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Estimates of Elasticity and Compressive Strenght in Soil Cement Mixed With Ijuk-Aren

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Abstract— Similar to concretes, soil cements have increasing strengths with age. More importantly, this type of material has lower elasticity comparatively to solely soils. Being used as road foundation materials, soil cements may have sufficient strength to support loads from vehicles. However, in a long run, repetitive loadings, such as those from vehicles, may damage soil cements foundations signified by cracking. To address this limitation, palm sugar fibers have been added to the soil cement mixture. It is found that fibers can increase the elasticity of soil cements. This study has also provided results of compression strength tests conducted in soil mechanic laboratory over 30 (thirty) remolded cylindrical samples of soil cements that have different ages, e.g., 3, 7, 14, 21, and 28 days, respectively. The samples are reconstructed of type SC soils, type I cements, and palm sugar fibers. The amounts of cement are 6% and 10% by weight of dry soils, while the portion of palm sugar fiber is 0,5% by weight of dray soils. Before being tested, the samples are stored under a constant temperature. Last but not least, the data series obtained from these tests are analysed and results in an important expression that can be used for estimating the compression strength and elasticity module of soil cements added with palm sugar fibers. Last but not least, the data series obtained from these tests are analysed and results in an important expression that can be used for estimating the compression strength and elasticity modulus of soil cements mixed ijuk-aren. The results obtained is empirical equation models forecast increased compressive strength and modulus of elasticity of soil cement mixed ijuk-aren.

Keywords— Soil-cement, Ijuk-aren, Compressive strenght, Elasticity

I. INTRODUCTION

Soil cement can be used as pavement in certain areas. Soil cement is an alternative soil improvement method by mixing soil and cement. This method has been widely used for a variety of countries. Coarse or fine grained soil material is clay soil, silt, sand, gravel and other similar materials are mixed with cement and water. The mixed soil cement using a certain ratio then hardened with a fixed shape. This mixture using a certain ratio in the plastis mixture then hardened and has a fixed shape. The chemical reaction of cement in order to improve the strenght occurred in the two processes, namely primary and secondary. Primary process is the occurrence of hydrolysis and hydration in cement where cement particles form bonds with grain mineral of the soil. Secondary process is a process that is influenced by increasing the strength of soil cement mixtures and also reduce plasticity and swelling properties of soil [7]. Soil cement mixture permanently have a high density and the settlement due to consolidation causes by the traffic load will not occur. Soil cement widely used as a pavement base for roads, residential street, parking areas, airport, shoulders, and materials handling and storage areas. In general, soil cement pavement is divided into three main components, according to the function in the structure of road pavement. These components are *Cement-Modified Soils* (CMS), *Cement-Treated Base* (CTB), and *Full-Depth Reclamation* (FDR). In highway construction pavement resist the load from vehicle. Repetitive load causes a shear stress to the pavement. Pavement made of soil cement which having a properties are hard and rigid, will still produces a cracks. These cracks are due to the shrinkage of the mixture, or drying due to cement hydration [6]. Highway with the repeated load of passing vehicles can accelerates and improve the cracks and it will show the reflective cracks. On the other hand, cracks occurred due to volumetric changes in the soil caused by pressure from repetitive load [12]. Cracks that occur can be minimized by adding natural or artificial fiber material into the soil cement [5]. Fiber material have a function to resist the tensile strength and improved the shear strength of the soil. Therefore fiber can improved the strength or bearing capacity of soil cement and reduced the potential of shrinkage cracks. The experimental results showed a significant effect from the addition of polypropylene fiber and high confining pressures on the mechanical behaviour of Portaway sand improved the stress-strain and bearing capacity [13]. The pineapple leaf fibres (PF) and oil palm fruit bunch fibres (OF), then mixing with cement as the binder of the soft soil, generally increased the compressive strength and the density remained largely unchanged over the range of fibres added [4]. Palm fibers are added into the soil cement provides compressive strength increased significantly [11]. Cement-treated aggregate base (CTAB) from two different base material (conventional crushed limestone base material and the other is a recycled concrete material) were used in the unconfined uniaxial compression tests at different ages. Test results finding a relationship between the compressive strength and elastic modulus of CTAB material [9]. Then the lateritic soil-cement mixtures showed a significant increasing in compressive strength and elasticity by adding cement and curing time [8].

II. EXPERIMENTAL PROGRAM

A. Materials Used

Soil was used in this research came from Km 13 road Samarinda-Balikpapan in East Kalimantan. Based on Unified Soil Classificaton System the soil type is clayey sands, sand clay mixtures (SC) see Fig. 1 and palm sugar fibers (ijuk-aren) was used as shown in Fig. 2 is a natural fiber and easily obtained. Physical and Chemical Properties of sugar palm fibers has been done [10]. Result of soil properties test is shown in Table I. Cement was used is type I and water are added according with the plan.

Fig. 1 SC Soil

Fig. 2 Ijuk-Aren

TABLE I
SOIL PROPERTIES TEST RESULT

PROPERTIES	RESULT
Specific Gravity	2.62
LL	18.33%
PL	11.20%
PI	7.13%
Coarse sand	2.00%
Medium sand	8.00%
Fined sand	55.00%
Silt	22.50%
Clay	12.50%

B. Experimental design

Three variables as componen in a mixture of soil cement with sugar palm fibers proportion, the variable are:

- content of cement: 6%, 10%,
- content of sugar palm fibers: 0,5%,
- specimen ages: 3, 7, 14, 21 and 28 days.

Content of cement and sugar palm fibers is determined by the weight of dry soil. Each specimens made by optimum moisture content (OMC) and maximum unit weight of dry soil (Fig. 3), then stored at temperature and humadity constant.

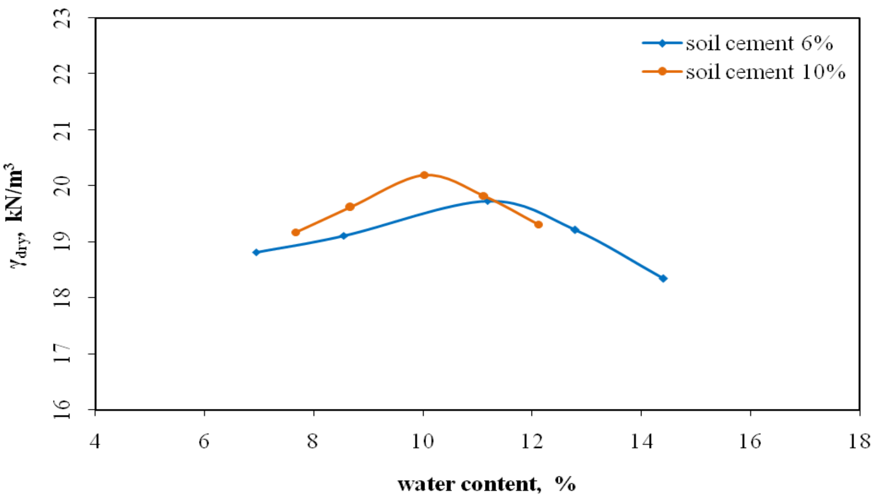

Fig. 3 Curve modified compaction test

C. Unconfined compression test

The unconfined compression test is uniaxial test and in the soil stress has occured, load is applied gradually increased until the speciment was failure [2]. This test is a special test from unconsolidated-undrained triaxial test where the confining pressure is zero. Specimens with a dimension of 2 inch in diameter and 4 inch in height. Specimen and equipment shown at Fig. 4. To satisfy the strength requirements mixture should be properly designed, especially for cement content. Most specifications require the minimum design strength of cement-treated base ranging from 350 to 500 psi (2.4 to 3.4 MPa) at 7 days [9, 14].

Fig. 4 Unconfined compression test

III. Results and Discussion

Soil mixed with cement indicates that cement can fill the pores and wrapping soil grain then soil becomes hard. On the other hand, maximum unit weight of dry soil increase but the optimum moisture content is decrease. Cement content is increase indicates that compressive strength increased significantly [11]. Table II, shows the compressive strength with cement content 6% and 10% and sugar palm fibers content 0,5% at different ages, show that the specimen ages has effect to compressive strength. Specimen A1, A2, A3 are for soil cement 6%+sugar palm fibers 0,5% and B1, B2, B3 are for soil cement 10%+ sugar palm fibers 0,5%.

TABLE III
Unconfined Compression test result

Time (days)	UCS (MPa)					
	Cement 6%+ ijuk-aren 0,5%			Cement 10%+ ijuk-aren 0,5%		
	A1	A2	A3	B1	B2	B3
3	1.57	1.44	1.56	1.65	1.94	1.68
7	2.55	2.51	2.70	3.64	3.25	3.22
14	3.01	2.90	2.94	4.28	4.12	4.27
21	3.24	3.09	3.43	4.94	4.92	4.85
28	3.49	3.40	3.58	5.33	5.30	5.27

Fig. 5 shows effect of variable mixtures in soil cement. Compressive strenght of soil cement mixed with sugar palm fibers increase than without sugar palm fibers. It is apparent that sugar palm fibers can improve the compressive strenght and of course will be followed by an increase of elasticity. Increased compressive strength of soil-cement is caused by friction between the surface of sugar palm fibers with soil cement and increased of cement content. This can be seen from scattered strength of each mixture and each age.

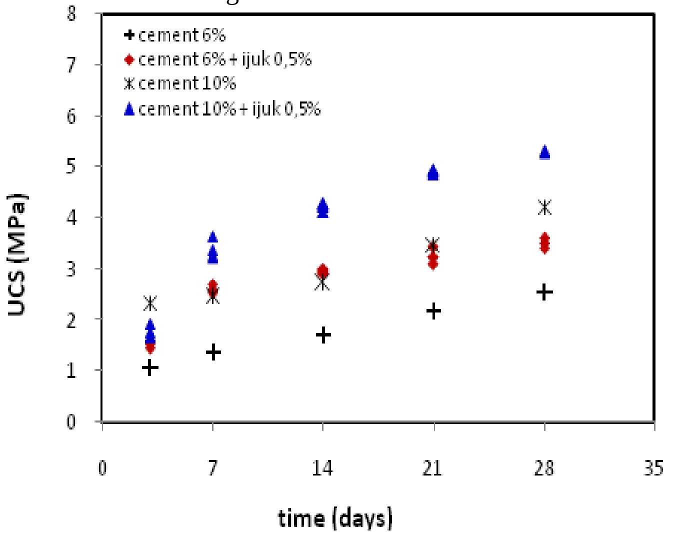

Fig. 5 Compressive strength development of soil cement

Estimation of the strength development of soil cement-treated base with time according to the experimental coefficients of the strength prediction model proposed by ACI Committee 209R-92 [1]. ACI model coefficients are calibrated with data obtained in this study. ACI provided the model in the form of Equation (1) with the coefficients *a*=4.0 and *b*=0.85 cement type I for normal concrete.

$$f_{cmt} = \left[\frac{t}{a + bt}\right] f_{cm28} \qquad (1)$$

where, f_{cmt} = compressive strength in MPa at time t,
f_{cm28} = reference 28-day compressive strength in MPa, and
a, b = experimental coefficients.

Fig. 6 shows the strength prediction curve of the test mixtures of soil-cement 6%, 10%, mixed sugar palm fibers 0.5%. Calibration of experimental coefficients ACI model to soil-cement test data resulted in a new set of coefficients a = 4.85 and b = 0.83. this new set of coefficient is expected to be applicable for the soil-cement is mixed with palm fibers.

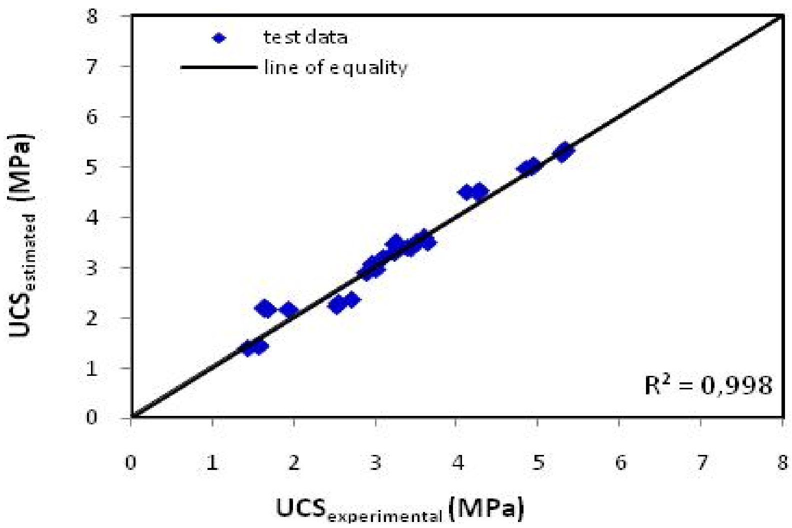

Fig. 6 Comparison UCS of experimental data and predicted values

Modulus of elasticity is obtained from the stress-strain relationship of the mixtures identified from the strength tests. Table III shows the modulus of elasticity based on the tests.

TABLE IIIII
MODULUS OF ELASTICITY OF THE SOIL CEMENT AT DIFFERENT CURING TIMES

Time (days)	Modulus of Elasticity (MPa)					
	Cement 6% + ijuk-aren 0,5%			Cement 10% + ijuk-aren 0,5%		
	A1	A2	A3	B1	B2	B3
3	46.66	46.26	42.88	39.65	37.27	40.36
7	70.31	64.57	65.14	58.35	62.64	62.08
14	72.39	74.39	70.80	82.39	79.31	82.11
21	77.88	79.30	82.48	95.15	86.09	77.88
28	84.25	84.96	86.38	102.57	102.01	88.25

Development of modulus of elasticity depending on the strenght development. Modulus of elasticity Equation model of ACI as shown in Equation (2). It should be noted that the ACI model was proposed for concrete applications and this is not appropriate for soil cement. Based on Equation (2), the experimental coefficient and exponents of compressive strenght ages were calibrated and resulted in Equation (3) as predicted modulus of elasticity of soil cement mixed with sugar palm fibers. This equation is based on estimates of the compressive strength of Equation 1, compressive strength age at 28 days and unit weight of the specimen.

$$E_{mct} = 0{,}043.\gamma_c^{1,5}.f_{cmt}^{0,5} \quad \text{(MPa)} \tag{2}$$

$$E_{mct} = 0{,}000285.\gamma_c^{1,5}.f_{cmt}^{0,75} \quad \text{(MPa)} \tag{3}$$

where, E_{mct} = modulus of elasticity in MPa at time t,
f_{cmt} = compressive strength in MPa at time t, and
γ_c = unit weight in kg/m^3.

The proposed model (Equation 3) provides a good agreement at high correlation with the test data. Proposed equation models by ACI are not appropriate for concrete at lower strength or early-age concrete, as shown from the experimental coefficient values has a wide range from the soil cement. Fig. 7 shows a comparison of the experimental and estimated of modulus of elasticity. With the approach of the linear line obtained a good level of confidence numbers R^2 = 0.9983. This equation is expected to be applicable for estimates a modulus of elasticity of soil cement mixtures with sugar palm fibers.

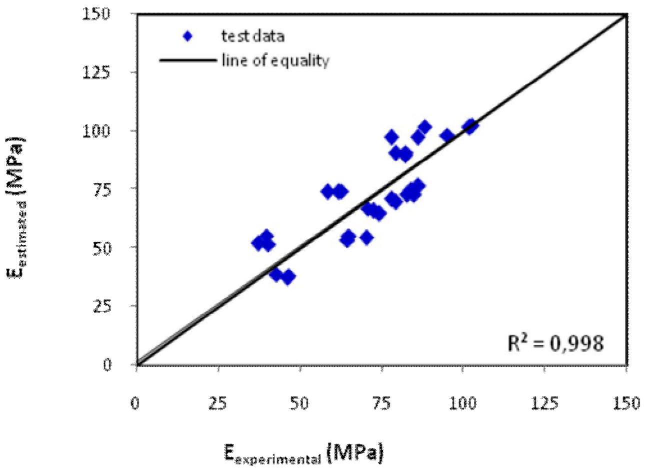

Fig. 7 Comparison modulus elasticity of of experimental data and predicted values

IV. CONCLUSIONS

Soil cement with sugar palm fibers was experimentally investigated for elasticity estimates. Based on the results of the study, the following conclusions can be drawn:

- the strenght of soil cement be affected by mixtures of sugar palm fibers, content of cement and ages,
- this study obtained estimates of the compressive strength of cement-soil mixed with palm sugar, and the equation $f_{cmt} = [t/(a+bt)]f_{cm28}$ with experimental coefficient a = 4,85 and b = 0,83,
- this study obtained estimates of the modulus of elasticity, the equation $E_{mct} = 0{,}000285.\gamma_c^{1,5}.f_{cmt}^{0,75}$ and levels of confidence numbers R^2 = 0.9983.

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