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## Experimental Study of Addition of Plastic Waste (PET) to the Shear Strength of Clay Soil

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### ABSTRACT

Soil is a very important element in the success of a development project and is part of the foundation used. Therefore, stable soil is needed to obtain the required soil bearing capacity. Such as clay has the characteristics of low bearing capacity and large shrinkage. This study aims to determine the increase in the value of the shear strength of clay with the stabilization of PET plastic waste. The purpose of this study is to see the value of the shear strength of clay with variations in the amount of plastic waste 0%, 3.5%, 4%, and 4.5%. Method used is SNI 3420:2016 for the shear strength test. As a result, the addition of shredded plastic waste can increase the value of the shear strength of the soil. The value of shear strength increased at the percentage of plastic addition of 3.5% of 0.5663 kg/cm<sup>2</sup> in the original soil test, the value of shear strength was 0.5271 kg/cm<sup>2</sup>, an increase of 7.43%. The conclusion is that there is an increase in the value of the shear strength of the soil stabilized by plastic waste at a variation of 3.5% of plastic waste, an increase of 7.43%.



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## 1. Introduction

Soil is a very important element that will affect the success of a construction project and is part of the foundation used in construction [1]. Therefore, stable soil is needed to obtain the required soil bearing capacity. Clay soil has the characteristics of low bearing capacity and high shrinkage expansion, thus making clay soil less suitable for use in construction such as for road subgrades. Road construction is very important to note because it serves to support the load on it [2]. The physical properties of clay generally lie between those of sand and clay. Clay soil is defined as soil that has smaller particles from 0.002 mm to 0.005 mm [3].

Clay soil is a type of soft soil that has cohesive soil characteristics and has a larger specific surface area, larger number of pores, and lower permeability than coarse-grained soils. High shrinkage properties are also characteristics of clay soils. Sifat kembang susut ini terjadi akibat perubahan nilai kadar air. This shrinkage factor can interfere with the strength of construction, so that it can cause physical damage, such as in road construction, it can cause damage to the pavement layer such as cracks and bumps [1].

Garbage is one of the environmental problems that occur in Indonesia, which causes environmental pollution and public health. Waste production itself is closely related to population growth which tends to increase every year [4]. Data from the Central Statistics Agency (BPS) in 2021 states that plastic waste in Indonesia reaches 66 million tons per year. Plastic is a type of long chain polymer atoms that are bonded to each other to form many repeating molecular units or monomers. Plastik terdiri dari polimer karbon saja atau juga dengan oksigen, nitrogen, klorin, atau belerang. The plastic itself has several advantages compared to other materials, namely strong and easy to form, anti-rust, resistant to chemicals, has high electrical insulating properties, and has lower processing costs. Behind the advantages of plastic, there are also disadvantages, which are difficult to recycle and dangerous to health if not used properly [5].

This research was conducted to reduce the amount of plastic waste that is difficult to decompose naturally and some that cannot be recycled, such as waste mineral water containers/plastic bottles so that later it can pollute the environment the waste. Selain itu, langkah ini merupakan upaya untuk perbaikan tanah untuk menjadi bahan stabilisasi pada tanah yang memiliki daya dukung rendah. So it is necessary to handle the problems that occur in plastic waste, namely by mixing PET (Polyethylene Terephthalate) plastic waste with clay to increase the carrying capacity of the soil.

### a. Clay

Clay will be plastic when mixed with water. This happens because the clay has mineral particles and is classified as clay. This clay when it has a moderate water content will be plastic and will be hard when in dry conditions [6]. High plasticity clay has a fine grain size so it has a low bearing capacity [7]. Clay soil contains water which is large in wet conditions, so that in this condition, clay soil has very low ability in support the load on it [8].

Clay soils that contain more montmorillonite than others will have expansive properties that damage the construction of roads or other buildings built on the soil [9]. The swelling pressure (swell pressure) occurs in clay (clay) due to there being a sufficient amount of water inside it. even if you have pressure expands which is quite large, but the power support the soil against the structure being built above it is very low [10].

### b. Soil Stabilization

Soil stabilization is an effort to change or improve the technical properties of the soil in order to meet certain technical requirements existing conditions, stabilization efforts are needed to improvement of the bearing capacity of peat soil. Stabilization on peat soil will be carried out chemically using soil organic and lime as stabilizing agent [11]. An alternative to improving soil properties by adding something on the land so that increase the carrying capacity of the soil is using soil stabilization [12]. There are several methods of soil stabilization in the laboratory,

namely stabilization with lime, stabilization with cement, stabilization with fly ash, etc [13]. Soil stability is an effort to increase the stability and carrying capacity of the soil. When the ground in the field is loose or very easily depressed, or when has a consistency index that is not suitable, the permeability is too high, or the other unwanted so not suitable for a development project, soil stabilization must be done [14]. Soil stabilization is one way to handle less subgrade good. Soil stabilization can be done by compacting or mixing other ingredients (additives) that can improve soil properties [1].

c. Plastic waste

PET is commonly referred to as Polyethylene Terephthalate and is produced from petroleum, through the reaction between ethylene glycol and Terephthalic acid. Due to its excellent wear, low balance, and high flexible modulus, it is considered a good additive for soil stabilization to improve soil properties [15]. Polyethylene Terephthalate is a resin thermoplastic plastic polymer of the group polyester. PET is widely produced in the chemical industry and used in fiber synthesis, beverage bottles and food containers, thermoforming applications, and combined with glass fibers in engineering resins. PET is one of the raw materials most important in textile crafts [5]. Soil stabilization is one way to handle less subgrade goods. Soil stabilization can be done by compacting or mixing other ingredients (additives) that can improve soil properties [16].

d. Shear strength

The strength of the embankment soil is determined by its mechanical properties, namely the inner angle of friction and cohesion (c). Soil friction is affected by the size, shape, and texture of the soil Coarse particles, are contributed mainly by the sand type of soil. Cohesion (c), which is provided by cohesive soil or fine particles, is the force that holds molecules or similar particles in it a land. Soil cohesion is affected by the distance between the molecules and the particle size distribution, moisture content, and pore water pressure. Percentage of cohesive (clay) and soil (sand) without cohesion in the soil mass, therefore, regulates the strength of the soil [17].

Shear strength or precisely this shear resistance needs to be known for analysis soil stability. Shear strength of a soil mass is the internal resistance of the land to the broad unity of the or displacement along the shear plane in the soil in question [18].

## 2. Research Method

This research is research using the direct shear test method. The place of sample testing will be carried out at the Soil Mechanics Laboratory, Faculty of Civil Engineering, Lancang Kuning University. The material used in this study is clay taken from the research location, namely Jalan Gunung Sari, Rumbai District, and Pekanbaru. The soil taken is disturbed soil which is excavated using a hoe which is then put into a sack. The soil is dried by drying it in the sun to dry. Meanwhile, the undisturbed land was taken using a hand bore. The second material is plastic waste, the plastic waste used is a type of PET obtained from landfills, the plastic waste is chopped with a size of 1 x 1 cm. with a mixture percentage of 0%, 3.5%, 4%, 4.5% of the weight of the soil. Soil samples will be tested for soil properties index to determine soil characteristics in the form of water content test, liquid limit test, plastic limit test, specific gravity test, and compaction test. The parameters used to increase the bearing capacity of the soil are shear strength, shear strength of the soil can be known by direct shear testing, to determine the cohesion value (c) and shear angle ( $\phi$ ) of the soil.

Here is a picture of the research location.



Source : Google Map 2017

**Figure 1.** Laboratory Research Locations

## Description and Technical

### 1. Population and Samples

Clay soil is soil that has certain mineral particles that can produce plastic properties that can occur in the soil if: mixed with air. Clay soil has the properties low permeability, less fine grain size of 0.002 mm, is highly cohesive, increases capillary water high, high shrinkage properties, and process slow consolidation [2]. Clay soil was taken from the research location, namely Jalan Gunung Sari, District Rumbai, Pekanbaru. The plastic waste used is a type of PET obtained from a landfill, the plastic waste is chopped with a size of 1 x 1 cm. Method used is SNI 3420:2016 for the shear strength test. The shear strength of the soil is the resistance force carried out by the grains of soil against pressure or pull. Based on this understanding, if the land experiencing the burden will be detained [19]:

- a. Soil cohesion depends on soil type and density, but not from tension normal acting on the shear plane.
- b. Friction between large grains of soil directly proportional to the normal stress at sliding field.

### 2. Sampling Techniques

The soil taken is disturbed soil which is excavated using a hoe which is then put into a sack. The soil is dried by drying it in the sun to dry. While the undisturbed land is taken using a hand bore. the plastic waste used is a type of PET obtained from landfills, the plastic waste is chopped with a size of 1 x 1 cm. with a mixture percentage of 0%, 3.5%, 4%, 4.5% of the weight of the soil.

### 3. Definition of Variable Operations

Soil samples will be tested for soil properties index to determine soil characteristics in the form of water content test, liquid limit test, plastic limit test, specific gravity test, and compaction test.

### 4. Instrument Analysis Tool

#### a. Soil property testing

The physical properties of the soil are the original state of the soil the land whose value will later be used for determine the type of soil. Soil properties index test to

determine soil characteristics in the form of water content test, liquid limit test, plastic limit test, specific gravity test, and compaction test. The parameters used to increase the bearing capacity of the soil are shear strength, shear strength of the soil can be known by direct shear testing, to determine the cohesion value (c) and shear angle (o) of the soil.

5. Data Analysis Techniques

The research methodology in this study is based on a laboratory approach, namely by conducting tests to obtain data. The collected data is then processed by performing calculations using the formula from the data from the tests carried out in the laboratory with the following provisions:

- a. For testing the water content using the SNI 1965-2008 standard.  
Is the ratio between the weight of water (Ww) with a solid grain weight (Wd) whose value is expressed in percent. The value of this water content very affects the behavior of the soil, especially during development [20].
- b. To test the sieve analysis using the standard SNI 3423-2008.  
The size of the soil particles differs from one soil type to another depending on the type of soil. Getting the value of the grain size of the soil, is done by testing the sieve analysis [21].
- c. For testing the specific gravity of the standard SNI 1964 – 2008.  
The specific gravity of soil is the ratio between the density of soil grains and the density of distilled water at a temperature and the same volume [22].
- d. For soil compaction testing using the standard SNI 1742-2008.  
Soil compaction in the laboratory is intended to determine the optimum moisture content and maximum dry density. This maximum moisture content and density can be used for determine the conditions that must be achieved in soil compaction work in the field [23].
- e. For the shear strength testing using the standard SNI 3420:2016.  
Shear resistance or commonly referred to as shear strength in the soil is very important to know for soil stability. The shear strength that occurs in a soil mass is the internal resistance of the soil per unit area to failure or displacement that occurs along the shear plane in the soil [24].

3. Results and Discussions

3.1 Soil Classification Test

After testing the original soil water content, the following results were obtained:

**Table 1.** Water Content Test

Sample Number		1	2	3
Cup Weight	(W1) Gr	11,44	11,43	11,43
Grail Weight + Wet Soil	(W2) Gr	44,71	47,60	48,77
Cup Weight + Dry Soil	(W3) Gr	38,46	40,33	41,31
Weight / Mass of Water	(Gr)	6,25	7,27	7,46
Dry Soil Weight / Mass	(Gr)	27,02	28,90	29,88
Water content	(%)	23,13	25,16	24,97
Average Water Content	(%)		24,42	

Source: Data analysis (2022)



In this test, the original soil moisture content value was 23.11%, the second experiment was 25.16%, and the third experiment was 24.97%. And obtained an average water content of 24.42%.

**Table 2.** Specific gravity test results

Number Pycnometer / Volumetric Flask	1	2	3
Dish Berat Weight	174,0	174,0	174,0
Dish Weight + Dry Soil	224,0	224,0	224,0
Dry Soil Weight (Ws)	50	50	50
Temperature T C (°C)	24,00	24,00	24,00
Relationship of Relative Density of Water (Table)	0,99732	0,99732	0,99732
Weight of Pumpkin + Water (At Temperature T C) W1 (Gr)	662,00	662,00	662,00
Weight of Pumpkin + Water + Soil (At Temperature T C) W2 (Gr)	692,78	692,78	692,78
Soil Fill (Cm3)	19,220	19,220	19,220
Density (Gs) Ws/Soil Content*Hub	2,59	2,66	2,57
Average Density (Gs mean)	2,607		

Source: data analysis (2022)

Based on the results of the soil density test above, the average soil density was 2,607. Based on table 2. the original soil in this study includes organic clay because the value of the specific gravity of the soil is included. into the range 2.58 – 2.65 [19]

**Table 3.** The results of testing the limits of the atterberg

	Liquid Limit (LL)			Plastic Limit (PL)		
	1	2	3	1	2	3
Lots of Hits	15	28	32	15	28	32
Cup Number	1	2	3	1	2	3
Cup Weight	11,44	11,43	11,43	9,16	11,3	11,32
Grail Weight + Wet Soil	45,74	33,44	52,41	16,42	17,63	18,3
Cup Weight + Dry Soil	33,8	25,02	37,64	14,29	15,67	16,31
Water Weight	11,94	8,42	14,77	2,13	1,96	1,99
Dry Soil Weight	22,36	13,59	26,21	5,13	4,37	4,99
Water content	53,4	61,96	56,35	41,52	44,85	39,88
Average Water Content	57,24			42,08		
Plasticity Index (%)	15,15					

Source: data analysis (2022)

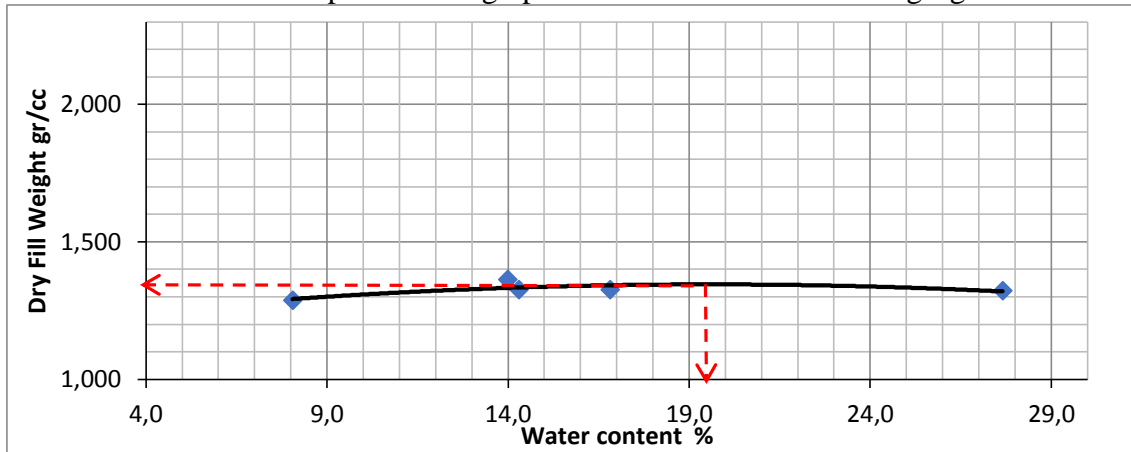
Based on the test results of the original soil atterberg limits, the liquid limit value is 57.24% and the plastic limit is 42.08% and the plasticity index value is 15.15%. The soil in this study belongs to the type of silty clay because the plasticity index value obtained in this test is between the plasticity index range of 7% - 17% [19].

**Table 4.** Compaction test results

Ingredient	Optimum Moisture Content (%)	Dry Density (gr/cm <sup>3</sup> )
Clay	19,3%	1,350

Source: data analysis (2022)

The compaction test graph can be seen in the following figure



Source: data analysis (2022)

**Figure 2.** Compaction test results graph

From the results of the compaction test, the optimum water content value was 19.3%, and the dry density was 1.350 g/cm. This optimum water content will be used as a soil mixer with plastic waste.

### 3.2 Shear Strength Test

The results of the shear strength test are shown in the following table.

**Table 5.** Shear Strength Test Results

No	Plastic grade (%)	Cohesi (C) (kg/cm <sup>2</sup> )	Sliding angle °	Direct Slide Strong (S)
1	0	0,1418	31,78	0,5271
2	3,5	0,1554	33,45	0,5663
3	4	0,1244	29,9	0,4820
4	4,5	0,1185	28,73	0,4594

Source: data analysis (2022)

The results of the shear strength test with the addition of chopped plastic waste can increase the value of the shear strength of the soil. This happens because the sharpness of the plastic pieces will increase the friction between the soil grains [16]. The highest value is in the variation of 3.5% of plastic waste. The increasing variation in the percentage of shredded plastic waste resulted in a decrease in the value of shear strength, namely the value of cohesion and shear angle. Because if the percentage of the mixture is too much, it will make it slippery and reduce the contact area of the clay grains with the clay [25].

## 4. Conclusion and Suggestion

### 4.1 Conclusion

From the results of research conducted, using plastic waste as a clay soil stability material, it can be concluded that there is an increase in the value of the shear strength of the soil stabilized by plastic waste at a variation of 3.5% of plastic waste, an increase of 7.43%.

### 4.2 Suggestion

Some of the suggestions put forward in connection with this research are as follows:

1. It is hoped that further research will be carried out for different mixture variations.
2. For further research, the size of the plastic pieces should be reduced so that the printing process of the test object is easier.

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