Application Shale Rating System to Hambalang Hill Clayshale Performance

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Abstract

A "shale rating system" based on durability, strength; and plasicity proposed by Franklin et al (1971) is applied for clayshale of Hambalang Hill. Several result for durability; strenght; and plasticity were collected and analyzed to investigate the clayshale from study area in Hambalang based on the shale rating system. From study, Hambalang shale has the shale rating starts from 0 (zero) to 7 (seven); they have a cohesion (c') value between 10 to 50 kPa; an angle internal friction (ϕ') between 2.5 to 24.0^o; anda critical slope angle between 10 to 35^o. Durability (I_{d2}) is lower than 55%; they have an undrained shear strength (S_u) between 20 – 30 kg/cm^2 and clayshale modulus between 10 to 20 MPa; and also an allowable bearing capacity between 2.0 to 4.0 MPa. The clayshale can be classified into stiff clay to very low rock class.

Keywords:*clayshale, shale rating system,durability, strength; plasticity.*

1. INTRODUCTION

Shales constitute about one-third of the rocks inthe land surface of the earth and about one-half byvolume of all sedimentary rocks. Not surprisingly,they are common in engineering projectseither in their excavated form as construction materialsin their natural and undisturbed state.In spite of its abundance, this important rocktype has until recently received little attention.In some ways, it is an unattractive and difficultmaterial to study because it is easily disturbedduring drilling, sampling, and specimen preparation.The strength, deformability and other characteristicsof a laboratory test specimen can changeby orders of magnitude if the rock is allowed to dryout, shrink, or swell.

A further experimental problemis that, whereas the minerals and microtextureof most rocks can be studied easily by using standardoptical methods, extremely fine-grained clayminerals require techniques such as scanning electron microscopyor X-ray diffraction (Putera et al, 2017).Shales also vary greatly in their properties andbehavior. At some locations shale slopes stand for many years at near-vertical angles, whereas atothers even 10-20o slopes suffer from continualerosion and creep. This has led to a distinctionbetween clayshales, the softer and more soil-liketypes, and indurated-shales, which, because of their greater cementation and compaction, behavemore like harder rocks. The practice of treatingshates as either a soillike or rocklike material hasbeen carried into construction specifications, wherepayment has often been based on a distinctionbetween soil and rock. Problems have occurred withshales of intermediate quality that behave neitheras soíl nor as hard rock and require specialtreatment.There is a clear need for a shale classificationsystem that is capable of distinguishing all gradesand qualities of shale and allows a correlationbetween the type of shale and its performance onengineering projects. A rating number R is assigned to a shaleaccording to measurements of the three propertiesconsidered fundamental to distinguish one shale fromanother: durability, strength, and plasticity.Tentative correlations have been developed betweenthe rating number and aspects of engineering performancesuch as excavating methods; foundation properties; and slope stability, especially relations between slope height and angle and mechanismsof failure in different types of shale). The suggested correlations are based on limited data,and their value and accuracy will improve with useand experience. Nevertheless, it is believed thatin their present form they serve to illustratetrends of behavior and will stimulate furtherresearch into the performance of this importantgroup of materials.

2. THEORY

Size–strengthclassificationbefore considering the subject of shale characterization,it may be helpful to discuss briefly theclassification of rocks in general. Of the manycharacteristics of a rock mass, two in particularappear to be important in determining rock –massbehaviorin engineering works: (a) the size of blocksinto which the rock mass is divided by intersectingsets of joints and other discontinuities and (b) theintrinsic strength of these blocks. Some classifications,such as that published by Bieniawski (1974) andBarton (1974), include a greater number of classificationparameters and as a result are somewhat moredifficult to apply. The two-parameter approach hasbeen found to be a useful starting point and onethat is readily comprehended and used.The size-strength classification is insufficient,however, when applied to shales or other rocks oflimited durability. A sample of shale excavatedfrom the rock mass initially plots at a single locationon the dliagram this location depends on thesize and strength of rock fragments. When the shaleis exposed to weathering, however, it becomes weakeror breaks down to smaller-sized fragments. The effectsof short-term weathering processes can berecorded on the diagram in the form of vectors thatrepresent weakening, disintegration or acombination of the two processes. Different shalesvary in their susceptibility to short–termweathering agencies, and a neasure of thissusceptibitity is essential in characterizing shale materials for engineering projects.

Hambalang hill is an intrusion area of igneous rock (Fig. 1). Geologically, intrusion will emerge when tectonic forceworks,(fault). Infrastructure built on faultarea have susceptibility tolandslides and ground movements. A number of landslides are always occurredin Hambalang hill area. Geomorphology of the Hambalang area consists of fluvial plain;steep volcanic; steep cliff; steep karst; ramps;and sedimentary hills rather steepto steep. Based on lithosgraphy aspect, Hambalang hill area is divided into five units of rock from the oldest to the youngest at early Miocene claystone, early Miocene limestone, andesite middle Miocene and Holocene alluvium.The tectonic activity of the Miocene-Pliocene period causes folding, fault, and breakthrough (Martodjojo, 1984). The direction of the main compression firm in Hambalang hillrelatively northwest-northwest, southwest-north-northeast and north-south direction. Endogenous processcausing Hambalang area to become mainland, while exogenous activity atcausing the rocks to erode.

Shale sample was collect from Hambalang hillarea, West Java at coordinates 6º33'16" south latitude and 106º53'22" east longitude. Sample core was carried out at 9,0 to 21.0 m depth using the diamond head boring machine. Standard of tube sampler was used for all undisturbed samples and some core boxes were used to monitor undisturbed samples. For At the shale layers was also from 2.5 to 21.0 m performed standard penetration of field test (SPT) to evaluate the number of blow (N-SPT). Shale layer has number of blow more than 50, so these layers were very stiff and coloured from light to dark grey (Putera Agung et al, 2013).

From soil mechanics laboratory by using the macro testing, analytical results of core samples show that soil properties of Hambalang shales have specific gravity (G_s) in the range between 2.62 to 2.65. By using the Atterberg limits test was found that liquid limit (LL) equals 31.75%, plastic limit (PL) equals 21.87%, and plasticity index (PI) = 9.88%. Grain size analysis shows that the material composition consists of silt (86.2%); clay (10%); and sand (3.8%). Thus, it indicates that silt soil type dominates of Hambalang shales. Clay mineral content of Hambalang shales are chiefly illite, with minor kaolinite. Illite content ranges from 7.8% to 90.8%; those of kaolinite, 18.7 % to 95.6%. This reflects the Hambalang shales were formed in the middle period of diagenesis and clay mineral of illite fraction is generally the highest.Hambalang shales is mainly controlled by sedimentation and consolidation process, residual soil type of weather rocks at the origin, weathering and erosion in the source area, transport processes and to the depositional environment. Each shale has a different depositional history and clay diagenesis is influenced by many different.Hambalang shales indicates similar characteristics has low porosity and permeability (Putera et al, 2016).

3. METHODOLOGY

The proposed shale rating system is shown in Fig. 2, the shale rating chart. A sample of shale isgiven a rating number on thê basis of (a) its slakedurability and strength if the shale is rocklike andhas a slake-durability index greater than 80 percentor (b) its slake durability and plasticity if theshale is 'soil-like' and has a slake-durability indexless than 80 percent.

Samples are initially subjected to the slake–durability test to assess their second – cycleslakedurabilityindex (I_{d2}) in percent, in accordance withISRM recommended procedures. If this index is foundto exceed 80 percent, the sample is further testedto measure the point-load-strength index.If the index is less than 80 percent, the fractionpassing the slake-durability test drum (Fig. 3) is subjectedto conventional Atterberg-limits determinations toevaluate plasticity index.

The point-load-strength test has been found to be convenient for strength classificatíon of rocks in general and of shales in particular. It requires no specimen preparation or naching and can be conducted in the field before the rock has had a chance to dry or break up. The index used for rating purposes is the strength obtained when the load is applied perpendicular to the bedding planes

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(for the strongest direction). Supplementary measurements can be made with the load applied parallel to the bedding planes to measure strength anisotropy and fissility. Samples are tested at their natural, noisture content. Point-load-strength values have been found to correlate closely with those obtained in the uniaxial compressive strength test. For classification purposes uniaxial strengths can be obtained by applying a factor of 24 to the point load strength values (Broch and Franklin, 1972).

3. ANALYSIS AND DISCUSSION

Figure 4 shows the test results obtained forsamples of shales collected in Hambalang hill as part ofthe current research program. The results have beensubdivided according to the geologic age of the formation tested. It can be seen that olderformations, as expected, are generally stronger andrnore durable and have higher rating values. Perhapsthe most characteristic feature of thís diagram,however, is the considerable scatter in durability,strength, and rating values for the majority offormations. The scatter reflects real differencesin shale properties as a result of differing degreesof Iithificâtion and of in-situ weathering.Evidently the character of these materials differssignificantly from place to place throughout theprovince and even from bed to bed within a singleformation. The index test results therefore giveimportant additional ínformation and thecharacteristics of these shales cannot be inferredfrom rock or formation names alone.

It may be noted that Hambalang shales are generally less durable and weak. Hambalang shales are dominated by detrital minerals (quartz), clay minerals (mainly illite and kaolinite). From evidence of XRD test (Putera, et al, 2015) shales at shallow depths and low temperatures, hydrous minerals such as illite and kaolinite form as a result of weathering or early diagenetic processes during meteoric water flow. Such early diagenetic processes may be considered a continuation of the weathering process even if the porewater is reducing.

The mainprimary minerals such as quartz are unstable when exposed to meteoric water of low ionic strength near the surface (weathering), but comprise a stable mineral assemblage during burial diagenesis at higher temperatures and lower flow rates. It is well known that arkoses have their quartz well preserved after exposure to greenschist facies or higher grades of metamorphism. Only if kaolinite potentially unstable clay minerals form at shallow depth will clay mineral reactions such as precipitation of illite take place at greater burial due to higher temperatures. In such well-sorted reservoir sandstones, nearly all the clay minerals are authigenic and the distribution of clay minerals then depends on the diagenetic processes.

Several observation was carried out in the laboratory of soil mechanics to find a correlationship between XRD in the micro and strength properties in the macro analysis. Based on slope stability analysis, slope safety factor (SF) indicated that the value exists in the range of 1.04 to 1.12. Critical heights from safety factor equals 1.0 is 4.30 m. The existing slope condition is susceptible to collapse or landslide when the high rainfall intensity occurred or the natural water content exceeds over 35% since the clay mineral (especially illite) absorbs the excessive water. Excessive pore water pressure causes the clay shale loss of cohesion. Then, illite will reduces the permeability easily and leads to the high pore water pressure exceeding total stress, and effective stress can be decreased. Furthermore, unstable kaolinite potential to separate clay mineral entirely and damage to soil bonding structure due to lower temperature and water existing around the quartz fractions. Climatic conditions in Hambalang hill area also has the highest intensity for rainfall in rainy season, especially in the southern of Jakarta, so that the area can allow the landslide.Thus far, there are several mechanisms which cause or affect shale/fluid interaction. There is an intense effort under way in the construction project to get a better understanding of each of these mechanisms. The stakes are high in that understanding and quantification of each of these phenomena is critical for foundation design which would stabilize shales. Rapid progress is being made and more results will become available in the near future. The current understanding of various mechanisms responsible for shale and water interaction indicate certain basic principles for improving foundation system to improve shale stability and bearing capacity at studi area (Fig. 5).

The long-term stable angle of a slope in shale canvary from about 80 to almost vertícal depending onthe durability of the shale material. Differentslope failure mechanisms occur in shales that havedifferent rating values.In shales of low durability mechanisms of slaking, erosion, and surface creeppredominate. Unprotected steep slopes exposed to continualerosion by surface runoff rainwater develop a pattern of erosion gulleys. The surface layer slakes, and thedebris is renoved by erosion as fast as it is producd. Although there is usually no safetyhazard associated with this mechanism, periodiccleaning of ditches is required, and the appearanceof the exposed eroded rock can be unattractive.Slopes that are protected from continuous erosiondevelop a weathering profile.

Instability of the surfacelayer is encouraged if undercutting occurs at thetoe of the slope. It is also accentuãted by water percolationalong the contact between weatheredand unweathered materials. The surface layer isusually more clayey and less permeable than the underlyingrocks and thus traps water. Eventually,a clay slope will reach a stable angle equal to approximatelyhalf the residual angle of shearing resistanceof the material (Bjerrum, 1976).

Allowable beâring pressure is generallycontrolled by, and can be estimated from, the intactrock strength and the intensity of jointing orbedding (the size strength parameters). In view of dífficultiesin making field measurements of joint defines three values for theempirical coefficient that depend only on majorvariations in the spacing of discontinuities: verywide, wide, and moderately close (Canadian Foundation Manual, 1978).

4. CONCLUSION

Illite and kaolinite play an important role to decrease cohesion, and quartz quartz acts as a medium water flow. Thus, shales in Hambalang hill more stable against sliding than after exposed to water. The corelationship between illite and or kaolinite and porosity of the shale is not good. The quantification of the impact of water invasion on effective stresses and shale strength is critical for shale stability analysis models. Both minerals of shale are very hard to release the water between and intra particle and contribute to produce the high excess pore water pressure exceeding the total stress, and induces the micro fissure.

Hambalang hill slope failures are generally morecomnon in shales that have lower ratings. In theseshales, the sliding surface nây pass through intactshale material and there may be only limitedinfluence from preexisting bedding and jointing.In the harder more durable shales, slope failures areinvariably controlled by the orientations ofpreexisting discontinuity sets. wedge or planarslides are bounded by slicling surfaces coincidentwith preexisting joints and bedding planes.

Foundation modulus is generally very low and not relevant tothe design of heavily loaded structures. The foundation modulus ofargillaceous rocks generally increases from clayshale modulus between 10 to 20 MPa; and also an allowable bearing capacity between 2.0 to 4.0 MPa. The clayshale can be classified into stiff clay to very low rock class.

5. CONCLUSION

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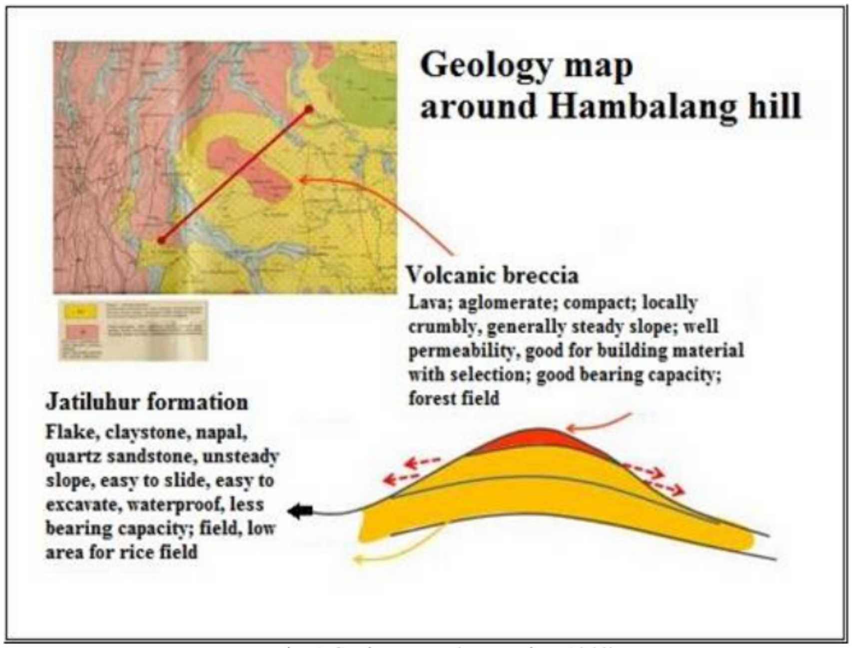

Fig. 1 Geology map (Bemmelen, 1949)

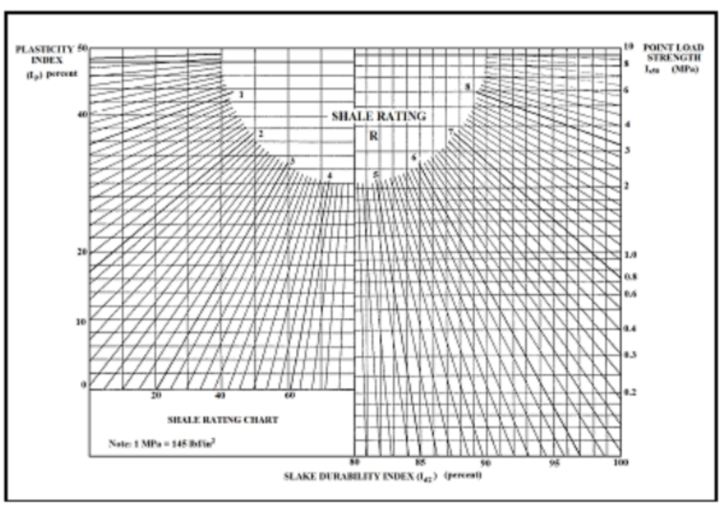

Fig. 1 Shale rating chart (Gamble, 1975)

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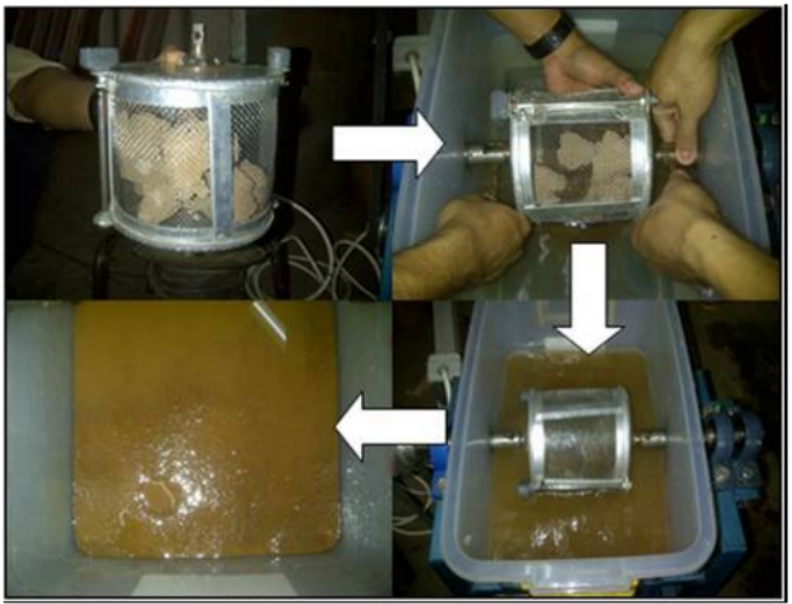

Fig. 2 Slake – durability test

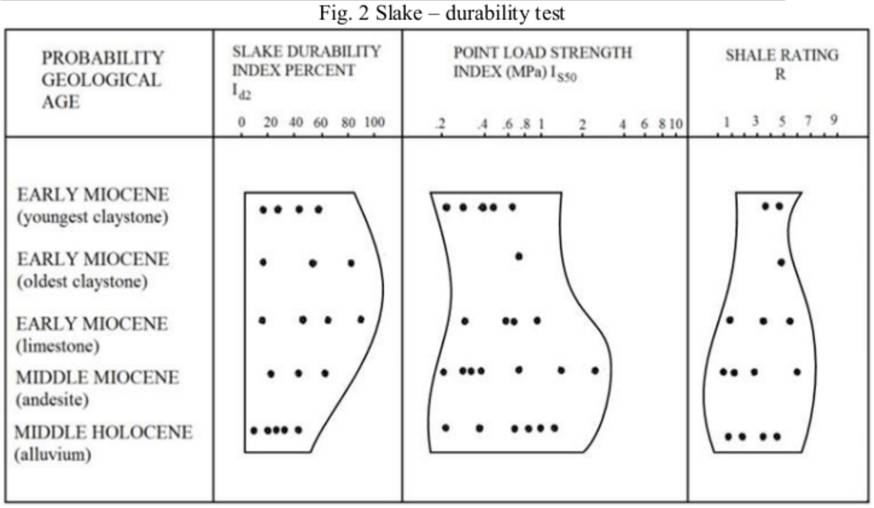

Fig. 4 Relation between age and index properties

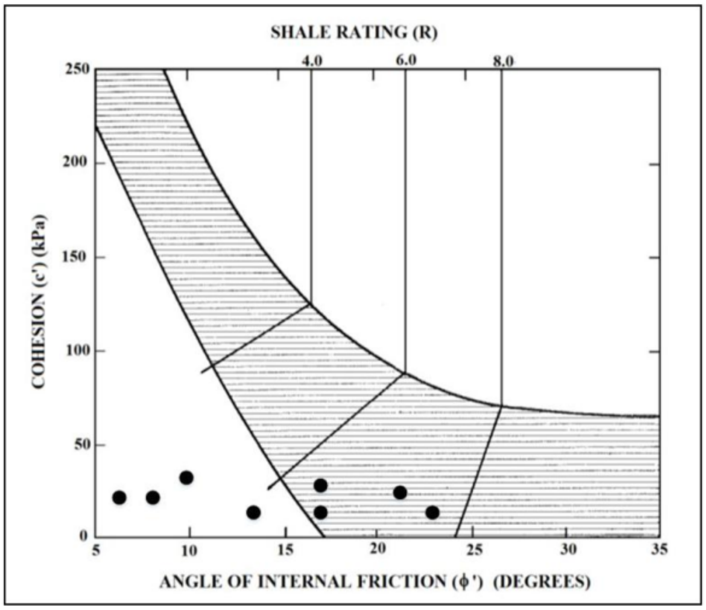

Figure 7. Trends in shear-strength parameters of nature of Hambalang clayshale

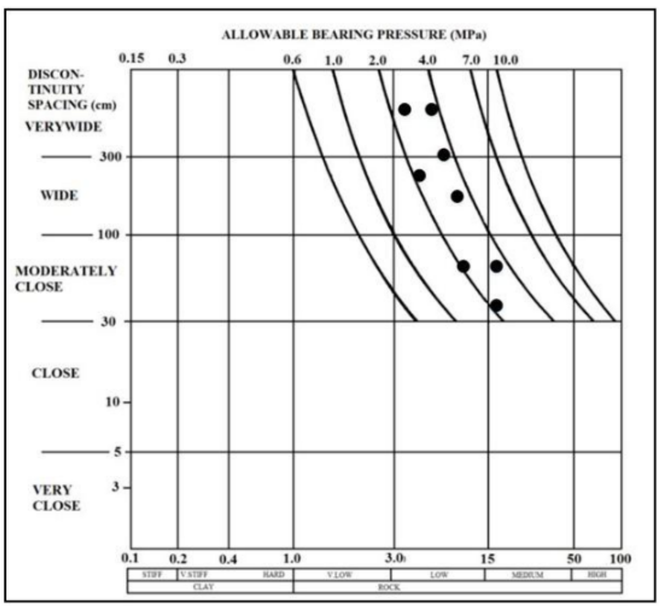

Fig. 10 Allowable bearing pressure for Hambalang clayshale

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