POTENTIAL LANDSLIDES ON WEATHERED GRANITIC ROCKS ALONG THE MYITKYINA-KANPETII CAR ROAD, KACHIN STATE

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Abstract

The Myitkyina-Kanpetii car road connects mainly Myitkyina-Waingmaw-Sadon-Kanpetii to China. It is about 80miles (96km) long that runs in east-west direction. Myanmar-China Border Gate is linked by this road consequently it transports goods for Kachin State so the economy of local people depends on it. During the rainy season, landslides often occurred along this road so local people encounter transportation and economic difficulties. This road is constructed on granitic batholiths thus two-third of the area is covered with granitic rocks. Based on field data, petrographic result and previous paper records, weathered granitic rocks are classified into two profile types: Type-A (without core-stones) and Type-B (with core-stones). Both types induce rockfalls and rock slope failures especially wedge failure and circular failure. We can deduce two potential landslides places for the study area. The first one is between the Bum Taung (N 25º 22' 54.8" and E 97º 44' 7.7") and Sadon village (N 25º 23' and E 97º 53' 12.1"). Another is between the Laphi village (N 25º 25' 30" and E 97º 59' 20") to Wai Mo village (N 25º 24' 30" and E 98º 03'). The main facts to induce landslides are a period of high rainfall, increase pore water pressure and reduce soil cohesion, steep slope nature, road construction across the slope, deforestation, lack proper drainage system, and need effective retaining wall.

Keywords: landslides, weathered granitic rocks, pore water pressure, soil cohesion

Introduction

The Myitkyina-Kanpetii car road situates within the eastern part of the Kachin State. It is the union road which connects mainly Myitkyina-Waingmaw-Sadon-Kanpetii to southwestern border of China. It is about 80miles (96km) long from Myitkyina to Kanpeti that runs in east-west direction. It is situated between Latitude 25°21' to 25°25' N and Longitude 97°25' to 98°07′ E in UTM maps (2597-7, 11, 15 & 2598-03). Location map of the study area is shown in figure (1). Annual rain fall rate of Kachin State is 78inches. The road is constructed on granitic batholiths so bedrock types are mainly granite, granodiorite and metamorphic rocks with minor amount of basic and ultrabasic igneous rock. Two-third of the area is covered with weathered granitic rocks. Granitic rocks of the study area are mainly composed of plagioclase feldspar, alkali feldspar, biotite, muscovite, quartz and hornblende with accessory iron oxides minerals.

The primary of landslides occurrence and potential regions are mountainous areas especially Eastern Highland and Western Ranges of Myanmar. The Myitkyina-Kanpetii car road falls within Eastern Highland. Myanmar-China Border Gate at Kanpetii adjacent to China border is connected by this road which is one of the entry gates to China. As a result, it is the main transportation route for goods so the economy of local people depends on it. During the rainy season, road site is rather difficult to access due to landslide often, consequently local people encountered transportation and economic difficulties. If we know potential landslides area, we can prevent it. Therefore, we should do many researches not only for landslides but also for prevention methods of landslides. Most of the people think that granitic rocks are not associated with landslides but huge and numerous slides have occurred in some granitic areas (Durgin, 1977). Granitic rocks are commonly weathered to as deep as 10-30 meters, and innumerable slides in weathered granites have been documented in tropical and humid regions, resulting in great numbers of casualties (Chigira, 2011).

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Many researchers have been done some research about petrology and mineralogy for Kachin State. But well known research about landslides and its prevention methods for the study area and its environs have not been yet. Therefore, this research work aimed to describe the potential landslides for the study area and to know how to prevent it.

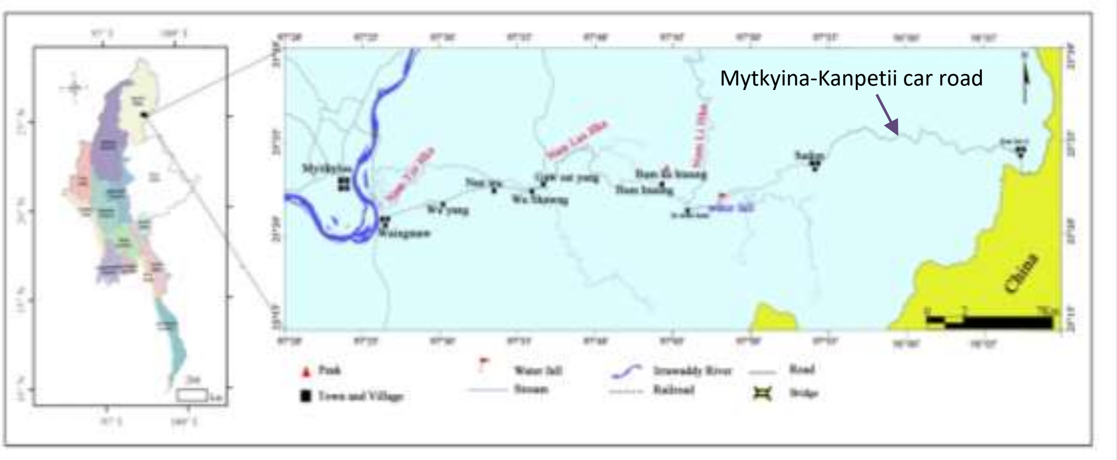


Figure 1 Location map of the study area.

Purposes and Method of Study

The main objectives of the study area are (1) to classify profile types of weathered granitic rocks, (2) to explain the relation of weathered granitic rocks and landslides, (3) to prepare sketch map for potential landslides area, and (3) to describe how to prevent it.

For field method, the UTM maps (2597-7, 11, 15 & 2598-03) are used as base map. The representative samples were collected to cut thin sections. Lithologic contacts and structural trends were measured by aiding Brunton transit and checked with the landsat images. The locations of the outcrops and potential landslide places were recorded by GPS navigator. The field data are plotted on Google Earth and UTM map linked with GPS data to illustrate the distribution of rock units and potential landslide places.

For laboratory work, the rock specimens collected from the field were prepared to more than (40) thin sections to examine the constituent minerals and rock types. The petrographic analysis is based on thin sections by using petrological microscope. Modal compositions were estimated not only in thin sections but also in hand-specimens. Soil genesis has been examined using field data, petrographic criteria and mineralogy of source rock. For the chemical data, major and minor oxides composition of rocks was determined by X-ray fluorescence method which was made at Mandalay University Research Centre.

Previous Work

The Myitkyina-Kanpetii car road is built on granitic batholiths and metamorphic rocks. Landslides often occurred along this road during the every rainy season. But many researches about landslides have been done conducted for the study area. Rhodes (1968) compared the landslides in granitic rock to ten other lithologies in humid tropical New Guinea. He found that silicic igneous rocks had the most landslides per unit area. Roddick, 1974 classified four transition stage of weathering granite: fresh rock (maximum of 15% weathered material), corestones (15 to 85% weathered rock enclosing remnants of fresh rock), decomposed granitoid (85 to 100% weathered disintegrated rock that can be broken down into granules), and saprolite (fine-grained residual rock that generally has an upper lateritic layer). A typical weathering profile of granite in subtropical climate consists of decomposed granite with core stones in the lower part and saprolite in the upper part (Ruxton & Berry, 1957). In the profile of weathered granite, the core stones are formed by spheroidal weathering (Ollier, 1967). If decomposed granite is removed from core stones, tors are left (Linton, 1955). Durgin (1977) pointed out that shallow landslides or debris avalanches occur preferentially in decomposed, weakly weathered granitic areas. In 1985, Komoo mentioned that although the characteristics of weathering profiles differ from place to place, two most common types of profiles are with and without core-stones. Granitic rocks are recognized to be very susceptible to weathering and are induced to landslides except the granites of North America and north Europe. These granites are not generally associated with landslides because most of the weathered granites on these continents have been eroded by glaciations (Chigira, 2011). Smooth-surfaced granite can reduce the effective friction angle with the overlying material. Besides, water flows through the thin permeable zone above the fresh bedrock, producing pore-water pressures and seepage forces during rainstorms. (O'Lough-lin, 1972; Swanston, 1967).

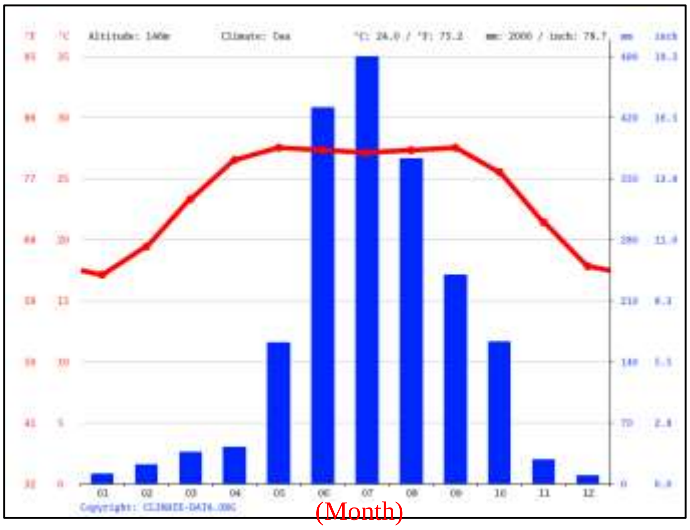
Rock types and their distribution

The Myitkyina-Kanpetii car road is constructed on granitic batholiths and metamorphic rocks. According to field data combined with thin section result and chemical data, the igneous rocks comprise in the study area are pegmatite, hornblende granite, granodiorite, diorite,dolerite, basalt, gabbro and peridotite. Metamorphic rocks include metaigneous (orthogranite, orthogranodiorite and amphibolite) and metasedimentary (slate, schist, biotite gneiss, migmatite). Exposure of granitoids especially granite and granodiorite are exposed along the road especially at GPS references (from Latitude 25°22' to 25°24' N and Longitude 97°41' to 97°47′ E) and (from Latitude 25°23' to 25°26' N and Longitude 97°50' to 98°05′ E). These granitoids are intruded into metamorphic, and have complex texture, i.e., transform from granitic to granodioritic composition within a batholith. Almost all of the igneous and metamorphic rocks of the study area possess highly jointed nature. They exhibit batholiths to semi-circular bodies with exfoliation nature. The core stones from weathered granitoids are formed by spheroidal weathering of granite.

The rock distribution along the road site is calculated by aiding field data combined with petrographic data. In relation to this result, the extent outcrop of hornblende granite with granodiorite is 40 to 60 %, diorite is 2%, dolerite is 5 to 15%, peridotite 1 to 2%, metagranite is 20 to 35%, metapelite is 5 to 20%, and sedimentary rock is 1 to 3%, of the overall abundance. These results point out two-third of the areas is covered by weathered granitic rocks and soil. Granitic rocks of the study area are mainly composed of plagioclase feldspar, alkali feldspar, biotite, muscovite, quartz and hornblende with accessory iron oxides minerals.

These batholiths were built on continental arc which associated with subduction zones; therefore, it possesses complex structure and rugged topography. Zhang, J.E. et. al., 2018 stated that the igneous rocks especially peridotite, andesite, hornblende gabbro, diorite, granodiorite and plagiogranite, from Eastern Kachin State possess arc geochemical signatures and ages of 177–166 Ma. Eastern Kachin State has long-term tectonic history so the rocks from the study area encountered long-termed physical and chemical weathering which caused the physical appearance and properties of granitic rock change as weathering progresses. According to field data joint with petrographic data, biotite is a particularly active agent in the weathering process and it expands to form hydro-biotite that helps disintegrate the rock into grus. The feldspars break down by hyrolysis and hydration into clays and colloids, which may migrate from the rock. Muscovite and quartz grains weather slowly and usually form the skeleton of saprolite. Saprolite is a fine-grained residual rock that generally has an upper lateritic layer.

The topography of the study area is very different from east to west, i.e., eastern part has high relief (within 1200m to 2100m height) with rugged terrain, the centre part has medium to high relief (between 600-1100m height) and the western part has low relief with soil cover and. Steep slope and landslides are more common in eastern part than centre part. Annual rain fall rate of Kachin State is 78 inches (Fig.2).



(Source:CLIMATE-DATA.ORG)

Figure 2 Annual rainfall and Temperature of Myitkyina Area.

The Myitkyina-Kanpetii car road through from Myitkyina to Waingmaw-Bum Taung-In Want Kaung-Sadon-Lu Kyi-Laphi-Waw Chon- Shan Ji-Wai Mo and Kanpetii. During the rainy season, landslides often occurred along this road: e.g., Landslides due to rainstorms in Wai Mo village (N 25º 24' 30" and E 98º 03') in 25th June 2019; and Rocks falls (size -100ft_30ft_20ft) between mile stone (105/106) km, and circular failure (size -100ft_30ft_20ft) between mile stone (105/106) km around the Waw Chon village group (N 25º 26' and E 98º 01' 30") especially between 105km and 108km in 19th July 2020 (source:21st July 2020 Myanmar Alinn Daily).

During the rainy season, small to deep landslide frequently occurred in two places. The first one is between the In Want Kaung village (N 25º 21' 35.2" and E 97º 45' 27.1") and the Sadon village (N 25º 23' and E 97º 53' 12.1"), and their height range is within 600m to 1200m. The second is between the Waw Chon village (N 25º 26' and E 98º 01' 30") and the Wai Mo village (N 25º 24' 30" and E 98º 03') and their height reached up to 2000m. These villages are built on fresh and decomposed granotoids and metamorphic especially metapelites and metagranitoids. Weathered granite soil has its own unique physical and chemical properties so it can cause easy weathering and particle breakage. Therefore, the susceptibility of landslides of the study area relies on slope angles of hill, soil cohesion, pore water pressure and a period of rainfall.

Result from Field data

Characteristic Profile Types of Weathered Granitic Rocks

Based on the field data, petrographic criteria and chemical data together with previous paper records, the weathering of granitic rocks from the study area can be classified into two profile types: Type (A) and Type (B). Both types of profiles are induced to landslides.

Type-A (without core-stones) contains three characteristic features: (1) fresh rock, (2) decomposed granitoid, and (3) thick layer of residual soil (Fig. 3). Type-A profile is recognized in the field by presence of a very thick layer of residual soil and completely weathered material. Besides, the soil-rock boundary between the overlain soil material and slightly weathered fresh rocks is very sharp. Some weathering profile can have a thickness of up to 21m (70ft). Both shallow and deep landslides are caused on Type-A profile.

Figure 3 Type-A Profile: (1) fresh rock (N 25º 24' 32.2" and E 97º 58' 01.5"), (2) decomposed granitoid (N 25º 22' 25.2" and E 97º 44' 57.3"), and (3) residual soil (N 25º 23' 46.2" and E 97º 38' 40.5").

Type-B (with core-stones) is especially found in granitic rocks with exfoliation texture and with highly jointed nature. This profile type includes (1) fresh rock, (2) core- stones, (3) decomposed granitoid, and (4) saprolite (Fig. 4). The core stones are formed by spheroidal weathering of granite and their size ranges from few centimeters to meters in diameter (Fig. 5). This profile type is easily noticed in the field by the presence of core stones (Fig.5). Besides, highly to moderately weathered materials contain core stones of various sizes.

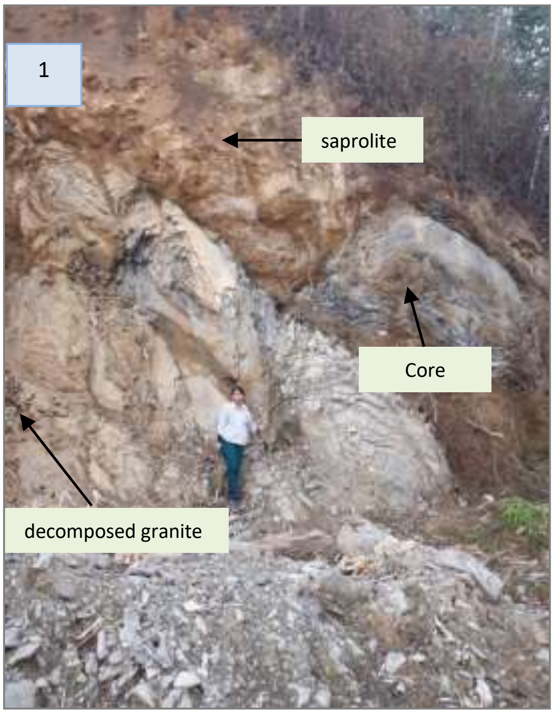


Figure 4 Core stone, decomposed granite and saprolite formed by spheroidal weathering of granite. (N 25º 24' 25.2" and E 97º 54' 56.1")

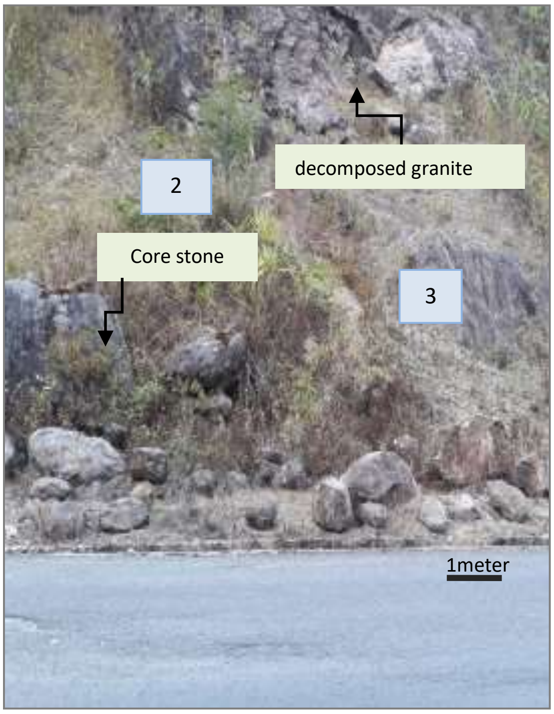


Figure 5 Various size of core stones fall at the side of the road. (N 25º 24' 35.2" and E 97º 53' 22.8")

The failure originated in **fresh granite** if having fracture and highly jointed nature. The susceptibility of fresh bedrock to rockfalls and rockslides depends upon the angle of shearing resistance of the jointed rock, the effective cohesion, and pore water pressure. As weathering progresses, decomposed granite forms along the joint planes and decreases the effective cohesion while increasing the void ratio. Rockfall especially debris flow and wedge failure may occur in fresh granite.

When the weathered zone developed, outward from the joints and isolates blocks or boulders of fresh rock to form **corestones** and which may roll down slopes during rainy periods, causing extensive damage. Rockfalls have been formed by presence of corestones. It consists of a large rock mass that falls off a steep slope, generating a stream of fast-moving debris.

During the stage of **decomposed granitoids**, granular disintegration takes place, and crystals become increasingly detached from each other. At this stage, biotite and feldspar weather first, to form microfractures and pores. The degree of saturation of the decomposed granite is important factor to safety. Saturated decomposed granite has essentially no cohesion when saturation reaches 100%, the apparent cohesion is zero, and pore-water pressures may cause failure. The weathering front in granitoids is abrupt, and water can be perched above the fresh impermeable bedrock. Subsurface water drains through the decomposed granitoid above the fresher rock. Rainstorms usually bring on the failures that produce rockfalls. The most widespread slide problems have been reported at granitoid decomposes stage (Matsuo, 1968; Durgin 1977). Rockfall (Fig.6) and rock slope failure may be occurred on granitoid decomposes areas.

Saprolite is the final stage of weathering results and shows brownish colour overlain by a red lateritic layer. Residual granitoid consists mainly of quartz, muscovite, and kaolinite. Although the presence of overburden pressures, the void ratio increases the pore spaces to decrease as the rock compresses. If tension cracks form at the head of failure plane where the soil will collapse, there is forming a failure (Fig.7). Durgin (1977) described a slope failure characteristic of saprolite is the slump or rotational slide. The rupture surface is no longer controlled by a fresh rock boundary as in earlier stages, but forms a circular failure surface. Rock slope failures especially circular failure may be formed at this stage.

Both types of profiles are found in the study area and these types induced rockfalls and rock slope failures especially wedge failure and circular failure.

Figure 6 Rockfall site at the sid e of the road. (N 25º 21' 35.8" and E 97º 45' 30.1")

Figure 7 Forming tension cracks indicate to occur circular failure. (N 25º 21' 35.2" and E 97º 45' 27.1")

Potential Landslides areas

The Myitkyina-Kanpetii car road through from Myitkyina to Waingmaw-Bum Taung-In Want Kaung-Sadon-Lu Kyi-Laphi-Waw Chon- Shan Ji-Wai Mo and Kanpetii. During the rainy season, landslides often occurred along this road. Therefore, this road often meets block of transportations and goods due to landslides within the rainy season every year.

According to the field data combined with petrographic criteria and previous causes records; we can estimate two potential landslides places for the study area as follows;

1. The first place is between the Bum Taung (N 25º 22' 54.8" and E 97º 44' 7.7") and Sadon village (N 25º 23' and E 97º 53' 12.1").
2. The second is between the Laphi village (N 25º 25' 30" and E 97º 59' 20") to Wai Mo village (N 25º 24' 30" and E 98º 03').

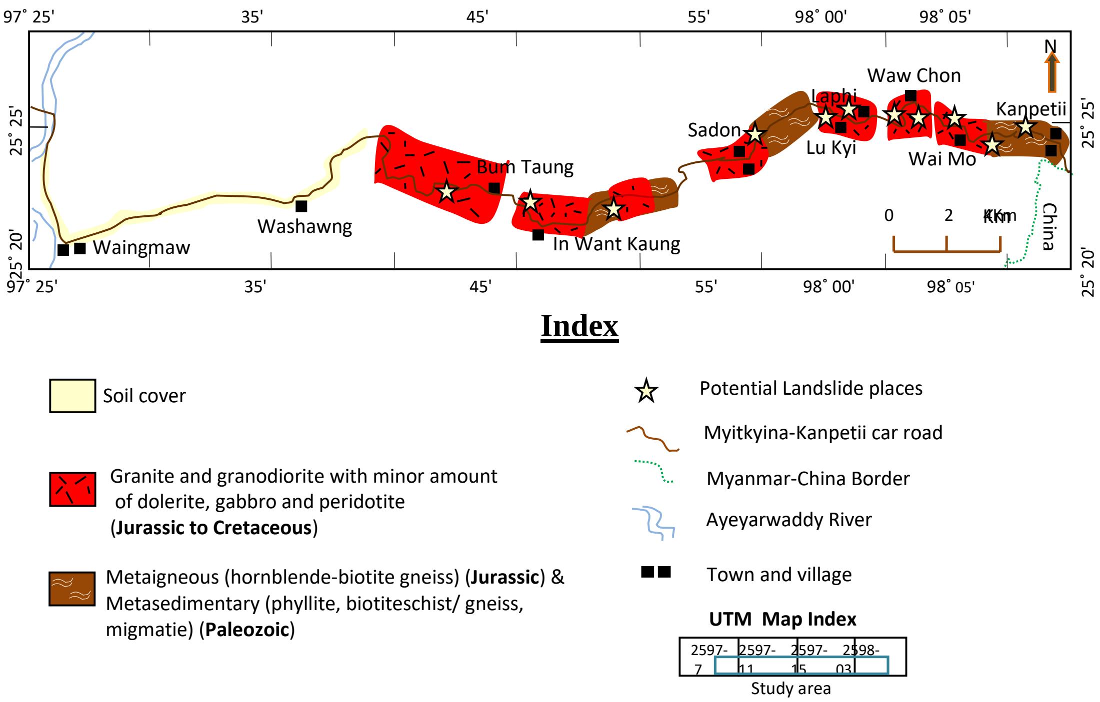


Figure 8 Sketch Map for potential Landslides places and granitic rocks distribution of the study area. (Modified after Me Me Aung, 2019a and Yar Zar Aung, 2019)

Causes of Landslides

Two characteristic profile types can recognize in the field are Type-A (without core- stones) and Type-B (with core-stones). Both types of profiles are common on weathered granitoids, and induced to landslides.

According to their profile types, and previous landslides records, two types of landslides can be recognized for the study area; (1) rockfalls, and (2) rock slope failure especially circular failure and wedge failure. Circular failure occurs on loose soil while wedge failure occurs on highly jointed granite and metamorphic rocks.

The main causes of landslides for the study area are (1) a period of high rainfall, (2) increasing pore water pressure and reduce soil cohesion, (3) steep slope nature, (4) road cutting along the slope, (5) deforestation, (6) lack of proper drainage system, and (7) require effective retaining walls.

The rockfalls are related to road construction across the slope, steep slope nature and a period of very high rainfall. Both rockfalls and rock slope failure depend on increasing pore water pressure and reduce soil cohesion. Soil reduces its cohesion because of water contents exceeds optimum moisture contents of the soil, oversaturated soils especially clayey soil loses their cohesiveness. Slope stability mainly depends on the cohesion of soil so-called shear strength.

Steep slope of soil that is slope of the hill is more than the angle of impose of soil, the angle of impose should not exceed the frictional angle (ϕ) of soil and infiltration of water into the soil that reach transition zone (i.e, Saprolite) and the water acts as a lubricant between hard rock and overlying weathered soil. The water in Saprolite becomes more pore water pressure and this pressure kick off the overlying soil. Also water added to the soil become heavier the existing soil and gravitational force exerted to the soil pull down the soil to downhill.

Smith (1970) stated the Mohr-Coulomb failure criterion which represents the linear envelope that is obtained from a plot of the shear strength of a material versus the applied normal stress. This relation is expressed as:

$$T = c + \sigma \tan \phi$$

Where T = Shear strength of the soil or rock

c = Cohesion of soil or rock

ϕ = internal frictional angle of soil or rock

If water invasion to the soil, the basic formula becomes as:

$$T = c + \sigma \tan \phi - \mu$$

Where μ = pore water pressure of soil or rock

So, it is clearly seen how water is important to the slope stability and causes of landslides. The more the pore water pressure contents effects the less the stability of the slopes.

Tree roots growing in the decomposed granitoid help stabilize the slope. At some sites, rainstorms have triggered failures a few years after road building and clear cutting of forests. The large, deep-seated failures involved rotational sliding and slumping. The tree roots probably had no stabilizing effect on deep slides. In addition, woodland soils have infiltration capacities that conduct rainfall to the subsurface rather than surface run-off.

Retaining walls are used to bound soils between two different elevations. Weep holes in retaining walls must be sized adequately to overcome surface tension and they allow water to escape from behind the wall. Although retaining walls have been constructed along the road of the study area, need to repair more effective style, i.e., need adequate size weep holes to drain water. (Fig.9)

Figure 9 Retaining walls, which have been constructed by granitoids, along the Mtitkyina-Kanpetii car road; (a) weep holes (b) wall without weep holes (c) damaged wall.

Discussion

Weathered soil, which have been formed by final stage of weathering results, and thick residual soil, may slides as circular failure or plane failure and combination of both. To prevent weathered soil landslide, it need to reduce the overburden weight and to draw out the infiltration water into the soil. So bench cutting the slope or gentle slope may reduce the weight of the soil. To draw out the infiltration water, installation of weep holes should be properly put in. Sometimes construction of retaining walls and installation of the weep holes are more effective to prevent landslides. Good drainage system is needed to prevent infiltration of rain water into the soil and it can reduce the pore water pressure of the soil.

Hills with weathered granitoids outcrop having steep slope can cause rockfalls and rock slope failure especially as wedge failure due to its highly jointed nature. To retain the strength of the jointed granitic rocks, rock bolts or anchors should be installed. Besides, forests on hillslope reduce the surface runoff and vegetation cover prevents erosion of the soil slope. The roots of the trees hold on the weathered soil firmly. Trees on hillslope reduce the surface runoff. So planting trees not only reduce the soil erosions but also the dwindling of pore water pressure.

Conclusions

The Myitkyina-Kanpetii car road connects from Myitkyina to Waingmaw-Bum Taung-In Want Kaung-Sadon-Lu Kyi-Laphi-Waw Chon- Shan Ji-Wai Mo and Kanpetii. Two characteristic profile types can distinguish in the field are Type-A (without core- stones) and Type-B (with core-stones). Both types of profiles are common on weathered granitoids, and induced to landslides. Two types of landslides can be found along the route are (1) rockfalls, and (2) rock slope failure especially circular failure and wedge failure. Circular failure occurs on loose soil while wedge failure occurs on highly jointed granite and metamorphic rocks.

In accordance with the field data combined with petrographic criteria and previous causes records; we can guess two potential landslides places for the study area as follows;

1. The first one is between the Bum Taung (N 25º 22' 54.8" and E 97º 44' 7.7") and Sadon village (N 25º 23' and E 97º 53' 12.1").
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The main causes of landslides for the study area are (1) a period of high rainfall, (2) increasing pore water pressure and reduce soil cohesion, (3) steep slope nature, (4) road cutting along the slope, (5) deforestation, (6) lack of proper drainage system, and (7) require more effective retaining walls.

The engineering properties of granitic rock change as weathering continues. Granitoids break down progressively from massive blocks to a deep layer of clay-size particles. Each stage of weathering is susceptible to specific landslides hazards. If the stage of weathering is identified at a site, it will provide clues to the engineering properties of the material and help the engineering geologist predict the slope-stability hazards of proposed actions. This research work is only based on field data and petrographic criteria to estimate potential landslides areas. Therefore, many researchers should do several geological and geotechnical research works especially soil mechanics and rock mechanics for this area.

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