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Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific Journals, Poland, Directory of Research Journals

ISSN 0974-5904, Volume 09, No. 03

International Journal of Earth Sciences and Engineering

June 2016, P.P.289-293

West Sumatra Landslide During in 2012 to 2015

ABDUL HAKAM AND BAMBANG ISTIJONO
Andalas University, Indonesia
Email: *ahakam2008@yahoo.com; bistijono1452@yahoo.co.id*

Abstract: During year 2012 to 2015, there are number of landslide occurred in West Sumatra - Indonesia which have been recorded. Those disasters had taken lives and destroyed public facilities. The West Sumatra is a province in Indonesia that located in the middle west of Sumatra Island. The province has area stretching from the west coast to the hills in the middle of the Island. The landslides in West Sumatra frequently occur along the hill and mountain areas of this province. The diversities of physiographic and geologic conditions as well as surface vegetation lead to the landslide in the West Sumatra. In addition, the landslide occurrences are also influenced by the weather and local climate. This condition was worsening by the change of land use in landslide potential area. In many cases, the main factor causes landslides are the reduction of the strength of the soils due to the rain. In the remedial action, the budget and available technology as well as local human capability are the most restrictions that necessary to be considered. This paper describes a review of the landslide in West Sumatra and treatment measures for the years 2012 to 2015. This work is very important to improve and to develop the efforts to reduce the landslide risk and treatment in the future.

Keywords: *landslides, ground condition, remedial action*

1. Introduction

The West Sumatra Province is geographically located in the west-central side of the Sumatra Island (Figure 1). In the middle of this province there are many hills that lay from the north to the south as part of the Bukit Barisan hill. The Bukit Barisan hill is also geologically formed due to the existence of the Semangko fault which divides the Sumatra Island into two parts, east and west. In addition, along the Semangko fault there are some active and non-active volcanoes which create a mountain area (Barber et al., 2005). The formation of soil deposit of the West Sumatra province in general is dominated by the volcano activity along Semangko fault. The area around the Semangko fault is known as volcanic area. The lowest area of the volcanic area, the ground is dominated by sediment material that likely originated from the volcanic area. The physiographic of the West Sumatra province then can be divided into three groups that are volcanic area, hill area and flat area as shown in Figure 2 (Sandy, 1985). These physiographic conditions form slopes with different types of soil, in where it will be shown that the landslide in the West Sumatra generally occurs.

In the last 3 years, it has been carried out the Landslide Reports in the West Sumatra by the Government Body. This paper shows a review of that landslide records that occurred in the West Sumatra in 2012 to 2015 (ESDM 2012 to 2015). This review is related to the incident location, type and geological condition of landslide, time of occurrence and remedial action that has been done.

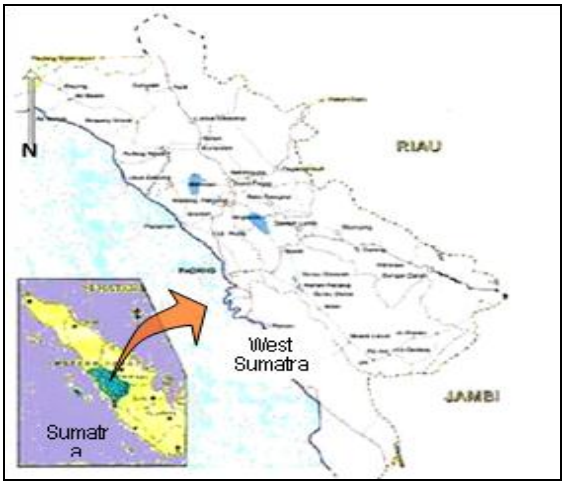

Figure 1 *Sketch of West Sumatra province*

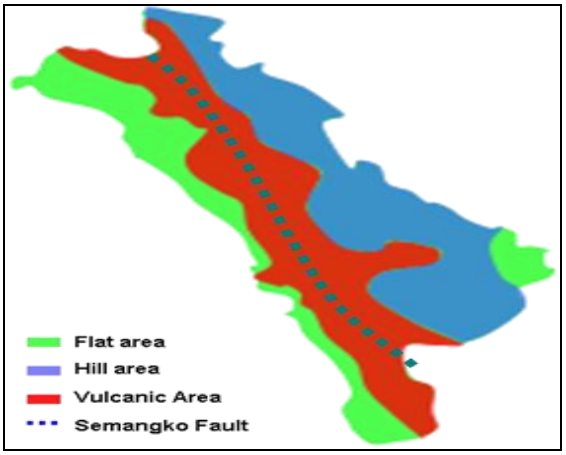

Figure 2 *Physiographic map of West Sumatra (adapted from Sandy, 1985)*

2. Landslide Outline

Theories to analyze the stability of the slope have been written in many textbooks in many languages (example: Huang, 1983 and Hakam, 2010). Those references have been elaborating type of sliding, factors cause sliding, slope stability analysis theories also the methods for designing the retaining structures. Here, landslide types and factors cause the sliding of slopes are written briefly in the following sections.

Slopes can be failure in term of sliding (general landslide), flow of soil (debris flow) and rock debris (rock fall). There is also a slow movement of slope that known as creep. A creep generally does not cause a collapse in slope but result in displacement that may lead cracks and damage to the facilities there on. The illustrations of those types of landslide are shown in Figure 3.

In general, the factors that cause a landslide can be divided into two groups: internal and external factors. Both factors theoretically cause of decreasing the strength of soil or increasing the force thus reducing the safety factor of the slope. External factors are all of the disturbance from the outside of the slope, either made by natural or human. The examples of the external factor which can reduce the slope safety are vibrations from human activities, earthquakes, additional loads, the removal of retaining forces on the down of the slope and also the loss of slope covering. The internal factors are changing in the moisture content of the soil, increasing the soil mass due to water intrusion, the absence of cemented material in soil mass, increasing the water table, heaving - shrinking of the soil mass, sudden reduce of water table and liquefaction.

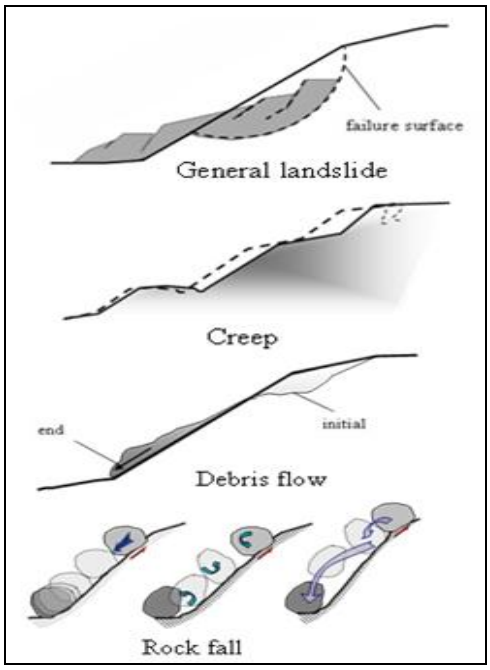

Figure 3 *Illustration of sliding types (Hakam, 2010)*

Further, common things that need to be considered in the dealing with landslide are topography, geology, water in the soil, climate and weather, vibration, history and time. These things directly or indirectly may trigger the slope stability.

3. Landslides in West Sumatra

Since there are many landslides in west Sumatra region, Division of Geology of Energy and Mineral Resources Department of West Sumatra province published annual reports of landslide. These good records of landslide are started in 2012 (Hakam et al, 2015). The summary of landslide records for last 4 years then are described in here. The recorded landslides in the West Sumatra are included any soil mass movements in general type of sliding, debris flows, creep and rock fall.

In the year 2015 the most type of landslides are general and debris flow. Only one incidence of rock fall had happened in South Padang. Based on the records, prior to till during the landslides there were heavy rain. Beside the rain, the land-use change is judged to be the other main reason which triggered the landslides. However this thought must be scientifically proved by conducting further research in the specific affected area.

The landslides that are reported in here are the ground movement in which resulting in damage to public and private facilities as well as fatalities. Many landslides in small scale that did not result in loss or casualties also occurred in the West Sumatra but not recorded in this reports. In 2012, the landslides have taken 11 lives in six locations. In 2013 only one event of landslide but took 20 lives at Maninjau Lake in Agam District. In 2014 there were four locations of landslide which resulted in the fatality of 7 lives.

Landslides in 2015 only resulted in material losses in the terms of damages to infrastructures and homes with no casualties. This indicates disaster preparedness has been developed, especially in case of landslides.

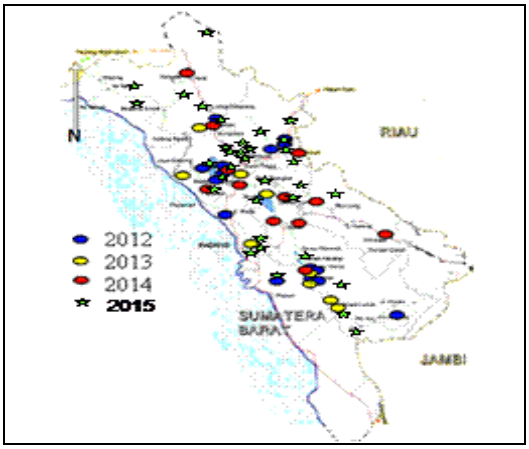

Figure 4 *Location of landslides (Modified from Hakam et al., 2015)*

In three years of the records, landslide locations in West Sumatra mostly occurred in volcanic area and some of the locations are in the hill area as shown in Figure 4 and 5. The geology of these locations is made of relatively unstable young rocks. Geotechnical studies on some locations of slope indicate the behavior of clay against water affected the landslides. The reduction of the soil shear strength caused by the increase of the water content affected the slope stability and lead to the landslides. An assessment for the landslide in Maninjau-Agam showed that the saturation in soil mass can reduce the soil cohesion by 75% (Hakam et al, 2013).

Similar to previous the years, the landslides in 2015 mostly occurred in the highlands. There are from total number of landslides of about 70% occurred in the volcanic area, 26% happened in the hill area and only about 5% occurred in the flat area. Indeed, topographical in highland areas have higher variation in slopes so the potential landslide are larger than the flat areas. For those reasons, mitigation measures to prevent the occurrence of landslides should be considered in highlands.

In Table 1 is shown the time of the occurrence of landslides over 3 years. It can be seen that landslides occurred mostly in the early months and the end months of the years. In those months that are recognized as rainy season in the West Sumatra. It is very rarely landslides happened in March to June where the rain is also rare. There is also generally heavy rain felt at the time prior to the occurrence of landslides. Thus it is needed good preparation of equipments, funding and human resources to deal with landslides especially in the rainy season. Although there is only one incident of landslide triggered by an earthquake, it must receive special attention. Many landslides also happened during Sumatra earthquake in 2009.

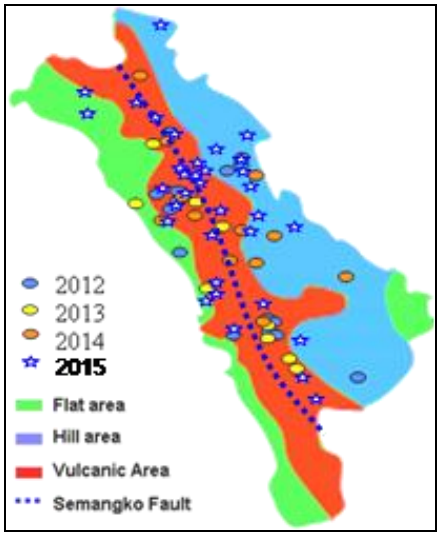

Figure 5 *Distribution of landslides (Modified from Hakam et al., 2015)*

The largest number of landslides occurs in November 2015 with 16 events. Then landslides often occur in December, January to May. Meanwhile, from June to October, the are only a few accidents (Figure 6). Similar to previous years that the landslides generally began with raining in advance. In previous years, the landslides are very rarely or not took place in March to June. It indicates there is potential shifts rainy climate in western Sumatra that affects the landslide occurrence.

The understanding of the factors that cause of landslide is very useful to determine the corrective and preventive actions in the future. The rain is certainly very difficult to be controlled, but the water which triggers the occurrence of landslides can be controlled well.

Table 1 *Occurrence time of recorded landslide*

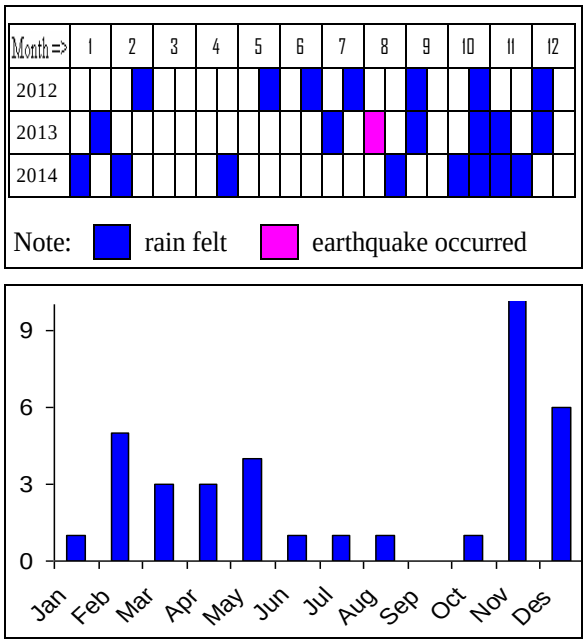

Figure 6 *Number of recorded landslide in 2015*

Remedial actions to solve the landslide in West Sumatra are conducted generally in terms of replanting trees. The main reason to do this action is because the landslides occurred along the open locations at the hill and mountain areas. But at certain locations, the landslides also occurred at the roadsides. In these cases the restorations are done by constructing retaining walls. For landslide which occurred along the rivers, the gabions are chosen. The remedial action to prevent water intrusion in to the soil mass by controlling the water above the slope is rarely done.

The conventional reparation of landslides in the West Sumatra is caused by the lack of technology as well as limited budget. The mort used structures to protect the important facilities from landslides are gabions and river stone masonries (Figure 7). That is combined by the lack of knowledge of slope stability and stabilization of authorized bodies which deal with

landslides. The improvement of human capacity must be done, especially in terms of prevention tasks of landslides. In additional, the enough budgets and the appropriate technology to prevent landslides must be considered better.

Figure 7 *Remedial action using gabions*

Investigations on landslide in sliding prone locations should be done so that appropriate solutions associate with landslide can be made up. An example of an investigation on the slope stability and its solution for Maninjau sliding in Agam has been conducted in 2013 (Figure 8). The investigation procedure is started by a field survey and laboratory tests of soil samples then followed by stability analysis and delivering a recommended solution. On the laboratory investigation the undisturbed and saturated soils are tested and those data are used for the analysis (Table 2). The landslide is triggered by the change the water content which significantly changed the soil properties. The study suggested that the slope protection might be done by re-plantation deep-strong root vegetations.

Figure 8 *Maninjau – Agam Landslide in 2013 (Hakam et al, 2013)*

Table 2 *Soil parameter of Maninjau (Hakam et al, 2013)*

Test name	Parameter	Sample		Unit
		S1	S2	
Water content	w	28.11	36.77	%
Unit weight	γ	1.79	1.85	t/m^3
Spesific Gravity	Gs	2.65	2.65	
Sieve analysis	Gravel	4.03	3.17	%
	Sand	14.57	39.87	%
Atterberg's Limit	LL	44.90	60.24	%
	PL	34.14	31.27	%
	PI	10.76	28.97	%
Direct Shear (soaked)	c	0.94	1.50	t/m^2
	ϕ	32.28	24.85	°
Direct Shear (wet)	c	1.05	2.06	t/m^2
	ϕ	27.32	31.11	°

4. Conclusions

Landslides in the West Sumatra generally occurred mostly in the highlands (hills and mountains) that have relatively steep slope and the disadvantage geotechnical conditions. The landslides that occurred from 2012 to 2015 have caused damage to infrastructures and fatalities. The cut of vegetations that covering slope surface and the change of land use have triggered landslides. Some landslides were also caused by inaccuracy of the artificial slopes design. Although in 2012 to 2015 there is only one landslide caused by an earthquake, it is important to notice that an earthquake can trigger landslides such that happened during the Sumatra Earthquake in 2009.

Mainly the landslides occurred during or after heavy rain. Along a year, landslides occurred in the rainy season i.e. in January, February and July to December. It is necessary to have a good preparation for the emergency response of landslides in those wet months.

Landslides often occurred in the highlands which land-use plan in that area often changed for the development purposes. The local government in the highlands area should take more consideration of sliding in the change of land use for any purposes.

Remedial actions for landslides in the West Sumatra are mainly associated with the availability of budget and technology. The plantation is more popular solution compared to preventive treatment such as surface water control. For a better solution in future it is necessary to develop understanding and to increase the human capacity related to the slope stability and protection.

5. Acknowledgements

We would like to thank the Ministry of Energy and Mineral Resources (ESDM) of West Sumatra province for providing the Report of Landslide in West Sumatra in which information and data in this paper are obtained.

We also thank to our students for helping and accompanying us to carry field investigations and to accomplish any activities related to this paper.

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