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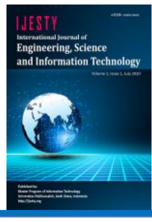

The Effect Of Holcim Cement Substitution On Fine-Grained Soils Its Influence On The Stability Of Soil Bearing Capacity Using The Terzaghi Method And Meyerhoff Method

Heri Sujatmiko*

Universitas 17 Agustus 1945 Banyuwangi, Indonesia

**Corresponding author Email: heri.untag@yahoo.com*

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Abstract

Soil is vital as a construction material and load support in civil engineering building work. The aim of stabilization itself is to increase the bearing strength of the soil by increasing soil cohesion and friction angles in the soil and maintaining good soil bearing strength so that it does not experience a decrease due to the influence of weather and air. Based on the Unified classification system, it is included in the OH classification or what is usually called clay soil with high organic plasticity, while based on the ASSHTO classification, the soil in Pancoran Village, Glagah District, Banyuwangi Regency is included in group A-7-5(25). The addition of Holcim Cement to clay soil from the Pancoran Village area, Glagah District, Banyuwangi Regency in the Direct Shear test obtained the most significant value in the 8.5% mixture with a curing time of 9 days for the φ value, namely φ = 19.8 ˚ from φ = 11.6 ˚ in the original soil or there was an increase amounted to 41.41% and for the c value, namely c = 9.75 kg/cm2 from c = 1.6 kg/cm2 in the original soil or an increase of 83.59%. The carrying capacity of soil tends to be greater after mixing cement additives. The maximum soil bearing capacity occurs when mixing 8.5% cement with nine days of curing, namely 66,458 t/m2 from 4,696 t/m2 of the original soil capacity or 92.93% for the Terzaghi method. Meanwhile, for the Meyerhoff Method, the maximum soil bearing capacity occurs when mixing 8.5% cement with nine days of curing, namely 92,696 t/m2 from 7,526 t/m2 of the original soil permit carrying capacity of 91.88%.

Keywords: *Soil, Cement, Bearing Capacity, Terzaghi Method, Meyerhoff Method.*

1. Introduction

Soil is vital in a civil engineering job, whether as a construction material or a load support. In the field, soil conditions that do not have the physical and technical quality requirements are often found [1]. Therefore, improving soil properties to fulfill the specified requirements is necessary. The Efforts to improve soil properties are called soil stabilization [2].

According to [3], there are several types of stabilization: physical, mechanical, and chemical [4]. Physically, soil stabilization can be carried out by thermal, which means that the soil is heated so that its properties change from its original properties. Mechanically, compaction is carried out to increase the soil density, while chemically, the soil is stabilized by mixing chemical compounds. The purpose of the stabilization itself is [5]:

1. Increase soil bearing strength by increasing soil cohesion and soil shear angle.
2. Maintained soil support that is already good, so it does not decrease due to the influence of weather and water.

Based on the background of the research described above, the formulation of the problem in this study is how significant the effect of stabilization of fine-grained soil with Holcim cement mixture on the bearing capacity with the Terzaghi method and the Meyerhoff method [6].

The objective of this research is the effect of stabilization of fine-grained soil with Holcim cement mixture on the bearing capacity with the Terzaghi method and the Meyerhoff method. Which, among others, have aims [7]:

1. Knowing the type of soil based on the Unified and AASHTO classification systems originating from Pancoran Village, Glagah District, Banyuwangi Regency.
2. Determine the effect of the addition of Holcim cement in the Direct Shear test on the cohesion value and the internal shear angle.
3. Determine the increase of the value of soil carrying capacity between the original soil conditions and soil mixed with Holcim cement in the Terzaghi method and the Meyerhoff method.

The results of this study are expected to provide suggestions in the form of the effect caused by the addition of Holcim Cement to the mechanism of the clay soil mechanics and obtain an overview of opportunities for alternative materials in construction planning [8].

1. How can Self-Reflection improve students' ability to write analytical exposition paragraphs?
2. What are students' responses to applying Self-Reflection in learning writing skills?

2. Literature Review

2.1. Theoretical Framework

Fine-grained soil is a definition of a term that is often used, namely clay. Clay has the properties of cohesion plastic, does not show dilation properties, and does not contain significant amounts of coarse matter. The clay grain fraction represents the weight of the soil grains, which is finer than 0.002 mm [9].

Clay with high plasticity can expand and shrink according to changes in its water content. According to [10], the effective stabilization to increase volume stability is in two ways, namely:

1. The soil becomes a passive mass because the particles bind together chemically or by applying high temperatures.
2. For example, slow moisture movement in the soil by closing the soil pores.

2.2. The Definition of Soil

In general, soil is defined as a material consisting of solid aggregates (granules) that are cemented (chemically bonded) to each other and from decayed organic matter (which has solid particles) accompanied by liquid and gas that fill the void spaces between the stable's particles [11]. Clay is an aggregate of particles with microscopic sizes originating from the chemical decomposition of the constituent elements of rock and is plastic in the range of moderate to broad water content. Soil weathering due to chemical reactions will produce a group of colloidal particles with a grain diameter smaller than 0.002 mm. Clay particles are shaped like sheets with special sheets, so clay has properties strongly influenced by surface forces [12] [13].

2.3. The Soil Classification System

The soil classification system is an arrangement of several types of soil that are different but have similar characteristics into groups and subgroups of users [14].

Two (2) types of soil classification methods are commonly used, namely:

1. Soil classification based on Unified System.
2. Soil classification by AASHTO method.

2.4. Soil Compaction Test

Compaction is the process of increasing the density of the soil by reducing the distance between the particles, resulting in a reduction in air volume using mechanical energy. In general, the higher degree of compaction is the soil's lower compressibility. The degree of soil density is measured based on dry density units, the mass of solid particles per unit volume of soil. The purpose of compaction is to improve soil properties. Some of the advantages obtained from this compaction effort include [15]:

1. Reduced subsidence, namely vertical movement in the soil mass due to reduced void ratio.
2. Increased soil strength
3. Reduced shrinkage or reduced volume due to reduced water content from the reference value during the drying process.

In this compaction, it is produced a relationship of a graph or curve between the dry unit weight (γd) and the water content that is given regularly during the subsequent soil compaction. After the graph is formed, the compacted soil possesses some of the optimum water content [16]. Where in this state, it has reached the maximum soil density. The degree of soil density is measured from its dry unit weight, and the relationship between dry unit weight (γd), wet unit weight (γb), and water content (w) is expressed by the following equation γ d = γ b

2.5. Direct Shear Testing

The direct shear test equipment uses a shear box made of iron, which functions as a different place for the shear strength test. The test object can be in the form of a square or circle. The test was carried out by placing the soil sample into a sliding box with the size of the specimen 6 x 6 cm, with a height of 2 cm and an area of 36 cm2 [17]. The sliding box consists of two equal parts in a horizontal direction. The normal force on the soil specimen is obtained by placing an object on it with a dead load of 8 kg, 16 kg, and 32 kg.

Everyday stress can be calculated by the equation below: $\sigma = \text{Normal Stress}$

$$\sigma = \frac{\text{Normal style that works}}{\text{Cross} - \text{sectional area of the soil sample}}$$

The equation can calculate the shear stress that opposes the shear movement below:

τ = Shear stress

$$\tau = \frac{\text{Shear force that opposes movement}}{\text{The cross} - \text{sectional area of the soil sample}}$$

In Hary C.H. (1992), Coulomb(1776) defines the function (σ) as:

τ = c + σ tg φ

With:

τ = soil shear stress (KN/m2)

c = soil cohesion (KN/m2)

σ = everyday stresses in the failure plane (KN/m2)

φ = ground shear angle (°)

2.6. Soil Bearing Capacity

Soil bearing capacity is the soil's ability to support the structure's load and transmit it due to its weight directly to the soil beneath it. Soil given a load such as a foundation load will experience distortion and settlement; if it continues to increase, the foundation settlement will also be more significant [18]. This condition indicates that a capacity collapse has occurred.

Soil bearing capacity where the soil can still support the load without collapsing.
Expressed by the equation:

$q_u = \frac{P_u}{A}$ dan $q_{ijin} = \frac{q_u}{SF}$

With:
Qu = ultimate bearing capacity (kg/cm 2)
Pu = ultimate load (kg) A = load area (cm2)
q ijin = allowable soil bearing capacity (kg/cm 2)
SF = Safety Factor

2.7. Soil Stabilization

Based on Bowles J.E (1984), the aim of soil stabilization efforts is:
1. Increase the bearing capacity of the soil by increasing the soil density
2. Reducing the value of soil permeability,
3. Lower the compatibility score.

2.8. Types of Soil Stabilization

Stabilization can include adding chemical ingredients, adding or replacing new materials, compaction, heating, and cooling. In an outline, there are three parts of stabilization: physical stabilization, mechanical stabilization, and chemical stabilization [19].

2.9. Cement

Cement is the most crucial constituent material. The function of cement is:
1. As an adhesive material between coarse and fine aggregates, they are united.
2. Filling the voids between the aggregate grains to form a compact or solid mass [20].

Treatment time has a vital role because the shear strength value of the soil increases with increasing curing time [21].

3. Research Method

3.1. Place and Time

Place of research: Laboratory of Soil Mechanics, SMK Negeri 1 Glagah Banyuwangi. Kuntulan Street No. 01 Banyuwangi. The Research Time is two months.

3.2. Preparatory Work

The activities carried out in preparatory work include taking test objects in the field, preparing work in the laboratory, and Field Work Soil sampling is fieldwork. The soil samples taken have disturbed and undisturbed soil. The soil sample that was born should not change the nature of the soil. The tubes in thin-walled cylinders with a specific diameter are used for testing original soil samples. The tube is inserted into the soil according to the stages, but the tube should not be lifted immediately to give the soil a chance to stabilize and attach to the tube wall. After that, the tube filled with soil was covered with a layer of paraffin to prevent water evaporation. When taking soil samples, there is no need to try to protect the soil's properties. Disturbed soil samples are put in a plastic bag or sack.

3.3. Laboratory Testing

The test was conducted at the Soil Mechanics Laboratory, SMK Negeri 1 Glagah Banyuwangi. Tests were carried out as follows.
1. Testing of physical properties.
2. Testing of Mechanical Properties.

3.3. The Test Performed

The tests carried out in the laboratory are divided into two, namely, testing the soil's physical properties and the soil's mechanical properties.
1. Soil Physical Properties Testing
   Testing the physical properties of the soil is carried out to find out the initial characteristics of the soil before changes are made because fine-grained soil will then be stabilized. This test consists of:
   a. Sieve Analysis.
   b. Hydrometer analysis.
   c. Soil water content testing.
   d. Soil-specific gravity testing.
   e. Soil volume weight testing.
   f. Soil liquid limits testing.
   g. Soil plastic limits testing.
   h. Soil shrinkage limit testing.

2. Soil Mechanical Properties Testing

   The soil mechanical property testing that was carried out is:

   a. Standard Proctor Testing.

   b. Direct Shear Testing (DST).

4. Result And Discussions

4.1. Test of Water Content

The results of the water content testing carried out in the laboratory are shown in Table 1 below.

Table 1. The results of testing the water content

No	Test	I		II	
		a	b	a	b
1	Weight Container (W1) gr	8,9	9,1	8,7	9,46
2	Container weight + wet soil (W2) gr	68,2	67,6	64,75	67,82
3	Container weight + dry soil (W3) gr	53,82	52,99	50,61	52,91
4	Water Weight (W2-W1) gr	14,38	14,61	14,14	14,91
5	Dry tanha weight (W3-W1) gr	44,92	43,89	41,91	43,45
6	Water content (W2-W3)/(W3-W1) x 100%	32,01	33,29	33,74	34,32
7	Average water content (WRT)	33,34%3			

4.2. Soil Volume Weight Test

The results of the soil volume weight testing conducted in the laboratory can be seen in Table 2.

Table 2. The results of the soil volume weight testing

No	Test	A	B	A	B
1	Ring diameter (d)	6,3	6,3	6,3	6,3
2	Ring height (T)	2,3	2,3	2,3	2,3
3	Ring Volume (V)	71,73	71,73	71,73	71,73
4	Ring weight (W1)	81.73	81.73	81.73	81.73
5	Ring weight + land (W2)	209,09	210,24	210,48	129,88
6	Land volume weight (W2-W1)/V	128,09	128,87	129,11	129,88
7	Average volume weight	1,79	1,80	1,80	1,81
8	Ring diameter (d)	1.80 gr/cm3			

4.3. Soil Specific Gravity Test

The results of the soil-specific gravity test conducted in the laboratory can be seen in Table 3 below.

Table 3. The results of the soil-specific gravity test

No	Test		1	2	3
1	Empty pycnometer weight	(W1) gram	20,52	21,36	21,74
2	The weight of the pycnometer+dry soil	(W2) gram	35,83	34,71	35,48
3	Weight of pycnometer+soil+water	(W3) gram	81,24	81,69	80,72
4	Weight of pycnometer+water	(W4) gram	71,92	73,51	72,43
5	Temperature	(t°)	28	28	28
6	BJ at temperature		0,99627	0,99627	0,99627
7	BJ at temperature (27.5)	27,5 W2-W1	0,99641	0,99641	0,99641
8	GS (T) soil specific gravity =	(W4-W1)(W3-W2) BJ water t°	2,56	2,58	2,52
9	Soil specific gravity at 27, =	Gs(t°) BJ water 27,5°	2,56	2,58	2,52
10	Average specific gravity	Gs rt	2,55		

4.4. Soil Grain Distribution Test

This research aims to determine the soil grains and percentage by looking at the limits of soil classification on specimens retained by sieve no. 200, so that the type of soil in this study is known. There are two steps in the grain analysis test: hydrometer analysis and sieving analysis. This test aims to determine the diameter of the soil grains smaller than 0.075 mm or pass the 200 filter. The results of the hydrometer analysis tests that were carried out in the laboratory can be seen in Table 4 and Table 5 below.

Table 4. The results of the hydrometer analysis sample 1

Time	Elapsed time min. T	Rl	R2	t	R' Rl + m	L	K	D (mm)	Rc = Rl – R2 + Cr	P K2 x R (%)
8.56										
8.58	2	37	-2.0	28	38	10.073	0.0126	0.028336	40.3	68.80
9.03	5	33	-2.0	28	34	10.728	0.0126	0.018495	36.3	61.97
9.33	30	30	-2.0	28	31	11.219	0.0126	0.007721	33.3	56.85
10.33	60	26	-2.0	28	27	11.874	0.0126	0.005617	29.3	50.02
2.48	250	22	-2.0	28	23	12.529	0.0126	0.002827	25.3	43.19
8.56	1440	17	-2.0	27	18	13.348	0.0126	0.001216	20.3	34.66

Table 5. The results of the hydrometer analysis sample 2

Time	Elapsed time min. T	R1	R2	t	R' R1 + m	L	K	D (mm)	Rc = R1 − R2 + Cr	P K2 x R (%)
8.56										
8.58	2	36	-2.0	28	37	10.273	0.0126	0.028565	39.3	67.09
9.03	5	32	-2.0	28	33	10.928	0.0126	0.018635	35.3	60.27
9.33	30	29	-2.0	28	30	11.383	0.0126	0.005578	32.3	55.14
10.33	60	27	-2.0	28	28	11.710	0.0126	0.007777	30.3	51.73
2.48	250	21	-2.0	28	22	12.693	0.0126	0.002845	24.3	41.49
8.56	1440	17	-2.0	27	18	13.348	0.0126	0.001216	20.3	34.66

This test aims to determine the composition of the percentage of grains retained on sieve no. 200. The results of the sieving analysis tests carried out in the laboratory can be seen in Table 4.6 and Table 4.7 below.

Table 6. The results of the sieving analysis sample 1

Sieve No	Opening (mm)	Mass retained (gr)		Mass retained (gr)		% finer by mass e/Wx 100%	Remarks
4	4.750	d1 =	0.00	e1 =	60.00	100.00	e7 = W - Sd
10	2.000	d2 =	0.65	e2 =	59.35	98.92	e6 = d7 + e7
20	0.850	d3 =	1.17	e3 =	58.18	96.97	e5 = d6 + e6
40	0.425	d4 =	1.33	e4 =	56.85	94.75	e4 = d5 + e5
60	0.250	d5 =	3.16	e5 =	53.69	89.48	e3 = d4 + e4
140	0.106	d6 =	5.33	e6 =	48.36	80.60	e2 = d3 + e3
200	0.075	d7 =	2.31	e7 =	46.05	76.75	e1 = d2 + e2
		Sd=	13.95				

Table 7. The results of the sieving analysis sample 2

Sieve No	Opening (mm)	Mass retained (gr)		Mass retained (gr)		% finer by mass e/Wx 100%	Remarks
4	4.750	d1 =	0.00	e1 =	60.00	100.00	e7 = W - Sd
10	2.000	d2 =	0.61	e2 =	59.39	98.98	e6 = d7 + e7
20	0.850	d3 =	1.15	e3 =	58.24	97.07	e5 = d6 + e6
40	0.425	d4 =	1.21	e4 =	57.03	95.05	e4 = d5 + e5
60	0.250	d5 =	3.24	e5 =	53.79	89.65	e3 = d4 +e4
140	0.106	d6 =	5.71	e6 =	48.08	80.13	e2 = d3 + e3
200	0.075	d7 =	2.86	e7 =	45.22	75.37	e1 = d2 + e2
		Sd =	14.78				

5. Conclusion

From the results of the research on the effect of stabilizing fine-grained soil with Holcim cement mixture on the carrying capacity with the Terzaghi method and the Meyerhoff method, it can be concluded that:

1. Based on the Unified classification system, it is included in the OH classification or what is usually called organic clay soil with high plasticity, while based on the ASSHTO classification of Pancoran soil, Glagah is included in group A-7-5(25).
2. The addition of Holcim Cement to clay soil from the Pancoran Village area, Glagah District, Banyuwangi Regency in the Direct Shear test obtained the most significant value in the 8.5% mixture with a curing time of 9 days for the φ value, namely φ = 19.8 ˚ from φ = 11.6 ˚ in the original soil or there was an increase of 41.41% and for the c value, namely c = 9.9 kg/cm2 from c = 1.6 kg/cm2 in the original soil or an increase of 83.84%.
3. The carrying capacity of soil tends to be greater after mixing cement additives. The maximum permitted soil bearing capacity occurs when mixing 8.5% cement with nine days of curing, which is 66,458 t/m2 of 4,696 t/m2. The bearing capacity of the original soil permits 92.93% for the Terzaghi method. Meanwhile, for the Meyerhoff method, the maximum soil permit capacity occurs when mixing 8.5% cement with nine days of curing, which is 92,696 t/m2 from 7,526 t/m2. The original soil permit capacity is 91.88%.

References

[1] F. Hussein, "Deep foundations: A survey on methods of construction, methods of calculation and a real-life design calculation," 2022.

[2] N. Ali, "Assessment of the Optimal Ratio of By-product Slag or Traditional Crushed Aggregate in a Replacement Mixture for Soft Soil Improvement and Optimal Replacement Thickness," *Geotech. Geol. Eng.*, vol. 41, no. 1, pp. 515–532, Jan. 2023, doi: 10.1007/S10706-022-02282-8/METRICS.

[3] R. M. Rasheed and A. A. B. Moghal, "Critical appraisal of the behavioral geo-mechanisms of peats/organic soils," *Arab. J. Geosci. 2022 1512*, vol. 15, no. 12, pp. 1–26, Jun. 2022, doi: 10.1007/S12517-022-10396-9.

[4] L. E. Sadek and K. M. Bahloul, "Numerical Simulation of Strip Footing Behavior on Reinforced Sabkha Soil," *SVU-International J. Eng. Sci. Appl.*, vol. 4, no. 2, pp. 36–46, Dec. 2023, doi: 10.21608/SVUSRC.2023.186565.1094.

[5] M. T. Alkhamis, A. AL-Rashidi, M. T. Alkhamis, and A. AL-Rashidi, "Finite Element Analysis of the Influence of Artificial Cementation on the Strength Parameters and Bearing Capacity of Sandy Soil under a Strip Footing," *Open J. Civ. Eng.*, vol. 13, no. 2, pp. 221–236, May 2023, doi: 10.4236/OJCE.2023.132017.

[6] A. S. Lees and J. Han, "A mobilised bearing capacity approach to the performance-based design of unpaved roads," *Transp. Geotech.*, vol. 44, p. 101177, Jan. 2024, doi: 10.1016/J.TRGEO.2023.101177.

[7] Z. Hu, Y. Wang, Y. Chen, and H. Xiao, “Deformation and failure mechanism of rapid stabilization for dredger fill in road engineering,” *Arab. J. Geosci.*, vol. 13, no. 6, pp. 1–11, Mar. 2020, doi: 10.1007/S12517-020-5271-6/METRICS.

[8] N. Ngoc Thang, D. Tran Ngoc Huy, and H. Chi Minh City, “Study On The Optimum Cement Deep Mixing Columns Configuration By Simplified Design Method,” vol. 19, no. 1, p. 2022.

[9] A. Dehghanbanadaki and S. Motamedi, “Bearing capacity prediction of shallow foundation on sandy soils: a comparative study of analytical, FEM, and machine learning approaches,” *Multiscale Multidiscip. Model. Exp. Des.*, pp. 1–18, Nov. 2023, doi: 10.1007/S41939-023-00280-8/METRICS.

[10] M. Y. Al-Aghbari, Y. Mohamedzein, and H. Al-Nasseri, “Potential use of structural skirts towards improving the bearing capacity of shallow footings exposed to inclined loadings,” *Int. J. Geotech. Eng.*, vol. 15, no. 10, pp. 1278–1283, Nov. 2021, doi: 10.1080/19386362.2019.1617477.

[11] D. R. VandenBerge, E. C. Reed, and R. Li, “Mobilized Bearing Capacity Analysis of Global Stability for Walls Supported by Aggregate Piers,” *J. Geotech. Geoenvironmental Eng.*, vol. 147, no. 6, p. 04021034, Jun. 2021, doi: 10.1061/(ASCE)GT.1943-5606.0002540/SUPPL_FILE/SUPPLEMENTAL_MATERIALS_GT.1943-5606.0002540_VANDENBERGE.PDF.

[12] H. Lee, S. J. Kim, B. H. Kang, and K. S. Lee, “Long-Term Settlement Prediction of Ground Reinforcement Foundation Using a Deep Cement Mixing Method in Reclaimed Land,” *Build. 2022, Vol. 12, Page 1279*, vol. 12, no. 8, p. 1279, Aug. 2022, doi: 10.3390/BUILDINGS12081279.

[13] D. Abdullah, R. Rahim, D. Hartama, A. Abdisyah, Z. Zulmiardi, and S. Efendi, “Application of Web Based Book Calculation using Deterministic Dynamic Programming Algorithm,” 2018, doi: 10.1088/1742-6596/1019/1/012040.

[14] C. C. Çadır, Z. Kaya, H. Yalcin, A. Erol, E. Uncuoğlu, and M. Akin, “Experimental Investigation of Soil Disturbance Effect on Bearing Capacity of Organic Soil,” *Int. J. Civ. Eng.*, pp. 1–16, Oct. 2023, doi: 10.1007/S40999-023-00904-7/METRICS.

[15] B. T. Son, N. T. Nu, N. T. Duong, and N. A. Ngoc, “APPLICATION THE POINT FOUNDATION (PF) METHOD FOR SOFT SOIL IMPROVEMENT: A CASE STUDY FROM VETNAM,” *Iraqi Geol. J.*, vol. 53, no. 2, pp. 1–18, Oct. 2020, doi: 10.46717/IGJ.53.2D.1MS-2020-10-23.

[16] C. C. Ezeh, A. Okonkwo, C. Henry, C. Chukwudi, and A. Chukwuemeka, “Assessment of Bearing Capacity and Compressibility of Soils of Enugu Shale, Southeastern Nigeria,” *Quest Journals J. Res. Environ. Earth Sci.*, vol. 9, pp. 2348–2532, 2023.

[17] M. Karumanchi and R. Nerella, “Shear strength parameters from digital tri-axial test and soils stabilization with extracted nanosilica,” *Nanotechnol. Environ. Eng.*, vol. 7, no. 1, pp. 307–318, Mar. 2022, doi: 10.1007/S41204-022-00238-0/METRICS.

[18] M. Md Nujid and D. Tholibon, “Failure Assessment of Strength and Bearing Capacity on Marine Stabilized Subgrade Soil,” *Artic. J. Fail. Anal. Prev.*, 2021, doi: 10.1007/s11668-021-01232-5.

[19] Z. Kaya and A. Erol, “Comparison of bearing capacities of undisturbed organic soils by empirical relations and 2D finite element analysis,” *Arab. J. Geosci.*, vol. 14, no. 19, pp. 1–16, Oct. 2021, doi: 10.1007/S12517-021-08364-W/METRICS.

[20] “Effectiveness of Recycled Plastic Pin for Improving Bearing Capacity of Embankment over Soft Soil - ProQuest.” .

[21] A. L. Ksheeraja and N. Srilatha, “Application of Geosynthetics for Geotechnical Challenges,” *Lect. Notes Civ. Eng.*, vol. 152, pp. 317–327, 2022, doi: 10.1007/978-981-16-1831-4_29/COVER.