same year the Malaysian Government instructed the PWD to prepare a National Slope Master Plan (NSMP) to reduce risks and losses due to landslides. The NSMP was completed and approved by the Government in 2009. There are ten components of the NSMP (PWD [1]). They are: 1) Policies and institutional framework; 2) Hazard mapping and assessments; 3) Early warning and real-time monitoring system; 4) Loss assessment; 5) Information collection, interpretation, dissemination, and archiving; 6) Training; 7) Public awareness and education; 8) Loss reduction measures; 9) Emergency preparedness, response and recovery; and 10) Research and development.

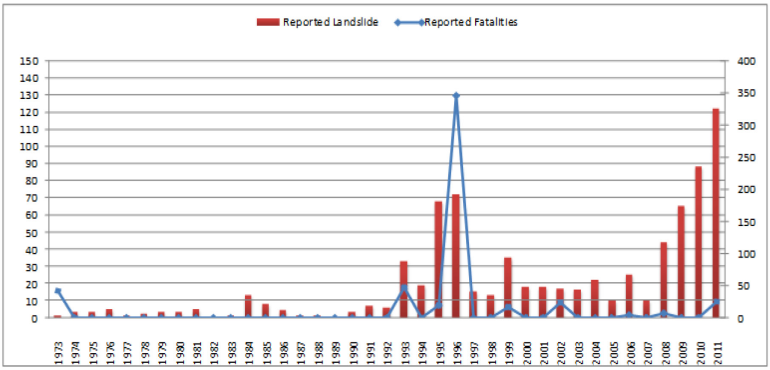

Figure 1: Annual landslides and fatalities in Malaysia.

The NSMP was planned to be implemented in three stages beginning from 2009 up to 2023. Some of the actions taken to manage landslide risks in Malaysia are presented.

2 Data collection, landslide hazard and risk mapping

Lack of a data base on slopes and landslides in Malaysia is one of the reasons why effective decision making on land use planning, maintenance, and quantitative assessment of risks has been difficult. Therefore, one of the first actions taken by the Slope Engineering Branch is to collect data by cataloguing slopes for effective slope management. Inadequate information may result in wastage of funding, difficulty in justifying budget allocation, wrong type of treatment for a slope, and difficulty in the preparation of yearly budgets. Even when money is spent on slopes, the safety of most of these slopes may not be assured if information on the slope is inadequate. A hazard rating based on a ranking system known as Slope Management and Risk Tracking or SMART has been developed. The SMART system has been applied elsewhere within Malaysia and is found to be valid for linear application, i.e., road slopes. To date, more than 25,000 man-made slopes along federal roads have been catalogued. Hazard mapping based on the SMART system and risk mapping of the slopes are in progress.

PWD was also given the task to catalogue slopes and produce hazard and risk maps in high-risk areas, especially cities and towns where sometimes development was carried out without proper planning, design and construction. To date, more than 400 km^2 of hilly areas around Kuala Lumpur, the capital of Malaysia, and Penang Island have been catalogued and mapped for hazards and risks. The information obtained from the studies has then been given to the relevant local authorities for development planning, inspection, maintenance, monitoring and other purposes. Several local authorities have used the data to successfully reduce the number of major landslides in their areas. However, not all authorities is proactively using the data given to them to carry out appropriate measures to mitigate landslides. Some of the reasons are due to lack of funds and technical personnel to tackle technical issues.

A budget for more hazard and risk mapping for landslide-prone areas with an approximately area of 1,700 km^2 has been approved. The new project should cover more than 95% of the landslide-prone areas in high-risk areas in Malaysia, as shown in Figure 2.

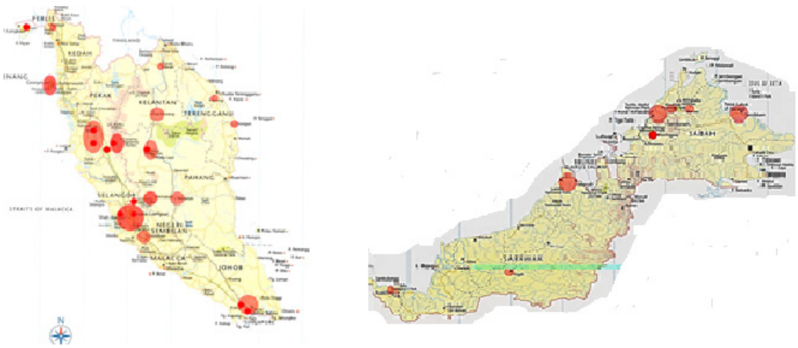

Figure 2: Landslide prone areas in Malaysia are shaded.

The spatial study is divided into two phases, i.e. (i) geomorphological mapping works and (ii) production of hazard map and documentation. In the geomorphological mapping works, LiDAR (Light Detection And Ranging) technology was used in the development of digital terrain models (DTM). Based on this DTM, a ground survey team will carry out field mapping and drainage investigation works. At this stage, qualitative risk analysis was carried out to obtain risk rating for the slope. In the near future, with more data quantitative analysis and risk rating will be given to these slopes.

3 Landslide monitoring and warning system

Landslide warning systems are intended to prompt the public to take precautionary measures to reduce their exposure to risk posed by landslips, and to assist engineers, contractors and others who are likely to suffer losses from landslips. The warning also alerts the relevant government departments and organizations to take appropriate actions, such as the opening of temporary shelters, search and rescue operations, closure of schools and relief work (Hong Kong Observatory, [2]). The Landslide Warning (LW) model can be divided into two functions: 1) for monitoring of regions susceptible to landslides; and 2) for critical locations where active landslides are present. For regions susceptible to landslides, a network of rain gauges will be used. It is based on rainfall as a triggering mechanism of landslides. An early warning system based on rainfall pattern and forecasting can be used in an area where studies have been conducted to correlate rainfall with landslides.

For locations where an active landslide is present, instruments such as automatic survey station, piezometer, inclinometer and other sensors can be installed in addition to rain gauges to monitor groundwater level fluctuation and any movement of the unstable slope mass. LW can be issued based on data collected via sensors or instrumentations, warning criteria based on threshold values, communication and information equipment as sensors and human interfaces as tools for dissemination of warning.

For a combination of related matters mentioned above, expertise in various fields is needed in the development of LW. They are listed below:

a. Instrumentation technologies related to landslides;
b. Landslide-related knowledge (process, behaviours, triggering mechanisms);
c. Communication technologies for remote data transmission, and
d. Information technologies for analysis and dissemination of warning.

The output of the LW consists of various levels of warning that can be used by the relevant authorities to execute appropriate measures (such as closing the road or issues evacuation order) and to minimize the effect of the landslides risks if it happens. PWD is discussing with various stakeholders headed by the National Security Council in the Prime Minister’s Department to establish a networking system for Landslide Warning System (LWS).

To date, the Slope Engineering Branch, PWD Malaysia has installed more than 30 rain gauges along federal roads. This rain gauge network is necessary infrastructure for LW. The Meteorological Department has also recently installed Doppler radars that have coverage over the whole of Malaysia; however, the radars have yet to be calibrated.

There is an ongoing study carried out by the Slope Engineering Branch for the development of a relationship between rainfall and landslides occurrences to determine the thresholds to be used in the LWS. With an abundance of data on past landslides occurrences over the country and rainfall data obtained from the Department of Irrigation and Drainage and the Meteorological Department, the relationship and thresholds can be determined. A pilot study has started along the Tapah to Cameron Highlands road in Perak. Perak is a state located north of the capital city of Kuala Lumpur.

A slope movement monitoring activity is being carried out at km 44 and 46 along a federal road from Simpang Pulai to Lojing, another road in the state of Perak. The geology around Mount Pass consists of a sequence of meta-sedimentary rocks that are confined within a 4 km-wide area surrounding the mountain complex. The rocks are highly deformed and adulated, and have undergone low to medium-grade dynamic metamorphism (Andrew Malone Ltd., [3]). The original sedimentary rocks are thought to have been deposited during the Ordovician period (Geological Survey of Malaysia, [4]). During the late Palaeozoic period it was deformed and metamorphosed. The meta-sedimentary rocks have been intruded by granite plutons that are predominantly Permian to Jurassic in age (Gobbet & Hutchinson, [5]). The exposed rock cut slope within the site includes quartz mica schist, graphitic schist, quartzite and phyllite with weathering grades varying from Grade II (slightly weathered) to Grade VI (residual soils). The residual soils are confined to the 3 to 6 m top section of the slopes. According to a study by Andrew Malone Ltd [3], the rock sequence is cut by a series of faults that are grouped into 3 categories. The first is the most prevalent within the graphitic schist unit, consisting of low to moderately dipping faults that are associated with quartz veining. The second consists of steep faults that cut sharply across the foliation.

At km 44, a cut slope has translated downward and outward by more than 30 m. Even during construction, this slope had already started to fail. It was initially designed for a cut of no more than 40 m high, which is quite common in Malaysia when tunnels and viaducts are deemed too expensive compared with cut and fill. PWD has drafted the Slope Design Guidelines (Slope Engineering Branch, [6]) to limit the height of cut and fill slopes to less than 40 m to facilitate maintenance of the slope and reduce environmental impact of the construction. At the same time the guidelines encourage the construction of tunnels and viaducts, which is more environmental friendly. This case clearly illustrates that the present method of cut and fill may not necessarily be more cost effective compared with tunnels and viaducts in the long run. Monitoring of the slope movement is carried out in real-time using surface monitoring device to measure the movements of the slope surface. In this case, two automatic total stations

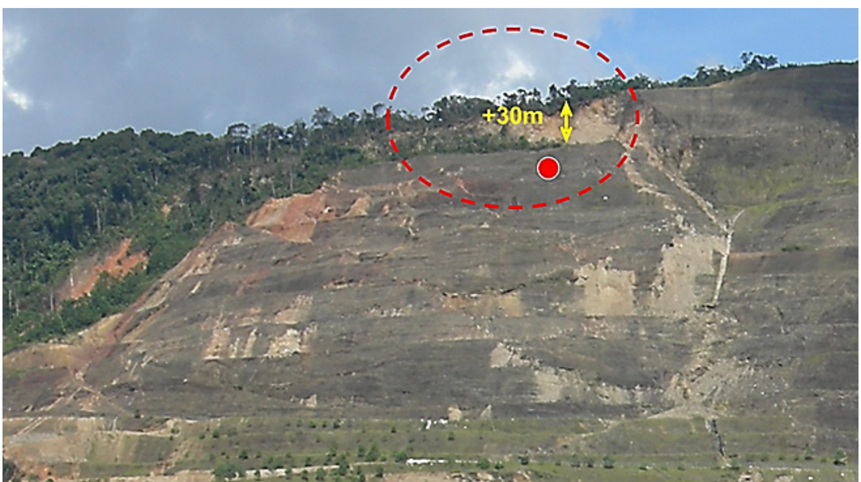

Figure 3: Landslip at Gunung Pass and location of one of the prism markers.

with prisms as markers are used to monitor the movements of the slope. Some of the actions taken include conducting round-the-clock inspections, monitoring and minor realignment of the road. Figure 3 shows the head scarp at the top of the mountain and the location of the markers on the slope surface.

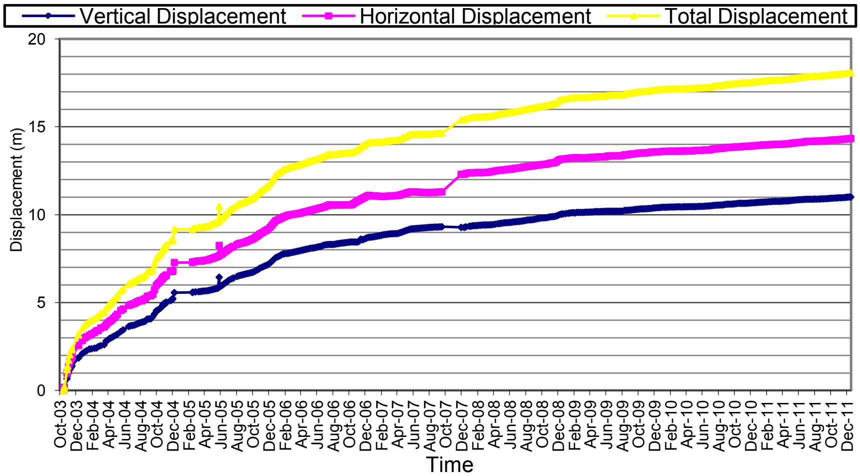

Figure 4: Largest movements at prism marker indicated in Figure 3.

Movements of the slope surface have been monitored since 2003. Initially, the monitoring was done manually until 2007 when two automatic total stations were installed and data was acquired at three-hour interval as opposed to once a day when measurements were taken manually. Figure 4 presents the movements of the most active marker near the head scarp. The slope face is still moving at a rate of 0.4m per year.

4 Slope inspection program

Slope inspection for all federal roads is carried out in preparation for the rainy monsoon seasons by the PWD technical staff with the help of the district engineer's staff. A few local authorities are also carrying out regular inspections on the slope under their authority. Efforts have been to create awareness amongst the local authorities so that regular inspection and maintenance are carried out to reduce the risk of landslides.

Emphasis during the slope inspection is placed on ensuring that the drainage system is well maintained, i.e., free of debris and any damage has to be reported and repaired. Another aspect of slope inspection is to detect signs that may indicate or cause instability such as tension cracks and seepage within the slopes. This program has just been initiated and guidelines for maintenance have been introduced. At the outset the process seemed quite simple. However, ensuring the effectiveness of the program requires a lot of groundwork, such as training

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for the inspectors – usually technicians and engineer's assistants, proper equipment, and of course enough personnel to carry out the inspections. Other impediments to the slope inspection program include inadequate facilities for inspection purposes. Usually cut slopes in Malaysia are constructed at more than 35° and some rock slopes are constructed at more than 75°, which means that a special ladder or stairs have to be provided for scaling the slopes. In actual fact, such facilities are generally ignored during the design. On top of this problem, the slopes are generally heavily vegetated. PWD is trying to remedy the situation by constructing facilities to facilitate inspection of the slopes.

Previously, there was no limit to the height of the cut slope, so the highest road cut slope is approximately 260m. Many slopes are more than 40m high which means only very physically fit personnel would be able to scale the slopes. Coupled with the inadequate facilities as mentioned above, the task of proper inspection is difficult. Apart from manual inspection, PWD are looking at ways to carry out remote inspection. One of the ways is to inspect using unmanned model helicopter or plane with viewing device attached; however, this is still undergoing trials and experiments.

Once the inspection process is completed, the next step would be to perform proper maintenance and repair. Apart from the physical impediments mentioned above that makes maintenance and repair difficult and costly, adequate funding is always an issue. For routine maintenance and minor repairs of road slopes, PWD is provided with approximately USD 33 million annually.

5 Guidelines

Manuals and guidelines facilitate routine works and procedures that need to be done quickly and efficiently. Several guidelines have been produced to help engineers, especially those in PWD to carry out their works. Guidelines are sometimes adopted with some modification from other established organizations that have already come up with a proper procedure.

Some of the guidelines that have been produced are slope design and maintenance guidelines. In the slope design guidelines, some cut slope and embankment dimensions are clearly spelled out, for example the maximum number of benches are now limited to 6 and the height between each bench shall not exceed 6 m. The minimum bench width of the slope is also specified. The factor of safety cut slope and treated slopes are specified.

Malaysia's slope maintenance guidelines have been adopted with some modification from the Hong Kong slope maintenance guidelines. In the guidelines, inspection program for slopes is presented including the personnel and the frequency of inspection. The guidelines also include what needs to be maintained and how it should be carried out. As in any other maintenance guidelines, special attention is paid to the condition of drains on the slopes. Any signs of instability have to be attended speedily before the condition becomes worse. Examples of well and poorly maintained slopes were shown by way of pictures and illustrations. The maintenance manual can be downloaded for free from PWD's website and the maintenance guidelines have been distributed to local authorities for maintenance of their slopes, which usually include slopes along municipal roads and around residential areas.

The Town and Country Planning Department, a federal agency, has also drafted development on hilly terrain and highlands guidelines in 2009 to ensure man-made slopes are well planned, suitably designed, well-constructed, and properly maintained. The guidelines are mandatory for developers if the local authorities choose to enforce them. Some states have since drafted more stringent guidelines to reduce the risks of landslides. Public pressure has resulted in the federal and state government to take more proactive actions to reduce major landslide disasters.

Works on regional rainfall-induced landslide warning system has started with some research being carried out along the road between Tapah to Cameron Highlands, a road that traverse through a hilly terrain area.

6 Training

In this component two strategies were proposed to increase knowledge and awareness among students, practicing engineers, stakeholders such as developers, local government officers, contractors, planners and geologists. In the case of students, one of the recommendations was to introduce curriculum and course templates for undergraduates and post graduates courses. Discussions with the academia from various local universities during the drafting of the NSMP did not yield a favourable response from them simply because there is no space for a new course to be taught within the already congested course schedule. It was suggested that special talks be given by practising engineers on relevant topics on slope engineering to under and post graduates students. The programme has already started with a few universities and will be expanded to other institutes that teach civil engineering and soil sciences (Abdullah [7]).

Currently more efforts are spent on training engineers and technical personnel from the local authorities so that they can response to the demand from the public to provide technical advice, carry out inspection on slopes and recognising signs of landslides so that they can take preventive actions should the need arises.

Other stakeholders include practicing engineers, planners, developers, contractors and geologists who would require training and awareness programmes. Developers and contractors in particular would require such training so that their works have better quality. PWD plans to work with the Malaysian Construction Industry Development Board to carry out a systematic courses and seminars for the construction industry players on good practices on slopes.

7 Public awareness and education

One of the first programmes to be rolled out upon the completion of the NSMP was public awareness and education. The programme was about creating awareness of slope safety by minimising the effects of landslides through proactive actions and measures that can be taken by community members as well as by government and private owners of slopes.

Generally, people tend to focus on safety only after a disaster happens, so the programme aimed at getting them thinking about averting disasters before they occur (Motoyama and Abdullah [8]).

Although the main target groups of the programmes were the communities-at-risk and the general public, there were other target groups consisting of the state and local governments, private slope owners, media, universities and schools.

The objective of the awareness programmes was to convey two key messages to the public. The first was to let the public know that there is a body of useful information that is available to the public on the phenomenon of landslides and tips on monitoring and maintenance. The second is that there is a government agency dedicated to safeguarding the interest of public safety.

Figure 5: Children lining up to receive prizes in a colouring contest in one of the public awareness programmes.

These messages were encapsulated in the campaign theme of “Learn, Maintain, Monitor and Report” and all activities of the awareness programmes were centered around this theme. The motif that tied all these activities together was the slogan “Safe Slopes Save Lives”, courtesy of the Geotechnical Engineering Office in Hong Kong.

One of the most important groups is the communities in at-risk areas because of the obvious risk to life and property. The assumption at the outset of the programme was that public awareness to this group would yield the best results among all the target groups because of the immediate safety concern to themselves.

Next to communities-at-risk, the most important target group was the local authorities. The authorities are the only government body with the charter to enforce safety guidelines and by-laws and engage in maintenance measures. Because they are the first line of contact with the residents, it is crucial that the engineering departments of the authorities are well-trained and well-equipped.

The outcomes resulting from this programme are significant in that they reflect institutional and long-term changes that affect the way hillside developments will be carried out in the future. They are as follows:

1. Awareness among local authorities in hilly areas for a proper slope management mechanism within their scope of work and the subsequent establishment of Slope unit within 3 local authorities in the high-risk states in the country
2. Establishment of state-level independent slope oversight committees for checking and approving all new development orders involving hills.
3. Reporters of newspapers providing regular coverage of slope issues in the local beat, and coverage now includes educational material in addition to problem cases.
4. Formation of SlopeWatch, a community-based organization that has grown into an non-governmental organization due to demand by residents for more information and advice on averting slope problems and pushing the authorities for stricter supervision of developers.
5. Residents associations in urban areas establishing sub-committees on slope monitoring so that residents can do their own monitoring and report to the authorities on any signs (Motoyama and Abdullah [8])

These are some of the changes that the programme has affected.

8 Setting up of Inter-governmental Committee on Slope Management (ICSM)

One of the action plans in the National Slope Master Plan is the setting up of the ICSM (PWD, [9]) at federal and state levels. Federal-level ICSM was set up in 2010. The primary purpose is to provide a mechanism for the active participation of all stakeholders, including technical experts and communities, in slope management planning and operations, where relevant role players consult one another and coordinate their activities on slope management issues.

The ICSM members include but not limited to the following organisations: Slope Engineering Branch; National Security Council; Town and Country Planning Department; Department of Environment; Department of Mineral and Geoscience; Malaysian Meteorological Department; Malaysian Centre for Remote Sensing; PWD Malaysia; Malaysian Highway Authority; Department of Survey and Mapping; Royal Malaysian Police Force; Malaysian Fire and Rescue Department; Social Welfare Department; the Red Crescent; highway concessionaires and other relevant governmental and non-governmental organisations.

The ICSM must advise and make recommendations on issues relating to slope management and the establishment of the landslide disaster management framework. The committee has recently agreed to form sub-committees headed by National Security Council to review the efficiency of the rescue operation for landslides and to facilitate information exchange among various agencies not only on landslide matters but also other information that any of the agencies have acquired.

9 Conclusion

Some of the slope management issues and actions taken by the Slope Engineering Branch of PWD Malaysia and other agencies are presented. PWD is at the forefront of managing landslide risks in Malaysia. The process commenced as soon as the Slope Engineering Branch was established within PWD and the drafting of the NSMP. The Malaysian Government has started to pay more attention to the landslide issues as public outcries grew louder. Some local authorities that are at the front line of public anger whenever major landslides occurred have yet to provide better services while others have used guidelines and relevant acts to act against errant developers and land owners. Landslide risk management requires the cooperation from all sectors of the society, from the federal and state government, local authorities, non-governmental organisations and the public for its success.

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