# SIBE2013

**The Second International Conference on Sustainable Infrastructure and Built Environment**

*Accelerating Sustainable Infrastructure Development – Challenges, Opportunities, and Policy Direction*

BANDUNG – INDONESIA
NOVEMBER 19TH – 20TH, 2013

## International Conference and Exhibition

Published by
Faculty of Civil and Environmental Engineering
Institut Teknologi Bandung – Indonesia

# LIST OF COMMITTEE

## STEERING COMMITTEE

Chair : Prof. Dr. Suprihanto Notodarmodjo (ITB)

Co-Chair : Dr. Puti Farida Marzuki (ITB)

1. Prof. Liang-Jenq Leu (NTU, Taiwan)
2. Prof. Naoshi Baba (Hokkaido University, Japan)
3. Prof. Iswandi Imran (ITB)
4. Prof. Syahril B. Kusuma (ITB)
5. Prof. Bambang Sugeng (ITB)
6. Prof. Prayatni Soewondo(ITB)
7. Prof. Arwin Sabar (ITB)
8. Dr. I Wayan Sengara (ITB)
9. Dr. Tri Padmi Damanhuri (ITB)
10. Dr. Muslim Muin (ITB)
11. Prof. Ade Sjafruddin (ITB)
12. Dr. Krisnaldi Idris (ITB)

## SCIENTIFIC COMMITTEE

Chair: Prof. Enri Damanhuri (ITB)

Co-Chair: Dr. Krishna S. Pribadi (ITB)

1. Prof. Shyh-Jiann Hwang (NTU, Taiwan)
2. Prof. Naoyuki Funamizu (Hokkaido University, Japan)
3. Prof. Tomoya Shibayama (Waseda University, Japan)
4. Prof. Carl Larsen (NTNU, Norway)
5. Prof. Tsunemi Watanabe (Kochi University of Technology, Japan)
6. Prof. Wisjnuprapto (ITB)
7. Prof. Ofyar Z. Tamin (ITB)
8. Prof. Masyhur Irsyam (ITB)
9. Prof. Amrinsyah Nasution (ITB)
10. Prof. Adang Surahman (ITB)
11. Prof. Indratmo Soekarno (ITB)
12. Prof. Ricky Lukman Tawekal (ITB)
13. Dr. Edwan Kardena (ITB)
14. Dr. Saptahari Soegiri (ITB)
15. Dr. Biemo W. Soemardi (ITB)
16. Dr. R. Driejana (ITB)

17. Dr. Iwan Kridasantausa Hadihardaja (ITB)
18. Dr. Mindriany Syafila (ITB)
19. Ir. Idris Maxdoni Kamil, M.Sc., Ph.D.

**ORGANIZING COMMITTEE**

| | |
|---|---|
| Chair | : Prof. Dr. Ir. Rizal Z. Tamin |
| Co-Chair | : Ir. Muhamad Abduh, MT., Ph.D. |
| Treasurer | : Dr. Ir. Dwina Roosmini |
| | Dr. Muchammad Chaerul, ST., MT. |
| | Endra Susila, ST., MT., Ph.D. |
| General Secretary | : Dr. Nita Yuanita, ST., MT. |
| | Dr. Benno Rahadyan, ST., MT. |
| | Rofiq Iqbal, ST., M.Eng., Ph.D. |
| Publication | : Ir. Iwan Kridasantausa, M.Sc., Ph.D., |
| | Dr. Russ Bona Frazila, ST., MT. |
| | Dr. Ing. Marisa Handayani, ST., MT. |
| Exhibition | : Dhemi Harlan, ST., MT., Ph.D. |
| | Dr. Paramashanti, ST., MT. |
| | Ir. R. Driejana, Ph.D. |
| Sponsorship | : Ir. Agus Jatnika Effendi, Ph.D. |
| | Ir. Erza Rismantojo, Ph.D. |
| | Emenda Sembiring, ST., MT. |
| Program | : Dyah Kusumastuti, ST., MT., Ph.D. |
| | Ir. Yuniati Z. Azzaino, MT., M.Sc., Ph.D. |
| | Joko Nugroho, ST., MT., Ph.D. |
| Parallel Session | : Prof. Dr. Herlien Dwiarti Soemari |
| | Dr. Kania Dewi, ST., MT. |
| | Dr. I Made Wahyu Widyarsana, ST., MT. |
| Social Event | : Ir. Ima Fatima, M.Eng, |
| | Dr. Ir. Katharina Oginawati, MS. |
| | Prof. Dr. Ing. Prayatni Soewondo, MS. |
| Logistic | : Dr. Ir. Saptahari M. Soegiri Poetra |

| | |
|---|---|
| | Dr. Sukandar, ST., MT. |
| | Ir. Rildova, MT., Ph.D. |
| Proceeding | : Ir. Indah Rachmatiah S. S., M.Sc., PhD. |
| | Dr. Irsan Soemantri Brodjonegoro, M.Sc., Ph.D. |
| | Ivindra Pane, ST., M.SE., Ph.D. |
| Catering Division | : Aine Kusumawati, ST., MT., Ph.D. |
| | Ir. Titi Liliani Soedirdjo, M.Sc. |
| | Dra. Barti Setiani Muntalif, Ph.D. |
| Transportation | : Dr. Ir. Sony Sulaksono Wibowo, MT. |
| | Dr. Ing. Ediansjah, ST., MT. |
| | Hasbullah Nawir, St., MT., Ph.D. |
| Acomodation | : Dr. Harmein Rahman, ST., MT. |
| | Suharyanto, ST., M.Sc. |
| | Hadi Kardhana, ST., MT., Ph.D. |

# SIBE2013

The Second International Conference on Sustainable Infrastructure and Built Environment

Faculty of Civil and Environmental Engineering
Institut Teknologi Bandung

# PROCEEDING BOOK

## TOPIC 7

*"Accelerating Sustainable Infrastructure Developement - Challenges, Opportunities, and Policy Direction"*

*In Collaboration with:*

*Sponsored by :*

IPC
Energizing Trade, Energizing Indonesia.

BUKIT BARUGA
HARMONI KEHIDUPAN

ISBN 978-979-98278-4-5

# Slope Stability Analysis Following Maninjau Landslide 2013

**Abdul Hakam, Febrin A Ismail, Fauzan, Bambang Istijono & Ricky Arnaldo**

[1] Disaster Studie Centre of Andalas University
[2] Kampus Unand – Limau Manis, Padang
Email: ahakam2008@yahoo.com

**Abstract.** The Landslide in Maninjau 26-01-2013 that happened in the dawn has taken the 22 lives. The location of landslide is in hill side of Maninjau Lake. The landslide it self might be triggered by the rain in several hours in the night. To determine the cause of the Padang landslide 2012, the field investigation was conducted. The physical and mechanical properties of the soil in the area are examined. The research of physical properties is especially useful for understanding the behaviour of soil in the change of water content. The type of soil that dominates the catchments area is fine grained soil. This type of soil will change the mechanical behaviour with the change of the water content. Using the test data, the slope stability is conducted to figure out the factor of safety the hill. It is concluded that the same phenomenon can be happened in surrounding area. It is suggested that the people together with the local government to install the early warning equipment in the typical areas.

**Keywords:** *landslide, soil property, slope stability analysis.*

## Introduction

Landslides and similar phenimena in Weat Sumatra are named as Galodo. Through these natural disasters the people of West Sumatra (called Minangkabau) take the lessons for themselves that what they have done in the past that may cause disaster. They have the responsibility against the natural surroundings. So the past mistake should not be repeated again in the future.

The Landslide in Maninjau on 26-01-2013 happened in the dawn has taken the 22 lives. This Galodo happened in the hillside of Maninjau lake area.

Maninjau lake area has been recognised as landslide prone area. In West Sumatra earthquake on 30-09-2009, these are lansdslide in many spot in this area. However, the Maninjau Lanslede on 26-01-2013 took place in a new hill spot that has no landslide experience before.


**Figure 1.** Location of Maninjau lake

**Figure 2**. Maninjau landslide spot

## Metodologhy

With the intention of finding out the technical reasons that cause the landslides in Maninjau, the field investigations have been conducted in the location. The field survey in the field has carried out the geometry of the landslide area. In addition, the soil samples have been taken from the location in 2 points. The soil samples then were taken into the laboratory for physical and mechanical parameters tests.

It is known that in the night before the disaster, it was rain in the surrounding area of Maninjau lake. It is predicted that the landslide of slopes in Maninjau is mainly triggered by the presence of intrusive water due to the rain. The tests of the soil samples were carried out also in associated with soil behavior related to its interaction with water. Then the experiment conducted on soil samples mainly are as follows:

a. Soil grain size distribution test: In general, the soil is classified into two main groups, those are fine-grained soil and coarse grained soil. The sieve test of soil is aimed to determine the distribution of the soil grain size that dominates in the soil structure of Maninjau landslide. The sieve test is performed using the series of sieves to separate the grains of the soil in certain sizes. The percentage of certain grain size of soil that passes through the sieves was plotted in a graph to determine the figure out the soil particle distribution. Based on this graph, the soil then can be classified in to either fine or coarse grained soils.

b. The Atterberg limits tests: These tests are aimed to obtain data of the water content in the soil that can change the consistency of the soil in the terms of plastic limit and liquid limit. In fact that if a soil has a moisture content that exceeds its liquid limit, then the soil mass can easily transforms from a solid form to a liquid form. The soil mass that has excessive water content in it can flow as the behavior of liquids. In nature, this flowing soil mass is usually move together with the other objects and is known as the mud flow or debris flow.

c. Shear strength testing: This test is performed in order to find out the technical values of the soil in terms of shear strength parameters. Basically the shear strength of soil is contributed by their adhesive (cohesion) and internal shear resistance (friction). The cohesion is generated by the chemical behavior of the soil minerals and the internal shear friction is influenced mainly by the shape and the size of soil particles. For the coarse-grained soils that have very little the adhesion between the grains, the shear strength of these soils are determined by the inter-particle friction resistance. The measurement of soil internal shear parameter values can be done by direct shear tests on soil samples both in the field and in laboratory. Meanwhile for the fine-grained soils, the shear strength is contributed mainly by cohesion between soil particles. The value of the cohesion parameter of this type of soils can be easily done by unconfined compression shear test (UCST).

d. The physical parameters tests: These tests are performed to obtain the values of the natural water content, the specific gravity and the unit weight of the soil. These parameters are required to identify soil type and also needed as the input data for the slope stability analysis.

The slope stability analyses then can be performed using the results of the soil parameters tests as the input data. The slope stability analyses are conducted with the variations of moisture conditions, that are using data from natural soil sampel and soaked sample. Based on the field survey that the actual landslide has a linear type of failure surface in slope. Then the slope stability analyses consider also by assuming the linear failure surface in the slope that has the same direction with the surface slope. The critical depths of failure surfaces in the slope can be determined from the stability analyses of the slope.

In order to suggest the remedial action of the slope, the critical depth of failure surface on the slopes must be determined. The critical depth is the depth of potential failure in slope that significantly affected by changes of the water content. Meanwhile the changes of water content for the uncovered slopes are strongly affected by the weather (rain and drought seasons). Since the cover of the slope has been opened by landslide, the best remedial method on the slope of the Maninjau landslide is the reforestation. The specific plants must be planted on the slopes. The plants' roots must increase the stability of slopes even for the weakest soil shearing resistance. The roots of selected plants should be able to reach the base area of failure line under the surface of the slope that determined as the critical depth.

**Figure 3**. Evacuation process

## Results and discussion

Based on viasual investigation on field, the slope geometry on location of Maninjau Galodo is estimates as shown in Figure 4. The Maninjau sloope can be categorized as non-steep slope since the slopes have average angle less than 45 degrees.

Eventhough the actual location there are found many grained soil particles, but the behavior of the cohesive soil dominates the slope stability. It seems that during the landslide the soil mass were moving together in terms of mudflow. The laboratory test of the soil samples gave the results in erms of the physical and mechanical parameters as shown in Table 1.

The laboratory test results of the two soil samples are shown in Table 1. It can be seen that the soil of the hill of Maninjau are made of fine grain soil. The soil sample has approximately mote than 50% of fine content. This indicates that the behavior of the slopes is dominated by the behavior of fine-grained soil. Generally soil deposit has fine soil particle content of 30% and over, the mechanical behavior will be dominated by the fine-grained soil contains.

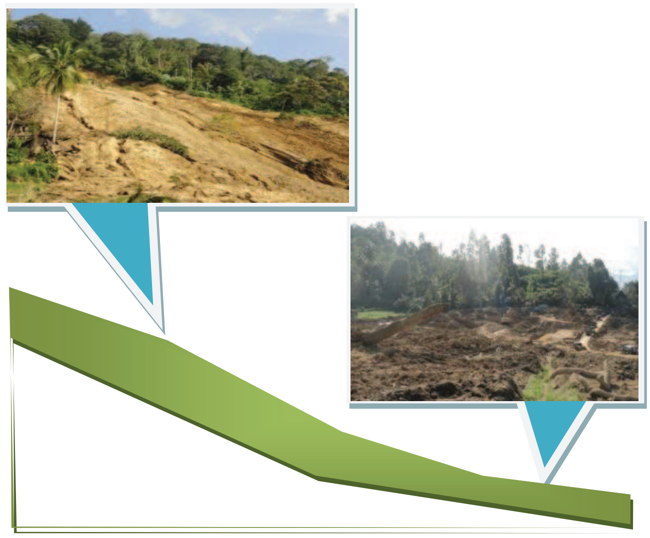


**Figure 4**. Post landslide condition

**Table 1** The test results of soil samples 1 and 2.

| 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 | ° |

Based on the test result in terms of the water content at plastic limit and liquid limit, the fine grain soil can be classified as inactive silt soil [1] in [2]. Based on the internal friction angle is about 30 degrees. This value indicate that if the soil loss their cohesion, the slope will remain stable if the angel of the slope less than 30 degree. But in the location, the angle of the slope is about 32 degrees (Figure 5). It means that the slope will loss the stabilitiy and move down if rain fall wetting the soil that causing the lost of soil cohesion.

The slope geometric and the average soil parameters obtained from tests are used to simulate the flat failure surface in slope stability analyses. The results show that the slopes are still in an actually location in a critical condition, with the lowest safety factor is less than 1.0 (Figure 6). While for the slope without cohesion the slope is more unstable.

Furthermore, to determine the critical depth of the slope failure surface by assuming to be parallel to the surface, the critical depth of failure is calculated as follows [3]:

$$D_{cr} = \frac{c}{\gamma} \frac{H^2 + L^2}{HL} \tag{2}$$

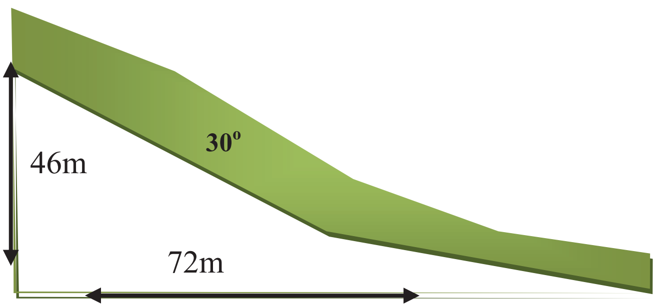
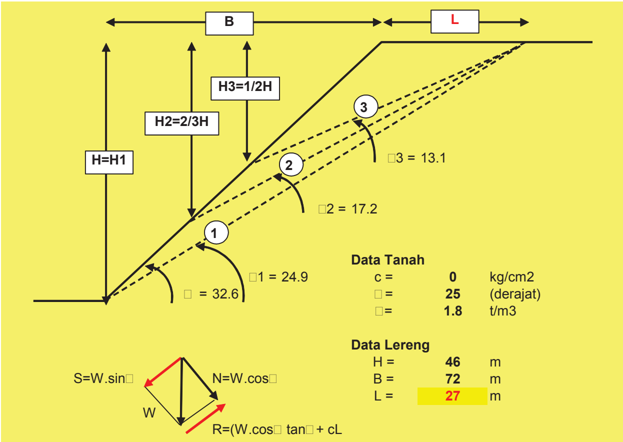



**Figure 5**. Maninjau landslide geometry

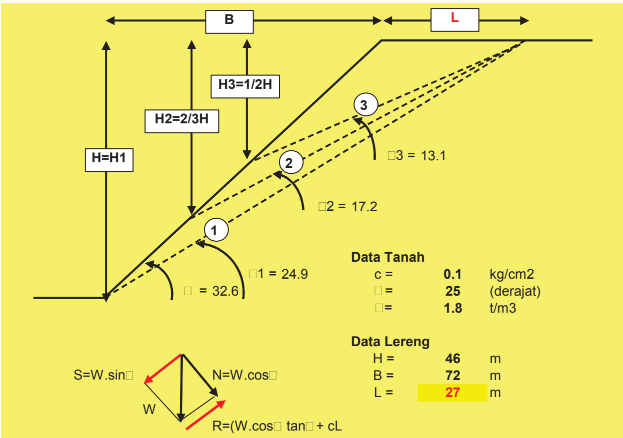
The critical depth also calculated by assuming that the slope behaves completely dominated by the soil cohesion. The result shows the depth of the slope is 1.22m.

Based on the calculation above, in order to prevent the landslides in the hillside of Maninjau, the action of re-planting may be done. Replanting of slope in addition serves to create a beautiful landscape also to reduce the influence of weather on physical and mechanical parameters of the soil. Types of trees suitable to be planted is that having the root to reach the depth exceeding 1.22 m. Technically, in order to maintain safety in heavy rain conditions that can lead to a reduction in soil strength, the recommended tree roots is one and a half times that of the critical depth that about 1.8m from the ground surface.




| No. | Lf | W | S | R tanpa c | SF | R dgn c | SF | status |
|---|---|---|---|---|---|---|---|---|
| Bdg. failure | m | (t)/m | (t)/m | (t)/m | tanpa c | (t)/m | dengan c | (dgn c) |
| Long | - | 82.80 | 44.58 | 32.54 | **0.73** | 32.54 | **0.73** | perkuatan |
| 1 | 109.17 | 1117.8 | 471.0 | 472.7 | **1.00** | 472.7 | **1.00** | **perkuatan** |
| 2 | 103.64 | 745.2 | 220.5 | 331.9 | **1.51** | 331.9 | **1.51** | **aman** |
| 3 | 101.64 | 558.9 | 126.5 | 253.9 | **2.01** | 253.9 | **2.01** | **aman** |

a. Slope without cohesion




| No. | Lf | W | S | R tanpa c | SF | R dgn c | SF | status |
|---|---|---|---|---|---|---|---|---|
| Bdg. failure | m | (t)/m | (t)/m | (t)/m | tanpa c | (t)/m | dengan c | (dgn c) |
| Long | - | 82.80 | 44.58 | 32.54 | **0.73** | 33.54 | **0.75** | perkuatan |
| 1 | 109.17 | 1117.8 | 471.0 | 472.7 | **1.00** | 581.9 | **1.24** | **aman** |
| 2 | 103.64 | 745.2 | 220.5 | 331.9 | **1.51** | 435.6 | **1.98** | **aman** |
| 3 | 101.64 | 558.9 | 126.5 | 253.9 | **2.01** | 355.5 | **2.81** | **aman** |

b. Slope with cohesion 0.1 kg/cm$^2$

**Figure 6.** The value of the safety factor for the length of the different collapse

## Conclusions

The results of the study conducted in the Maninjau landslide - 2013 area showed that the soil is dominated by fine-grained soil. The soil in the landslide are has the shear resistance that can decrease as the water content increases. In normal condition, it can be concluded that the slope is not in stable condition, more over on wet condition the slope may become unstable and lead to landslide.

To prevent the disaster of the same event, then the slopes of Maninjau should be regreened by planting trees with strong and deep enough roots. To maintain the stability of slopes in the rain season, the planted trees technically advisable to have roots that can penetrate the soil to a depth of more than 1.8 meters from the ground surface.

## References


[1] Skempton, A.W. , *The Colloidal Activity of Clays*, Proceedings, 3rd Int. Conf. Soil Mechanics and Foundation Engineering, London, Vol. 1

[2] Murthy, V N S., *Geotechnical Engineering: Principles and Practice of Soil Mechanics and Foundation Engineering*, Marcel Dekker Inc, 2008

[3] Hakam, A, *Stabilitas Lereng dan Dinding Penahan Tanah- Untuk Mahasiswa dan Sarjana Teknik Sipil*, Engineering Faculty of Andalas University, 2010.