BUKTI KORESPONDENSI

ARTIKEL JURNAL INTERNASIONAL BEREPUTASI

Judul artikel : UTILIZATION OF COIR FIBER TO IMPROVE THE BEARING CAPACITY AND TENSILE STRENGTH OF EXPANSIVE CLAY

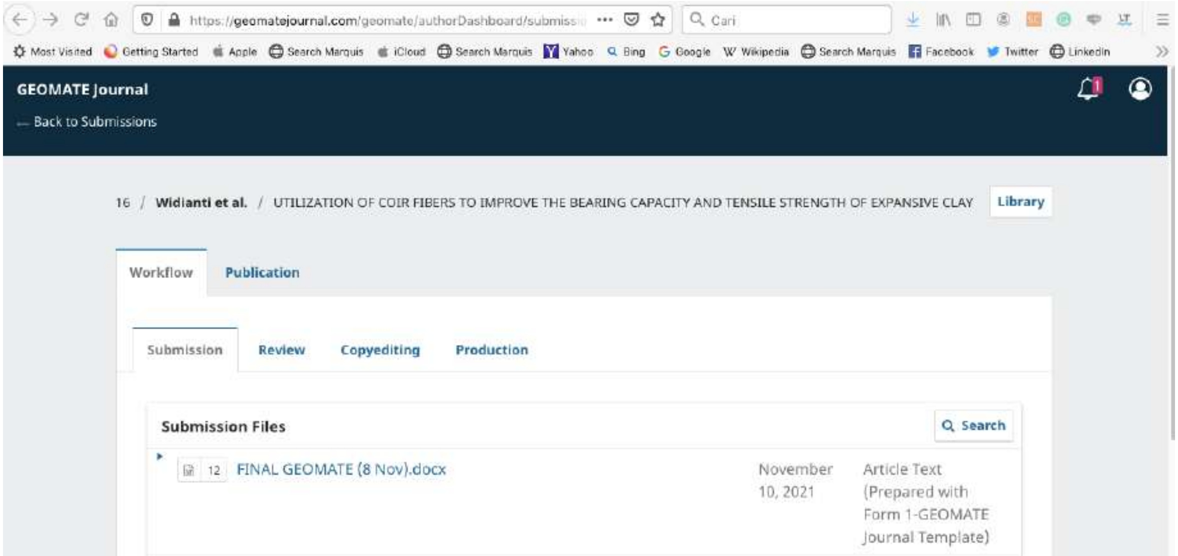
Jurnal : International Journal of GEOMATE, Vol. 23, No. 95, Juli 2022

Penulis : Anita Widianti, Angesta Artha Bhakti Negara, Tjokro Seigia Elmino, dan Lazuardi Ramadhani

No	Perihal	Tanggal
1.	Bukti Submit Artikel danArtikel yang Disubmit	10 November 2021
2.	Bukti Penyampaian Hasil Review oleh Reviewer 1 dan Komentar Reviwer	17 April 2022
3.	Bukti Tanggapan dari Author dan Pengiriman Revisi Pertama Artikel oleh Author	30 April 2022
4.	Bukti Penyampaian Hasil Koreksi oleh Editor	30 April 2022
5.	Bukti Tanggapan dari Author dan Pengiriman Revisi Kedua Artikel oleh Author	5 Mei 2022
6.	Bukti Penyampaian Hasil Review oleh Reviewer 2 dan Komentar Reviwer	20 Mei 2022
7.	Bukti Tanggapan dari Author dan Pengiriman Revisi Ketiga Artikel oleh Author	31 Mei 2022
8	Bukti Tanggapan dari Editor	1 Juni 2022
9.	Bukti Proses Proof dan Artikel yang Telah Diproof	1 Juni 2022
10.	Bukti Artikel telah Dipublikasi Online	1 Juli 2022

1. Bukti Submit Artikel dan Artikel yang Disubmit (10 November 2021)

1. a. Bukti Submit Artikel



1. b. Bukti Artikel yang Disubmit

International Journal of GEOMATE, Month, Year Vol.00, Issue 00, pp.000-000
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/Year.Issue.PaperID
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

UTILIZATION OF COIR FIBER TO IMPROVE THE BEARING CAPACITY AND TENSILE STRENGTH OF EXPANSIVE CLAY

*Anita Widianti[1], Angesta Artha Bhakti Negara[2], Tjokro Seigia Elmino[3] and Lazuardi Ramadhani[4]

[1,2.3.4.]Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, Indonesia

*Corresponding Author, Received: 00 Oct. 2018, Revised: 00 Nov. 2018, Accepted: 00 Dec. 2018

ABSTRACT: Reinforcement is a method to improve soil that has a low bearing capacity and tensile strength. Coconut coir waste is an alternative reinforcement material because coir fiber has high tensile strength, high shear strength, and high resistance to compressive stress. Research on the soaked and unsoaked California Bearing Ratio (CBR), the swelling, and the tensile strength focusing on expansive clay reinforced with coir fiber has not been widely conducted. For this reason, this study will examine these parameters. The content of coir fiber used is between 0.00% to 1.25% by weight of the mixture. The test results showed that the soaked and unsoaked CBR reached the maximum value at 1% fiber content. Originally of poor quality, the soil condition became quite good after being reinforced with an optimum fiber content of 1%. All specimens swell when soaked. The swelling value tended to increase with the addition of coir fiber. So the expansive clay must be chemically stabilized to reduce swelling. The split tensile strength reaches the maximum value at 0.6% fiber content.

Keywords: Expansive clay, Coir fiber, California Bearing Ratio, Swelling, Tensile strength

1. INTRODUCTION

Expansive clay is soil that causes many problems in construction because it has a low bearing capacity, high plasticity index, and high shrink-swell behavior influenced by its water content [1-2]**.** Low bearing capacity can result in the collapse of the bearing capacity of the foundation or slope failure. There have been many methods of soil improvement to enhance the physical and mechanical properties of clay. One of them is by providing soil reinforcement, namely inserting material into the soil to increase stability, reduce compressibility, and lateral deformation [3]. One of the materials used is fiber which is mixed randomly into the soil. Soil and fiber will behave as a composite material, which is called eco-composite [4]. This behavior is like plant roots that contribute to improving the strength of the soil. Fibers with relatively high tensile strength will help soils that cannot withstand tensile forces [5]. Muntohar et al. [6] explained that the reinforcement work from low strain to soil collapse strain. After the soil collapse strain has passed, the reinforcement can still provide tensile stresses to prevent sudden failures. The principle of strengthening soil using fibers is the adhesion between the fibers and the soil grains. This condition causes shear strength and bearing capacity increasing, while compressibility and lateral deformation decrease. Adding fiber to the soil can change the soil condition from brittle to ductile [7].

Reinforcement can use various kinds of fiber, one of which is a fiber taken from coconut fiber. Although the fiber is biodegradable, it has high durability and strength [8]. The fiber's strength varies depending on the length, diameter, and degree of fiber's defect [8-9].

Carrijo et al. [11] explained that 35% of the total weight of coconut is coir which consists of 75% fiber and 25% pitch. Coir fiber contains 54% cellulose and 46% lignin [11-12]. Due to the high lignin content, the degradation of coir occurs more slowly than other natural fibers. The age of coir can reach ten years [14]. Coir fiber can maintain its tensile strength when wet and has high stretch. Compared to synthetic fiber, coir fiber is more elastic and has a higher coefficient of friction [13-14]. Coir fiber also has advantages: lightweight, resistant to microbial decomposition, resistant to fungi, biodegradable, environmentally friendly [11-12], and available in abundance at low prices in many Asian countries [15-16]. Indonesia is the largest coconut producer in the world based on 2019 Food and Agriculture Organization (FAO) data. Coconut production in Indonesia reached 17.13 million tons/year in 2019 [19].

Structural materials still rarely use coir waste. So far, coir fiber for fuel, household appliances, handicraft materials, simple water filters, environmentally friendly briquettes, or planting media [8]. Coir fiber as a construction material is an alternative to reduce coir fiber waste and is expected to help overcome environmental problems [20].

The California Bearing Ratio (CBR) is a parameter to indicate the bearing capacity of the subgrade. Research on the effect of coir fiber content on the CBR value of clay soil has been carried out and shown to increase soil bearing capacity. The optimum amount of fiber content to produce the maximum CBR value has disclosed various results, namely between 0.5% to 1.5% [6-7, 19-23].

Research of CBR, swelling, and split tensile strength focusing on expansive clays reinforced with coir fiber has not been widely conducted. Shukla et al. [23] conducted soaked and unsoaked CBR tests on expansive clays mixed with coir fibers. The test results show that the CBR value increases with the increase in fiber content. The maximum CBR value is 1% mixture. Munirwan et al. [1] also carried out CBR research on expansive soils reinforced with 2 and 3 cm fiber's length. Mixing is performed by two methods, namely mixing randomly and mixing in the form of layers. Direct mixing with a fiber length of 3 cm and a fiber content of 0.4% resulted in the highest CBR value.

According to Anggraini et al. [22], coir fiber can significantly increase the tensile strength of clay. Fiber can improve friction in the soil. The optimum fiber content for the soil mixture is 1%. Menezes et al. [24] analyzed the mechanical behavior of clay-sand soil by adding coir fiber. The highest tensile strength value is soil with 0.75% coir fiber reinforcement. The addition of fiber also makes the soil-fiber mixture more ductile.

In this study, laboratory tests on soaked CBR, unsoaked CBR, swelling, and split tensile strength of expansive clay mixed with coir fiber to assess the effectiveness of the fibers as soil reinforcement.

2. METHODOLOGY

2.1 Materials

In this study, the soil used was expansive clay from Sentolo, Kulon Progo, Yogyakarta, Indonesia. Widianti et al. [25] have tested the physical properties of the soil. The test results obtained included specific gravity (Gs) = 2.64; liquid limit (LL) = 89.91%; plastic limit (PL) = 38.86%, shrinkage limit (SL) = 16.33%, and plasticity index (PI) = 51.05%. The soil used contained 86.64% fine grains and 13.36% coarse grains. Based on the classification according to AASHTO, the soil is classified as clayey soil indicated as poor subgrade material (A-7-6). Based on the classification according to USCS, the soil is classified as clay high plasticity (CH). According to Skempton, the value of soil activity is 3.18, indicating active clay (containing the mineral Montmorillonite). From the standard proctor compaction test, the Maximum Dry Density (MDD) = 12.8 kN/m^3, and the Optimum Moisture Content (OMC) = 29.9%. All parameters were obtained from laboratory testing based on ASTM standards.

Coir waste is widely available in the markets. Table 1 presents data on the average diameter and fiber tensile strength values. The fibers length is 30 mm to 50 mm (for CBR test) and 60 mm to 80 mm (for split tensile strength test), then randomly distributed into the soil.

Table 1 The tensile strength of coir fibers

Sample	Length (mm)	Average diameter (mm)	Tensile strength (MPa)
1	100	0.15	92.20
2	100	0.21	110.36
3	100	0.21	121.86
4	100	0.23	143.39
5	100	0.23	147.20
6	100	0.32	107.41
	Average tensile strength		120.40

2.2 Variation of Specimens

The tests in this study were the soaked CBR, unsoaked CBR, and split tensile strength test of expansive clay mixed with varying coir fiber content. Table 2 and Table 3 show the variation and number of the specimens. The MDD and OMC values of clay became a reference in the compaction process.

Table 2 Variation and number of CBR specimens

Sample Number	Mixed Variation	Number of Specimens	
		Soaked CBR	Unsoaked CBR
1	Without fiber	2	2

	reinforcement			
2	With fiber reinforcement	0.25%	2	2
3		0.50%	2	2
4		0.75%	2	2
5		1.00%	2	2
6		1.25%	2	2

Tabel 3. Variation and number of split tensile strength specimens

Sample Number	Mixed Variation		Number of Specimens
1	Without fiber reinforcement		2
2	With fiber reinforcement	0.40%	2
3		0.60%	2
4		0.80%	2
5		1.00%	2

2.3 Testing Procedures

The CBR specimen is cylindrical with a 15.24 cm diameter and a 17.78 cm height. Previously the specimen was soaked in water for four days to determine its strength at the worst subgrade conditions (for the soaked CBR value). The CBR test was carried out based on ASTM D1883-07e2. Static load continued to be applied gradually to the specimens until the displacement value was 12.7 mm (0.5 inches), as shown in Fig. 1.

Fig. 1 CBR test

The split tensile strength specimen is a cylinder with a 7 cm height and a 3.5 cm diameter. Fig. 2 shows the test using an unconfined compressive strength machine based on ASTM C-496. The loading was carried out at a speed of 0.96 MPa/min until the specimen cracked.

3. RESULTS AND DISCUSSIONS

3.1 The CBR Value of Coir Fiber-Reinforced Expansive Clay

Fig. 3 demonstrates the relationship between penetration and stress on the piston for the expansive soil reinforced with varying coir fiber content.

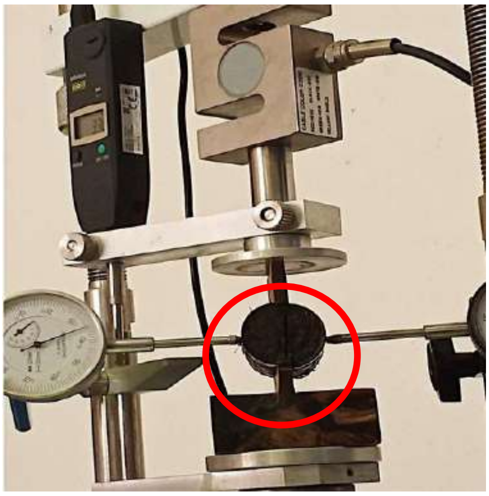
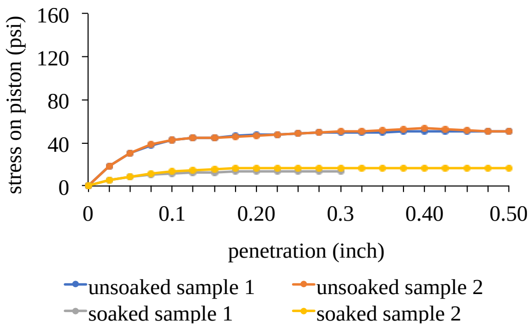
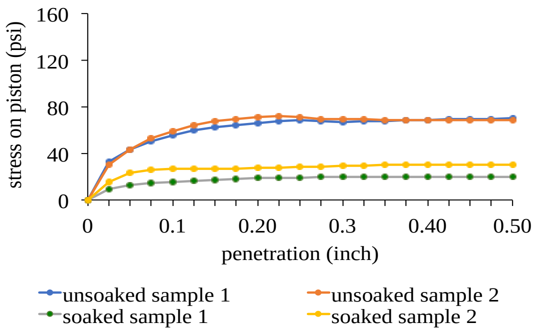


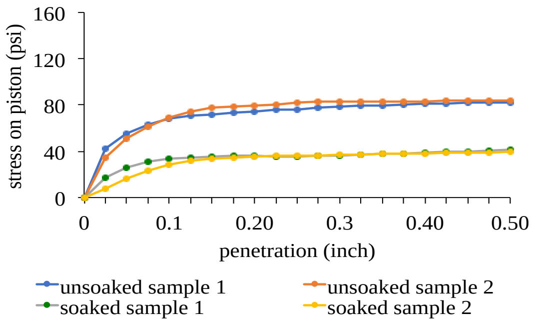
Fig. 2 Split tensile strength test



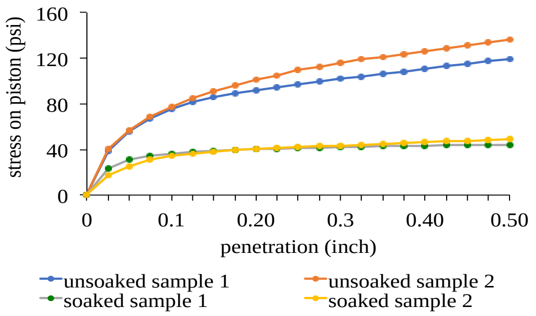
(a)



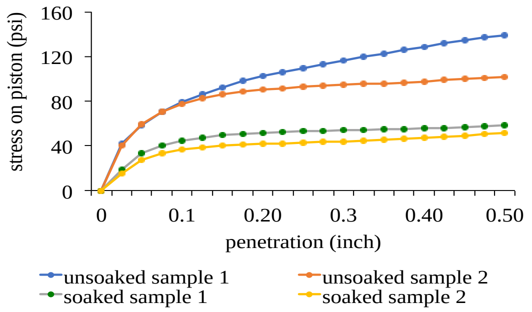
(b)



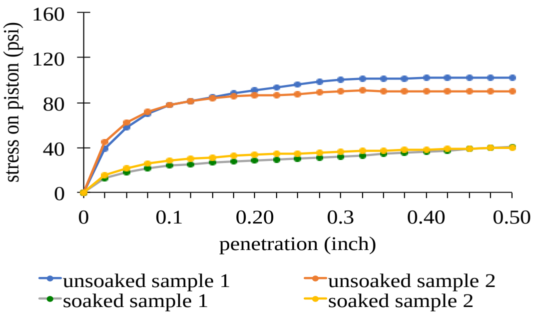
(c)



(d)



(e)



(f)

Fig.3 Relationship between penetration and stress on the piston (a) 0%; (b) 0.25%; (c) 0.5%; (d) 0.75%; (e) 1,0%; (f) 1.25%

Based on Fig. 3 it can be determined the CBR value as shown in Fig. 4.

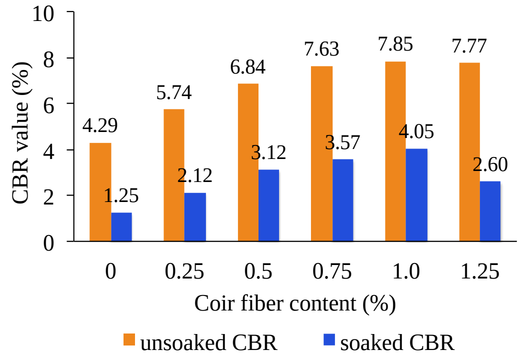


Fig.4 Relationship between coir fiber content and CBR value

Fig. 4 depicts that the soaked and unsoaked CBR values have increased along with the increasing coir fiber content mixed into the soil. Soil with 1% fiber content produces maximum CBR value. At this level, the unsoaked CBR value increases from 4.29% to 7.85% (an increase of 83% from the expansive clay CBR value), while the soaked CBR value increases from 1.25% to 4.05% (an increase of 224% from the clay CBR value). At the level of 1.25%, the CBR value begins to decline. These results are the same as those conducted by Singh and Mittal [7], Lekha et al. [26], and Shukla et al. [23].

According to Hejazi et al. [4], coir fibers have a good resistance response-ability and high friction coefficient. The fiber randomly mixed into the soil in a certain amount increased the friction between the soil particles and the fiber surface. The soil's shear strength increased, thereby increasing the soil's bearing capacity [13,16]. Shukla et al. [23] explained that the soil-fiber mix increases the bonding or interlocking between the two. Soil grains cannot withstand horizontal forces. The fibers will help resist through their tensile strength when the soil grains move horizontally. At higher than optimal fiber content, the CBR value will decrease. The fiber will interact with each other. The amount of soil grain available is not enough to create a strong bond between the soil and the fibers [24-25].

The CBR value can show the quality of the soil, as shown in Table 4. Clay soil with an unsoaked CBR value of 4.29% has poor quality. After being reinforced with an optimum fiber content of 1%, the CBR value was 7.85%, thus increasing the soil quality to fair.

Table 4 Pavement quality rating [27]

CBR (%)	General Rating
> 50	Excellent
20-50	Good

7-20	Fair
3-7	Poor
0-3	Very poor

3.2 The Swelling Value of Coir Fiber-Reinforced Expansive Clay

Fig. 5 presents the effect of coir fiber content as a mixture on the swelling value. It shows that all the specimens mixed with fibers swelling after soaking. The more coir fibers added, the higher the swelling value obtained. The average swelling value for soil without fiber is 0.96%. This value increases to 3.50% for a blend with a fiber content of 1.25%.

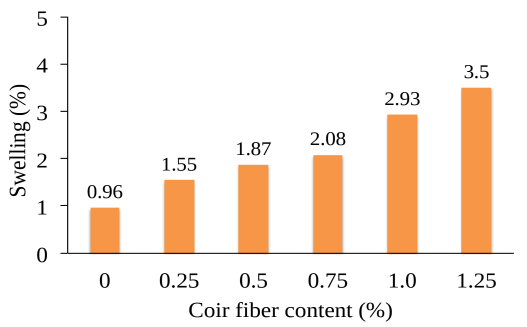


Fig. 5 Relationship between coir fiber content and swelling

Swelling occurs because the more fiber is added, the more voids between the clay and coir fibers. Water will fill the pores between the soil grains, resulting in saturated water content. The tension in the water between the soil particles tends to push the soil particles away from each other, resulting in swelling. Therefore the expansive clay must be chemically stabilized to reduce swelling. Soil grains will undergo a chemical reaction with the added material resulting in the flocculation of soil particles. These enlarged grains will reduce swelling [28].

3.3 The Split Tensile Strength Value of Coir Fiber-Reinforced Expansive Clay

Tensile strength testing until the specimen cracks or collapses. Fig. 6 depicts the results of the tensile strength test for each variation in the laboratory.

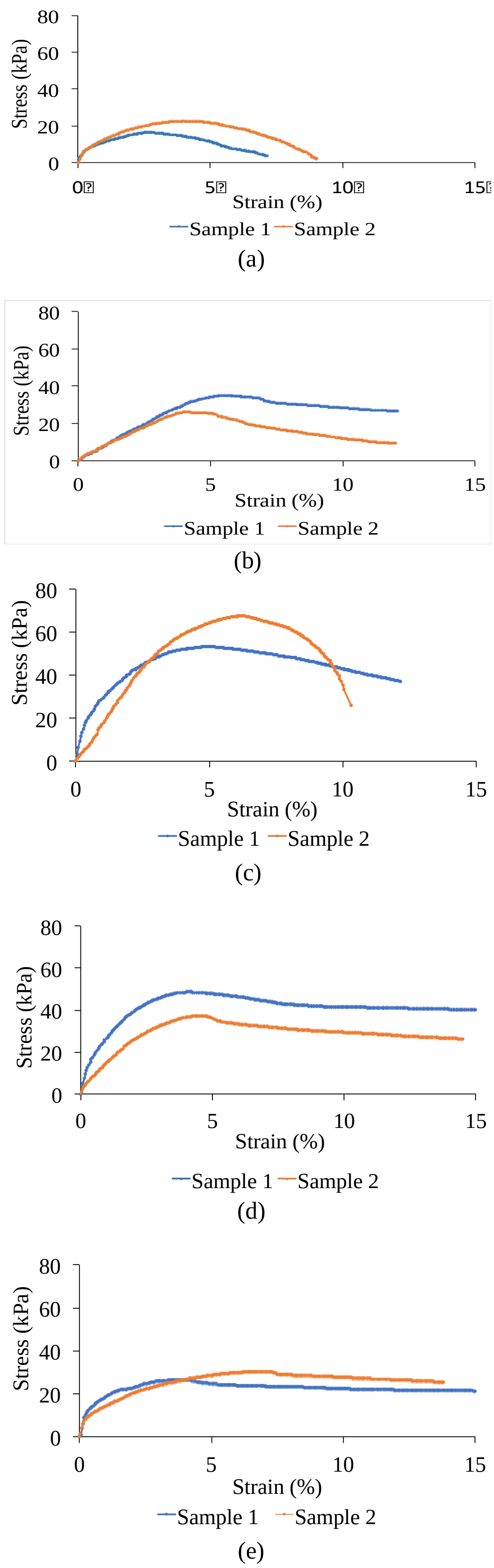


Fig.6 Relationship between strain and stress (a) 0%; (b) 0.4%; (c) 0.6%; (d) 0.8%; (e) 1,0%

Fig. 6 shows that all the specimens mixed with the fiber become more ductile and have greater strain. Based on Fig. 6 it can be determined the split tensile strength value as shown in Fig. 7.

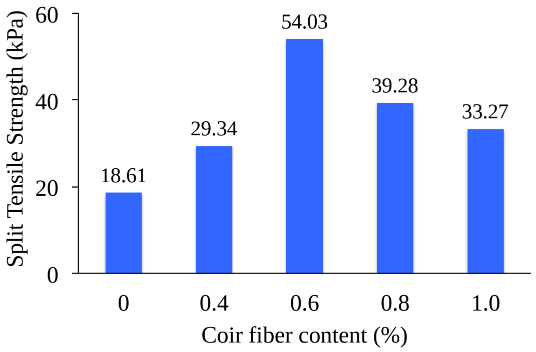
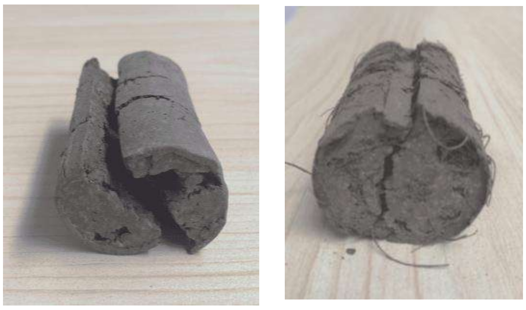


Fig. 7 Relationship between coir fiber content and split tensile strength

Fig. 7 depicts that the tensile strength value of the specimen without coir fiber is 18.61 kPa. The tensile strength value tends to increase with increasing fiber content. The tensile strength value reached the highest with 0.6% fiber content with a value of 54.03 kPa (there was an increase of 190% from the tensile strength of clay). This value is the optimum fiber content to achieve maximum tensile strength. If it exceeds the optimum level, the effectiveness of the interaction between the fiber and the soil will decrease. The fibers' interlocking with soil will reduce because those fibers interact with each other [24].

Fig. 8 shows a specimen after testing. Lateral deformation and rupture occur along the stress plane in unreinforced soil (Fig. 8a). However, with fiber reinforcement, soil stiffness increases. The soil only cracked along the stress plane (Fig. 8b).



(a) (b)

Fig. 8 The split tensile strength specimen after testing (a) without fiber content, (b) with 1.00% fiber content

4. CONCLUSION

a. The addition of coir fiber as soil reinforcement can significantly increase the soaked CBR, the unsoaked CBR, and the tensile strength of the soil.
b. The soaked and unsoaked CBR value reached a maximum value at the fiber content of 1.0%. More than 1.0% of the CBR value has decreased.
c. The swelling value tends to increase with the addition of coir fiber. Expansive clay must be chemically stabilized to reduce swelling.
d. The split tensile strength value reached a maximum value at the fiber content of 0.6%.

5. REFERENCES

[1] R. P. Munirwan, Munirwansyah, Marwan, P. J. Ramadhansyah, and V. Kamchoom, “Performance of Coir Fiber Addition for Clay as a Sub-Grade for Pavement Design,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 712, no. 1, 2020.

[2] Y. Zaika and E. A. Suryo, “Design of improved lime expansive soil for embankment of flexible pavement,” *Int. J. GEOMATE*, vol. 17, no. 60, pp. 90–95, 2019.

[3] N. Suffri, M. Jeludin, and S. Rahim, “Behaviour of the Undrained Shear Strength of Soft Clay Reinforced with Natural Fibre,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 690, no. 1, 2019.

[4] S. M. Hejazi, M. Sheikhzadeh, S. M. Abtahi, and A. Zadhoush, “A simple review of soil reinforcement by using natural and synthetic fibers,” *Constr. Build. Mater.*, vol. 30, pp. 100–116, 2012.

[5] M. Ali, “Coconut fibre - A versatile material and its applications in engineering,” *2nd Int. Conf. Sustain. Constr. Mater. Technol.*, vol. 2, no. 9, pp. 1441–1454, 2010.

[6] A. S. Muntohar, A. Widianti, E. Hartono, and W. Diana, “Engineering properties of silty soil stabilized with lime and rice husk ash and reinforced with waste plastic fiber,” *J. Mater. Civ. Eng.*, vol. 25, no. 9, 2013.

[7] R. R. Singh and E. S. Mittal, “Improvement of local subgrade soil for road construction by the use of coconut coir fiber,” *Int. J. Res. Eng. Technol.*, vol. 3, no. 5, pp. 707–711, 2014.

[8] E. R. Sujatha, S. Sai, C. Prabalini, and Z. F. Aysha, “Influence of random inclusion of coconut fibres on the short term strength of highly compressible clay,” in *IOP Conf. Series: Earth and Environmental Science*, 2017, pp. 1–6.

[9] H. P. Singh and M. Bagra, “Improvement in CBR Value of Soil Reinforced With Jute Fiber,” *Int. J. Innov. Res. Sci. Eng. Technol.*,

vol. 3297, no. 8, pp. 2319–8753, 2007.
[10] J. Oroh, F. P. Sappu, and R. C. Lumintang, “Analisis sifat mekanik material komposit dari serat sabut kelapa,” *J. Online Poros Tek. Mesin Unsrat*, vol. 1, no. 1, 2013.
[11] O. A. Carrijo, R. S. de Liz, and N. Makishima, “Fiber of green coconut shell as an agricultural substrate,” *Hortic. Bras.*, vol. 20, no. 4, pp. 533–535, 2002.
[12] G. L. S. Babu and A. K. Vasudevan, “Evaluation of strength and stiffness response of coir-fibre-reinforced soil,” *Proc. Inst. Civ. Eng. Improv.*, vol. 11, no. 3, pp. 111–116, 2007.
[13] L. V Torio-Kaimo, A. M. San Diego, and M. T. M. Alcantara, “Unconfined Compressive Strength of Clay Reinforced with Kerosene-Treated Coir Fiber,” *Int. J. GEOMATE*, vol. 18, no. 69, pp. 97–103, 2020.
[14] S. Gowthaman, K. Nakashima, and S. Kawasaki, “A state-of-the-art review on soil reinforcement technology using natural plant fiber materials: Past findings, present trends and future directions,” *Materials (Basel).*, vol. 11, no. 4, 2018.
[15] R. K. Kar, P. K. Pradhan, and A. Naik, “Effect of randomly distributed coir fibers on strength characteristics of cohesive soil,” *Electron. J. Geotech. Eng.*, vol. 19 G, pp. 1567–1583, 2014.
[16] J. Mathew and K. Ramesan, “Comparative Study On Effect Of Soft Soil Stabilization Using Coir Fibres And Polypropylene Fibres,” *IOSR J. Mech. Civ. Eng.*, no. 2015, pp. 61–2016, 2016.
[17] T. Maliakal and S. Thiyyakkandi, “Influence of Randomly Distributed Coir Fibers on Shear Strength of Clay,” *Geotech. Geol. Eng.*, vol. 31, no. 2, pp. 425–433, 2013.
[18] A. Ahmad Lone, I & Bawa, “Utilization of fly-ash and coir fibre in soil reinforcement,” *Int. J. Civ. Eng. Technol.*, vol. 9, no. 8, pp. 341–346, 2018.
[19] “Top 20 Countries, Net Production Value of Coconuts 2018,” *http://www.fao.org/faostat/en/#rankings/countries_by_commodity*, 2019.
[20] J. D. Nyuin, N. S. Khalil, and C. Petrus, “Performance of Sand Reinforced with White Coir Fibre,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 429, no. 1, 2018.
[21] P. M. Chaple and A. I. Dhatrak, “Performance of coir fiber reinforced clayey soil,” *Int. J. Eng. Sci.*, vol. 2, no. 4, pp. 54–64, 2013.
[22] V. Anggraini, A. Asadi, B. B. K. Huat, and H. Nahazanan, “Effects of coir fibers on tensile and compressive strength of lime treated soft soil,” *Measurement*, vol. 59, pp. 372–381, 2015.
[23] D. Shukla, S. Rajan, A. K. Saxena, and A. K. Jha, “Soil Stabilization Using Coconut Coir Fibre,” *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 3, no. 9, p. 5, 2015.
[24] L. C. P. de Menezes, D. B. de Sousa, S. F. Sukar, and S. R. de M. Ferreira, “Analysis of the Physical-Mechanical Behavior of Clayey Sand Soil Improved with Coir Fiber,” *Soils and Rocks*, vol. 42, no. 1, pp. 31–42, 2019.
[25] A. Widianti, W. Diana, and M. R. Alghifari, “Shear Strength and Elastic Modulus Behavior of Coconut Fiber-Reinforced Expansive Soil,” in *IOP Conference Series: Materials Science and Engineering*, 2021, vol. 1144, no. 1, p. 12043.
[26] B. M. Lekha, S. Goutham, and A. U. R. Shankar, “Evaluation of lateritic soil stabilized with Arecanut coir for low volume pavements,” *Transportation Geotechnics*, vol. 2. pp. 20–29, 2015.
[27] E. Barnas and B. Karopeboka, “Penelitian Kekuatan Tanah Metode CBR (California Bearing Ratio) di SPBG Bogor 1 Bubulak JL KH R Abdullah bin Nuh (Soil Strength Research using the CBR (California Bearing Ratio) Method at SPBG Bogor 1 Bubulak JL KH R Abdullah bin Nuh),” *J. KaLIBRASI-Karya Lintas Ilmu Bid. Rekayasa Arsitektur, Sipil, Ind.*, vol. 9, 2014.
[28] H. C. Hardiyatmo, *Tanah Ekspansif, Permasalahan dan Penanganan (Expansive Soil, Problems and Solutions)*, 1st ed. Yogyakarta: Gadjah Mada University Press, pp. 19-24, 2014.

2. Bukti Penyampaian Hasil Review oleh Reviewer 1 dan Komentar Reviwer (17 April 2022)

16 Review Results

Prof. Zakaria Hossain <zakaria@bio.mie-u.ac.jp>
Min 17/04/2022 09.23
Kepada: Anita Widianti <anitawidianti@umy.ac.id>

- Dear Dr. Anita Widianti, Angesta Artha Bhakti Negara , Tjokro Seigia Elmino , Lazuardi Ramadhani:

  Paper ID: 16

  Paper Title: UTILIZATION OF COIR FIBER TO IMPROVE THE BEARING CAPACITY AND TENSILE STRENGTH OF EXPANSIVE CLAY

  Thanks for your kind contribution. We have editorial/reviewers' comments regarding your submission to GEOMATE Journal, .

  Please send the revised paper within a maximum of 2 weeks upon receiving this message. Please send responses to reviewers by authors in a separate file. An example of "Response to Reviewers by Authors" can be found on the journal website.

  File Name should be as follows: Paper ID-Your Name-Revised Paper

  Example: 7501_Author Name_Revised Paper; 7501_Author Name_ Response to Reviewers

  Revised Paper Submission Link:

  https://form.jotform.com/geomate/journal-revised-paper

  Best regards.

  Prof. Dr. Zakaria Hossain, Editor-in-Chief

  International Journal of GEOMATE, E-mail: editor@geomatejournal.com

----

Reviewer C:
Recommendation: Revisions Required

----

1. Originality

3

2. Quality

3

3. Relevance

3

4. Presentation

3

5. Recommendation

3

Please write total scores (out of 25) (sum of 1 to 5 above):

15

Please indicate technical or editorial corrections for the author's guide

General Comments
This is an interesting paper on soil improvement. There is a good presentation of the laboratory study content. The paper is generally well organised and presented. There are improvements to make in English expression throughout the paper. Some examples are provided below. The paper doesn't consider how this method could actually be used in practice. How could such intimate mixing be achieved in practice? How much energy was consumed per kg to achieve the mix? The relevance of the paper to engineering would be increased if these matters could be considered at least as limitations.

Mandatory comments
1) Abstract: 'Research on the soaked and unsoaked California Bearing Ratio (CBR), the swelling, and the tensile strength focusing on expansive clay reinforced with coir fiber has not been widely conducted. For this reason, this study will examine these parameters.' These statements do not belong in the Abstract. The Abstract must focus on the content of the research not the purpose or rationale.
2) Abstract: 'The split tensile strength' please clarify this terminology. This can be called 'indirect tensile test'.
3) Introduction: 'Low bearing capacity can result in the collapse of the bearing capacity of the foundation or slope failure.' Please clarify the use of 'collapse'. 'Reduction' may be a better term.
4) Introduction: 'reinforcement work from low strain to soil collapse strain. After the soil collapse strain has passed, the reinforcement can still provide tensile stresses to prevent sudden failures.' Use 'peak' strain not 'collapse' strain.
5) Introduction: 'This condition causes shear strength, and bearing capacity increased while compressibility and lateral deformation decrease.' Should be 'This condition increases shear strength, and bearing capacity while compressibility and lateral deformation decrease.'
6) Introduction: 'fiber taken from coconut fiber.' Should be 'fiber from coconuts.'
7) Introduction: 'has advantages' should be 'has other advantages'
8) Page 2: Mixing methods are worthy of further discussion. It is the difficulty of mixing that makes this method of reinforcement infeasible in many applications. Simplifying mixing is probably more significant than demonstrating the effectiveness of the mixed material.
9) Page 2: 'were obtained' these words are in a different font size – please check all text complies with the journal format.
10) Page 2: 'then randomly distributed into the soil' this is difficult to achieve or validate. Please explain how the statement is justified.
11) Table 3: Ensure the table is on a single page.
12) Fig. 1 is not distinctive it should be deleted.
13) The journal standard is metric units. Please convert the units of psi and inches to metric.
14) Page 4: 'good resistance response-ability and' should be 'good resistance response and'
15) Paragraphs that commence: 'Fig. 3 demonstrates, Fig. 4 depicts, Fig. presents... ' give the text the sense of being an extended caption. It is better to write about the results and then note the figure number that relates to the point being made.

16) Page 5: 'Swelling occurs because the more fiber is added, the more voids between the clay and coir fibers.' Does this behavior depend on compaction? The statement does not seem to be validated in the study.
17) Section 3.3: 'Tensile strength testing until the specimen cracks or collapses.' This sentence is not clear.
18) Discussion/Conclusion: 'The tensile strength value reached the highest with 0.6% fiber content' this finding may be very dependent on the conditions of the mixing and other parameters. The generality of the study is limited without considering this.
19) The Conclusions are simply stated. The use of a-d is not needed in the Conclusion.

Your Opinion

3. Encourage to resubmit with major revision

Best Regards.

Prof. Zakaria Hossain (Ph.D. Kyoto University, Japan)

Editor-in-Chief, International Journal of GEOMATE

Chairman, International Conference of SEE & GEOMATE

3. Bukti Tanggapan dari Author dan Pengiriman Revisi Pertama Artikel oleh Author (30 April 2022)

On Sat, Apr 30, 2022 at 10:47 AM Mr. Anita Widianti <noreply@jotform.com> wrote:

16 : Mr. Anita Widianti : Journal Revised paper

Paper ID number	16
Revised Title	UTILIZATION OF COIR FIBER TO IMPROVE THE BEARING CAPACITY AND TENSILE STRENGTH OF EXPANSIVE CLAY
Full Name	Mr. Anita Widianti
E-mail	anitawidianti@umy.ac.id
Co-authors E-mails	angestaarta07@gmail.com tjokroseigiaelmino@gmail.com lazuardiramadhani2@gmail.com
Revised Paper (Word)	16_Anita Widianti_Revised Paper.docx
Response to Reviewers	Response to reviewer by Author.pdf
(Form 2) Copyright	Form 2-GEOMATE Journal Copyright ver21.pdf

Response by Authors to Reviewer's Remarks/Comments

Utilization of Coir Fiber to Improve The Bearing Capacity and Tensile Strength of Expansive Clay

Authors: Anita Widianti, Angesta Artha Bhakti Negara, Tjokro Seigia Elmino and Lazuardi Ramadhani

The authors have summarized their replies to the Reviewers' comments in this response letter in a two column format. A revised manuscript is submitted addressing all the comments to the Journal of GEOMATE for possible publication.

	General Comments	***Authors Response***
	This is an interesting paper on soil improvement. There is a good presentation of the laboratory study content. The paper is generally well organised and presented. There are improvements to make in English expression throughout the paper. Some examples are provided below. The paper doesn't consider how this method could actually be used in practice. How could such intimate mixing be achieved in practice? How much energy was consumed per kg to achieve the mix? The relevance of the paper to engineering would be increased if these matters could be considered at least as limitations.	The author appreciates valuable comments from reviewer C. We have added an explanation of specimen preparation in 2. Methodology. We've fixed English throughout the revised manuscript.
	Mandatory Comments	
	Reviewer_C's Comments	***Authors Response***
1	Abstract: 'Research on the soaked and unsoaked California Bearing Ratio (CBR), the swelling, and the tensile strength focusing on expansive clay reinforced with coir fiber has not been widely conducted. For this reason, this study will examine these parameters.' These statements do not belong in the Abstract. The Abstract must focus on the content of the research not the purpose or rationale.	The statements is removed in the revised manuscript. We have added an explanation of the research method.
2	Abstract: 'The split tensile strength' please clarify this terminology. This can be called 'indirect tensile test'.	We've fixed it. The revised manuscript replaced the word 'split' with 'indirect'.
3	Introduction: 'Low bearing capacity can result in the collapse of the bearing capacity of the foundation or slope failure.' Please clarify the use of 'collapse'. 'Reduction' may be a better term.	The sentence is corrected in the revised manuscript as per the reviewer's comments.

		' Low bearing capacity can result in the collapse of the foundation or slope failure.'
4	Introduction: 'reinforcement work from low strain to soil collapse strain. After the soil collapse strain has passed, the reinforcement can still provide tensile stresses to prevent sudden failures.' Use 'peak' strain not 'collapse' strain.	We've fixed it. The word 'collapse' is replaced with 'peak' in the revised manuscript by the reviewer's comments.
5	Introduction: 'This condition causes shear strength, and bearing capacity increased while compressibility and lateral deformation decrease.' Should be 'This condition increases shear strength, and bearing capacity while compressibility and lateral deformation decrease.'	The sentence is corrected in the revised manuscript as per the reviewer's comments.
6	Introduction: 'fiber taken from coconut fiber.' Should be 'fiber from coconuts.'	The sentence is corrected in the revised manuscript as per the reviewer's comments.
7	Introduction: 'has advantages' should be 'has other advantages'	The sentence is corrected in the revised manuscript as per the reviewer's comments.
8	Page 2: Mixing methods are worthy of further discussion. It is the difficulty of mixing that makes this method of reinforcement infeasible in many applications. Simplifying mixing is probably more significant than demonstrating the effectiveness of the mixed material.	Literature review and methodology are added about fiber mixing.
9	Page 2: 'were obtained' these words are in a different font size – please check all text complies with the journal format.	The font size is corrected in the revised manuscript as per the reviewer's comments.
10	Page 2: 'then randomly distributed into the soil' this is difficult to achieve or validate. Please explain how the statement is justified.	We have added an explanation of specimen preparation in 2. Methodology. '2.3 Preparation of Specimens'
11	Table 3: Ensure the table is on a single page.	The table is corrected in the revised manuscript as per the reviewer's comments.
12	Fig. 1 is not distinctive, it should be deleted.	Fig. 1 is removed in the revised manuscript as per the reviewer's comments.
13	The journal standard is metric units. Please convert the units of psi and inches to metric.	The units are corrected in the revised manuscript as per the reviewer's comments.
14	Page 4: 'good resistance response-ability and' should be 'good resistance response and'	The sentence is corrected in the revised manuscript as per the reviewer's comments.

15	Paragraphs that commence: ‘Fig. 3 demonstrates, Fig. 4 depicts, Fig. presents… ‘ give the text the sense of being an extended caption. It is better to write about the results and then note the figure number that relates to the point being made.	The sentences are corrected in the revised manuscript as per the reviewer's comments.
16	Page 5: ‘Swelling occurs because the more fiber is added, the more voids between the clay and coir fibers.’ Does this behavior depend on compaction? The statement does not seem to be validated in the study.	Paragraphs about swelling are corrected in the revised manuscript according to reviewers' comments.
17	Section 3.3: ‘Tensile strength testing until the specimen cracks or collapses.’ This sentence is not clear.	The sentence is removed in the revised manuscript as per the reviewer's comments. The testing procedure is described in 2.4 Testing Procedure. 'Static load continued to be applied gradually at a constant rate (0.96 MPa/min) until the failure of the specimens, as displayed in Fig. 2.'
18	Discussion/Conclusion: ‘The tensile strength value reached the highest with 0.6% fiber content’ this finding may be very dependent on the conditions of the mixing and other parameters. The generality of the study is limited without considering this.	The conclusions are corrected in the revised manuscript as per the reviewer's comments.
19	The Conclusions are simply stated. The use of a-d is not needed in the Conclusion.	The conclusions are corrected in the revised manuscript as per the reviewer's comments.

4. Bukti Penyampaian Hasil Koreksi dari Editor (30 April 2022)

Prof. Zakaria Hossain <zakaria@bio.mie-u.ac.jp>

Kepada: Anita Widianti; angestaarta07@gmail.com; tjokroseigiaelmino@gmail.com; lazuardiramadhani2@gmail.com

Sab 30/04/2022 10.38

Thanks Anita.

Please do the following corrections:

1. Fig.1: Provide a good quality figure in the vertical direction or draw a schematic diagram of it
2. List of references: Y. Zaika and E. A. Suryo,Y. Zaika and E. A. Suryo, should Zaika Y. and Suryo E.A.

Follow this style for all. See template. Not italic in the list of references.

3. Check others overall throughout the paper.

Best Regards.

Prof. Zakaria Hossain (Ph.D. Kyoto University, Japan)

Editor-in-Chief, International Journal of GEOMATE

Chairman, International Conference of SEE & GEOMATE

5. Bukti Tanggapan dari Author dan Pengiriman Revisi Kedua Artikel oleh Author (5 Mei 2022)

16 : Mr. Anita Widianti : Journal Revised paper

1 lampiran

Anita Widianti

Kepada: Prof. Zakaria Hossain <zakaria@bio.mie-u.ac.jp>

Kam 05/05/2022 16.58

16_Anita Widianti_Revised Pa...
2 MB

Herewith I am sending my revision as your request.
Figure 1 has been replaced by a schematic diagram.
We have corrected the style for all references throughout the revised manuscript.
We have checked others overall through the paper.
Thank you.

Best regards

Anita Widianti

6. Bukti Penyampaian Hasil Review oleh Reviewer ke-2 dan Komentar Reviwer (20 Mei 2022)

Fwd: 16: GEOMATE Journal Review and Evaluation: Notifier

Prof. Zakaria Hossain <zakaria@bio.mie-u.ac.jp>
Jum 20/05/2022 10.48

Kepada: Anita Widianti <anitawidianti@umy.ac.id>;angestaarta07@gmail.com <angestaarta07@gmail.com>;tjokroseigiaelmino@gmail.com <tjokroseigiaelmino@gmail.com>;lazuardiramadhani2@gmail.com <lazuardiramadhani2@gmail.com>

FYI

Best Regards,

Prof. Zakaria Hossain (Ph.D. Kyoto University, Japan)

Editor-in-Chief, International Journal of GEOMATE

Chairman, International Conference of SEE & GEOMATE

---------- Forwarded message ---------
From: **Jotform** <noreply@jotform.com>
Date: Fri, May 20, 2022 at 11:45 AM
Subject: 16: GEOMATE Journal Review and Evaluation: Notifier
To: <geomatejournal@gmail.com>

16: GEOMATE Journal Review and Evaluation: Notifier

Paper ID number	16
Paper Title	UTILIZATION OF COIR FIBER TO IMPROVE THE BEARING CAPACITY AND TENSILE STRENGTH OF EXPANSIVE CLAY
i. Originality	4
ii. Quality	4
iii. Relevance	3
iv. Presentation	4
v. Recommendation	3
Total (sum of i to v)	18

Opinion	2. Accept with minor revision
General comments	A good research using coconut coir waste as additive for soil improvement.
Mandatory changes	1. significant of the study Please elaborate the signifance of study as the age of coir is only can reach for ten years. Then propose on what should be done to the soil after 10 years age. 2. There are many researches conducted using this material, therefore please define and mention the gap of research. 3.If the fibre is randomly distributed, do you have any idea on how to make evenly distributed/spread into soil mixture. Otherwise the strength is not evenly achieved. 4.Content of soil:fibre is measured by weight or volume or other method ? 5. Result shows that the indication for the optimum CBR is 7.85%. Then can you propose/any idea on how to increase the value in order to improve pavement quality?
Suggested changes	Please improve the paper as suggested above.
Reviewer's E-mail (Remove before sendiing to author)	

7. Bukti Tanggapan dari Author dan Pengiriman Revisi Ketiga Artikel oleh Author (31 Mei 2022)

16: Journal Revised paper

Paper ID number	16
Revised Title	UTILIZATION OF COIR FIBER TO IMPROVE THE BEARING CAPACITY AND TENSILE STRENGTH OF EXPANSIVE CLAY
Full Name	Mrs. Anita Widianti
E-mail	anitawidianti@umy.ac.id
Co-authors E-mails	angestaarta07@gmail.com tjokroseigiaelmino@gmail.com lazuardiramadhani2@gmail.com
Revised Paper (Word)	20-26-16-Anita-July-2022-95.docx
Response to Reviewers	May 31-Response to reviewer by Author.pdf
(Form 2) Copyright	Form 2-GEOMATE Journal Copyright ver21.pdf

Response by Authors to Editor's Remarks/Comments

Utilization of Coir Fiber to Improve The Bearing Capacity and Tensile Strength of Expansive Clay

Authors: Anita Widianti, Angesta Artha Bhakti Negara, Tjokro Seigia Elmino and Lazuardi Ramadhani

The authors have summarized their replies to the Editor's comments in this response letter in a two column format. A revised manuscript is submitted addressing all the comments to the Journal of GEOMATE for possible publication.

	General Comments	*Authors Response*
	A good research using coconut coir waste as additive for soil improvement.	The author appreciates valuable comments from the reviewer.
	Mandatory Comments	
	Editor's Comments	*Authors's Response*
1	Significant of the study Please elaborate the signifance of study as the age of coir is only can reach for ten years. Then propose on what should be done to the soil after 10 years age.	Based on the literature review, it is stated that the age of coir can only reach ten years. To extend the life of the fiber can be treated using alkali. For this reason, we are conducting further research on fibers soaked in Sodium Hydroxide before being mixed into the soil.
2	There are many researches conducted using this material, therefore please define and mention the gap of research.	The research gap has been described in the 6th paragraph of the Introduction. A further explanation has been added. "Research on CBR, swelling, and tensile strength focusing on expansive clay reinforced with coir fibers has not been widely conducted. The research carried out has focused more on the CBR value, not discussing the swelling value."
3	If the fibre is randomly distributed, do you have any idea on how to make evenly distributed/spread into soil mixture. Otherwise the strength is not evenly achieved.	We explained in the Introduction that the fibers mixed into the soil at random would behave like plant roots contributing to an increase in soil strength. Fibers mixed randomly into the soil in a certain amount increase the friction between the soil particles and the fiber surface. Increasing the shear strength of the soil will improve its bearing capacity.

		There is no clear relationship between the coir fibers' orientation and the soil's shear strength. The soil-fiber mixture increases the bonding or interlocking between the two. Fibers with relatively high tensile strength will help soil grains that cannot withstand horizontal forces. At higher than optimal fiber content, the strength will decrease. The fibers will interact with each other. The number of soil grains available is insufficient to create a strong bond between the soil and the fibers.
4	Content of soil:fibre is measured by weight or volume or other method ?	Content of soil: fiber is measured by weight, as described in the Abstract. "The content of coir fibers was between 0.00% to 1.25% by weight of the mixture". We have added this sentence in 2.2. Variation of Specimens.
5	Result shows that the indication for the optimum CBR is 7.85%. Then can you propose/any idea on how to increase the value in order to improve pavement quality?	We have added an explanation in 3.2 Swelling Value of Coir Reinforced Expansion Clay that this chemical stabilization will also increase the CBR value and tensile strength.

8. Bukti Tanggapan dari Editor (1 Juni 2022)

16: Journal Revised paper

geomate <noreply@jotform.com>

Kepada: Anita Widianti

Rab 01/06/2022 08.56

Dear Mrs. Anita Widianti,

Thanks. You have successfully submitted the revised paper. We would take necessary action as early as possible.

Best regards.

Prof. Dr. Zakaria Hossain

9. Bukti Proses Proof (1 Juni 2022)

geomate <noreply@jotform.com>

Kepada: Anita Widianti

Rab 01/06/2022 08.46

Thanks. The final paper must contain the page numberig, Vol., Issue, year and all other information in publishable format.

Page Proof (Int. J. of GEOMATE)	
Paper ID	16
Full Name	Ms. Anita Widianti
Page Proof (PDF)	20-26-16-Anita-July-2022-95.pdf
	20-26-16-Anita-July-2022-95_4294.docx
	Form 2-GEOMATE Journal Copyright ver21.pdf
Corresponding Author's E-mail	anitawidianti@umy.ac.id
All Authors E-mail seperated by comma	anitawidianti@umy.ac.id, angestaarta07@gmail.com, tjokroseigiaelmino@gmail.com,

International Journal of GEOMATE, July, 2022, Vol.23, Issue 95, pp.20-26
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2022.95.16
Geotechnique, Construction Materials and Environment

UTILIZATION OF COIR FIBERS TO IMPROVE THE BEARING CAPACITY AND TENSILE STRENGTH OF EXPANSIVE CLAY

*Anita Widianti[1], Angesta Artha Bhakti Negara[2], Tjokro Seigia Elmino[3] and Lazuardi Ramadhani[4]

[1,2.3.4.]Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, Indonesia

*Corresponding Author, Received: 10 Nov 2021, Revised: 17 April. 2022, Accepted: 28 May 2022

ABSTRACT: Reinforcement is a method to improve soils with low bearing capacity and tensile strength. Coconut coir waste is an alternative reinforcement material because coir fibers have high tensile strength, high shear strength, and high resistance to compressive stress. This study performed the soaked and unsoaked California Bearing Ratio (CBR), the swelling, and the indirect tensile strength tests focusing on expansive clay reinforced with coir fibers. The content of coir fibers was between 0.00% to 1.25% by weight of the mixture. The fibers were cut into 30 mm to 50 mm long pieces, then mixed randomly into the soil in various content. The mixture was compacted based on the maximum dry density and the optimum moisture content of the clay. The test results revealed that the soaked and unsoaked CBR reached the maximum values at 1% fiber content. Originally of poor quality, the soil condition became quite good after being reinforced with an optimum fiber content of 1%. All specimens swelled when soaked. The swelling values tended to increase with the addition of coir fibers. Hence, the expansive clay must be chemically stabilized to reduce swelling. The tensile strength reached the maximum value at 0.6% fiber content.

Keywords: Expansive clay, Coir fiber, California Bearing Ratio, Swelling, Tensile strength

6. INTRODUCTION

Expansive clay is soil causing numerous problems in construction due to its low bearing capacity, high plasticity index, and high shrink-swell behavior influenced by its water content [1-2]. Low bearing capacity can result in the collapse of the foundation or slope failure. There have been many methods of soil improvement to enhance the physical and mechanical properties of clay. One of them is by providing soil reinforcement by inserting material into the soil to increase stability and reduce compressibility and lateral deformation [3]. One of the materials used is fiber mixed randomly into the soil. Soil and fiber will behave as a composite material called eco-composite [4]. This behavior is like plant roots that contribute to improving the strength of the soil. Fibers with relatively high tensile strength will help soils that cannot withstand tensile force [5]. Muntohar et al. [6] explained that the reinforcement works from low to peak strain. After the peak strain has passed, the reinforcement can still provide tensile stress to prevent sudden failure. The principle of strengthening soil using fibers is the adhesion between the fibers and the soil grains. This condition increases shear strength and bearing capacity while compressibility and lateral deformation decrease. Adding fibers can change the soil from brittle to ductile [7]

Reinforcement can use various kinds of fiber, one of which is coconut fibers. Although the fibers are biodegradable, they have high durability and strength [8]. The fibers' strength varies depending on the fiber's length, diameter, and degree of the defect [9-10].

Carrijo et al. [11] asserted that 35% of the total weight of coconut is coir, consisting of 75% fibers and 25% pitch. Coir fibers contain 54% cellulose and 46% lignin [11-12]. Due to the high lignin content, the degradation of coir occurs more slowly than other natural fibers. The age of coir can reach ten years [13]. Coir fibers can maintain their tensile strength when wet and have high stretch. Compared to synthetic fibers, coir fibers are more elastic and have a higher coefficient of friction [13-14]. Coir fibers also offer other advantages: lightweight, resistant to microbial decomposition, resistant to fungi, environmentally friendly [11-12], and abundant at low prices in many Asian countries [15-16]. Indonesia is the largest coconut producer based on 2019 Food and Agriculture Organization (FAO) data. Coconut production in Indonesia reached 17.13 million tons/year in 2019 [17].

Structural materials still rarely apply coir waste. So far, coir fibers have been utilized for fuel, household appliances, handicraft materials, simple water filters, environmentally friendly briquettes, and planting media [8]. As a construction material, coir fibers become an alternative to reduce coir fiber waste and are expected to help overcome environmental problems [18].

The California Bearing Ratio (CBR) is a parameter to indicate the bearing capacity of the subgrade. Research on the effect of coir fiber content on the CBR value of soil has been carried out and revealed to increase soil bearing capacity. Fiber is mixed into the soil randomly. The optimum amount of fiber content to produce the maximum CBR value has disclosed various results, between 0.5% to 1.5% [19-23]. According to Nyuin et al. [18], there is no clear relationship between the coir fiber's orientation and the soil's shear strength.

Research on CBR, swelling, and tensile strength focusing on expansive clay reinforced with coir fibers has not been widely conducted. The research carried out has focused more on the CBR value, not discussing the swelling value. Shukla et al. [24] performed soaked and unsoaked CBR tests on expansive clay mixed with coir fibers. The test results discovered that the CBR values increased with the increase in fiber content. The maximum CBR value was 1% mixture. Munirwan et al. [1] also conducted CBR research on expansive soil reinforced with 20 mm and 30 mm fibers. Mixing was performed randomly and in layers. Random mixing with a fiber length of 30 mm and a fiber content of 0.4% resulted in the highest CBR value.

As Anggraini et al. [25] discovered, coir fibers could significantly increase the tensile strength of clay. Fibers could improve friction in the soil. The optimum fiber content for the soil mixture was 1%. Menezes et al. [26] analyzed the mechanical behavior of clay-sand soil by adding coir fibers. The highest tensile strength value was soil with 0.75% coir fiber reinforcement. The addition of fibers also generated a more ductile soil-fiber mixture.

In this study, laboratory tests on soaked and unsoaked CBR, swelling, and tensile strength of expansive clay mixed with coir fibers aimed to determine the effectiveness of the fibers as soil reinforcement.

7. METHODOLOGY

2.4 Materials

This study deployed expansive clay soil from Sentolo, Kulon Progo, Yogyakarta, Indonesia. Widianti et al. [27] tested the physical properties of the soil, obtaining specific gravity (Gs) = 2.64, liquid limit (LL) = 89.91%, plastic limit (PL) = 38.86%, shrinkage limit (SL) = 16.33% and plasticity index (PI) = 51.05%. The soil contained 86.64% fine grains and 13.36% coarse grains. Following the classification of AASHTO, it belongs to clayey soil, indicated as a poor subgrade material (A-7-6). Based on the USCS classification, it is classified as clay with high plasticity (CH). According to Skempton, the value of soil activity is 3.18, signifying active clay (containing the Montmorillonite mineral). The standard proctor compaction test disclosed the Maximum Dry Density (MDD) = 12.8 kN/m^3 and the Optimum Moisture Content (OMC) = 29.9%. All parameters were obtained from laboratory testing based on ASTM standards.

Coir waste is abundantly available in the markets. Table 1 exhibits the average diameter and fiber tensile strength values.

Table 1 The tensile strength of coir fibers

Sample	Length (mm)	Average diameter (mm)	Tensile strength (MPa)
1	100	0.15	92.20
2	100	0.21	110.36
3	100	0.21	121.86
4	100	0.23	143.39
5	100	0.23	147.20
6	100	0.32	107.41
	Average tensile strength		120.40

2.5 Variation of Specimens

This study performed the soaked and unsoaked CBR and indirect tensile strength tests of expansive clay mixed with coir fiber content. Tables 2 and 3 display the variation and number of the specimens. The content of coir fibers was between 0.00% to 1.25% by weight of the mixture.

Table 2 Variation and number of CBR specimens

Sample Number	Mixed Variation		Number of Specimens: Soaked CBR	Number of Specimens: Unsoaked CBR
1	Without fiber reinforcement		2	2
2	With fiber reinforcement	0.25%	2	2
3		0.50%	2	2
4		0.75%	2	2
5		1.00%	2	2
6		1.25%	2	2

2.6 Preparation of Specimens

The fibers were cut into pieces with lengths of

30 mm to 50 mm, then mixed randomly (ignoring the fiber orientation) into the soil in various content. The mixture was compacted according to proctor standards. MDD and OMC values of clay became a reference in the compaction process.

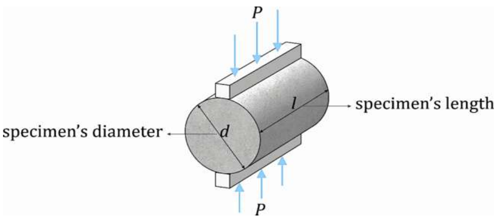
Table 3. Variation and number of indirect tensile strength specimens

Sample Number	Mixed Variation		Number of Specimens
1	Without fiber reinforcement		2
2	With fiber reinforcement	0.40%	2
3		0.60%	2
4		0.80%	2
5		1.00%	2

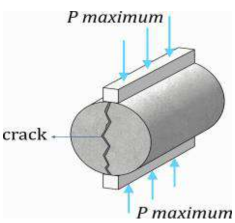
2.7 Testing Procedure

The CBR specimens were cylindrical with a 15.24 cm diameter and a 17.78 cm height. The specimens were previously soaked in water for four days to determine their strength at the worst subgrade condition (for the soaked CBR values). The CBR tests were carried out based on ASTM D1883-07e2. Static load continued to be applied gradually to the specimens until the displacement value was 12.7 mm (0.5 inches).

The indirect tensile strength specimens were cylinders with a 3.5 cm diameter and a 7 cm length. The tests utilized an unconfined compressive strength machine based on ASTM C-496. Static load continued to be applied gradually at a constant rate (0.96 MPa/min) until the occurrence of cracks marked the failure of the specimens, as displayed in Fig. 1.



(a)



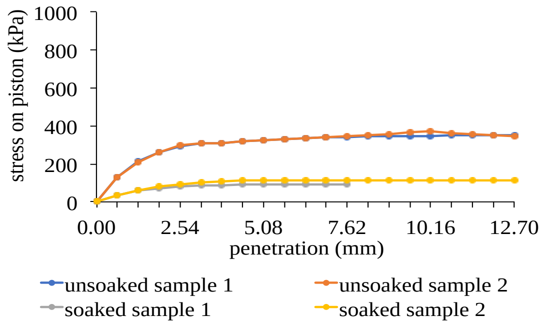
(b)

Fig. 1 Schematic diagram of indirect tensile strength test (a) during loading, (b) at failure

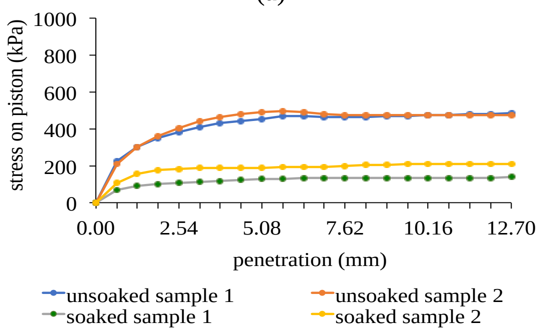
8. RESULTS AND DISCUSSION

3.1 The CBR Values of Coir Fiber-Reinforced Expansive Clay

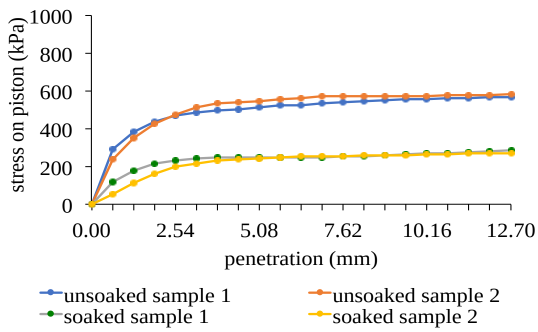
The relationship between penetration and stress on the piston for the expansive soil reinforced with various coir fiber content is portrayed in Fig. 2.



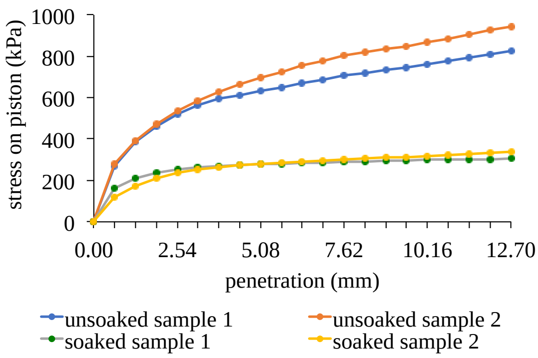
(a)



(b)



(c)



(d)

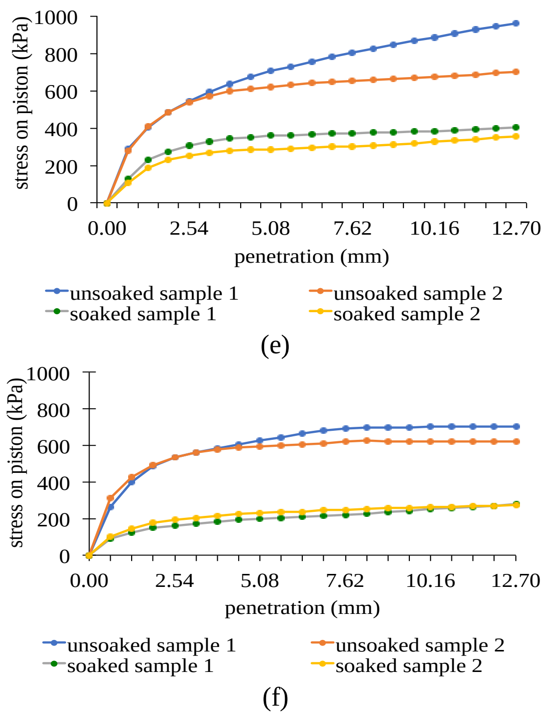


Fig. 2 Relationship between penetration and stress on the piston (a) 0%, (b) 0.25%, (c) 0.5%, (d) 0.75%, (e) 1.0% and (f) 1.25%

Based on Fig. 2, the CBR values were determined, as depicted in Fig. 3.

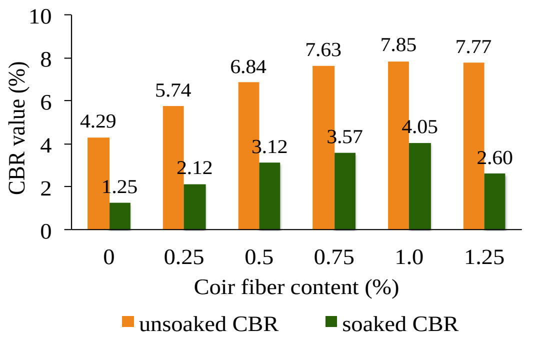


Fig. 3 Relationship between coir fiber content and CBR values

The soaked and unsoaked CBR values increased along with the increasing coir fiber content mixed into the soil. Soil with 1% fiber content produced a maximum CBR value. At this content, the unsoaked CBR values increased from 4.29% to 7.85% (an increase of 83% from the expansive clay CBR values), while the soaked CBR values increased from 1.25% to 4.05% (an increase of 224% from the clay CBR values). At the level of 1.25%, the CBR values began to decline. These results are similar to those conducted by Singh and Mittal [7], Lekha, et al. [28], and Shukla et al. [24].

Hejazi et al. [4] disclosed that coir fibers had a good resistance response and high friction coefficient. The fibers randomly mixed into the soil in a certain amount increased the friction between the soil particles and the fiber surface. The soil's shear strength increased, increasing its bearing capacity [14,16]. Shukla et al. [24] revealed that the soil-fiber mixture increased the bonding or interlocking between the two. Soil grains cannot withstand horizontal force. The fibers will help resist their tensile strength when the soil grains move horizontally. At higher than optimal fiber content, the CBR values will decrease. The fibers will interact with each other. The amount of soil grain available is not enough to create a strong bond between the soil and the fibers [25-26].

The CBR values can demonstrate the quality of the soil, as described in Table 4. Clay soil with an unsoaked CBR value of 4.29% has poor quality. After being reinforced with an optimum fiber content of 1%, the CBR value was 7.85%, thus increasing the soil quality to fair.

Table 4. Pavement quality rating [29]

CBR (%)	General Rating
> 50	Excellent
20-50	Good
7-20	Fair
3-7	Poor
0-3	Very poor

3.2 The Swelling Values of Coir Fiber-Reinforced Expansive Clay

The compaction of the CBR specimens was carried out by controlling the water content of the clay at the optimum moisture content, which was 29.9%. The water content increased after the specimens were soaked for four days and after being mixed with fibers (Fig. 4). This increase was accompanied by an increase in swelling (Fig. 5).

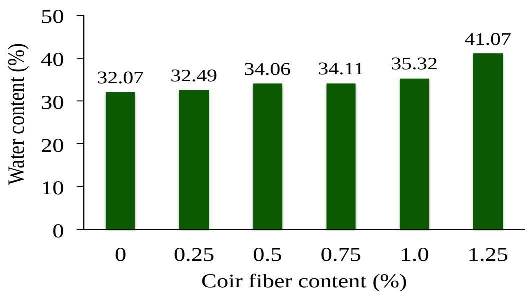


Fig. 4 Relationship between coir fiber content and water content after soaked for four days

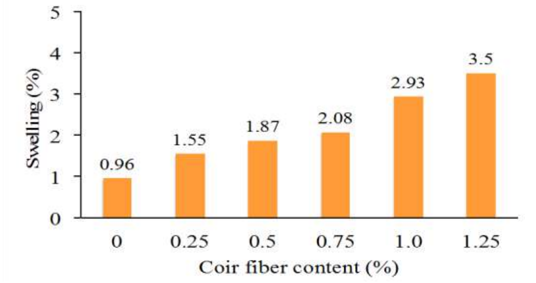
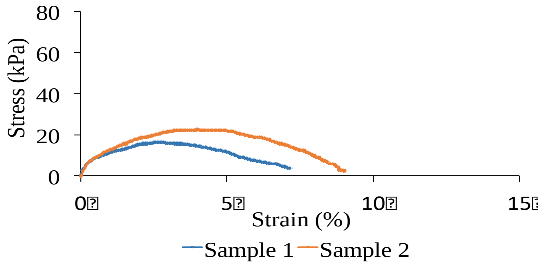


Fig. 5 Relationship between coir fiber content and swelling

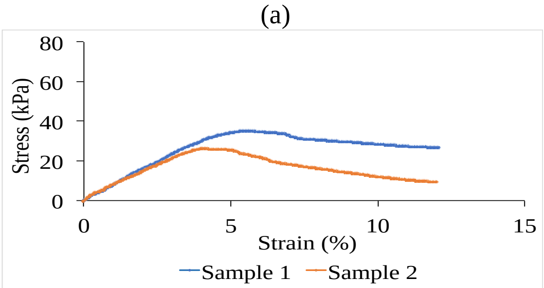
Water content has become one of the factors causing soil swelling. The tension in the water between the soil particles tended to push the soil particles away from each other, resulting in swelling. The existing fibers were unable to withstand the expansion. The more coir fibers added, the higher the swelling value obtained. The average swelling value for the soil without fiber was 0.96%. It increased to 3.50% for the mixture with 1.25% fiber content. Therefore, the expansive clay must be chemically stabilized to reduce swelling. Soil grains will undergo a chemical reaction with the added material, resulting in the flocculation of soil particles. These enlarged grains will minimize swelling [30]. This chemical stabilization will also increase the CBR value and tensile strength [25,31].

3.3 The Tensile Strength Values of Coir Fiber-Reinforced Expansive Clay

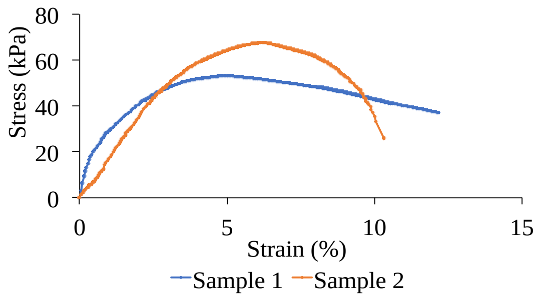
The results of tensile strength testing for each variation in the laboratory are shown in Fig 6. All the specimens mixed with the fiber become ductile and have greater strain. Based on Fig. 6, the tensile strength value can be determined, as shown in Fig. 7.



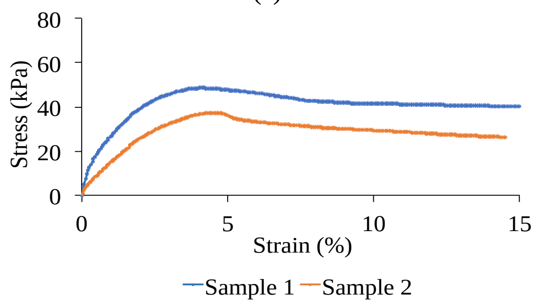
(a)



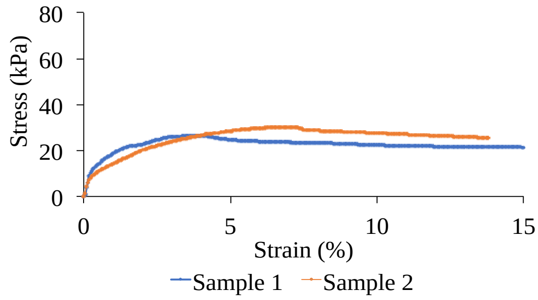
(b)



(c)



(d)



(e)

Fig. 6 Relationship between strain and stress (a) 0%, (b) 0.4%, (c) 0.6%, (d) 0.8% and (e) 1.0%

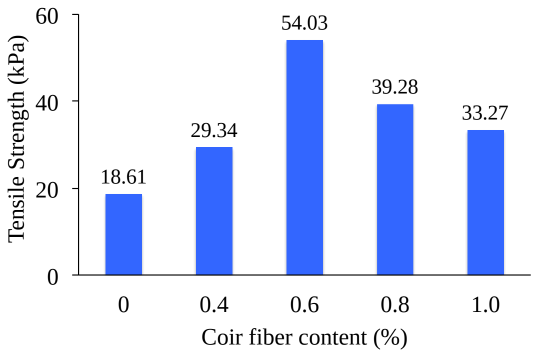


Fig. 7 Relationship between coir fiber content and tensile strength

The tensile strength value of the specimen without coir fibers was 18.61 kPa. The tensile strength value tended to increase with increasing fiber content. The tensile strength reached the highest value of 54.03 kPa with 0.6% fiber content (there was an increase of 190% from the tensile strength of clay). It was the optimum fiber content to achieve maximum tensile strength. If it exceeds the optimum level, the effectiveness of the interaction between the fibers and the soil will decrease. The fibers' interlocking with soil will reduce because those fibers interact [26].

Fig. 8 exhibits specimens after testing. Lateral deformation and rupture occurred along the stress plane in unreinforced soil (Fig. 8a). However, with fiber reinforcement, soil stiffness increased. The soil only cracked along the stress plane (Fig. 8b).

(a) (b)

Fig. 8 The indirect tensile strength specimens after testing (a) without fiber content and (b) with 1.0% fiber content

9. CONCLUSION

The addition of coir fibers as soil reinforcement mixed randomly (ignoring the fiber orientation) could significantly increase the soaked CBR, the unsoaked CBR, and the tensile strength of the soil. The soaked and unsoaked CBR reached its maximum value at 1.0% fiber content, while the indirect tensile strength reached its maximum value at 0.6% fiber content.

The swelling values tended to increase with the addition of coir fibers. Expansive clay must be chemically stabilized to reduce swelling.

10. REFERENCES

[1] Munirwan R. P., Munirwansyah, Marwan, Ramadhansyah P. J., and Kamchoom V., Performance of Coir Fiber Addition for Clay as a Sub-Grade for Pavement Design, IOP Conf. Ser. Mater. Sci. Eng., vol. 712, no. 1, 2020.

[2] Zaika Y. and Suryo E. A., Design of Improved Lime Expansive Soil for Embankment of Flexible Pavement, International Journal of GEOMATE, vol. 17, no. 60, 2019, pp. 90–95.

[3] Suffri N., Jeludin M., and Rahim S., Behaviour of the Undrained Shear Strength of Soft Clay Reinforced with Natural Fiber, IOP Conf. Ser. Mater. Sci. Eng., vol. 690, no. 1, 2019.

[4] Hejazi S. M., Sheikhzadeh M., Abtahi S. M., and Zadhoush A., A Simple Review of Soil Reinforcement by Using Natural and Synthetic Fibers, Constr. Build. Mater., vol. 30, 2012, pp. 100–116.

[5] Ali M., Coconut fibre - A Versatile Material and Its Applications in Engineering, 2nd Int. Conf. Sustain. Constr. Mater. Technol., vol. 2, no. 9, 2010, pp. 1441–1454.

[6] Muntohar A. S., Widianti A., Hartono E., and Diana W., Engineering Properties of Silty Soil Stabilized with Lime and Rice Husk Ash and Reinforced with Waste Plastic Fiber, Journal of Materials in Civil Engineering, vol. 25, no. 9, 2013, pp. 1260-1270.

[7] Singh R. R. and Mittal E. S., Improvement of Local Subgrade Soil for Road Construction by The Use of Coconut Coir Fiber, Int. J. Res. Eng. Technol., vol. 3, no. 5, 2014, pp. 707–711.

[8] Sujatha E. R., Sai S., Prabalini C., and Aysha Z. F., Influence of Random Inclusion of Coconut Fibres on The Short Term Strength of Highly Compressible Clay, IOP Conf. Series: Earth and Environmental Science, 2017, pp. 1–6.

[9] Singh H. P. and Bagra M., Improvement in CBR Value of Soil Reinforced With Jute Fiber, Int. J. Innov. Res. Sci. Eng. Technol., vol. 2, no. 8, 2013, pp. 3447–3452.

[10] Oroh J., Sappu F. P., and Lumintang R., Analisis Sifat Mekanik Material Komposit dari Serat Sabut Kelapa (Analysis of Mechanical Properties of Composite Materials from Coconut Coir), J. Online Poros Tek. Mesin Unsrat, vol. 1, no. 1, 2013, pp. 1-10.

[11] Carrijo O. A., De Liz R. S., and Makishima N., Fiber of Green Coconut Shell as An Agricultural Substrate, Hortic. Bras., vol. 20, no. 4, 2002, pp. 533–535.

[12] Babu G. L. S. and Vasudevan A. K., Evaluation of Strength and Stiffness Response of Coir-Fiber-Reinforced Soil, Proc. Inst. Civ. Eng. Improv., vol. 11, no. 3, 2007, pp. 111–116.

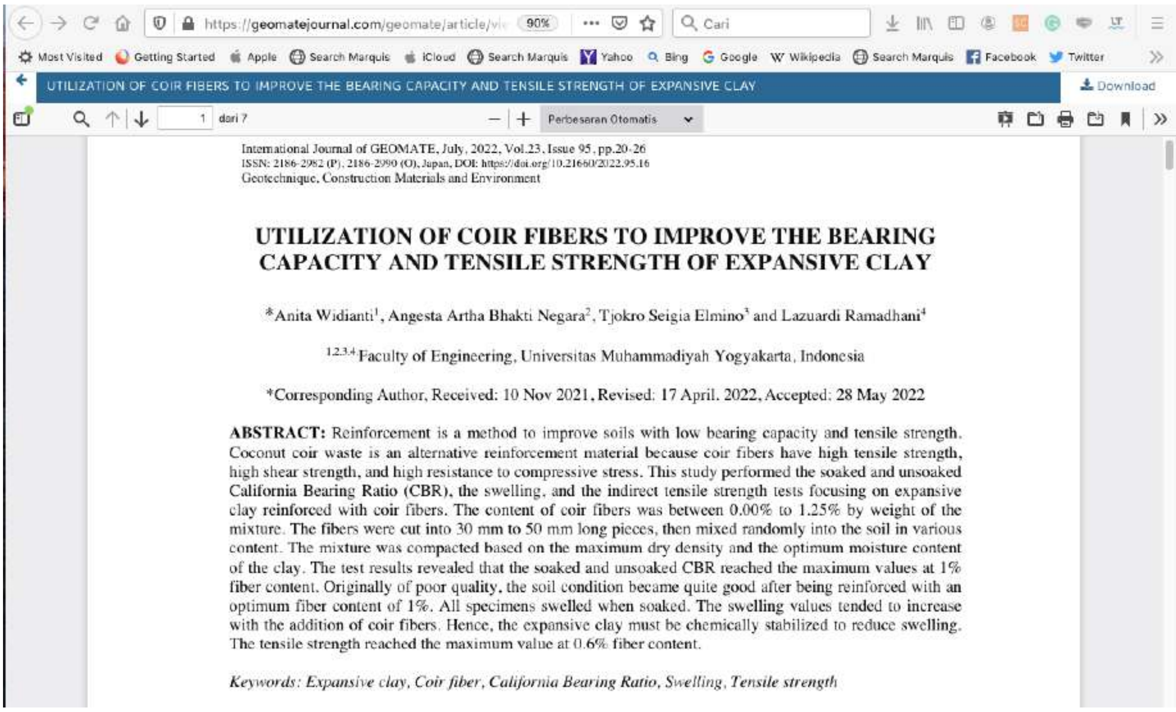
[13] Gowthaman S., Nakashima K., and Kawasaki S., A State-of-The-Art Review on Soil Reinforcement Technology Using Natural Plant Fiber Materials: Past Findings, Present Trends and Future Directions, Materials (Basel)., vol. 11, no. 4, 2018, pp. 1-23.

[14] Torio-Kaimo L. V, San Diego A. M., and Alcantara M. T. M., Unconfined Compressive Strength of Clay Reinforced with Kerosene-Treated Coir Fiber, International Journal of GEOMATE, vol. 18, no. 69, 2020, pp. 97–103.

[15] Kar R. K., Pradhan P. K., and Naik A., Effect

of Randomly Distributed Coir Fibers on Strength Characteristics of Cohesive Soil, Electron. J. Geotech. Eng., vol. 19 G, 2014, pp. 1567–1583.
[16] Mathew J. and Ramesan K., Comparative Study On Effect Of Soft Soil Stabilization Using Coir Fibres and Polypropylene Fibres, IOSR J. Mech. Civ. Eng., no. 2015, 2016, pp 61-66.
[17] Top 20 Countries, Net Production Value of Coconuts 2018, http://www.fao.org/faostat/en/#rankings/countries_by_commodity, 2019.
[18] Nyuin J. D., Khalil N. S., and Petrus C., Performance of Sand Reinforced with White Coir Fiber, IOP Conf. Ser. Mater. Sci. Eng., vol. 429, no. 1, 2018.
[19] Ayininuola G. M. and Oladotun P. O., Geotechnical Properties of Coconut Coir Fiber Soil Mixture, J. Civ. Eng. Res., vol. 6, no. 4, 2016, pp. 79–85.
[20] Peter L., Jayasree P. K., Balan K., and Raj S. A., Laboratory Investigation in the Improvement of Subgrade Characteristics of Expansive Soil Stabilised with Coir Waste, Transp. Res. Procedia, vol. 17, no. December 2014, 2016, pp. 558–566.
[21] Bhatt H., Nitish J., and Harshit V., Performance and Analysis of Coir Fiber as Soil Reinforcement., Int. J. Res. Appl. Sci. Eng. Technol., vol. 5, no. 11, 2017, pp. 67–72.
[22] Anandhamurugan A., Karuppasamy K., and Jagan S., Study on the Stabilization of Soil Using Coir Fibers, Int. J. of Advanced Research in Basic Engineering Sciences and Technology, vol. 3, no. 4, 2017, pp. 101–110.
[23] Mir I. A. and Bawa A., Utilization of Waste Coconut Coir Fiber in Soil Reinforcement, Int. J. Civ. Eng. Technol., vol. 9, no. 9, 2018, pp. 774–781.
[24] Shukla D., Rajan S., Saxena A. K., and Jha A. K., Soil Stabilization Using Coconut Coir Fiber, Int. J. Res. Appl. Sci. Eng. Technol., vol. 3, no. 9, 2015, pp. 305-309.
[25] Anggraini V., Asadi A., Huat B. B. K., and Nahazanan H., Effects of Coir Fibers on Tensile and Compressive Strength of Lime Treated Soft Soil, Measurement, vol. 59, 2015, pp. 372–381.
[26] Menezes L. C. P., Sousa D. B., Fucale S., and Ferreira S. R. M., Analysis of the Physical-Mechanical Behavior of Clayey Sand Soil Improved with Coir Fiber, Soils and Rocks, vol. 42, no. 1, 2019, pp. 31–42.
[27] Widianti A., Diana W., and Alghifari M. R., Shear Strength and Elastic Modulus Behavior of Coconut Fiber-Reinforced Expansive Soil, IOP Conference Series: Materials Science and Engineering, vol. 1144, no. 1, 2021, p. 12043.
[28] Lekha B. M., Goutham S., and Shankar A. U. R., Evaluation of Lateritic Soil Stabilized with Arecanut Coir for Low Volume Pavements, Transportation Geotechnics, vol. 2. 2015, pp. 20–29.
[29] Barnas E. and Karopeboka B., Penelitian Kekuatan Tanah Metode CBR (California Bearing Ratio) di SPBG Bogor 1 Bubulak JL KH R Abdullah bin Nuh (Soil Strength Research using the CBR (California Bearing Ratio) Method at SPBG Bogor 1 Bubulak JL KH R Abdullah bin Nuh), J. KaLIBRASI-Karya Lintas Ilmu Bid. Rekayasa Arsitektur, Sipil, Ind., vol. 9, 2014, pp. 91-112.
[30] Hardiyatmo H. C., Tanah Ekspansif, Permasalahan dan Penanganan (Expansive Soil, Problems and Solutions), 1st edition, Gadjah Mada University Press, Yogyakarta, 2014, pp. 19-23.
[31] Phanikumar B. R., Raju J., and Raju R, Silica Fume Stabilization of An Expansive Clay Subgrade and The Effect of Silica Fume-Stabilised Soil Cushion on Its CBR, Geomech. Geoengin., vol. 15, no. 1, 2020, pp. 64–77.

10. Bukti Artikel telah Dipublikasikan Online (1 Juli 2022)



International Journal of GEOMATE, July, 2022, Vol.23, Issue 95, pp.20-26
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2022.95.16
Geotechnique, Construction Materials and Environment

UTILIZATION OF COIR FIBERS TO IMPROVE THE BEARING CAPACITY AND TENSILE STRENGTH OF EXPANSIVE CLAY

*Anita Widianti[1], Angesta Artha Bhakti Negara[2], Tjokro Seigia Elmino[3] and Lazuardi Ramadhani[4]

[1,2,3,4] Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, Indonesia

*Corresponding Author, Received: 10 Nov 2021, Revised: 17 April. 2022, Accepted: 28 May 2022

ABSTRACT: Reinforcement is a method to improve soils with low bearing capacity and tensile strength. Coconut coir waste is an alternative reinforcement material because coir fibers have high tensile strength, high shear strength, and high resistance to compressive stress. This study performed the soaked and unsoaked California Bearing Ratio (CBR), the swelling, and the indirect tensile strength tests focusing on expansive clay reinforced with coir fibers. The content of coir fibers was between 0.00% to 1.25% by weight of the mixture. The fibers were cut into 30 mm to 50 mm long pieces, then mixed randomly into the soil in various content. The mixture was compacted based on the maximum dry density and the optimum moisture content of the clay. The test results revealed that the soaked and unsoaked CBR reached the maximum values at 1% fiber content. Originally of poor quality, the soil condition became quite good after being reinforced with an optimum fiber content of 1%. All specimens swelled when soaked. The swelling values tended to increase with the addition of coir fibers. Hence, the expansive clay must be chemically stabilized to reduce swelling. The tensile strength reached the maximum value at 0.6% fiber content.

Keywords: Expansive clay, Coir fiber, California Bearing Ratio, Swelling, Tensile strength