IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 05, Issue 06 (June. 2015), ||V1|| PP 48-54

Influence of Swell on Stress-strain behaviour of Expansive Soils Under Various Confining Pressure

Elsy Elisabet Hangge[1], Hary Christady Hardiyatmo[2], Agus Darmawan Adi[3], Ahmad Rifa'i[3]

[1](Doctorate student at Civil Engineering and Environmental Department, Faculty of Engineering,Gadjah Mada University,Yogyakarta,Indonesia, Jl. Grafika No.2,Kampus UGM,Yogyakarta-55581,Indonesia)
[1](Lecturer at Civil Engineering Department, Faculty of Science and Engineering,Nusa Cendana University,Nusa Tenggara Timur,Indonesia, Jl. Adi Sucipto-Penfui,Kupang,Nusa Tenggara Timur,Indonesia) (elsy_hangge@mail.ugm.ac.id)
[2](Professor at Civil Engineering and Environmental Department, Faculty of Engineering,Gadjah Mada University,Yogyakarta,Indonesia, Jl. Grafika No.2,Kampus UGM,Yogyakarta-55581,Indonesia)
[3](Associate Professor at Civil Engineering and Environmental Department, Faculty of Engineering,Gadjah Mada University,Yogyakarta,Indonesia, Jl. Grafika No.2,Kampus UGM,Yogyakarta-55581,Indonesia)

Abstract: - Information about the expansive's soil behaviour under load is well captured by monitoring the relationship between stress and strain for a soil. This paper presents the results from a laboratory investigation of stress-strain behaviour development of expansive soils under various confining pressure. The applied confining pressures, are equal to 50, 70 and 90 kPa. The effect of confining pressure on triaxial test before and after swelling is reported. It was found that the stress-strain behavior of expansive clay improved upon the addition of confining pressure on triaxial test before and after swell. The test result have shown a significant decreace in shear strength and elasticity modulus influence of the amount of swell. Both the shear strength and elasticity modulus were reduced by 73% to 88% at the amount of confining pressure after swell triaxial test than before swell.

Keywords:- *Stress-strain, expansive soils, confining pressure,swelling*

I. INTRODUCTION

Expansive soils exhibit a swelling potential upon absorbing water. Such soils may be identified by their high plasticity index (PI), fine particle characteristics, and mineralogy, such as montmorillonite, illite and kaolinite. The plasticity index represents the range of water content in which the soil remains plastic. A plastic soils has a large value of PI. In general, the higher the PI, the greater the amount of clay particles present, and the more plastic the soil. The more plastic a soil, (1) the more compressible it will be; (2) the higher its shrinkage-swell potential is, and (3) the less permeable it will be [1] [2]. Understanding shear strength and volume change behavior of natural expansive soils is of significant interest in construction practices in regions with widespread distribution of shale-weathered expansive soils whose behavior are subject to alternate drying (drought) and wetting (precipitation) with seasonal changes [3]. Generally, in expansive soils, the change of moisture content may lead to tangible changes in specific physical and mechanical properties of them. Hence, a soil with a high percent of clay and wet content of less than optimal moisture carries out large loads and experiences small deformation; But with the increase of the wet content, bearing capacity of soil decreases and its deformation increases. However, hydraulic conductivity of clay soils is small and with a trivial change in its humidity, high expansion, and contraction is caused [4]. Shear strength of soils is needed for many stability problems of the geotechnical engineering, including design of foundation, prediction of the stability of slopes and embankments, and calculation of earth pressures against retaining structures. Al-Mhaidib and Al-Shamrani have found a significant influence of the amount of swell on the measured shear strength of expansive soils. In particular, the average value of the shear strength for sample allowed to reach ultimate vertical swell was only about 10% of that for samples that were sheared before swelling [5]. A review of the available literature indicated that studies concerned with the effect of swelling on stress-strain behavior of expansive soils are limited.

In this study, expansive clay samples with optimum moisture content and maximum dry density for swelling triaxial test were prepared. The influence of swell on stress-strain behaviour, shear strength and elasticity modulus of expansive soils under various confining pressure is investigated. The confining pressure apllied to triaxial test before and after swell 50, 70 and 90 kPa. In addition, stress-strain, shear strength and elasticity modulus were calculated and the result were evaluated.

II. MATERIAL AND TESTING PROGRAM

1. Material

The soil used in this study is expansive shale brought from Soko, Ngawi regency, East Java, Indonesia. The index properties are summarized in Table 1. Based on the liquid limit and plasticity index, soil is classified as a CH (ASTM D2487-00). Seed's method is based on the swell potential of remoulded specimens that were compacted at their Standard Proctor maximum dry density and optimum moisture content values and inundated under 1 psi pressure. Based on swelling potential oedometer test, activity and percent clay size, Soko clay have classified as high swelling potential. The Atterberg limits and swell potentials of clays depend on the quantity of water that clay can imbibe. The higher the plasticity index, the greater the quantum of water that can be imbibed by the soil and hence the greater would be its swell potential. The colloid content constitutes the most active part of the soil contributing to swelling and a high colloid content naturally means a greater possibility of expansion [6].

Table 1 Properties of index of expansive soil

Property	Amount
Specific gravity	2.62
Liquid limit (%)	101.38
Plastic limit (%)	34.82
Plasticity index (%)	66.56
Percent finer passing No.200 sieve	96.77
Clay (%) (<0.002 mm)	30
Activity (PI/C)	2.45
Swell potential (%) (Seed's method)	13.46 (High)
Optimum moisture content (%)	32.40
Maximum dry unit weight (kN/m^3)	12.30
USCS classification (ASTM D2487-00)	CH

2. Sample Preparation

In this test, the disturbed soil was compacted in accordance with the modified compaction test (ASTM D-698-00) at an initial density 12.30 kN/m^3 and water content 32.40 %. To ensure uniformity of testing, soil samples were dried, pulverized into a powder in batches and screened through sieve No.40. Soil samples were oven-dried for 24 hours and then thoroughly mixed to the chosen molding moisture content. They were then stored in air-tight plastic bags to avoid loss in moisture content, and were allowed to cure at room temperature for 24 hours to obtain uniform distribution of moisture content.

The 35 mm-diameter, 70 mm-height specimens for swell triaxial test were statically compacted in split mold where the desired density was achieved. The soils was compacted in three layers, where tamping each layer until the accumulative mass of the soil placed in the mold were compacted to a known volume. After a specimen was formed, removed from the mold and determined the mass and dimension.

3. Equipments

In this studies, the swell tests were used conventional triaxial apparatus (ASTM D4767-02) with paraffin volume gauge for measured the volume of water entering or leaving the specimen. A schematic diagram of the testing system is shown in Fig. 1. This test method covers the determination of strength and stress-strain relationships of a cylindrical specimen of either an undisturbed or remolded saturated cohesive soil. The most direct method of determining the amount of swelling is to perform a one-dimensional swell test by utilizing the oedometer apparatus. Swell potential of expansive soils is commonly obtained from oedometer swell tests under fully lateral restraint condition. Surface heave predicted from results of oedometer tests is usually conservative and largely differs from heave actually observed in the field. The conventional triaxial swell tests, on the other hand, furnish more realistic loading conditions and offer a more satisfactory way of measuring swelling of expansive soils.

The triaxial cell was placed on the platen of a load frame, which was raised at a constant speed preselected for the test. The axial load, required to load the specimen to failure, can be applied through a piston passing through the top of the triaxial cell. An external proving ring measures the applied load. Pressure gauge measure the cell pressure, back pressure (a pressure applied to the pore water), and changes in pore water pressure. Vertical displacement is measured by a dial gauge and volume change is measured by paraffin volume gauge of the type reported by Bishop and Henkel in 1962 [7]. Paraffin volume gauges were placed between triaxial cell and the pressure gauges. A constant pressure source, typically an air compressor with an air/water interface, supplied pressure to the cell and back pressure to the test specimen.

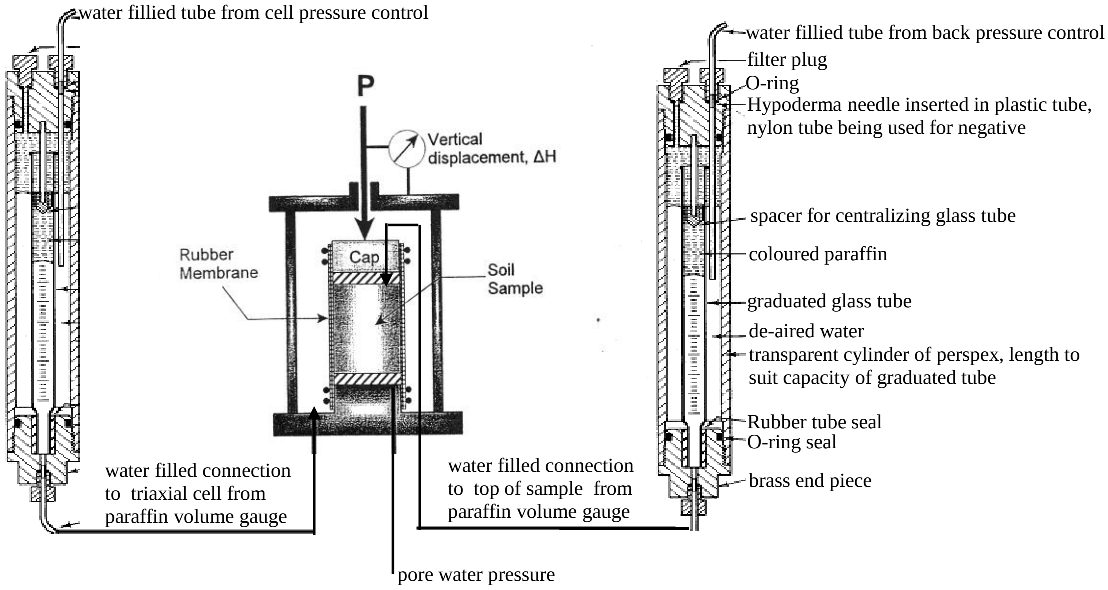

Figure 1. Schematic diagram of swelling test using triaxial and paraffin volume gauge.

4. Testing procedure

After specimen was removed from the split mould, it was placed on the lower pedestal of the triaxial cell. Coarse porous stone and filter paper were placed at the ends of the sample. A rubber membrane was placed around the sample and was sealed by rubber O-rings at top and bottom. The outer chamber was bolted onto the base and filled with water and the confining pressure (σ_3) was applied. The applied confining pressures, are equal to 50, 70 and 90 kPa.Initial dial gauge and paraffin volume gauge readings were taken. The swelling processed by applying back pressure to the specimen pore pressure to drive air into solution. Final readings of swell were taken until the change in vertical and volumetric swell under the applied confining pressure at which time the swell test was terminated. Thereafter, the specimen was sheared with constant rate using the motorized srew control cylinder. During shear the chamber pressure shall be kept constant while advancing the axial load piston downward against the specimen cap using controlled axial strain as the loading criterion. Specimen drainage was not permitted during shear.

III. RESULT AND DISCUSSION

Table 2 summarized the influence of different confining pressure on shear strength and elasticity modulus by triaxial test before and after swell. The shear strength and the elasticity modulus increases with an increase in amount of confining pressure. This increase in both shear strength and elasticity modulus correlates well with the increase in confining pressure. The stress-strain curve of expansive clay improved upon the addition of confining pressure on triaxial test before and after swell. This trend existed for all specimen test before and after swell on triaxial test.

Table 2 Triaxial test of Soko Clay before and after swell

Test	Initial condition			Shear test condition			σ_3 (kPa)	ε_f (%)	$\Delta\sigma_f$ (kPa)	Es (kPa)	S_V (%)	S_{vol} (%)
	w_i (%)	γ_b (kN/m^3)	S_0 (%)	w_f (%)	γ_b (kN/m^3)	S_f (%)						
Before swell	31.21	16.2	72.52	31.21	16.2	72.52	50	12	438.53	7483.41	-	-
	32.16	16.2	73.63	32.16	16.2	73.63	70	12	518.37	8254.32	-	-
	32.38	16.2	73.67	32.38	16.2	73.67	90	12	576.19	9635.24	-	-
After Swell	32.10	16.2	74.10	50.17	14.90	99.70	50	7	51.09	1330.49	8.57	27.02
	32.23	16.2	74.29	46.95	14.90	97.03	70	8	81.91	1922.74	6.14	22.57
	32.24	16.2	74.30	42.85	15.40	94.44	90	9	110.87	2554.51	2.43	15.44

1. Swelling behaviour

Figs. 2 and 3 show the variation of vertical and volumetric swell (as a percentage) with the elapsed time under the applied confining pressure of 50, 70 and 90 kPa. The percentage of vertical swell is defined as the ratio of the change in specimen height upon wetting to the specimen initial height. The percentage of volumetric swell is defined as the ratio of the change in specimen volume from paraffin volume gauge measuring upon wetting to the specimen initial volume. Initial condition of all specimen prepared at an optimum moisture content 32.40 % and maximum dry unit weight 12.30 kN/m^3 have found by Proctor standart test. Fig. 4 and 5 shows that the value of vertical and volumetric swell increase with an decrease in confining pressure. At low confining pressure, a greater increase occurred in both vertical and volumetric swell. When the confining pressure is increased from 50 kPa to 70 kPa, both the vertical and volumetric swell decreased by about 40 % and 16 %. While the confining increased from 70 kPa to 90 kPa, both the vertical and volumetric swell decreased by about 60 % and 31 %. This decreace in both vertical and volumetric swell correlates well with the increase in confining pressure. This result shown that the swelling potential of expansive soils is influenced by state of stress. Al-Mhaidib found stress path triaxial test provided good prediction of vertical swell and swell overburden triaxial test provide lower values of vertical swell than those from the swell overburden oedometer test [8].

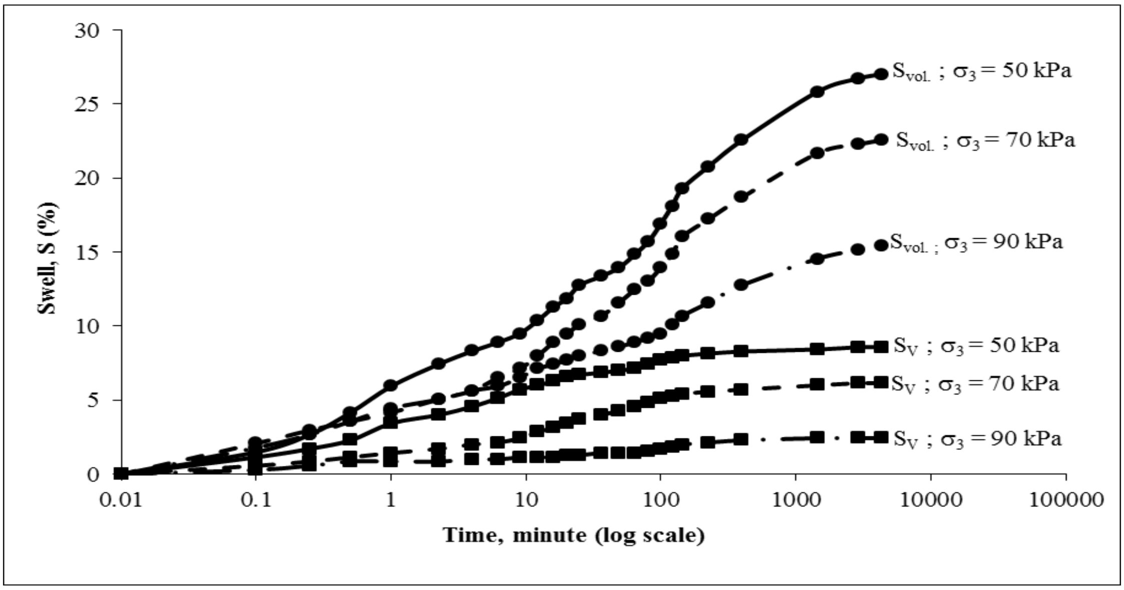

Figure 2. Vertical and volumetric swell versus time under various confining pressure at constant initial water 32.40 % content and dry density 12.30 kN/m^3.

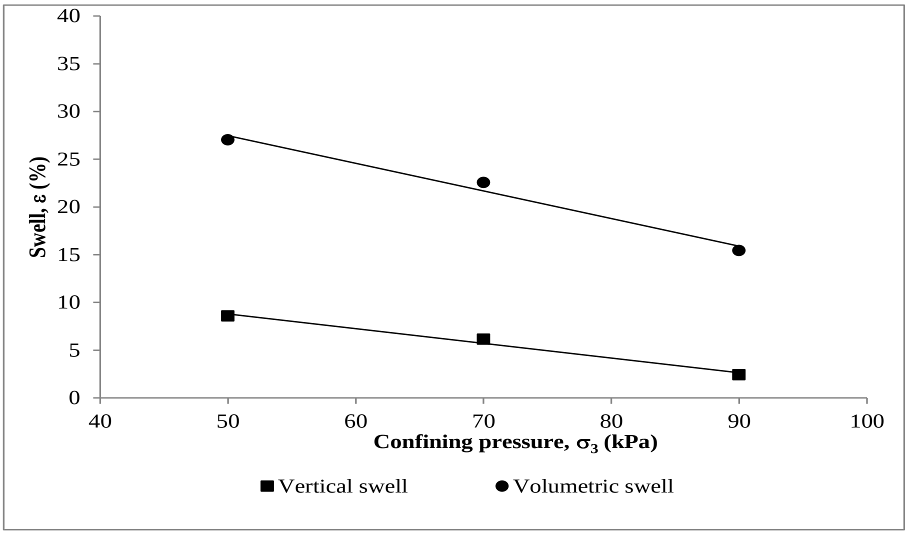

Figure 3. Vertical and volumetric swell versus confining pressure from triaxial test at constant initial water 32.40 % content and dry density 12.30 kN/m^3.

2. Stress-strain behavior

Fig. 4 shows the stress-strain behaviour of expansive soil on triaxial test before and after swell under the applied confining pressure of 50, 70 and 90 kPa. All stress-strain behaviours shown in the Fig. 4 exhibited a ductile behavior with a continuous deformation until a steady state was reached. The stress-strain behavior of expansive clay was influenced by change the water content of specimen and the confining pressure applied on swell triaxial test. The stress-strain behaviour of both triaxial test before and after swell shown linear relationship over a short range of load, followed by non-linearity small-strain stiffness over the rest range of loading. At swell triaxial test, the maksimum stress point was not clearly observed on all amount of confining pressure, It reversed at unswell triaxial test. In fact, the stress-strain behaviour of expansive soils was found a ductile with a continuous deformation until a steady state was reached.

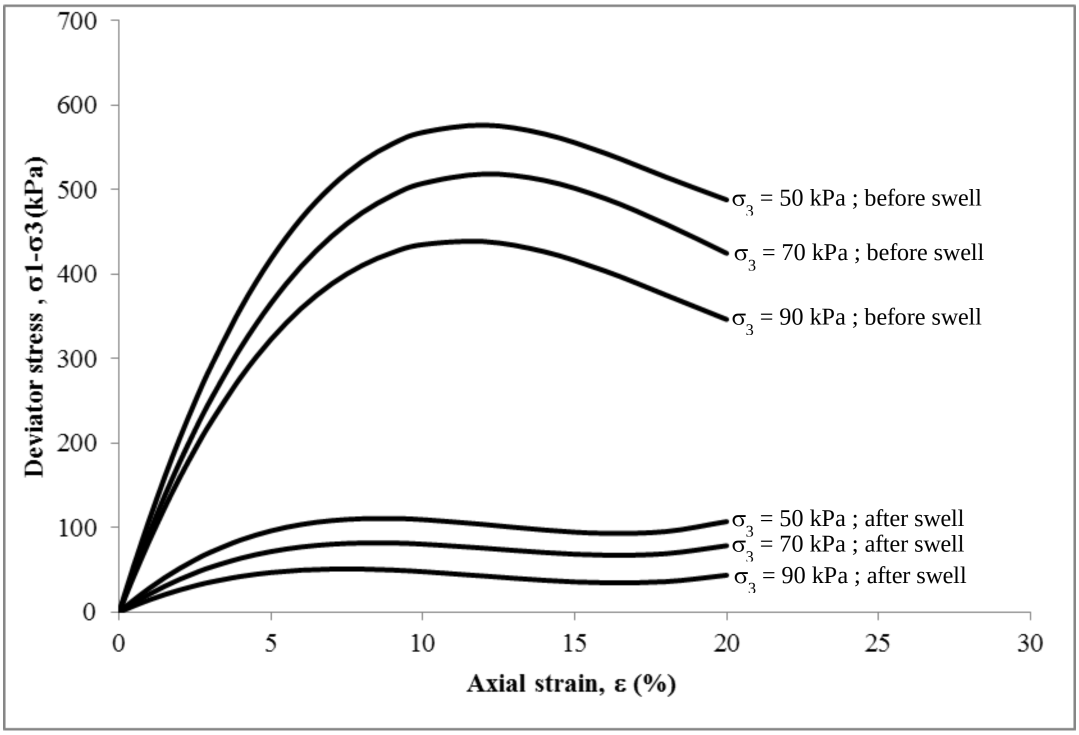

Figure 4. Stress-strain behaviour of expansive clay under various confining pressure at constant initial water 32.40 % content and dry density 12.30 kN/m^3.

3. Shear strength and modulus of elasticity

Fig. 5 and 6 shows variation of the shear strength and modulus of elasticity of expansive soil as a function of confining pressure and swelling potential. The shear strength and elasticity modulus, increase with an increase in confining pressure for all specimen before and after swell triaxial test. Significant decrease of shear strength and elasticity modulus were found on specimen triaxial test after swell. The decrease in shear strength and elasticity modulus for confining pressure 50, 70 and 90 kPa on after swell triaxial test were repeatedly about 88.39%, 84.20% 80.76% and 82.22%, 76.70%, 73.48% of the shear strength and elasticity modulus before swell triaxial test. Al-Mhaidib and Al-Shamrani found that the average value of the shear strength was about one-third of the shear strength value for samples sheared without allowing for swell to take place [5].

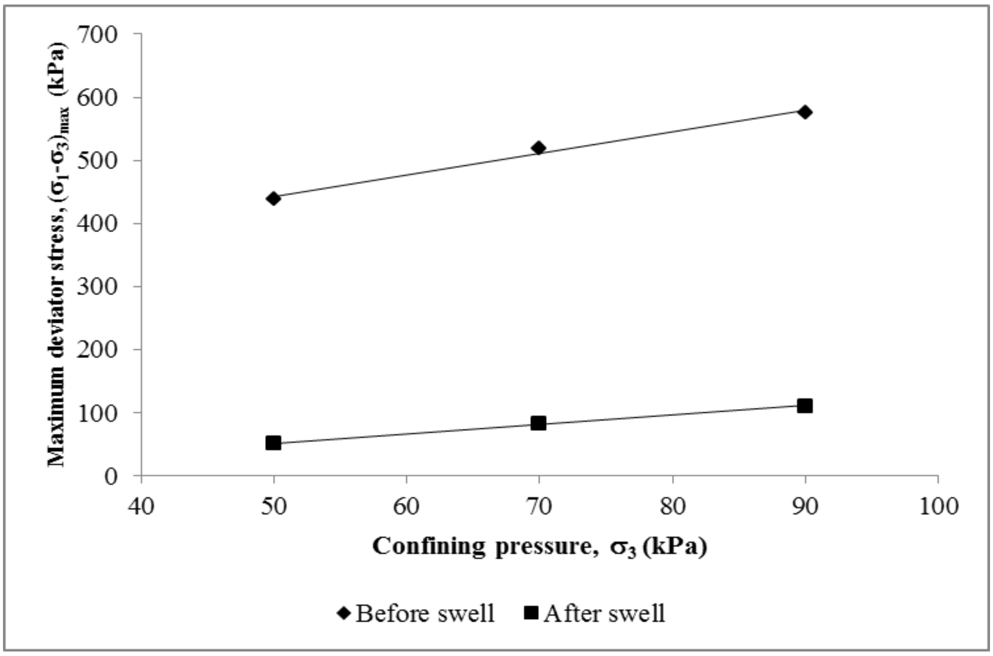

Figure 5. Shear strength of expansive clay under various confining pressure before and after swell triaxial test at constant initial water 32.40 % content and dry density 12.30 kN/m^3.

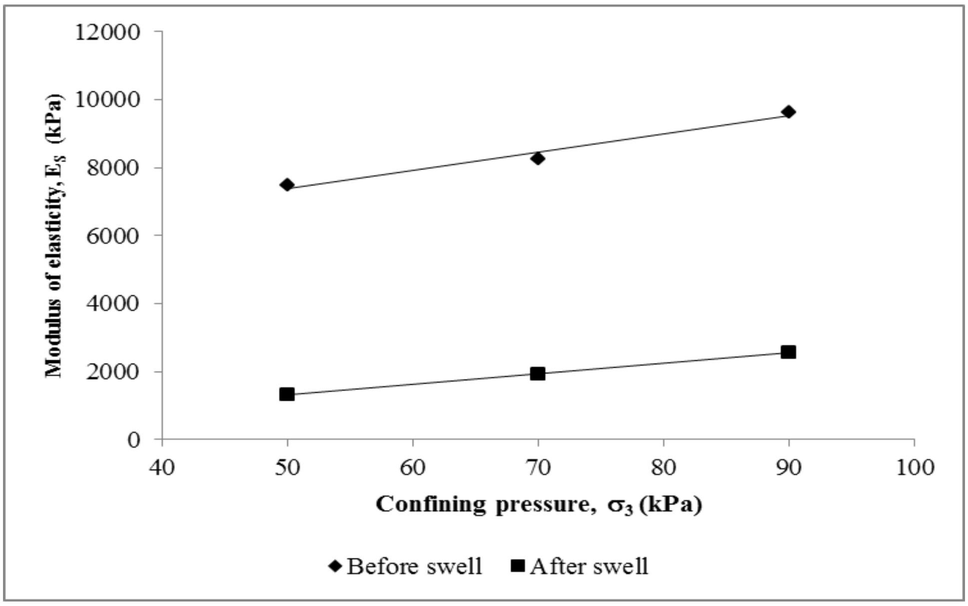

Figure 6. Modulus of elasticity versus confining pressure before and after swell triaxial test at constant initial water 32.40 % content and dry density 12.30 kN/m^3.

IV. CONCLUSION

Based on the results in this study that have been implemented. The conclusion can be summarized as follows :

1. The amount of swell has been found to significantly influence the stress-strain behavior. This is indicated from stress-strain curve before and after swell triaxial test. All stress-strain behaviours shown exhibited a ductile behaviour with a continuous deformation until a steady state was reached. The stress-strain behavior of expansive clay was influenced by change the water content of specimen and the confining pressure applied on swell triaxial test.
2. The amount of swell has been found to significantly influence the shear strength of expansive soils. The average value of the shear strength for all specimen that were allowed to swell was approximately 12 % -20 % of the shear strength before swell specimen test. The shear strength of expansive soil linearly increase with increasing applied confining pressure
3. The elasticity modulus of expansive soil linearly increase with increasing applied confining pressure. The amount of swell has been found to significantly influence the elasticity modulus of expansive soils. The average value of elasticity modulus for all specimen that were allowed to swell was approximately 18 % - 27 % of elasticity modulus before swell specimen test.

ACKNOWLEDGEMENTS

The author is grateful to the Indonesian Directorate General of Higher Education (DIKTI) for the funding that made this research possible.

REFERENCES

[1] L.W. Abramson, T.S. Lee, S. Sharma, and, G.M. Boyce, *Slope stability and stabilization methods* (New York, John Wiley & Sons, Inc., 2002).

[2] B. Chittoori, and A.J. Puppala, Quantitative estimation of clay mineralogy in fine-grained soils, *Journal of geotechnical and geoenvironmental engineering, ASCE, Nopember* 2011, 997-1008.

[3] B. Lin, and A. Cerato, (2014) Hysteretic Shear Strength and Shear-Induced Volume Change of Natural Expansive Soils Weathered from Shale. Geo-Congress 2014 Technical Papers: 1347-1356.

[4] M. Karimi, A. Salemnia, and J. Ahadiyan, Evaluation of strength parameters of stress-strain development in clay soil and clay-sand soil,*International Journal of Civil and Structural Engineering,Vol.1*,No.3, 2010, 644-660.

[5] A. Al-Mhaidib, and M. Al-Shamrani, (2006) Influence of Swell on Shear Strength of Expansive Soils. *Advances in Unsaturated Soil, Seepage, and Environmental Geotechnics*, 160-165.

[6] S. M. Rao, Identification and classification of expansive soils, in Al-Rawas A. A. and Goosen M.F.A. (Ed), *Expansive soils recent advances in characterization and treatment*, 2 (London: Taylor & Francis, 2006) 15-24.

[7] A. W. Bishop, and D. J. Henkel, *The Measurement of Soil Properties in The Triaxial Test,* (London, Edward Arnold, 2nd Edition, 1962).

[8] A. Al-Mhaidib, Swelling behaviour of expansive shale, in Al-Rawas A. A. and Goosen M.F.A. (Ed), *Expansive soils recent advances in characterization and treatment*, 19 (London: Taylor & Francis, 2006) 273-287.