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The Potential Usage of Bitumen Cold Mix and Tire Chips as Stabilization Material on Clay Soil Strength Characteristics

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ABSTRACT

Clay is a soil with fine particle size less than 0.002 mm, low permeability, cohession, high swelling, and slow consolidation process. Due to that problem it needs some improvement to stabilize the condition of soil before the process of construction conducted. The purpose of this study is to determine the effect of adding shredded tire and cold mix bitumen as the value of shear strength changing are cohession, friction angle, and shear strength with triaxial unconsolidated undrained test. To see the effect of those mixture, this study uses 48 soil samples with 4 variation of shredded tired (0%, 1%, 1,5%, and 2%) and 4 variation of cold mix bitumen (0%, 1%, 2%, dan 3%). The result of this study showed that the adding of shredded tired and cold mix bitumen in soil compositition can increase parameters of soil. The optimum cohession is on variation 1% SB+2% B (T99B2SB1) with the value 0.61 kg/cm^2. Meanwhile the optimum value of friction angle is on variation 1.5% SB+ 1% B (T98.5B1SB1.5) with the value 7.43^o. The shear strength as the sum of cohession and friction angle tends to increase with the optimum value about 0.995 kg/cm^2 in variation 2% bitumen and 1% shredded tire (T99B1SB1). From the study, the adding of shredded tired and cold mix bitumen improve the shear strength. The optimum value of shear strength is on variation 2% B+1% SB (T99B1SB1) with the value 0.995 kg/cm^2. This study shows that stabilization material used in this research can be an alternative material for soil stabilization.

Keywords: *Stabilization; Bitumen; Waste Tire; Tire Chips; Shear Strength*

INTRODUCTION

As the basic layer of construction which functions to support the main element and structural supports, soil strength is a fundamental consideration. If construction is built on problematic soil, it will experience problems. Generally, the geotechnical problem will face the potential risk in scale of moderate to high risk, such as land subsidence to structural failure. If the condition of the basic soil is not immediately addressed, it will affect the feasibility of the infrastructure. Therefore, soil improvement methods as part of the construction planning aspect need to be considered. The right method will make it easier to map risk mitigation.

Soil stabilization as an improvement method has been proven to improve the properties of soil including physical properties and soil behavior [1], [2]. In principal, the process of soil improvement with stabilization is carried out by adding certain additive materials to the base soil or compacting it with mechanical equipment. Additive material can be added in the form of chemical materials or production waste materials. One of the disposal waste factory that can be used as mixed construction material is waste tyre. The use of waste tyre can be the alternative solution of geo – material to manage the environmental issues. Waste tyre that has been exposed create a suitable breeding place for pests and insects and thus poses health risk. Moreover, the increase of tyre sale will represent the growth rate of disposal waste. Based on

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data releases by ETRMA (European Tyre and Rubber Manufacturers Association), the volume of waste tyre generated per year has reached 1.5 billion [3]. This number is expected to increase as the number of vehicles increases worldwide.

The use of waste tires in construction projects has been developed. The characteristics of tyres with light mass, reliable insulation in absorbing heat, high water resistant, as well as high durability and compressibility are some parameters to be explored in the form of fibers or sheets [4]. In road construction, rubber fibers from waste tires are used in asphalt mixtures as a lightweight filler [5] to improve road quality and extend their service life. In application of earthwork, shredded scrap tires are used as a lighweight fill material in embankment. The result of research generally showed that the use of tire shreds as an environmentally acceptable lightweight fill in highway applications of properly confined.

Currently, the concept of sustainability by utilizing recycled and enviromentally friendly materials is often used in stabilization. Apart from waste tire, the substantive material that is often used in road stabilization work is cold mix bitumen. CMA (Cold Mix Asphalt) is believed to be an economical and environmentally friendly alternative stabilization material because the aggregate mixing process is carried out without a heating process. The use of CMA as a stabilization material is generally applied in road construction. In road construction with flexible pavement, CMA is used as the top layer of pavement. Although its application is still limited to rural road construction with relatively low vehicle volumes [6].. However, recent research reveals the potential of CMA in withstanding relatively high traffic loads. Studies show an increase in the stability and durability of road quality by mixing emulsified asphalt with sandy soil types [7]. The results of this study are strengthened by experimental studies conducted by several researchers who studied bitumen as a stabilization reinforcement material [8], [9]. The research results show a tendency that the addition of bitumen to coarse-grained soil increases the shear strength of the soil and reduces soil permeability.

To study how the shear strength of the soil performs if those materials are mixed with clay soil, research was carried out. Research was carried out on a laboratory scale to evaluate the shear strength of soil at different mixture proportions. Soil shear strength parameters were obtained through triaxial testing on mixed soil samples. It is hoped that the results of the study will become a basis for consideration for relevant stakeholders in utilizing waste tires and cold mix bitumen as construction materials.

MATERIALS AND METHODS

Preparation of Sample and Test Specimen

The method proposed in this research is a laboratory experiment. Clay soil samples were taken with disturbed sampling technique using a conventional digging tool. Furthermore, the stabilization material used as mixture is tyre chip in length of 100 mm x 100 mm. To uniformize the size after cutting, the tyre chip are graded using a No. 10 sieve. The chip that pass through the No. 10 sieve will be used for mixture. Emulsified cold mix bitumen is also added to the composition of the stabilization mixture. The variations in the composition of the mixture used to make the test specimens are 0%, 1%, 1.5%, and 2% respectively for variations in tyre chip while 0%, 1%, 2%, and 3% for variations in the addition of cold bitumen. mix to the dry weight of the soil.

Laboratory Testing

After the soil samples and mixture has been prepared, then the laboratory testing is carried out. Laboratory testing includes soil properties and soil mechanics to determine the characteristics of soil types including soil shear strength. In mechanical testing, Triaxial UU (Unconsolidated Undrained) testing was carried out on 48 test specimen. Each specimen consists of 3 samples for 16 variations of mixture composition shown in Table 1.

Tabel 1. Variations in test specimen

Test Code	Weight percentage (%)			Number of Test Specimen
	Clay soil (T)	Cold Mix Bitumen (B)	Tyre Chip (SB)	
T100B0SB0	100	0	0	3
T100B1SB0	100	1	0	3
T100B2SB0	100	2	0	3
T100B3SB0	100	3	0	3
T99B0SB1	99	0	1	3
T99B1SB1	99	1	1	3
T99B2SB1	99	2	1	3
T99B3SB1	99	3	1	3
T98,5B0SB1,5	98,5	0	1,5	3
T98,5B1SB1,5	98,5	1	1,5	3
T98,5B2SB1,5	98,5	2	1,5	3
T98,5B3SB1,5	98,5	3	1,5	3
T98B0SB2	98	0	2	3
T98B1SB2	98	1	2	3
T98B2SB2	98	2	2	3
T98B3SB2	98	3	2	3
Total Number of Test Specimen				48

Testing Procedure

In soil stabilization process, the initial stage carried out before mixing variations is drying the soil. Soil drying is done using the dry air technique under sunlight. Then after drying, the soil sample will be ground and sieved using sieve No 4. To ensure that all test specimen meet the required optimum water content, a Standard Proctor Test is carried out. The procedure refers to ASTM D – 698 2006 and AASHTO Test Designation T – 99 1982. The compaction test result will be plotted into curve then the optimum water content and maximum dry weight can be obtained. After the sample has been conditioned respectively to its optimum water content, the soil is mixed with tyre chip and bitumen as its variation. The mixture is then stored in a bag and left ± 16 hours. Next, the test specimen is molded and ready to be tested. The procedure of Triaxial UU refers to the ASTM D – 2850 – 95.

In Triaxial UU, the results of stress – strain on the test specimen will be process in the form of graphs and Mohr Circle. From the test results, shear strength parameters will be obtained, namely cohesion, c and internal friction angle, θ for each mixture variation.

RESULTS AND DISCUSSION

Physical Properties of Clay Soil

From the result of soil properties testing, the soil samples used can be classified into the CL (Clay) and A – 7 – 6. This classification is based on USCS (Unified Soil Classification System) and AASHTO (American and Transportation Officials Classfication). The recapitulation of thus properties can be seen in Table 2.

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Tabel 2. Physical properties of clay

Parameter	Notation	Unit	The Result
Water content	w	%	24,45
Liquid limit	LL	%	46,80
Plastic limit	PL	%	23,88
Index Plasticity	IP	%	22,92
Optimum water content	w_{opt}	%	26
Maximum dry unit weight	γ_d	gr/cm3	1,564
Specific gravity	G_s		2,64

Triaxial Testing on Natural Soil

In the research, triaxial testing on natural soil was carried out to determine the shear strength parameters of soil before stabilization. Based on these results, the cohesion (c) and friction angle (ϕ) values obtained for natural soil were 0.39 kg/cm2 and 1.83°, respectively. Using the soil shear strength equation, the shear resistance value can also be calculated as 0.4667 kg/cm^2. The test results that have been obtained is being a reference for comparing changes in shear strength parameter values after stabilization

The Effect of Adding Tire Chip and Cold Mix Bitumen on Soil Cohesion

The test result of adding the mixture variaton on changes in cohesion values and friction angles can be seen in Table 3. From the test result of Triaxial UU below, the addition of waste tires and cold mix bitumen on soil shows the increment of soil strength. The T99B2SB1 mixture composition with 2% bitumen and 1% tire chip shows the highest cohesion value around 0.61 kg/cm^2 when compared to other mixture compositions. Meanwhile, the lowest cohesion value was shown in the percentage of 3% bitumen and 0% tire chips (T100B3SB0) with a cohesion value of 0,25 kg/cm^2. This test result could be depicted in the graph shown in Figure 1.

Table 3. The value of cohesion and friction angle on the mixture composition

Mixture composition	Cohesion	Friction Angle
T100B0SB0	0,39	1,83
T99B0SB1	0,56	2,88
T98,5B0SB1,5	0,58	6,07
T98B0SB2	0,59	7,13
T100B1SB0	0,42	2,83
T99B1SB1	0,26	7,17
T98,5B1SB1,5	0,36	7,43
T98B1SB2	0,43	2,52
T100B2SB0	0,42	4,38
T99B2SB1	0,61	4,19
T98,5B2SB1,5	0,41	4,72
T98B2SB2	0,46	4,82
T100B3SB0	0,25	4,91
T99B3SB1	0,41	5,38
T98,5B3SB1,5	0,46	2,78
T98B3SB2	0,37	1,61

The effect of adding tire chips and bitumen on soil does not always show a linear relation. The addition of bitumen material up to 3% and tire chips up to 2% causes the increment of soil cohesion. When the stabilization material has reached the optimum composition level, the addition of material with a higher content tends to reduce the cohesion value. This is because the mixture of soil and emulsified bitumen becomes more fluid. The more bitumen can cause the loss of soil strength due to the lubricating effect of the particles so that the interlocking between the particles becomes hampered.

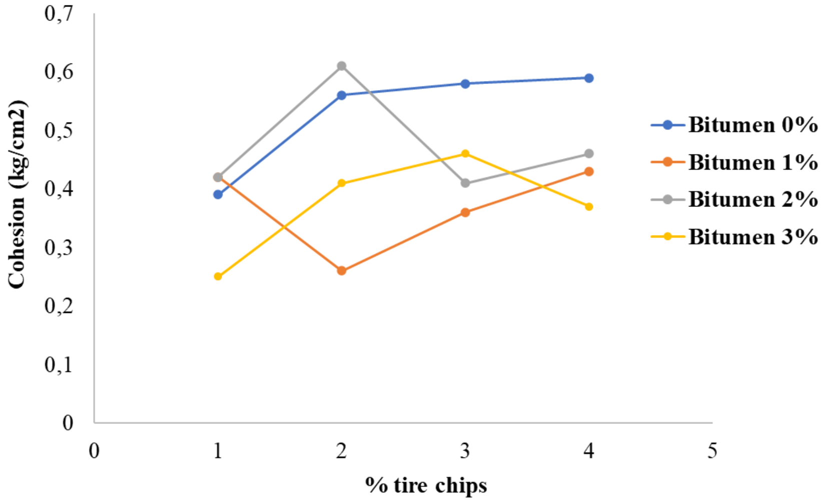

Figure 1. Figure 2. Relationship between tire chips and Cold Mix Bitumen on Soil Cohesion

The Effect of Adding Tire Chips and Cold Mix Bitumen on Soil Friction Angles

In terms of internal friction angle, changes in values for each mixture composition can be seen in Figure 2.

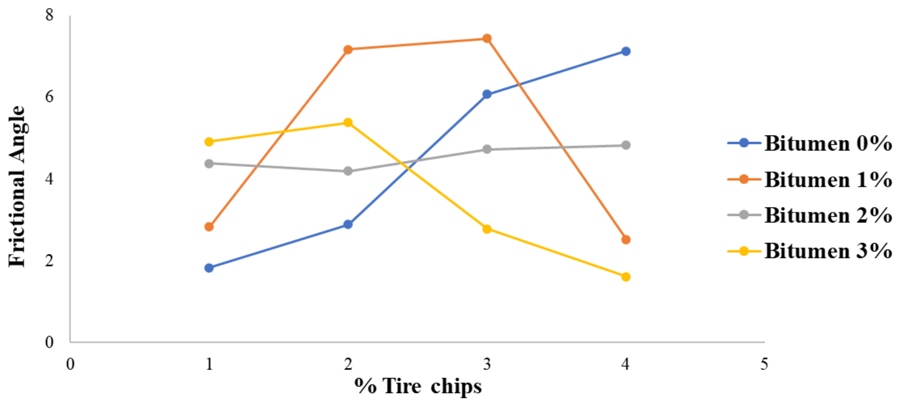

Figure 3. Relationship between tire chips and bitumen to frictional angle

For soil without the addition of cold mix bitumen, the soil friction angle value tends to increase due to the addition of tire chips up to 2% of the total weight of the soil. The higest frictional angle due to the addition of 2% tire chips is 7.13^{o} and the lowest friction angle value without the addition of tire chips is 1.83^{o}. The addition of 3% bitumen to soil mixture at higher level of tire chips tends to reduce the friction angle value**.** It occurs because soil with high bitumen content has maximum dry density due to good adhesion between soil particles. This condition will certainly increase the value of the soil friction angle. However, even though bitumen acts as an adhesive in the mixture, if adding tire chips in high content it actually reduces the value of the friction angle. This is because when tire chips and bitumen are added continuously, the possibility of the fibers to get contact with each other increases. This condition will reduce friction between soil grain.

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The Effect of Adding Tire Chips and Cold Mix Bitumen on Soil Shear Strength

From Triaxial UU testing, the soil shear strength paramaters are obtained. Based on the anaylsis, the shear strength value of the soil changes due to the addition of tire chips and bitumen at different mixture content as shown in Figure 3.

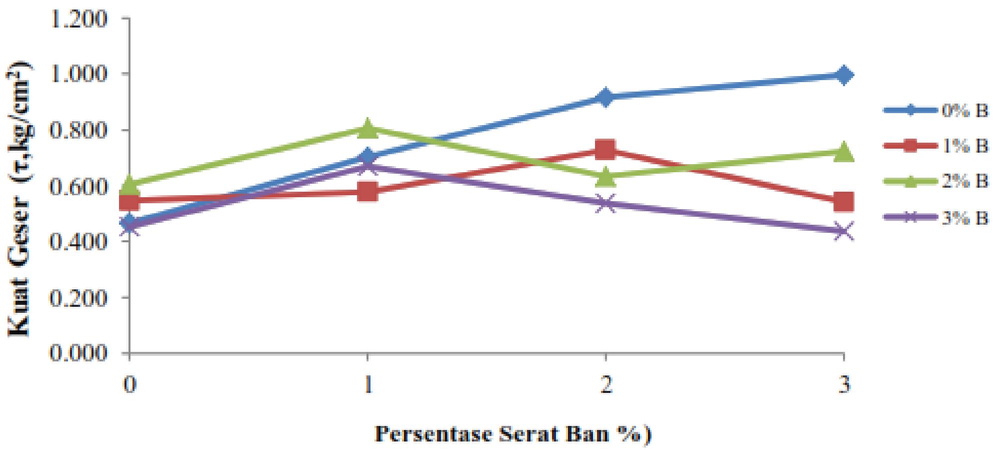

Figure 4. Relationship of shear strength due to tire chips addition

In Figure 3, it can be seen that there is a change in the shear strength value of the soil before and after adding stabilizing material in the form of bitumen and tire chips. The highest increment in shear strength was at a percentage of 2% bitumen and 1% tire chips. However, the shear strength value tends to decrease if the higher variation of mixture is added. By mixing soil with higher composition of tire chips, it will increase the porosity of the soil. Due to the porous, the bond between soil aggregate is at a low degree of locking. Although the addition of asphalt to the mixture can increase soil density through the mechanism of filling pores. However, when two stabilizing materials are added, the optimum mixture composition is difficult to determine.

In the research, the increase in shear strength with the addition of stabilization material is influenced by the void number. Soil pores filled by uniform tire chips at high composition and the adhesion between soil aggregate with a high percentage of bitumen actually increases the number of pores. The greater the pore number, the smaller the relative density, resulting in lower soil shear strength.

CONCLUSION

Based on the test results obtained, it can be concluded that the addition of cold mix bitumen and tire chips can be used as alternative stabilization materials. The addition of bitumen and tire chips in the composition of the soil mixture has the effect of increasing the soil shear strength parameters, both in the cohesion value (c) and the internal friction angle (ϕ). The maximum soil cohesion value occurs at a percentage of 1% addition of tire chips and 2% bitumen (T99B2SB1) with a cohesion value (c) of 0.61 kg/cm^2. The maximum friction angle value (ϕ) occurs when adding 1.5% tire chips and 1% bitumen (T98.5B1SB1.5) with a value of 7.43^o. Based on the results of research that has been carried out, it was found that the addition of bitumen and tire chips can increase the value of soil shear strength (τ). The optimum value of soil shear strength (τ) is at a percentage of 2% bitumen and 1% tire chips.

Further research on varying mixture compositions needs to be carried out to determine optimum conditions to obtain high shear strength values. For further research, it is recommended to use the percentage of both mixture at smaller intervals, 0.25% - 0.5% . Smaller intervals are intended to obtain more accurate research results. Apart from that, the pattern of tire fiber cuts can also be varied in further research with the form of irregular pieces or rubber powder.

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