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Abstract. Soil has a significant impact on construction, so it must fulfill the specified requirement. Problems are often found in certain soils, such as soft clay, due to the low bearing capacity and the high consolidation settlements. One method that can be applied to improve these properties is with additional materials into the soil as reinforcement. This study used coir fiber waste as an additional material because it has a high tensile strength value. The test carried out is a one-dimensional consolidation test to analyze the effect of coir fiber content on the consolidation settlement parameters, namely the coefficient of consolidation (Cv) and the compression index (Cc). The variation of fiber content is determined at 0%; 0.25%; 0.50%; 0.75%; 1.00%; and 1.25% by weight of the mixture. Based on the test results, the addition of coir fiber decreased the Cc value and increased the Cv value. The clay without coir fiber has a Cc of 0.543, while clay with added 1.25% fiber content has a Cc of 0.332 (decreased 38.9%).

INTRODUCTION

Indonesia has more than 10% area or about 20 million hectares of soft soils. The soft soil consists of soft clay and peat [1]. Soft clay has clay mineral content and high water content so that the shear strength of the soil is low. Soft clay also has a high soil degradation value, causing the bearing capacity of the soil to be low and the compression to be high [2]. If the soft soil is not stabilized, it can damage the structure above it before reaching the design life of the construction.

One of the stabilization methods is to strengthen the soil by inserting a strong and sturdy material to increase the bearing capacity and stability. At the same time, the settlement and lateral deformation are reduced. Waste coir fiber is expected to be an alternative reinforcement material because this natural material is lightweight and can be obtained in large quantities at low prices [3]. Coir fiber has a high lignin and cellulose content, making it strong and durable compared to other natural fibers [4]. The high lignin content makes coir fiber resistant to microbes damage and salinity, so the slow degradation process among other natural fibers [2]. Due to its high cellulose content, coir retains its tensile strength when wet. Compared to synthetic fibers, coir fibers are more elastic and have a higher coefficient of friction than synthetic fibers [5].

Research conducted using waste coir fiber has increased the soil's bearing capacity [6-8]. Peter et al., Suffri et al., and Widianti et al. [9-11] have studied the effect of coir fiber on shear strength, while Anggraini et al. and Menezes et al. [12-13] have focused on exploring its tensile strength. Fiber added to the soil at a certain content will increase and interlocking between the two. Fibers with high tensile strength will help resist when the soil grains move horizontally [14].

There has not been much research on compressibility in coir fiber-reinforced soil. Kar and Pradhan [15] reviewed the consolidation of cohesive soil added with coir fibers. The results showed the compression index (Cc) value and the coefficient of volume change decreased when the fiber content in the soil increased, whereas the

coefficient of consolidation (Cv) increased. The optimum fiber content to achieve maximum strength is 0.8% of the dry weight of the soil. Lawer and Bello [16] conducted research using various contents of coir fiber. The test results showed that the compression index decreased with increasing fiber content and reached the optimum value at 0.6% fiber content. Jeludin et al. [17] compared the addition of crushed coir fiber and coir fiber of varying lengths on intermediate plasticity clay. Soil samples reinforced with coir fiber with a 20 mm length of as much as 1% gave the most significant effect on compressibility behavior.

This research focuses on the consolidation settlement parameters of stabilized clay soil using a coir fiber waste with 1 cm to 3 cm lengths. The selection of coir fiber as a stabilizer in this study is an effort to utilize coir fiber waste as a structural material. It is expected that the economic value of coir fiber waste can increase.

MATERIALS AND METHOD

Soil

The soil used in this study is clay from Sentolo, Kulon Progo, Yogyakarta, Indonesia. Clay is obtained in lumps, then crushed, and must be passed through sieve number 40. The soil is then put in an oven at a temperature of 105-110^{O}C to remove the water content. In previous study, the physical and mechanical properties of the soil were tested by Widianti et al. [11]. The results of the study can be seen in Table 1.

TABLE 1. The physical and mechanical properties of the soil samples [11]

Parameters	Method Standard	Values
Specific Gravity, Gs	ASTM-D854-10	2.63
Consistency limits:		
Liquid Limit, LL (%)	ASTM-D4318-10	89.91
Plastic Limit, PL (%)		38.86
Shrinkage Limit, SL (%)		16.33
Plasticity Index, PI (%)		51.05
Particle sizes distribution:		
Sand (%)	ASTM-D422-63	13.36
Silt (%)	ASTM-D6913-04	70.58
Clay (%)		16.06
Proctor standard compaction:		
Maximum Dry Density, MDD (kN/m^3)	ASTM-D698-10	12.64
Optimum Moisture Content, OMC (%)		29.90
Soil Classification (USCS)	ASTM-D2487-11	CH

Coir Fiber

Coconut coir is mostly obtained from the traditional markets. The coir fibers are separated from the coconut husk and dried in the sun. Data on the tensile strength of coir fibers derived from previous studies are presented in Table 2. The fibers are cut into pieces with 1 cm to 3 cm lengths.

Mix design

The coir fiber content variations used were 0%, 0.25%, 0.50%, 0.75%, 1.00%, and 1.25% of the mixture's total weight. The coir fibers were mixed randomly into the soil until homogeneous and compacted at the clay's maximum dry density and optimum moisture content.

TABLE 2. Tensile strength of coir fibers [11]

Sample	Length (mm)	Diameter (mm)	Tensile strength (MPa)
1	100	0.28	92.20
2	100	0.28	72.50
3	100	0.21	110.36
4	100	0.23	143.39
5	100	0.32	107.41
6	100	0.21	121.86
		Average	107.95

Testing procedures

The test carried out was a one-dimensional consolidation using an Oedometer with loads of 34.7 kPa, 69.4 kPa, 138.8 kPa, and 277.6 kPa. The testing standard used was ASTM D2435/D2435M–11 [18]. The sample used a ring mold with 2 cm height and 6 cm diameter. Consolidation testing and the specimen can be seen in Figure 1.

(a) (b)

FIGURE 1. (a) Consolidation testing (b) the specimen

RESULTS AND DISCUSSION

The relationship between pressure and void ratio

The relationship between load and deformation for clay is generally represented in terms of the pressure-void ratio. The graph of the relationship between pressure and the void ratio is shown in Figure 2.

Figure 2 depicts that the sample without coir fiber has a fairly sharp drop curve. The soil sample with 1.25% coir fiber content has a curve that is not too sharp at the decrease in the value of the void ratio that occurs. The more coir fiber content is added, the more gentle the slope of the graph, meaning that the decrease in the value of the void ratio is getting smaller. Figure 2 also shows that the sample without coir fibers experienced a change in the value of the void ratio, which tended to be high along with the addition of pressure. The void value is 1.62 at a pressure of 34.7 kPa and decreases to 1.13 at 277.6 kPa (a percentage decrease of 30.2%). The sample with 1.25% coir fiber content

had a void value of 1.35 at a pressure of 34.7 kPa, then decreased to 1.05 at 277.6 kPa (a percentage decrease of 22.2%). At each addition of certain coir fiber content into the soil, the difference in the reduction of the void ratio value decreases with the addition of pressure.

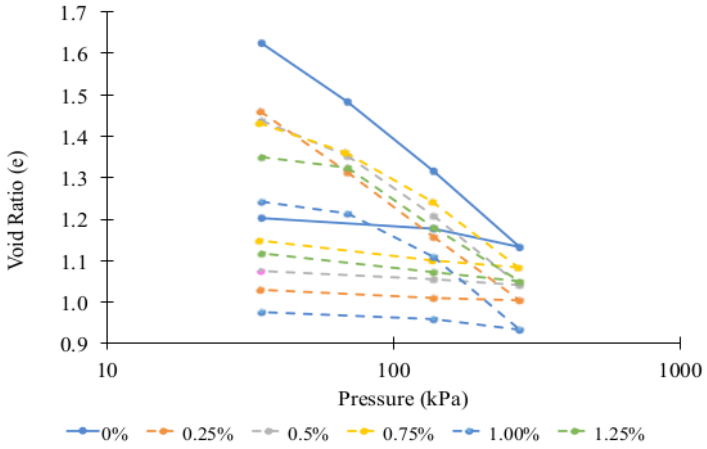

FIGURE 2. Relationship between pressure and void ratio

The effect of coir fiber on compression index (Cc)

The compression index (Cc) is the value of the ratio between changes in void ratio and changes in pressure, which is obtained from the pressure-void ratio curve. The compression index value can be seen in Figure 3. The sample without the addition of coir fiber has a compression index value of 0.543. This value tends to decrease along with the increase in coir fiber content added to the soil. In the sample with a fiber content of 1.25%, the compression index value becomes 0.332 (a percentage decrease of 38.9%). This condition occurs because axial loads shift the soil grains vertically and horizontally. Friction between grains will resist the shift, but soft clay has no coefficient of friction. The fibers in the soil will provide tensile resistance to the displacement of the soil grains. In addition, the friction between the fibers and the soil grains will help to resist the soil grains' movement so that soil compression is reduced.

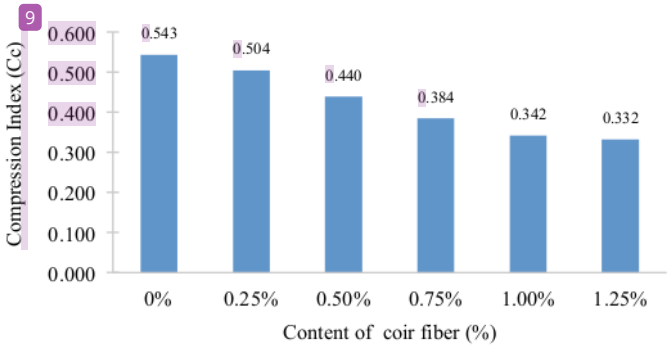

FIGURE 3. Effect of coir fiber content on the compression index

The effect of coir fiber on the coefficient of consolidation (Cv)

The coefficient of consolidation (Cv) is a coefficient that describes the speed of the consolidation process in a soil sample. The greater the value of this coefficient, the faster the consolidation process occurs. The coefficient of consolidation was obtained from the root of time-the cumulative settlement graph at each pressure and fiber content. The summary of Cv values is shown in Figure 4.

Figure 4 depicts that the consolidation coefficient (Cv) value increases with the increase in coir fiber content used at each loading. For example, at a loading of 34.7 kPa, the sample without the addition of coir fibers has a Cv value of 0.97 x 10^{-3} cm^2/s. The soil sample with a fiber content of 1.25% has a Cv value of 2.71 x 10^{-3} cm^2/s. (an increase of 179,4% from the sample without fiber content). This increase in value is due to the fiber filling the soil. The increase in the coefficient of consolidation's value can be caused by the coir fiber content that fills the soil voids. Soil takes longer to pass the existing water. The consolidation rate will increase when the fiber is introduced into the soil. The Cv tends to increase and reduce the time needed to achieve primary consolidation (t_{90}) [17].

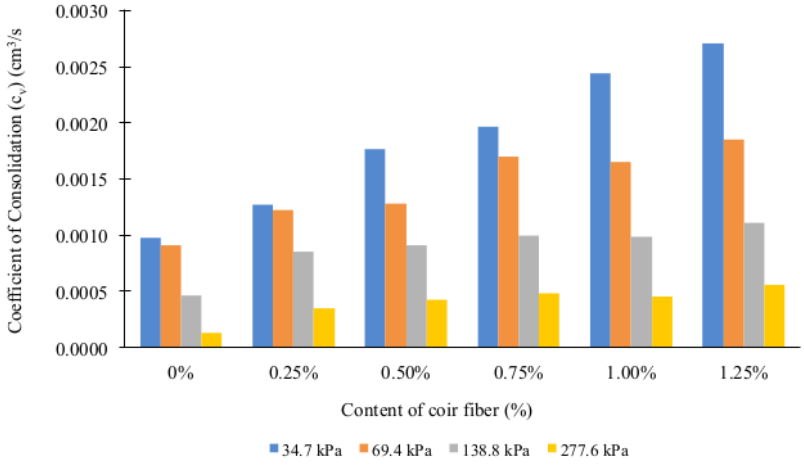

FIGURE 4. Effect of coir fiber on the coefficient of consolidation

CONCLUSIONS

Based on the test results obtained, the conclusions obtained are as follows.

1. The higher the coir fiber content, the lower the void ratio value. The void ratio value in the soil reinforced with coir fiber will decrease with the increase in the applied pressure.
2. The higher coir fiber content inserted into the soil, the lower the compression index value produced. Clay without the addition of coir fiber has a Cc of 0.543. Clay with the addition of 1.25% fiber content, Cc value 0.332 (decreased 38.9%).
3. The higher the coir fiber content inserted into the soil, the higher the coefficient of consolidation value.

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