

PERILAKU KINERJA STABILITAS LERENG TANAH TROPIS (THE BEHAVIOR OF SLOPE STABILITY PERFORMANCE OF TROPICAL SOILS)

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ABSTRAK

Perilaku ketidak stabilan tanah tropis terjadi karena material tersebut sangat mudah mengalami perubahan karakteristik baik secara kimiawi maupun secara fisik. Di daerah pegunungan, kestabilannya dapat mengakibatkan terjadinya longsoran, baik longsoran tanah maupun longsoran batuan yang kesemuanya tergantung dari tingkatan dekomposisi nya setelah mengalami proses pelapukan. Pengujian yang dilakukan pada 2 (dua) contoh tanah yang berasal dari Sumedang dan Subang memperlihatkan perilaku dari karakteristik properties material yang sangat tergantung dari originalitas batuan dasar berasal dan tingkat dgradasi yang disebabkan oleh kondisi lingkungan yang dipengaruhi oleh iklim tropis mencakup 'temperature tinggi', 'kelembaban tinggi', dan 'curah hujan tinggi'. Beberapa literatur menyebutkan bahwa material tropis tersebut dinyatakan sebagai 'lapukan tanah tropis ditempat' karenanya sangat mudah mengalami perubahan karakteristik propertisnya baik secara kimia maupun secara fisik. Untuk itu pada aktifitas selanjutnya dalam menghadapi tanah tropis seperti ini baik pada pekerjaan lereng dengan galian tinggi atau penggunaannya sebagai material timbunan perlu memperhatikan karakteristik perubahannya karena dapat mengakibatkan ketidakstabilan konstruksi baik selama maupun setelah selesai. Dalam penelitian ini difokuskan pada pengamatan untuk membuktikan bahwa perubahan karakteristik propertisnya yang mengakibatkan terjadinya banyaknya longsoran di beberapa tempat di Indonesia terutama setelah beberapa saat dikerjakan konstruksinya serta bagaimana dalam menjaga dan menanggulangnya.

Kata kunci : Tanah tropis, lingkungan iklim tropis, perubahan pada karakteristik propertis material, daerah pegunungan, kejadian longsoran

ABSTRACT

The instability performance of tropical soils is usually occurred due to those materials can easily changes of its character both in chemically and physically. In the mountainous regions, those instabilities can affect the landslide evidences, either soil slopes or rock slopes which are depending upon the grade level of decomposition of material performed by weathering process. The changes in character have been tested against for two sample of tropical soil from Sumedang and Subang showed that the phenomenon of the characteristic properties is dependent upon its deposition from the geological origin which is dominated with the quarterly deposit and the level of degraded environmental condition in tropical climate both 'high temperature', 'high humidity' and 'high rainfall'. Some literatures noted those materials have been stated as Tropical Weathered In-situ Materials (TWIM"s) due to characteristic properties can easily changes either in chemically or physically. Therefore, the further activity on managing those typical soils either in high slope cutting

works or using as fill materials have to be carefully pay attention due to can cause the decreasing the stability within during and after construction. In this research is intended to recognizing and interpreting the causing affect of the occurrences of many slope failures in many places in the tropical environment such as in a number of places Indonesia, after have been immediately constructed and how to protect them from the changes in its characteristic properties.

Keyword : Tropical soil, tropical climate environment, changes in material characteristic properties, mountainous regions, landslide occurrences

INTRODUCTION

Tropical soils are the materials which have been deposited in the Tropical Environment and have experienced weathering processes. They can be found in a large area within tropical zones such as in Indonesia. The problems related to the tropical soils as they are easily changes in its characteristic properties either chemically and physically as a result from the weathering processes. The changes in material characteristic are declared in chemically changes due to the deposited of those materials from the kinds of the geological rock origin have been induced by the environment tropical changes as a result from high temperature, high humidity and high rainfall. The changes in material characteristic are declared in physically due to as a result from the earthwork activities. Therefore, the further activity on managing those typical soils related to earthwork activities either in constructing works of the high slope cutting or using those materials as fill materials, have to be carefully pay attention due to can cause the decreasing the stability within during and after construction. In this research is intended to recognizing and interpreting the causing affect of the occurrences of many slope failures in many places in the tropical environment such as

in a number of places Indonesia, after have been immediately constructed and how to protect them from the changes in its characteristic properties

LITERATURE REVIEW

The Tropical Zone is that part of the earth sides which situated between 23.5^o North and 23.5^o South of the Equator (see Figure 1). This environment is influenced by Tropical Climates which exist in this zone and are characterized by 'high temperature', 'high humidity' and 'high rainfall' (Strakhov, 1967 and Clark and Small, 1982). Van Bemmelen (1949) outlined the geological sequence of tropical volcanic soils. He summarized that tropical volcanic soils may have been built as intrusions of basaltic or andesitic neck and dyke formations from volcanoes. Then, he has also studied that those material are generally of pyroxene andesite, associated pyroclastic deposits ranging from air-fall ash to volcanic mudflow deposit (lahar). Cook and Younger (1991) also stated that the tropical soils have range in their characteristics which are having the compositions of properties and mineralogy ranging from soft clays to andesitic volcanic rocks.

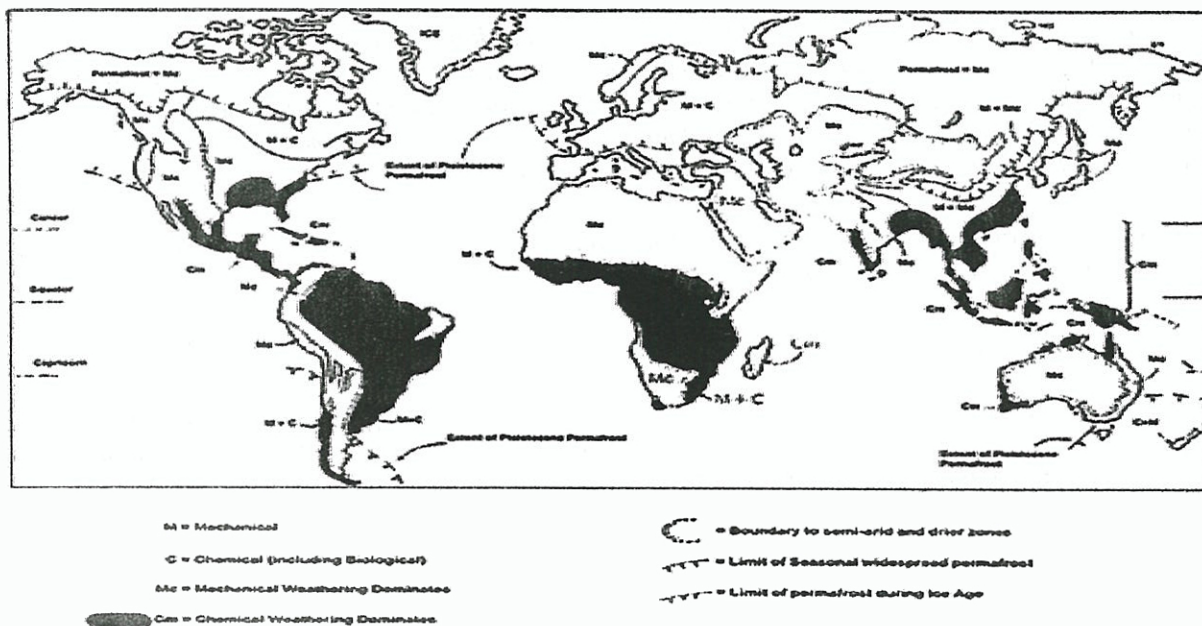


Figure 1. World Wide Distribution of Tropical Soils (Strakhov, 1967 and Clark and Small, 1982)

Refer to the above statement, Cook and McGown (1997) described due to their behavior that the tropical soil can be named as Tropical Weathered In-situ Materials (TWIM's), see Figure 2. Those statement is corresponded with the previously studied by Clark and Small (1982), which they stated that the most distinct feature of tropical soils, especially of their mineralogy, might be totally different to temperate soils such as in Europe, USA and Rusia, due to they are mainly dominated by chemical decompositions into significant levels as a result of the differing contrast of the weather between hot and wet climates.

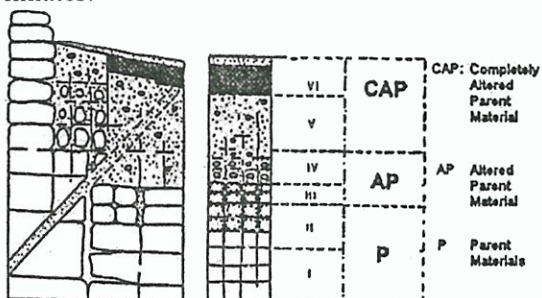


Figure 2. Typical Profiles of Tropical Weathering Products and Classification based on Weathering Levels (Cook and McGown, 1996)

The other previous studied by Ollier (1969) has also reported that the weathering processes may be influenced by the physical disintegration of materials and the chemical decomposition of broken or unbroken rock materials to produce new materials within the varying climates, (temperature, humidity and rainfall), see Figure 3. In those Figure showed the relationship between climate and the rate of weathering types.

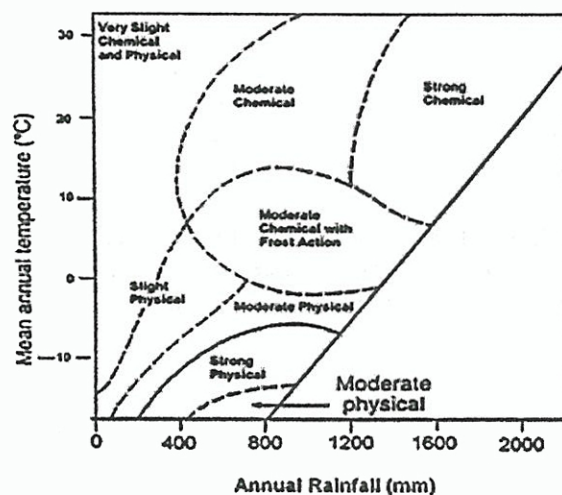


Figure 3. The Relationship between Climate and Weathering Type (Ollier, 1969)

The evidence of contrasted climate change in tropical environment will be more influencing the instability of soils and has been studied by a number of researcher by measuring from the currently temperature record from year to year, see Figure 4, which can be impacting to the changes in character of tropical soils, either soils and rock origins which tend to be easily experiencing to weathering grade process (Munarto ES (2010) and Smith et al. (2009).

To deal with the tropical soil which is mainly in the mountainous environment, the occurrences of slope failure has long been subjected throughout a number of the research and showed that the impact of hydrogeological conditions has received relatively little attention (J J Jiao, 2001). Then, he stated that the permeability characteristics in slopes of weathered tropical soil suffered one or more landslides and impacting the confined groundwater zones on the slope stability (see Figure 5).

From the Figure 4 and Figure 5 can be seen that there are the connectivity between, the soil characteristic properties. For example, in the graph of risk and impact of Global Warming (Figure 4) number I showed the risk to unique and threatened system and the real time condition can be seen the occurrence of landslide as seen in Figure 5, which is caused by the stability characteristics in slopes of weathered tropical soil suffered one or more landslides. Hence, the global warming might be caused by the changes of environmental tropical situation and in the real time changes of the land use function. In Figure 5, shows the instability of slope which has been identified as caused by the changes in water pattern that might be influencing the stability of slope due to changes of the land-use function.

In order to retain and as well as to maintain the stability performance, therefore to be taken into account as the awareness feels. Hence, the construction are built in the tropical soils, can be necessarily designed by implementing the factors correlated to the rainfall distribution (Geology and Geo-physical Research Center (2008)), as seen in Figure 6, Munarto ES (2010). Furthermore, the response

of those impact, will changes the characteristic of material in chemically. This statement has clearly described by Fitpatrick (1983). He reported that the chemical processes involved in chemical weathering are hydrolysis, solution, oxidation, reduction and hydration, and as shown in Figure 7.

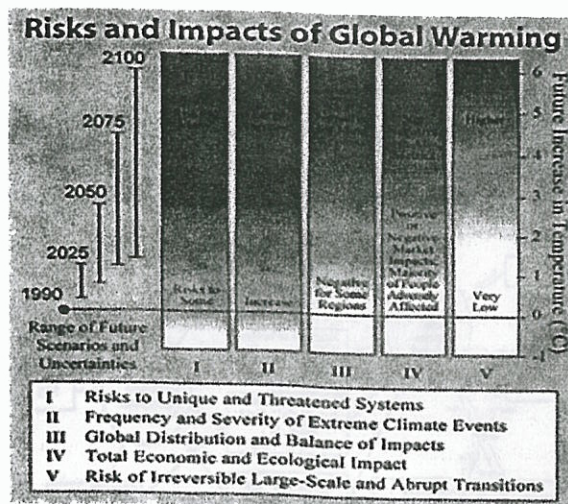


Figure 4. Revised graphical description of risks and impacts of climate change by IPCC, (Smith et al., 2009)

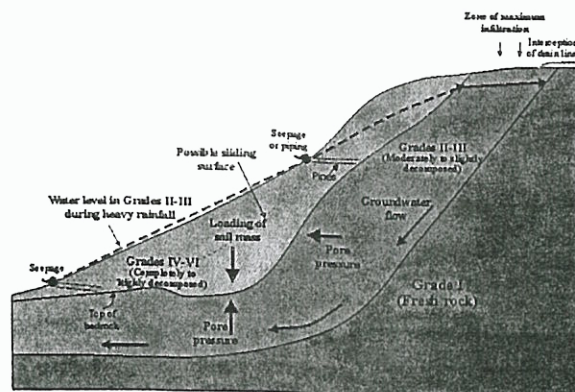


Figure 5. The Stability characteristics in slopes of weathered tropical soil suffered one or more landslides (J J Jiao, 2001).

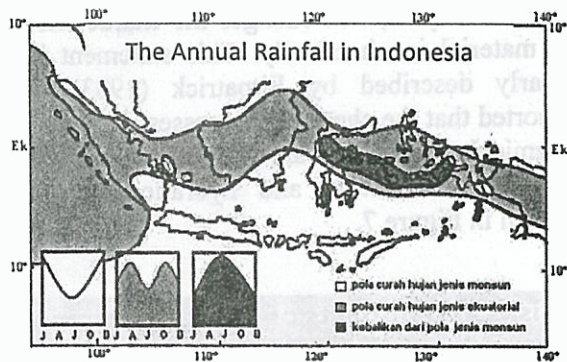


Figure 6. The Ordinary Annually Rainfall in Indonesia, Geology and Geo-physical Research Center (2008)

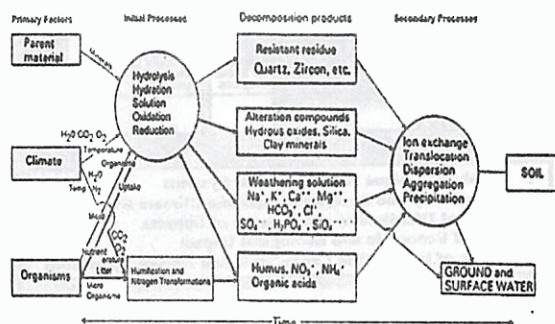


Figure 7. Chemical Weathering Processes (After Fitzpatrick, 1983)

The effect of changes in material characteristic then will impact to the variation in Engineering Properties of rock basaltic as a Response with the Increased Tropical Weathering materials (Tuncer and Lohnes, 1977) as seen in Figure 8. The changes of mineral character were also already studied by Morin and Tudor (1975) and the result was reported in Figure 9. Further, the changes of the material character as a result of chemical reaction on performing the weathering grades, which might plays a minor role, particularly in some structured sedimentary and metamorphic rocks, Blight (1988).

Dealing with chemical and physical weathering, Fookes et al. (1988) summarized the factors can be identified, there are involving:

- 1) Breakdown of parent materials structure in which the constituent elements (ion molecules) are released.

- 2) Separation of some of the released constituent elements in the mixture. Reconstitution of some of the released constituent elements to form new minerals.

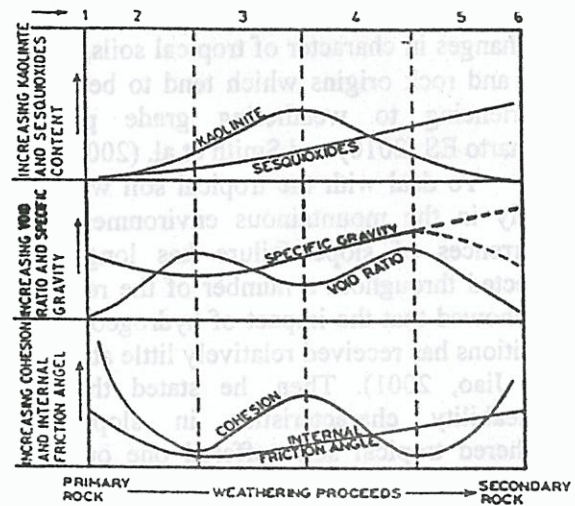


Figure 8. Variation in Engineering Properties of rock basaltic as a Response to Increased Tropical Weathering (Tuncer and Lohnes, 1977)

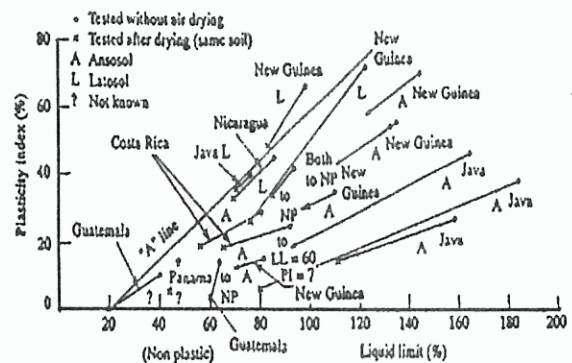


Figure 9. Effect of drying on Atterberg Limit Value of Some Tropical Soils refer to Cassagrande Classification System, (Morin and Tudor, 1975)

HYPOTHESIS

The stability performances of slope in tropical environment are controlled by the rate of decomposition process which is corresponding to the changes in its character chemically and

physically related to the period of specify session of weather conditions.

RESEARCH METHODOLOGY

In order to determine and proving the hypothesis, the number of study was taken, confined as follows:

Firstly the study to deal with the changes of characteristic of tropical soils, both in chemically and physically.

Secondly, the study related with analyzing and evaluating the occurrences of landslide has occurred in the several number locations in Indonesia in relation with the choosing availability the kinds of the retrofitting technology that are suitable to be implemented, especially on marinating the material from the changes in characteristic properties from the potentially of the instability occurrences either in the slope stability (naturally and cutting works) or uses as fill materials on building the road embankment.

ANALYSIS AND PRESENTATION OF THE RESULTS

Characteristic of TWIMs

Based upon the literature study then can be stated, that the mineralogy and soil / rock structures critically affected to the weathering processes of the materials in tropical environment and so involving the changes in their engineering characteristics. The sampled tropical soil were studied, there are derived from Sumedang dan Subang, West Java, Indonesia.

Mineralogy

Mineralogy is the important part on determining TWIMs behaviours, due to their ability to absorb water. The water is not only being governed by particle size but also by the type of any clay mineral present. Clay minerals are commonly found in TWIMs include some of kaolinite, halloysite, illite, montmorillonite,

vermiculite and chlorite, and amorphous or allophone.

The amount of clay mineral of the tropical soils is showing their currently classification before and after alteration to determine the changes of their character, see Figure 10 and Figure 11.

On those figures showed that there are the significantly changes of their containing clay mineral due to reacted with other constituent during changes of its environmental condition such as caused by earthworks and changes of the water pattern. Hence the material can become saturated and changed their behavior performance. The result of those changes is clearly presented on Figure 12.

Further, The changes of clay mineral occurrences on existing minerals are frequently govern the engineering properties of the material and directly determine their strength and compactability performances. Regarding to the decreasing strength performance, hence the perform of TWIMs stability dependent upon the type of containing clay minerals such as follows:

- 1) TWIMs containing kaolinite minerals may exhibit small amounts of swelling and were good for use as fill materials.
- 2) TWIMs containing montmorillonite minerals exhibit large amounts of swelling and therefore can cause many problems during and post-construction.

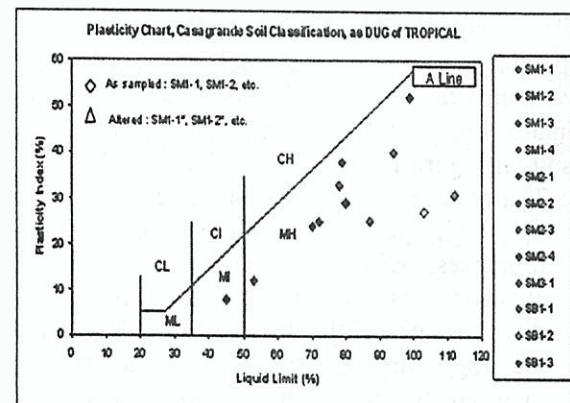


Figure 10. The classification of clay mineral of tropical soils before changes their characteristic, either chemically or physically.

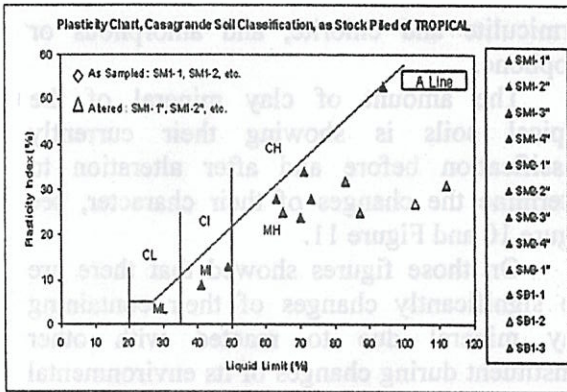


Figure 11. The classification of clay mineral of tropical soils after changes their characteristic, either chemically or physically

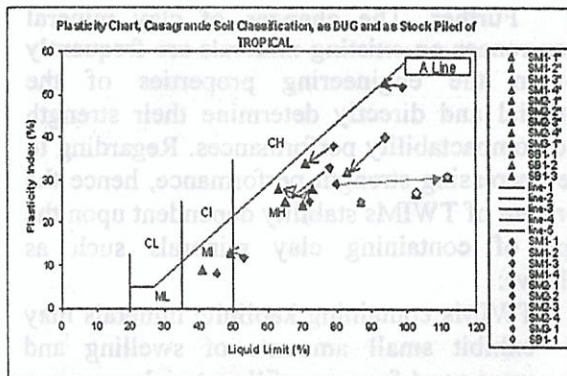


Figure 12. The changes of clay mineral which showed the losing fine aggregates

Referring to the result as presented on Figure 12 can be seen that the tropical weathered soils can changes in the characteristic properties depending upon the geological origin and the environmental tropical changes such as high climate, high humidity and high rainfall. The result on Figure 12 can be described as follows:

- 1) The material with has been experienced by the high potential of the decomposed processes, with the changes in material characters is shown with the up arrow directions or a little changes to the left. The materials are categorized as a stable material due to not any changes at all in characteristic properties.
- 2) The materials with has been experienced by the high decomposed processes, with the changes in material characters is shown

with the right arrow directions. The materials are categorized as un-stable material due to easily any changes in characteristic properties.

- 3) The materials with has been experienced by the high decomposed processes, with the changes in material characters is shown with the left arrow directions. The materials are categorized as a material to be selected on earthwork activities due to the changes in characteristic properties is containing the high presented of fine grains, that is meant the materials can be stocked piled first before uses.

Structure:

The structure of soils is mainly developed by the combination of the texture, fabric and discontinuity patterns to making up the mass or unit, where:

- 1) Texture: the morphology, type and size of the component particles
- 2) Fabric: the spatial arrangement of component particles
- 3) Discontinuities: the nature and distribution of surface separating element of fabric, materials of soil-rock masses.

The Occurrences of Landslide of TWIMsc as caused by decreasing the Shear Strength to Its Stability Performances

In the high lands/uplands such as mountainous regions, the effects of deforestation or human activities might change the environmental balance and intending the rate processes of the decomposition soils as a result of the weathering materials.

In many regions of Indonesia, those can cause the occurrences of landslide evidence. The typical of landslide can be such as topsoil erosion and deep slope failure due to the decreasing soil/rock strength, which renders for intending some areas becoming unstable.

The occurrence of deep landslide can be as a natural landslide or man-made which is the rate of slip movement can be rapidly if the

decomposition of materials is well influenced by the changes of the water pattern distribution.

Other factors that might be affecting to the decreasing stability of shear strength of tropical soil/rocks are caused by earthquakes, however in this paper is not intended to be discussed.

Natural Landslide

The occurrences of natural landslide have been distinguished in North Sumatera regions in the section of the link road between Tarutung – Sipirok at KM 139+000 Medan that was previously studied, see Figure 13. On those figure can be seen that the alignment of road has moved down since 1996-1997 if compared with the currently situation in 2008.

Referred to the result showed in Figure 12, it was clearly seen that the landslide has occurred on those national road as a result of the decreasing stability of natural slope which has been disturbed by the changes of the character of soils either caused by the water pattern changes which is as an impact of the environmental changes as a result of man-made activity then have changed the environmental balance. Hence, the changes of material characteristic properties of the soil in this landslide location due to mainly influences by the chemical changes as an impact from the high humidity as a result from the changes of water pattern affected from the environmental changes.

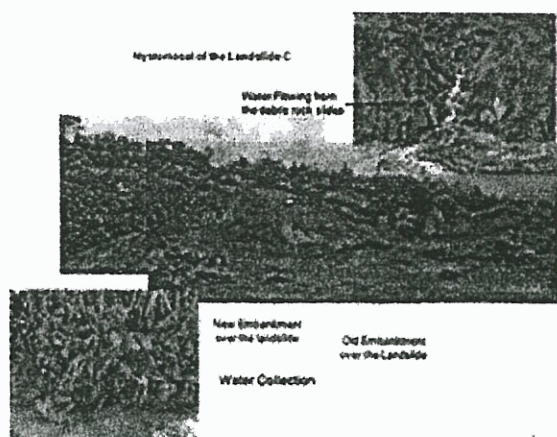


Figure 13. The occurrences of natural landslide in North Sumatera Province.

Slope Cutting Failures

The occurrences of slope cutting landslide might be mainly to deal with the man-made activity in order on building the infrastructure such as roads which is comply with the standard requirement of ideal alignment for road user to be safely and comfortable.

Due to the limitation of the adjacent land, sometime the cutting works were done with the steeply slope without referring to the allowable shear strength character of those individually typical soils or rocks within the tropical environment. By the time, the water pattern has also changed and will directly influencing the changes of those material characters.

The study to deal with slope cutting of national road over laying on the volcanic weathered soil was taken at Papua and West Sumatera Provinces as seen in Figure 14 and Figure 15.

In Figure 14, the occurrences of slope cutting is really caused by the changes of characteristic properties of tropical weathered soils as a result by the man-made activity. The cut slope failure is caused by the change of material characters due to man-made activities which is resulting an opened surface. The changes of the material characteristic properties in this location are caused by the physical changes as a result of the cutting works. Hence, the material characteristic properties have been experienced by the high temperature and high rainfall due to the opening surface of the soils by cutting works. In this case, the materials has changes its mineralogy and tended to becoming the fine grains with high presented of clay content. In the originally the materials is unstable after cutting works applied and will be unstable as well if uses as a directly fill materials.

Whilst on Figure 15, the occurrences of landslide is caused by the changes on its material characters in naturally as a result of the loosening of the unity bonded each rock segment and intended by the changes of water pattern flows on the top hilly area and resulting the rate of the weathered process.

The material character properties showed in Figure 15 then can be easily lose of its stability when the earth quake strikes and it was happen in West Sumatera Barat earthquake in 2009 which has been hit in this location.

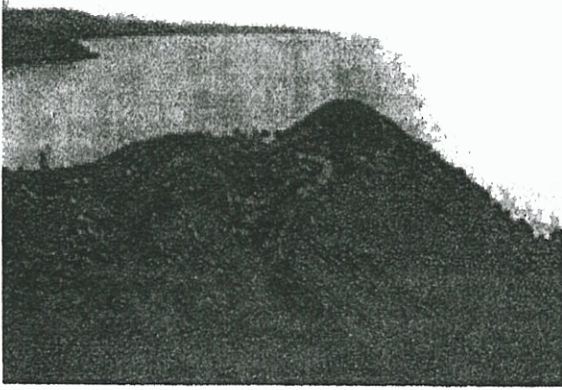


Figure 14. Typical Cut Slope Disasters in National Road Links at Papua, contains of tropical rock deposits

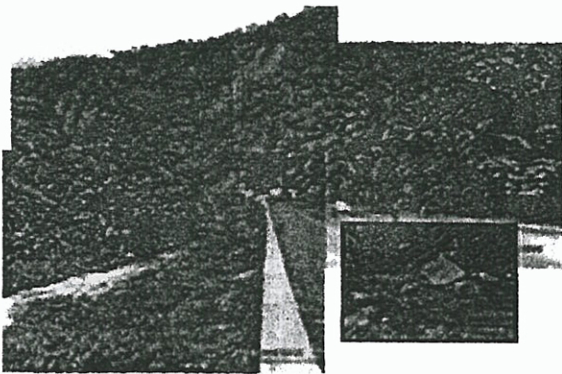


Figure 15. Typical of Steeply and highly Slope Cutting Failures at National Link Roads, Lembah Anai KM 64+000, Padang, West Sumatera in 2009 after earthquake

Again, refer to Figure 12, it can be stated that the occurrences of those landslide due to;

- 1) Firstly, changes of the material characteristic as a result of occurring open cut works. Hence, the material has directly reacted with oxidation process as they have contacted with the air.
- 2) Secondly, the occurring altered materials becoming more extended due to an effect

from the water pattern changes, either run-off or sub-surface water. Hence the fine grains will be washed away after reacted with water and if the amount of clay mineral is extremely high then might be will swells. Of course the potentially swells is dependent upon the contained clay mineral types.

- 3) Thirdly, the occurrences of earthquake evidence, the unstable materials tend to easily slip and the mass rock or un-bonded rocks will falls due to there is not any connection between the jointed rocks.

Criteria on Choosing the Technology

Criteria on Choosing Countermeasure Technology referred to the Occurrences of Land Slide Evidences are needed to be stated to the influences of dominantly factors, between the internal factors such as the weathering grades of decomposition materials and the influenced external factor such as water pattern changes, condition of slope which might be natural and man-made slope either fill or cut slopes, the mode of slope failures which are as an eroded slope surface, deep slope failure due to releasing or decreasing the shear strength.

The other importance is on applying the countermeasure technology that can be arranged based upon the analyzing landslide occurrences have been evaluated then the typical of landslide can be determined, including such as:

- 1) Determining the landslide type, either soils or rocks due to the methodology are different between those types.
 - a) For soil landslide, the stability of slope is controlled by the shear strength parameters
 - b) For rock landslide, the stability is controlled by the discontinuity pattern of geology structures, likes: jointing, faulting, folding and foliations in which its dip/strike and direction are measured.
- 2) Determining the cause factors of the landslide occurrences; either, internal factors and external factors is likely as the

ordinary activity to be prepared, as well as on choosing the countermeasure appropriate technologies, such as point 3.

- a) Internal factors such as the grade of decomposition rocks, the geological rock origin and the number kinds of developed geological structures, and angle and height of slope.
 - b) External factors such as the water pattern between run off and subsurface water, the land-use condition and the other influencing factors producing instability.
- 3) On choosing the type of countermeasure technology between soil and rock landslide. Hence some of technology can be applied and presented as follows:
- a) Geometric Slope Design (Figure 16)
 - b) Surface protection using vegetation which has a long roots (Figure 17)
 - c) Protection against the debris flows (Figure 18)

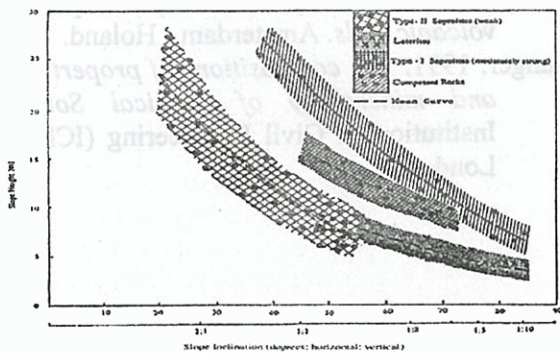


Figure 16. The recommendation on preliminary design of slope (ordinate) and height (abscise) for several soil types.

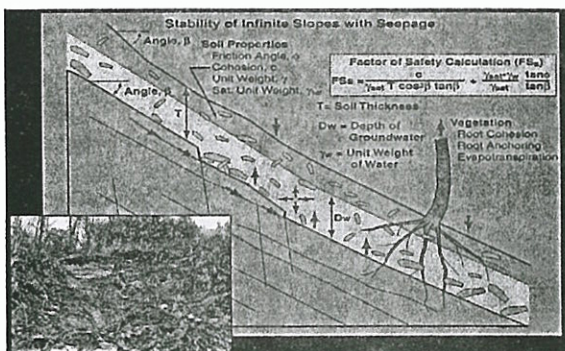


Figure 17. Typical of slope surface protection using vegetation

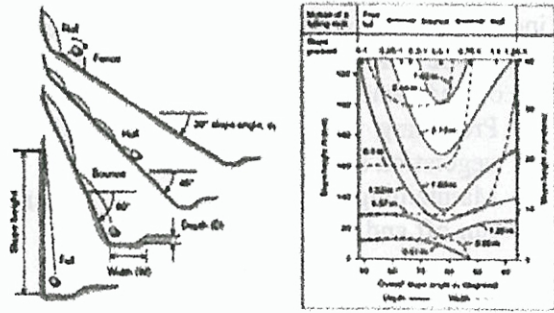


Figure 18. Typical construction using catchment area or fench barrier, depending upon the adjacent lands

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- 1) Tropical climates environment, which the region is having 'high temperature', 'high humidity' and 'high rainfall'
- 2) The stability performances in tropical environment zones are controlled by the rate of decomposition process and deposited as in different weathering grade levels and can be caused by either chemically or/and physically.
- 3) The factor of decreasing the stability of tropical soil can be caused by many factors, internally, by decomposition process and externally, by environmental changes or/and earthwork activity.

Recommendations

- 1) It is necessary on evaluating the stability of Tropical soils by analyzing the changes on its material characteristic properties for earth works, such as on its deposited condition related either in cutting works or uses as fill materials of road construction.
- 2) On managing the tropical soils can be performed by choosing an appropriate technology with the main stress is to minimizing the occurrences changes in material characteristic properties.

- 3) The technology in order to protect the increasing rate of changes on its characters should be prioritized before implementing the other technology types, such as:
 - a) Protecting the outcrop surface, using vegetation and other technology.
 - b) Maintaining the water pattern either run-off and sub-surface

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