The Effect of Filled Discontinuity to Shear Strength Parameter of Tuff

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Abstract

The influence of infilling material on rock samples often becomes a problem in determining the shear strength. In fact, discontinuity such as joint is often encountered in rock mass. The presence of discontinuity will change the behavior of rock mass. This phenomena become worst when the joint filled by infilling material. There many problems in the design and construction due to the presence of filled joint rock. Concerning with the signification the effect of filled joint to its shear strength it is necessary to carry out tests on rock samples. A series of laboratory experimentation is carried out to model the filled joint by using Tuff as a joint block and clay infilling material. In these tests is varying parameters of normal stress, infilling thickness and roughness of joint surface. From the test it is showed that the shear strength of a joint decreased significantly with the presence of infilling material in the aperture of a joint. However, the reduction of shear strength depends on the thickness of infilling material.

Keywords: Sediment rock, Tuff, Discontinuity, Infilling material, Shear strength

1. Introduction

In Indonesia, environmental changes such as cyclical drying and wetting conditions and swelling have been believed to lead to deterioration of the mechanical properties of the rock mining. As an effect of very high rainfall rate in Indonesia, rock changing such as the weathering process occurs very often.

The sliding surface in a slope may consist of a single plane continuous over the full area of the surface, or a complex surface made up of both discontinuities and fractures through intact rock. Determination of reliable shear strength values is a critical part of slope design because, as will be shown in later chapters, small changes in shear strength can result in significant changes in the safe height or angle of a slope. The choice of appropriate shear strength values depends not only on the availability of test data, but also on a careful interpretation of these data in light of the behavior of the rock mass that makes up the full-scale slope (Hoek & Bray, 1981).

Generally, rock sample that is tested in laboratory is small and massive. Otherwise, rock sample even it is taken from same formation can have different shear strength because of the discontinuity and heterogeneous characteristic (Saptono, 2009). The existence of the discontinuity especially joints will change the rock behavior. Based on its nature, joint with weaker infilling is known to exhibit lower strength and higher deformability (Mohd Amin & Kassim, 1999). Filled joint also usually initiate the unstable condition of slope design.

2. Geological Setting

The rock sample is taken from Semilir Foramtion and Nglanggeran Formation on Pleret District (Figure 1) is Tuff. Tertiary volcanic rocks in the Southern Mts., located between Sub District of Piyungan and Parangtritis, Bantul - Yogyakarta, are called Semilir Formation and Nglanggeran Formation; both stratigraphically are interfingering. Semilir Formation characteristically comprises of pumice breccias and tuffs, whereas Nglanggeran Formation is predominantly composed of andesitic breccias and lavas. Sindet Formation mainly consists of pumice breccias and tuffs, but also co-ignimbrite breccias. The co-ignimrite breccias are typically comprise of andesitic blocks having 3-5 m in diameter together with pumice that set in tuff matrix. The lower boundary of the Sindet Formation is probably alternating epiclastic material of sandstones and mudstones which is partly calcareous.

The upper part of this formation is concordantly overlain by Wonolelo Formation, that is well exposed at Pucung village, Wukirsari-Imogiri. Wonolelo Formation is widely distributed from Piyungan to the south and southwest until Parangtritis areas. divisions reflect clearly the geovolcanic history in the area, starting from construction periods of composite volcano(es) to the destruction phases of caldera formation (Mulyaningsih, 2006; Bronto, 2010).

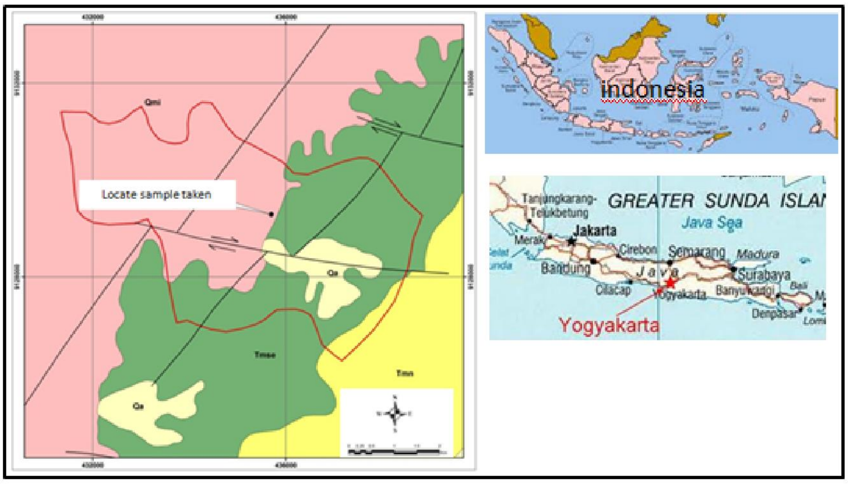

Fig. 1. Location of taken the sample from Pleret Distric, Bantul Region, Yogyakarta

3. Previous Study

The clean discontinuity surface with rock to rock contact and no infilling, in which the shear strength is derived solely from friction angle of the rock material. However, if the discontinuity contains an infilling, the shear strength properties of the fracture are often modified, with both the cohesion and friction angle of the surface being influenced by the thickness and properties of the infilling. For example, for a clay-filled fault zone in igneous rock, it would be assumed that the shear strength of the discontinuity would be that of the clay and not the igneous rock.

In the case of calcite filled fracture, a high cohesion would be used in design, but only if it were certain that the discontinuity would remain healed after any disturbance caused by blasting or digging process when excavating the slope. The presence of infillings along discontinuity surfaces can have a significant effect on stability. It is important that infillings be identified in the investigation program, and that appropriate strength parameters be used in design.

The effect of the infilling on shear strength will depend on both the thickness and strength properties of the infilling material. With respect to the thickness, if it is more than about 25–50% of the amplitude of the asperities, there will be little or no rock-to-rock contact, and the shear strength properties of the fracture will be the properties of the infilling (Goodman, 1970). For example montmorillonite and bentonitic clays, and clays associated with coal measures have friction angles ranging from about 8 to 20°and cohesion values ranging from 0 to about 200 kPa. Some cohesion values were measured as high as 380 kPa, which would probably be associated with very stiff clays.

All natural discontinuity surfaces exhibit some degree of roughness, varying from polished and slickensided sheared surfaces with very low roughness, to rough and irregular tension joints with considerable roughness. These surface irregularities are given the general term asperities, and because they can have a significant effect on the stability of a slope. The effect of surface roughness in shear strength have discovered by Patton. In Patton’s criteria friction angle from laboratory that is used Mohr-Coulomb criteria is described as true internal friction angle with asperities. Patton found that asperities can be divided into two classes: first- and second-order asperities. The first-order asperities are those that correspond to the major undulation on the bedding surfaces, while the second-order asperities are small bumps and ripples on the surface and have higher values. Because of that theory, to get true internal friction angle, friction angle that we got from laboratory test should be diminished with first- or second-order.

After being corrected by Patton criteria about true internal friction angle, the parameters are corrected with Barton criteria to consider the effect of infilling material in shear surface.

4. Experiments

First test is carried out thin section test to identification of the name rock sample. Rock sample is identified with thin section on petrology analysis as Vitric Tuff included with glass 85%, quartz 7%, lithic 3% and K-Feldspar 5% (Figure 2) and infilling material is clay with Bioclastik 5%, calcite 20%, Micrite 68%, sparit 3%, opaq mineral 2% and Galukonit 2% (Figure 2).

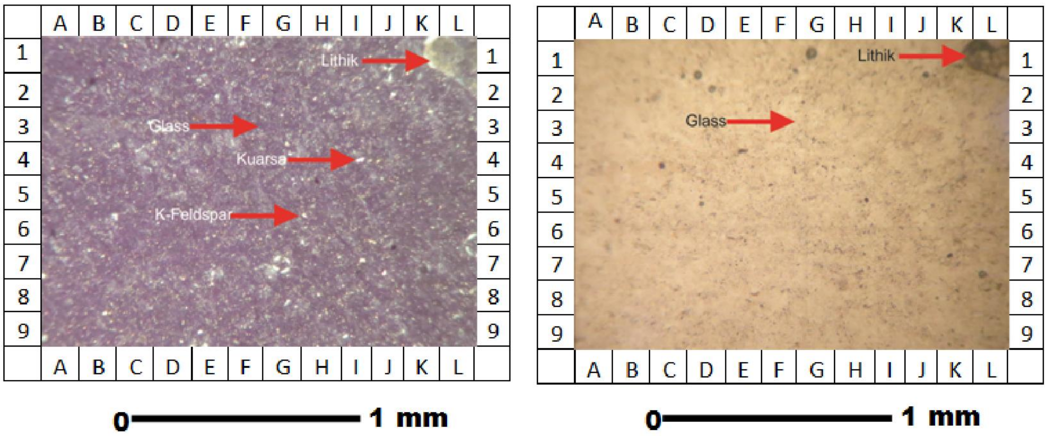

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Fig. 2. Tuff thin section analysis

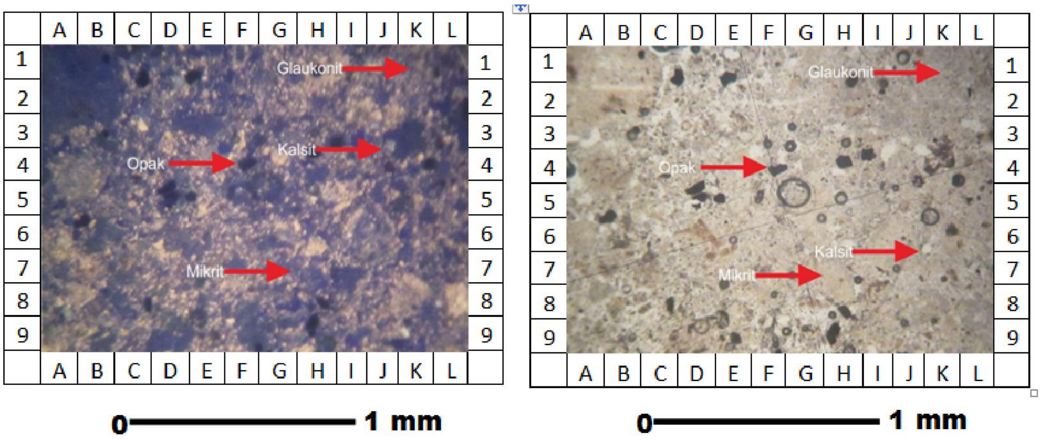

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Fig. 3. Thin section analysis as clay as infilling material

Second test is carried out mechanical properties included unconfined compressive stress test and direct shear test. Unconfined compressive stress test carried out to know classification based on compressive strength. Direct shear test obtained the values of cohesion and friction angle of the rock, whose results will be compared to the thickness parameter infilling material.

5. Discussion

Uniaxial Compressive Strength test we know that Tuff is soft rock based on ISRM 1979 because its UCS is 5.52MPa. The UCS is used as reference to know the limit of normal stress in shear strength test. Ladanyi & Archambault (1972) said that normal stress can't be more than 15% of UCS, and less than 20% based on Graselli Theory (2001). In the other hand, 12,5% is the limit for normal stress that can be applied in shear strength test of Indonesian rocks based on Saptono (2012). That means that normal stress that is applied should be less than 0,69 MPa.

Shear strength test is carried out in two conditions. First condition is sample without infilling material and second condition is sample with infilling material 0.25 mm and 0.5 mm of amplitude asperities. To know the amplitude asperities, shear surface is digitized by digitization tool as shown in Figure 4.

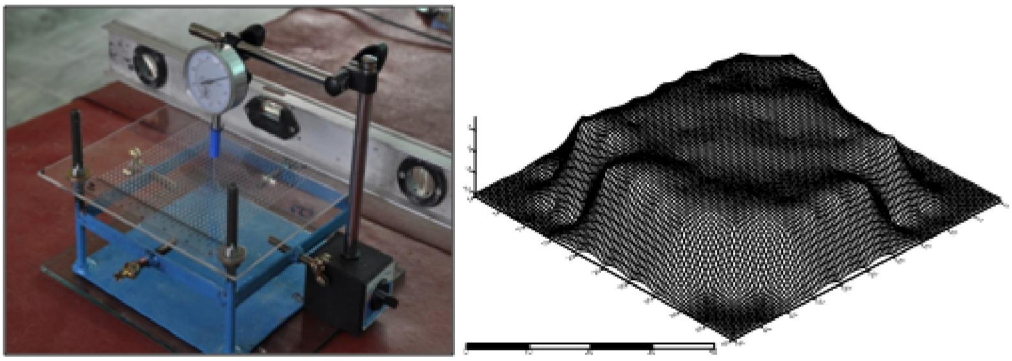


Fig. 4. Digitization Tool and 3D surface

All of the tests are residual shear strength test. The result of the shear strength tests is presented in Table 1 and Fig 5.

Table 1 Shear Strength Test Parameters

Condition	**Parameters**	
	Cohesion (c) , kPa	**Friction Angle (ϕ)**
Natural	86.06	27.34^0
0.25 cm infillings	18.74	5.77^0
0.5 cm infillings	9.30	5.83^0

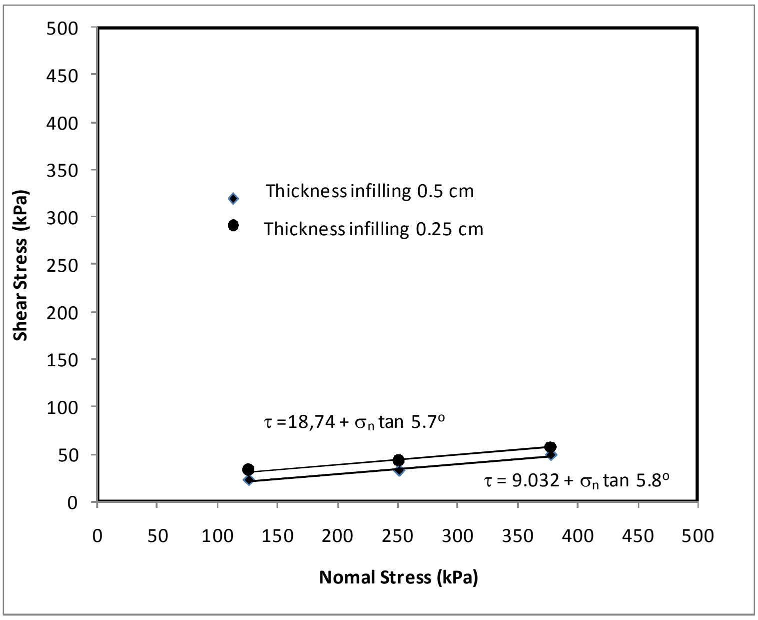
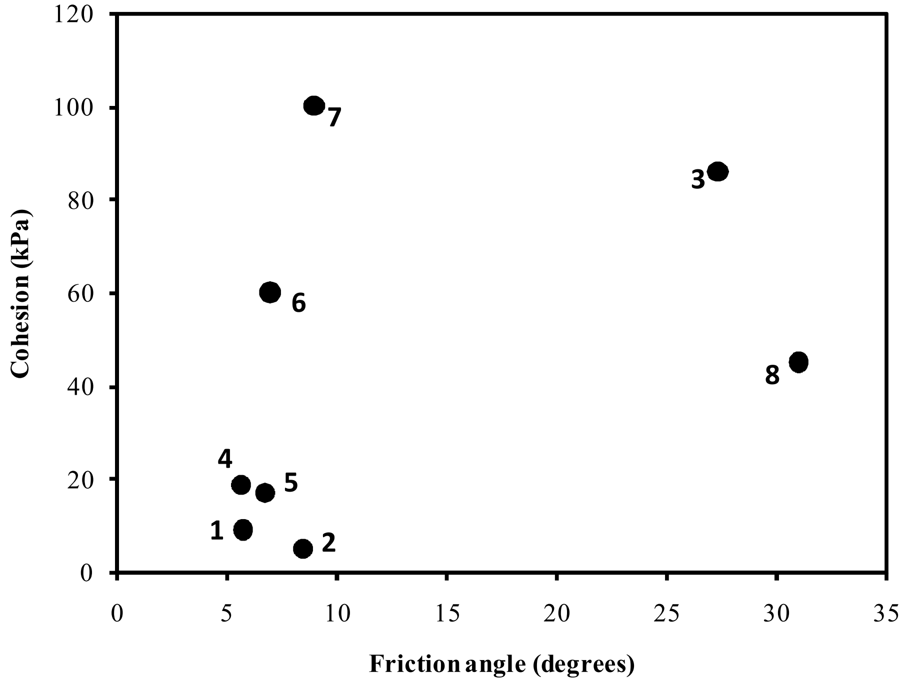


Fig. 5. Cohesion and friction angle of Tuff with infilling material 0.25 cm and 0.5 cm respectively

As mentioned previously, friction angle from shear strength test should be corrected by second-order. But, only sample with natural condition that is corrected because the shear surface of others samples is covered by infilling material, so the asperities is ignored. Second-order of sample with natural condition is 17.3°, so the true internal friction angle is 10.04°.

After correcting by Patton, it is shown that friction angle in natural condition is bigger than filled condition. Friction angle of sample filled 0.25 cm decreases 42.53% than friction angle of Tuff. In the other hand, 41.93% is the decreasing of sample filled 0.5 cm than Tuff.



1. Tuff, 0.25 cm clay infillings
2. Tuff, 0.5 cm clay infillings
3. Tuff
4. Bentonite seams in chalk
5. Montmorilonite clay
6. Bentonite triaxial test
7. Lignote/marl contact
8. Schists/quartzites; stratification, thick clay

Fig. 6. Shear strength of filled discontinuities (Modified from Hoek & Bray, 1981)

Figure 6 shows that different than friction angle, cohesion decrease sufficiently. The thicker infilling material has the smaller cohesion. It is shown that cohesion of sample filled 0.25 cm of amplitude and sample filled 0.5 cm of amplitude decrease 73.63% and 86.91% from Tuff. Sample filled 0.25 cm amplitude has bigger cohesion than sample 0.5 cm amplitude because there is some contact that occurred in asperities due to the smaller thickness.

In order to decide the cohesion and friction angle with Barton criteria graphic analysis is done. Barton considered that shear strength of natural discontinuities as being made up three components which are a basic frictional component, a geometrical component controlled by surface roughness (JRC) and an asperity failure component controlled by the ratio (JCS/σ_n). JRC is taken from cross section of model digitization and JCS is the result of UCS of infilling material. Based on Barton criteria, we know that infilling material affect cohesion and friction angle of sample filled 0.25 cm of amplitude 75.38% and 2.85 % lower than natural condition. Different than sample filled 0.25 cm of amplitude, sample filled 0.5 cm of amplitude has 90.56% and 25.71% lower cohesion and friction angle than natural condition.

6. Conclusion

The infilling material affects cohesion as much as 86.91% with Patton's criteria and 90.56% with Barton's criteria if compared with natural condition of Tuff. In the other hand, friction angle sample with infilling material is decreasing up to 42.93% for Patton's criteria and 25.71% for Barton's criteria than friction angle of Tuff.

References

Amin, M., Yau, O.N., Huei, C.S., and Abdullah, R.A., 2008, Characteristic of Filled Joint Under

Shear Loading, *Geology Society of Malaysia Bulletin*, Vol. 54.

Barton, N., 1974, A Review of Shear Strenght of Filled Discontinuities in Rock, Norwegian Geotechnical Institute Publication, Oslo.

Barton, N., 1976, The Shear Strength of Rock and Rock Joints, International Journal of Rock Mechanics and Mining Service, Vol. 13, 255-279.

Barton, N.R. and Bandis, S.C., 1990, Review of Predictive capabilities of JRC-JCS Model in Engineering Practice In Rock Joints, Proc. Int. Sypmposium on Rock Joints, Roterdam.

Brace, Paulding, Scholz, 1966, Dilatancy in The Fracture of Crystalline Rocks, Journal of Geophysical Research, America.

Bronto, S., 2010, Geologi Gunung Api Purba, Publikasi Khusus Badan Geologi – Kementrian Energi dan Sumber Daya Mineral, 154.

Brown, E.T., 1981, Rock Characterization Testing and Monitoring: ISRM Suggested Methods, Pergamon Press, England.

Grasselli, G., 2001, Shear Strength of Rock Joints Based on Quantified Surface Description, Thesis, Italy.

Griffith, A.A., 1925, The Phenomena of Rupture And Flow in Solids, Vol. 221, Royal Society, London.

Hoek, E and Bray, J.W., 1981, Rock Slope Engineering, Spon Press, London.

Hoek, E., 1983, Strength of Jointed Rock Masses, Geotechnique, No.3, Vol.23, pp.187-223.

Ladanyi, B., and Archambault, G., 1972, Simulation of Shear Behaviour of a Jointed Rock Mass, Proc. 11th Symposium Rock Mechanic, New York.

Mulyaningsih, S., 2006, Geologi Lingkungan di Daerah Lereng Selatan Gunungapi Merapi, Yogyakarta, pada Waktu Sejarah (Historical Time), Disertasi, Institut Teknologi Bandung.

Patton, F.D., 1966, Multiple Modes of Shear Failure in Rock, Proc. 1st Cong. ISRM (Lisbon.

Saptono, S., 2009, Pengaruh Ukuran Conto Terhadap Kekuatan Batuan, JTM, No. 1/2009, Vol. XVI, hlm. 1- 6.

Saptono, S., 2012, Pengembangan Metode Analisis Stabilitas Lereng Berdasarkan Karakterisasi Batuan di Tambang Terbuka Batubara. Disertasi Doktor, Rekayasa Pertambangan, Institut Teknologi Bandung.