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THE ANALYSIS OF ENGINEERING PROPERTIES OF SOILS FACILITATING THE MECHANISM OF LANDSLIDES IN HAKHA AREA, CHIN STATE, MYANMAR

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Abstract

The most destructive landslides had happened in Hakha on 27th July 2015and fortunately, no one faced to death in this event. However, the huge size posed a great impact on vulnerability of the town infrastructure, housings and inhabitants. In order to support the local people and regional planners, landslide investigation was carried out to produce potential landslide hazard zonation map. This paper mainly aims to present which factors play the main role in failure mechanism in this study area. Three types of landslides had been recorded in this area and the phenomena of landslides were detail investigated especially landslides in Mt. Rung and Hakha environs. The occurrence of numerous cracks on the middle and bottom potion of the landslide slope caused the critical condition for the ability to sustain this area. Therefore, to analyze this hazardous condition, the engineering properties such as physical, mechanical properties and dispersive nature of landslide materials were analyzed. From the analysis of grain size distribution and Atterberg's limit test results, those landslide materials are low plasticity Clayey SILT (ML)by the application of unified soil classification system(USCS). The several controlling factors of landslides were noted from the field investigation and laboratory analysis in which the most crucial factor of dispersive nature to accelerate landslide when it combines with intense rainfall had been verified in this paper.

Keywords: Landslides, Hakha, numerous cracks, Mt. Rung, dispersive nature

Introduction

The disastrous landslides were happened in most areas of Chin state due to abnormal heavy rainfall especially in July, 2015. Hakha is about 128 miles far from Kalay and about 2309 m above sea level which is the city

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of Chin State (UTM map 2293/10, one inch one mile map 84E/10). It is situated on steep slope (over 30°) of north south trending mountain ranges which is part of western ranges of Myanmar. In rainy season, Hakha area usually receives the annual rainfall intensity about 100 inches and the temperature in winter ranges from (-)6 °C to 37.8°C. Before the critical event of landslides in Hakha, antecedent rainfall intensity, a triggering event, became over the normal historical rainfall range that greatly changed the soil water condition in that area. The initial crack signs on the slopes, the abrupt increase of water level on the roads and the deterioration of houses gave the warning signs to move local people that saved the loss of human lives. On 27th July,2015, the saturation the soil caused a disastrous landslide which was a remarkable event in the history of Chin State. The rapid debris flow together with the breach of lake on the slope of Mt.Rung, numerous cracks in middle and lower portion in western part of its slope including along the ring road, very huge landslides in 2/2mile post along the way of Hakha –Gantgaw road as well as 3/3 mile post on Hakha -Titein road were successively happened due to this triggering event. As a consequence of this, the schools and 540 numbers of houses in Myohaung quarter could not withstand to continue to living in this dangerous area. Based on those facts, staff and members from Department of Geology and Survey Enterprise (DGSE) and Myanmar Geoscience society (MGS) had collaboratively investigated to produce hazard zonation map of Hakha area to support the local authorities. Apart from landslide zonation map, this paper mainly emphasizes on the engineering properties of soil that generate the failure mechanism of landslides in that area.

Regional Geology Around Hakha Environs

In this area, Kennedy Sandstone Formation (Middle to upper Eocene), Chunsung Mudstone-Turbidite Formation (Middle Eocene to Paleocene), Falam Mudstone-Micrite Formation(upper Cretaceous) and recent alluvial/colluvial formation are regionally exposed. The regional geological map is shown in figure 1. Due to tectonic process of Indo-Burma plate, heavily jointed nature and numerous local folds are observed. Most of the beddings show not only west but also east dipping in the study area as shown in figure. Around Mt. Rung and Hakha envions, Falam Mudstone, Chungsung mudstone turbidities and colluvial soils are well exposed.

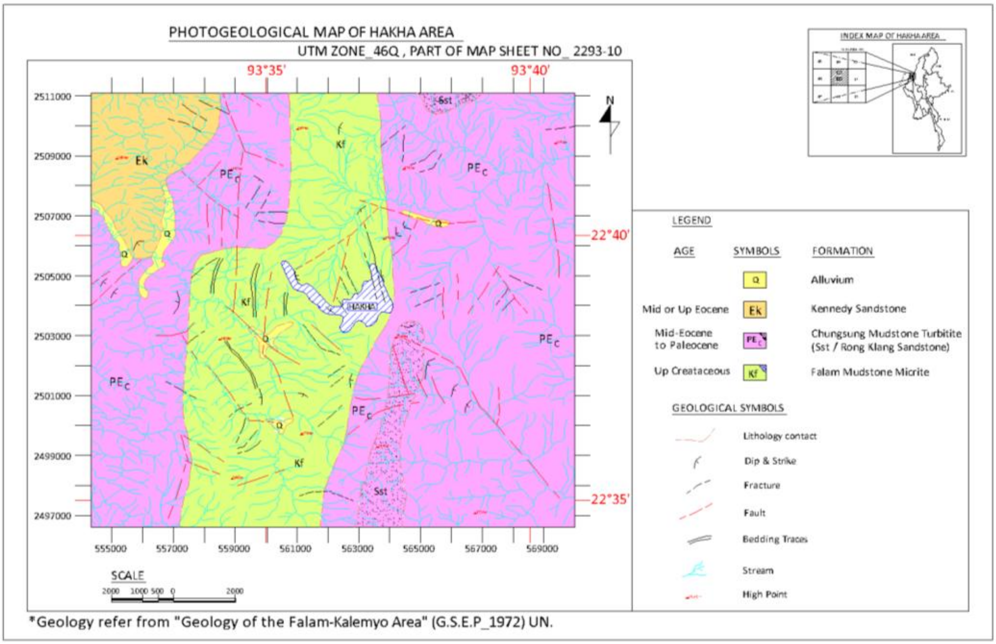

Figure 1: Regional geology of the Hakha enviorns

Triggering Event

Karnawati (1996 &2000) suggested that the triggering rainfall characteristics are strongly controlled by the permeability of soil/rock covering the slope and the initial groundwater table.

The monthly rainfall data from May to October (1989-2015) was collected from department of hydrology and meteorology. The precipitation was collected to figure out the triggering event and their relation to landslide is shown in figure. The rainfall in July 2015 is abnormally higher than other months of previous years. There was about 30 inches of daily rainfall from 26 to 31 in landslide events. Before this tragedy, there was no record or evidence of earthquake during this landslide event. The heavy rainfall from the consequence of recent storm and antecedent rainfall from this effect are the major triggering factors to cause those disastrous landslides. Large scale landslides in different places of Hakha environ were subsequently happened.

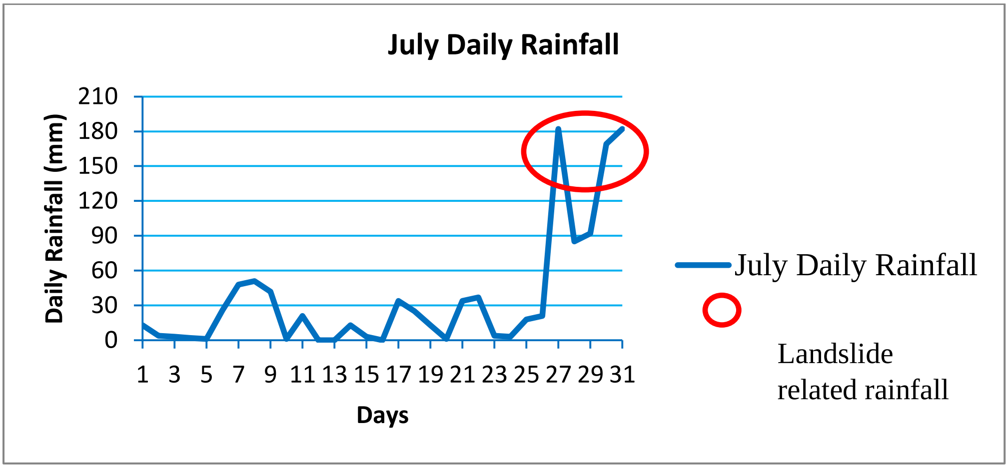

Figure 2: The daily rainfall in the month of July 2015

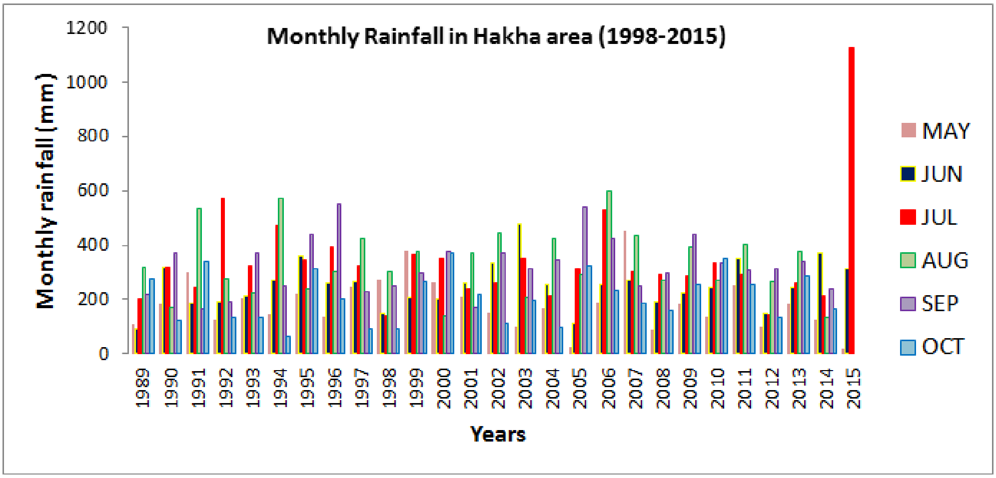

Figure 3: The monthly rainfall of Hakha area from 1998 to 2015

Landslide Investigation

Myo Haung quarter is located in the middle and base of Mt. Rung slope and the occurrences of destructions of Pagoda, churches, about 540 numbers of bulidings/houses, schools, retaining walls and numerous cracks almost all over the road were recorded and shown in figures 4 (a-i). Among those landslides, some failures showed that the slides happened again on former landslide materials. The types of landslides are based on inclination of slope, heterogeneity, weathering grade, bedding nature and types of lithology. Three types of landslides are classified in the study area according to the classification of Varnes 1978 .

(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

Figure 4: The destructions of houses school and houses in Myohaung quarter (a to i)

The most common destructive type is deep seated rotational slide, the second is flow type and the third is translational type or plane failure. Among them, Mt.Rung is the biggest and it is reactivated on ancient giant old landslide which can be inferred from the Landsat images.

The landslide crown can be sharply observed on the top of the Mt. Rung which is about 500m wide. Before this event, the lake was situated in the middle of this slope and currently there was no trace of it and left only the landslide materials. On the slope face, the small seepages from indurated shale layer were observed which is one of the critical factors to cause this failure. The landslide materials in Mt. Rung slope are composed of colluvial soils consist of various sizes of sandstone and mudstone fragments such as 3cm to 6cm and some consist of 30 cm to boulder size sandstone. Under this colluvial soil, very thin bedded, very fissile indurated shale from which the groundwater seepages are common and thick bedded sandstone are interbedded. Those medium to thick sandstone beds are well exposed on the top of the Mt. Rung, dipping the same direction of the landslide direction and this is also one of the critical factors to failure. Another factor is the heterogeneity and unconsolidated condition of colluvial soils which appeals the infiltration of water that increase the pore pressure together with decrease of effective stress based on the intensity and duration of rainfall, permeable and less impermeable characteristics of the layers of the slope.

Based on thorough field investigation, the ancient landslide scars on top of the Mt. Rung from Landsat images and relation to landslide materials and failure conditions, all those cracks and failures are interconnected on this slope. As a result, the length of the Mt. Rung slide is about1000m to the bottom. Therefore, this can be concluded that this Mt. Rung landslide is reactivated deep seated rotational slide as shown in figure (5).

The flow type of failure can be clearly observed at 2/2 mile post of Hakha-Gantgaw Road. They can be usually observed on very steep slope with narrow valley composed of highly jointed rock or soil. The rain water shall be trapped temporarily due to collapse of soil from valley side and abruptly flow down with very high speed after intense rainfall. Another huge landslide was recorded beside this and two fish farms near the base of the slope covered with those landslide deposits.

The translational slide or plane failures are very common along the high way road. The slope cutting and bedding direction are in the same direction and this has the effect of causing the plane failure. The typical plane failure at 3/3 mile post of Hakha-Matupi road is shown in figure (6).

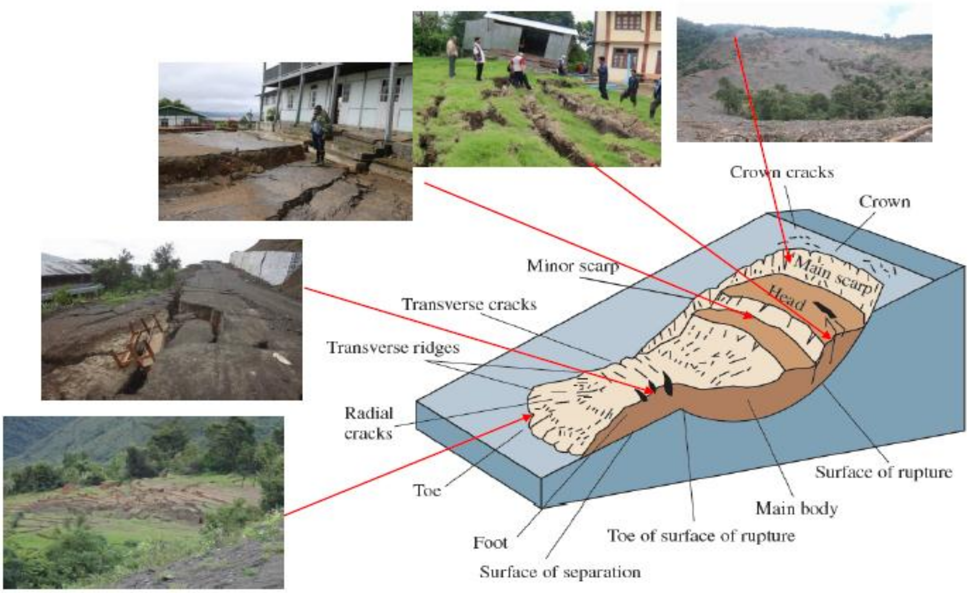

Figure 5: Reactivated deep seated rotational slide of Mt. Rung

(a) (b)

Figure 6: Flow type failure in (a) and Plane failure in (b)

Engineering properties of Soil

The samples were collected from the landslide materials for the determination of their physical and mechanical properties. The grain size distribution test, Atterberg limit test, triaxial test and the dispersive tests were carried out. The samples from the depth of 4 ft and 12 ft in the Saling Church compound, from the middle area of the Mt. Rung slope, proposed new settlement area, Chaunsung indurated shales were analyzed and the result are shown in table. According to Unified Soil Classification System, the landslide materials are low plasitcity clayey silt (CL,ML)with PI value of 6.25 to 11.27. Most of the landslides are found in indurated shale of Chunsung Mudstone - Turbitide Formation and the samples were remolded for triaxial test and dispersive test. The result of remolded samples show the cohesion values 165-167 MPa and the friction angle value 23º-28º. This higher strength value is resulted due to the remolded sample conditon.

Dispersive nature of Landslide materials

During field investigation, the numerous cracks are observed on the slopes. There were traces of forcibily break out natures on the soil surfaces among the cracks. Those natures in landslide of Hakha area are not quite common as usual tension cracks of landslide in other places. The uplifting of some soil blocks among the cracks are noticebly seen in figure (7). This fact needs to be explained by the determination of dispersive test.

Dispersive clays have a higher relative content of dissolved sodium in pore water. Dispersive clays have an imbalance in the electrochemical forces between particles. This imbalance causes the minute soil particles in a dispersive clay to be repulsed rather than attracted to one another. Consequently, dispersive clay particles tend to react as single-grained particles and not as an aggregated mass of particles.Dispersive clays are defined as the condition of slurry in which the idividual clay particles do not aggregate into flocs. Dispersion occur in those soil wherein the repulsive forces between the particles when saturated exceeds the attractive forces. This is caused by the reduction in concentration of cations in pore fluids, resulting in deflocculation and dispersal of the clay particles. Therefore when the soil is in the presence of relatively pure water, the clay particles repel each other and go into suspensions. (Reeves et.al 2006).

(a) (b)

(a) (b)

Figure 7: The nature of forcibly break down of cracks on the slope (a-e)

The collected samples from the landslide areas were tested with distilled water according to ASTM D It is divided into four Grade; Grade I-no reaction: no colloidal cloud develops. Even though the crumb may slake and particles spread away from the original clod because of this slaking activity, no trace of a colloidal cloud is observed in the water.

Grade II- slight reaction: A colloidal cloud is observable, but only immediately surrounding the original clod. The cloud has not spread any appreciable distance from the crumb. Grade III- moderate reaction : a colloidal cloud emanates an appreciable distance from the crumb. However, the cloud does not cover the bottom of the glass, and it does not meet on the opposite side of the glass bottom from the crumb. Grade IV- severe reaction: The colloidal cloud spreads completely around the circumference of the glass.

The cloud may not completely obscure the bottom of the glass, but the cloud does completely cover the circumference of the glass. In extreme cases, the entire bottom of the glass is covered by the colloidal cloud.

4ft(0:02 Sec) 4ft(0:45 Sec) 4ft (1:01Sec)

Result: Grade3(Moderate reaction)

Figure 8: Dispersive test on the sample (depth- 4ft) from Sangling Church, Hakha, GPS Point: (0563476 E, 2504958 N)

12ft (0:11 Sec) 12ft (0:40 Sec) 12ft (1:02 Sec)

Result: Grade3(Moderate reaction)

Figure 9: Dispersive test on the sample (depth- 12ft) from Sangling Church, Hakha GPS Point: (0563476 E, 2504958 N)

Indurated Shale (0:00 Sec) Indurated Shale (0:46 Sec) Induratd Shale (1:26 Sec)

Grade 4: Severe reaction

Figure 10: Dispersive test on the sample from the lope Surface of Chunsung Mudstone (Indurated Shale) GPS Point: 0560517E, 2506832N

The samples shows Grade 3 (moderate reaction) to Grade 4 (severe condition) as shown in figure (8-10). From the dispersive test, the formation of cracks are due to high content of sodium content in soil when they in contact with rainwater and forcibly break down.

The soils are derived from the weathering of parent materials of chunsung mudstone Formation. Not only the soil but also the weathering nature of indurated shale shows the numerous cracks and small pieces of rock fragments as shown in figure (11). On landslide surface, the black colour small pieces of rock flour from which the water seep out as in figure (11- d)can be observed. Those rock flour samples were collected for dispersive test and the result show Grade IV severe reaction when in contact with distilled water.

(a)

(b)

(c)

(d)

Figure 11: The dispersive nature of rock fragment (indurated shale)from Chunsung Formation

Conclusion

According to laboratory result, the occurrence of numerous cracks in the middle and at the bottom potion of the landslide slope in which the dispersive nature of soils or rocks not only on the surface but also in subsurface are the most crucial factors to sustain the stability of the slope. The dispersive nature of soils has to be clearly understood prior to the appropriate landslide mitigation measures taken. Although dispersive nature is well understood and easy to control the surface condition, it is still difficult to control the extent of those soils in subsurface condition and related water.

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