Direct Shear Strength Improvement through Soil Stabilization using Dry Dust Collector and Silica Sand from Industrial Waste

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Abstract. Nowadays, Green technology call for research on the utilization of industrial waste to solve civil construction problems, e.g. broken roads, foundation crack, etc. This study aims to analyze the characteristics of clay after soil stabilization using Dry Dust Collector (DDC) and Silica Sand (SS) from industrial waste. Laboratory test was employed for finding the parameters, i.e. water content, specific gravity, plasticity index, and mechanical test (proctor compaction standard and direct shear strength). The result showed the best friction angle for mix soil with SS and DDC with 5 percent of SS. Cohesion number increased for the mix soil which contained only one type of waste. The shear strength increased 32.26 percent for the mix soil with 1.5 percent DDC and 5 percent SS. This study showed mechanical characteristic improvement of clay after DDC and SS addition.

1 INTRODUCTION

Industries often generate much waste when producing any goods. Coloring and compounding plastic resin industries in EJIP industrial park in Cikarang, West Java, give three ton of dry dust collector waste (DDC) every month. In the other hand, mineralogy industries create 50 ton silica sand waste (SS) every month. DDC and SS have chemical characteristics which are useful for soil stabilization. But there is a problem to implantation this method related to high cost in collecting DDC and SS. Therefore some innovations and infrastructure in managing industrial waste are emerged. Factory owners need a lot of collectors with very high cost. Therefore, some researches on industrial waste utilization are needed.

The novelty of this study is in stabilizing the clay using DDC and SS which is useful to support building constructions as well as roads. Two kinds of stabilization, i.e. physical and chemical stabilizations, were used for increasing the strength, decreasing the swelling potential, and improving physical and mechanical of clay. This study is useful in Indonesia since industrial waste increase every year, and adhere green technology by utilizing the waste for infrastructure development.

Many studies have been conducted to utilize industrial waste for additive in construction. Wardana (2009) proposed soil stabilization through the use of marble powder and other stabilizers. This research shows that testing result showed decreasing of soil swelling and rising the compression strength, but the stabilizers use showed better in decreasing soil swelling and the compression strength similar to lime addition. This research also recommended the soil depth and optimum composition of stabilizers. In addition, it is recommended to test the performance not only based on soil plasticity, but also the allowance of soil swelling, so soil will have the ability to support the foundation as well as the vehicles on the road although in expansion. Paddle only affected at the surface of the soil as well.

Aulia (2006) proposed to use the waste of pulp and paper industry as clay stabilizer. The result showed the clay from Grobogan regency with specific gravity of 2.68 and solid paper-waste addition up to 15% showed the decreasing of liquid limit up to 58.40%, increasing of plasticity limit up to 44.74%, decreasing of plasticity index by 13.66%, increasing of shrinkage limit up to 17.16%, and decreasing of clay fraction by 71.40%. Solid pulp and paper waste addition up to 15% could change soil unified system from class H to MH or OH which there is no class change based on AASHTO. Cohesion value (c) for all addition of solid pulp and paper waste up to 10% with 7 days aging are decreased, but the shear angles (ϕ) are increased. For pulp and paper addition greater than 10% and 7 days aging, the shear angle (ϕ) tends to decreased again. Umam (2017) studied about sand gradation and clay ratio influence on soil's shear

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strength. This result concluded that clay addition to the sand would increase internal shear angle of the soil and decrease cohesion value. Cohesion value was not influenced by granules size of sand but influenced by small granules of sand. Stabilization method was also developed through the use of waste from PERTAMINA, i.e. spent catalyst RCC 15 (Gunarti, 2014), which showed the significant increase of clay's carrying capacity. These result that showing carrying capacity improvement will be used as preliminary data of this study. Another result was the increase of constrained compressive strength (qu) compared to the original soil from the stabilization of soil using spent catalyst RCC 15 and lime because the soil did chemical process that create the bond among granules that change particles size into the sandy and non-cohesive.

This paper proposed the soil stabilization using dry dust collector (DCC) and silica sand (SS) from industrial waste. This first time research also utilized the industrial waste for improving capability and strength for construction development that adhere the green technology concept.

2 METHODS

2.1 Kind of Test and Location

The laboratory test for physical and mechanical characteristic was done at Soil Mechanic laboratory in Universitas Islam 45 Bekasi to find direct shear strength, water content, specific gravity, and plasticity index.

2.2 Materials

For laboratory tests, this study used some materials, i.e. clay (disturbed and not disturbed clay in Universitas Islam 45 Bekasi), Dry Dust Collector (null and 1.5 percent composition compared to clay dry weight), and silica sand (null, 2.5, and 5 percent composition compared to clay dry weight). A direct shear test tool was used with JIS standard (Figure 1).

Figure 1: Direct Shear Test

2.3 Methods

Figure 2 shows the research framework. Two separate materials (original and stabilized through the use of DDC and SS). Each material was tested to find: atterberg limit, water content, specific gravity, sieve analysis, Proctor standard compaction, and shear strength. After testing and validation, the results were concluded and discussed.

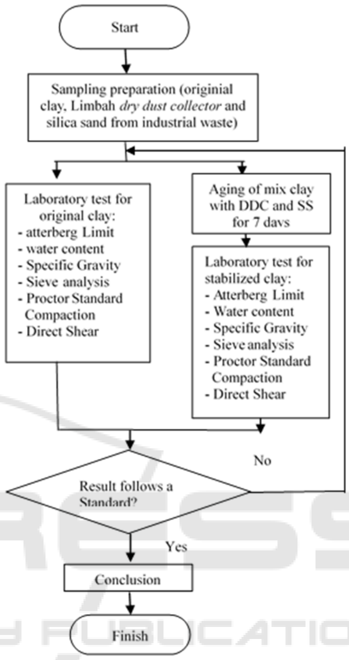

Figure 2: Research Framework

3 RESULT AND DISCUSSION

3.1 Physical Characteristics of the Original Clay

3.1.1 Undisturbed Clay's Characteristics

Table 1 shows the five physical test results of undisturbed clay.

Table 1: Physical test result of undisturbed clay

No	Soil Description		
	Kind of Test	**Undisturbed Soil depth 1.00-1.50m**	**Undisturbed Soil Depth 1.50-2.00m**
1	Specific Gravity	2.603	2.691
2	Water Content	58.51	48.72
3	Liquid Limits	87.65%	74.80%

4	Plasticity Limits	31.02%	28.36%
5	Plasticity Index	56.63	46.44

Plasticity index can be used as a base to identify soil expansion. Fathani (1994) study, based on Chen criteria gives an expansive criterion if PI greater than 35%. If pass filter number 200 greater than 95% and liquid limit > 60%, then the soil has a very high expansive criterion. Table 1 shows undisturbed soil has PI of 56.63% for 1.00 – 1.50 meters depth and 46.44% for 1.50 – 2.00 meters depth. Percent of pass sieve fraction number 200 is 85.538% for 1.00 – 1.50 meters depth and 62.716% for 1.50 – 2.00 meters depth. Liquid limits is 87.65% for 1.00 – 1.50 meters depth and 74. 80% for 1.50 – 2.00 meters depth. The tests showed that soil has high expansive criterion. Hardiyatmo (1994) said that soil will degrade if having gradation coefficient (Cc) of 1 and 3, with uniformity coefficient (Cu) greater than 15. In this study, both Cc and Cu is null because none of the samples has pass sieve below 10 percent. Therefore, this kind of soil is categorized as bed in degradation which is not pass for gradation and uniformity coefficient. Based on unified criteria and the liquid limits, it was found that the soil has liquid limits of 87.65 for 1.00 – 1.50 meters depth and 74. 80% for 1.50 – 2.00 meters depth (greater that 50%). Therefore, the soil is categorized as CH (organic clay with high in plasticity).

3.1.2 Disturbed Clay's and Stabilized Clay's Characteristics

Testing results for disturbed and stabilized clay are shown in Table 2.

Table 2: Physical Test Result of Disturbed and Stabilized Clay

Additive Composition Code	Additive DDC	Additive SS	Kind of Test SG	LL	PL	PI
	%			%	%	%
A	0	0	2.6232	58.10	31.54	26.55
B	1,5	0	2.5469	57.35	27.21	30.14
C	0	2,5	2.5767	55.50	27.62	27.87
D	0	5	2.6208	51.40	27.53	23.87
E	1.5	2.5	2.5642	52.75	27.60	25.15
F	1.5	5	2.5766	53.42	26.78	26.63

Table 2 shows the mix of DCC and SS decreased Plasticity of 23.87 for original and disturbed soil from 26.55 (Code D). PI value for some composition code were both decreased and increased because there is a characteristic change of the granules as the result of physical characteristic of granules change from clay to sandy soil after chemical and aging of stabilized clay.

3.1.3 Mechanical Characteristics of Disturbed and Stabilized Clay

Table 3 shows testing of direct shear results for disturbed and stabilized clay.

Table 3: Direct Shear Test for Disturbed and Stabilized Clay

Additive Composition Code	Additive DDC	Additive SS	Kind of Test: Compaction γd (t/m3)	Compaction Wopt (%)	Direct Shear ϕ (º)	Direct Shear C Kg/cm2
	%					
A	0	0	1,380	30,50	18	0,0115
B	1,5	0	1,372	31,80	13	0,0415
C	0	2,5	1,375	31,62	11	0,0440
D	0	5	1,384	31,00	21	0,0225
E	1,5	2,5	1,364	30,75	19	0,0280
F	1,5	5	1,384	30,00	22	0,0255

Compaction value, γd, for Code A is 1.380t/m^3 with optimum water content (Wopt) of 30.50% for disturbed clay. The highest γd value is shown for code D and F (1.384 t/m3 for 5% DDC and SS addition).

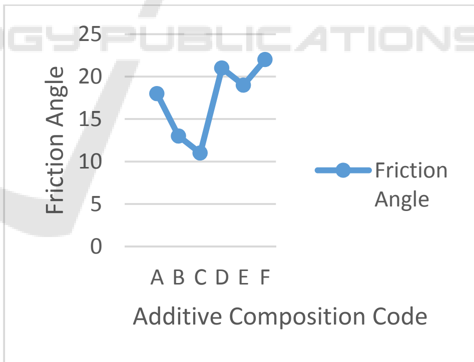

Figure 3: Friction Angle Chart

Figure 3 shows a fluctuation of friction angles. The highest friction angle is code F (increased 22.22% compared to original clay) with the composition of DDC and SS are 1.5% and 5% respectively. SS addition, physically, made clay more sandy, whereas DDC addition made the clay more sticky. The increase of friction angle for stabilized clay improve the soil compactness because SS could change a particle size, makes the soil more heterogeneous, and the cavities are filled. Soil compactness of stabilized clay (code F) can be seen by comparing the γd_{max} value that is higher than the original clay.

Hakam et al (2010) said that in direct shear strength test, the more compact the clay, the higher its friction angle (ϕ), and vice versa. In addition, the higher the clay added, the higher cohesive (c) value but the smaller of its friction angle.

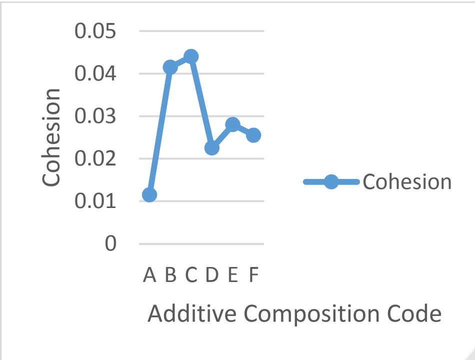

Figure 4: Cohesive Value Chart

Figure 4 shows the change of cohesive value. The highest cohesive value is code C (0% DDC and 2.5%SS) which increased 282.62% from its original value. Large number SS addition (code D and F with 5% addition) affect sandy characteristic of the clay. Therefore, decreasing the cohesive force between particles. The increase of cohesive, significantly showed at clay with only one additive as shown in table 3 (code B and C). However, the addition of DDC and SS still increase the cohesive value and stabilized the original clay.

Maximum shear strength value was found at composition of 1.5% DDC and 5% SS (code F) which improve 32.36% compared to the original clay. It implies that the stabilization through addition of DDC and SS improve the mechanical characteristics.

4 CONCLUSIONS

Clay in Universitas Islam 45 Bekasi has high expansion and bed degradation which does not follow the gradation and uniformity coefficient. This soil is categorized as CH (un-organic clay with high plasticity). Friction angle is increased for clay with 5% silica sand (with or without DDC). But, cohesion value increased for only one additional stabilizer (silica sand or dry dust collector). Best shear strength found at composition of 1.5% DDC and 5% SS (code F). This composition increase the shear strength of 32.26% compared to the original clay. This study concludes that a mix clay with additional DDC and SS has better mechanical characteristics.

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