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Evaluation of Swelling – Shrinkage of Soil Stabilized with Cement and Spent Bleaching Earth

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Abstract
This research aims to investigate the effect of using Spent Bleaching Earth (SBE) as a soil stabilizer in cement-stabilized soil. The study employs a 5% Portland Composite Cement (PCC) ratio based on the dry soil weight, with SBE as a stabilizing agent at ratios of 5%, 10%, 15%, and 20% of the Portland Composite Cement weight. Curing periods of 0 days, 7 days, and 14 days are used, with a focus on the expansion and shrinkage characteristics. The best results were obtained in a mixture with a 10% SBE variation as a soil stabilizer, under a 14-day curing period, with a plasticity index of 14.149%, Expansion (CBR Soaked) of 1.178, Expansion Pressure of 1,706 kg/cm2, and free expansion index of 13.333%. Test results indicate that mixtures with various amounts of SBE as a soil stabilizer in cement-treated soil and different curing periods can reduce soil expansion, as evidenced by decreasing values of plasticity index, Expansion (CBR Soaked), expansion pressure, and free expansion index. Therefore, it can be concluded that SBE as a soil stabilizer, along with prolonged curing, can reduce the soil's expansion and shrinkage characteristics.

Keywords: Cement, Soil, Spent Bleaching Earth, Stabilization, Swelling.

1. Introduction

The construction of a structure can also be carried out on land with low bearing capacity. One type of soil with low bearing capacity is expansive soil. Expansive soil is a type of clay soil that exhibits significant swelling and shrinkage. The swelling and shrinkage properties of the soil are strongly influenced by the water content in the soil. If the water content in the soil increases, it will affect the soil's bearing capacity. The quality of roads and residential land will be good when supported by a good subsoil condition. [10]

Soil stabilization is categorized into four types: physical soil stabilization, chemical soil stabilization, hydraulic soil stabilization, and geosynthetic soil stabilization. In this study, chemical soil stabilization is employed, utilizing cement and Matos soil stabilizer additives. Bentonite serves as an additive to augment soil swelling due to its property of expanding upon exposure to water.[7]

SBE can be utilized as a pozzolan material. This study aims to investigate the effect of SBE waste as an additive in the stabilization of clayey soil using cements [10].

In light of this, the primary objective of this study is to examine the impact of incorporating SBE as an additive in soil stabilization with cement. Consequently, the study seeks to assess how the SBE mixture and variations in curing time affect the expansion and shrinkage characteristics of the cement-stabilized soil.

2. Materials and Method

One of the efforts to mitigate the swelling and shrinkage tendencies of the soil is soil stabilization. This study employs Portland Composite Cement and Spent Bleaching Earth as soil stabilization materials to examine the soil's swelling and shrinkage characteristics both before and after the stabilization process.

The evaluation of soil swelling and shrinkage characteristics includes conducting tests for the Atterberg Limit[1], Swelling (California Bearing Ratio (CBR) Soaked) (SNI-1744-2012)[3], Free Swelling Index (IS: 2720-1977)[6], and Swelling Pressure (ASTM D4546-96) [2]. The results regarding swelling and shrinkage characteristics can be obtained following the experiments.

In this study, the conducted testing involves the assessment of soil swelling characteristics by employing a blend of cement and SBE. The mixture proportions include disturbed soil mixed with 5% cement, as well as 5%, 10%, 15%, and 20% of SBE. Each mixture variation is subjected to curing periods of 0 days, 7 days, and 14 days. Following the completion of these tests, the author will proceed with data analysis.

Soil sampling in this research was carried out on Capkala soil and bentonite. Capkala is situated on Capkala Road, Bengkayang Regency, West Kalimantan [8].

This This research involves testing soil swelling and shrinkage characteristics using a mixture of Portland composite cement and SBE. The mixture comprises soil mixed with 5% Portland composite cement and varying proportions of SBE, specifically 5%, 10%, 15%, and 20%. The curing time for these mixtures is set at 0, 7, and 14 days.

Table 1. Variations of soil mixture

Mix	Code
Disturbed Soil	S
Disturbed Soil + PCC 5%	SC-05
Disturbed Soil + Bentonite 40%	SB-40
Disturbed Soil + Bentonite 40% + PCC 5%	SBC-05
Disturbed Soil+ Bentonite 40%+ PCC 5% + Spent Bleaching Earth 5%	SBCS-05
Disturbed Soil + Bentonite 40%+ PCC 5% + Spent Bleaching Earth 10%	SBCS-10
Disturbed Soil + Bentonite 40%+ PCC 5% + Spent Bleaching Earth 15%	SBCS-15
Disturbed Soil + Bentonite 40%+ PCC 5% + Spent Bleaching Earth 20%	SBCS-20

Table 2. Result Of Plasticity Index and Classification

Code	Curing	IP	AASTHO	USCS
S	0	21.937	A-7-6	MH
S	7	21.710	A-7-6	MH
S	14	20.394	A-7-6	MH
SC-05	0	16.297	A-7-6	OL
SC-05	7	16.011	A-7-5	OL
SC-05	14	15.815	A-7-5	OL
SB-40	0	36.437	A-7-6	MH
SB-40	7	35.708	A-7-6	MH
SB-40	14	35.612	A-7-6	MH
SBC-05	0	24.131	A-7-5	MH
SBC-05	7	22.643	A-7-5	MH
SBC-05	14	21.718	A-7-5	MH
SBCS-05	0	19.497	A-7-5	MH
SBCS-05	7	19.094	A-7-5	MH
SBCS-05	14	18.138	A-7-5	MH
SBCS-10	0	14.996	A-7-5	OL
SBCS-10	7	14.563	A-7-5	OL
SBCS-10	14	14.149	A-7-5	OL
SBCS-15	0	20.290	A-7-5	MH
SBCS-15	7	19.861	A-7-5	MH
SBCS-15	14	19.466	A-7-5	MH
SBCS-20	0	21.133	A-7-5	MH
SBCS-20	7	20.782	A-7-5	MH
SBCS-20	14	19.992	A-7-5	MH

After the necessary data is collected from test in laboratory, then there is a manual analysis of *Atterberg Limit, Swelling (California Bearing Ratio Soaked),Swelling Pressure, and Free Swelling Index.*

3. Result and Discussion

3.1 Compaction Test

Table 2. Compaction Test Result

Code	OMC (%)	MDD (gr/cm^3)
S	21,500	1,391
SC-05	20,200	1,397
SB-40	24,500	1,313
SBC-05	23,600	1,336
SBCS-05	23,000	1,345
SBCS-10	22,800	1,364
SBCS-15	22,500	1,389
SBCS-20	22,300	1,412

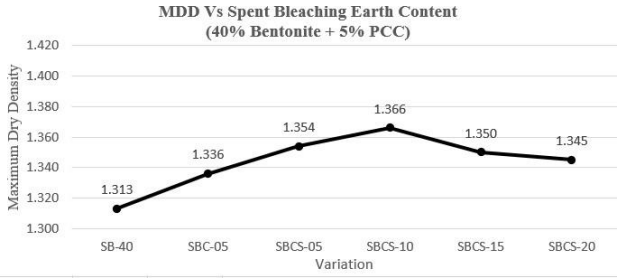

Figure 1. Graph of the Effect of Spent Bleaching Earth on Maximum Dry Density

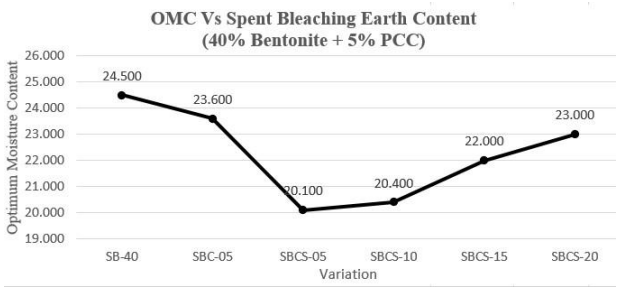

Figure 2. Graph of the Effect of Spent Bleaching Earth on Optimum Moisture Content

Based on **Table 2** and Figures 3 and 6, it is evident that soil density increases with the addition of bentonite in the mixture. Additionally, the optimum soil moisture content decreases, reaching its peak at an SBE content of 10%.

3.2 Specific Gravity

Table 3. Specific Gravity Test Results

Code	Specific Gravity		
	0	7	14
S	2.569	2.573	2.576
SC-05	2,582	2,619	2,650
SB-40	2,325	2,327	2,334
SBC-05	2,359	2,493	2,531
SBCS-05	2,429	2,452	2,454
SBCS-10	2,463	2,468	2,476
SBCS-15	2,360	2,379	2,384
SBCS-20	2,339	2,348	2,354

Based on **Table 3**, soil mixed with 40% bentonite has the lowest density, while soil mixed with 40% bentonite, 5% PCC, and 10% spent bleaching earth during a curing period of 14 days results in the highest density. Therefore, it can be concluded that density will increase with the addition of spent bleaching earth (SBE).

3.3 Atterberg Limit Test

Table 4. Plasticity Index Test Results

Code	Plasticity Index (%)		
	0	7	14
S	21,937	21,710	20,394
SC-05	16,297	16,011	15,815
SB-40	36,437	35,708	35,612
SBC-05	24,131	22,643	21,718
SBCS-05	19,497	19,094	18,138
SBCS-10	14,996	14,563	14,149
SBCS-15	20,290	19,861	19,466
SBCS-20	21,133	20,782	19,992

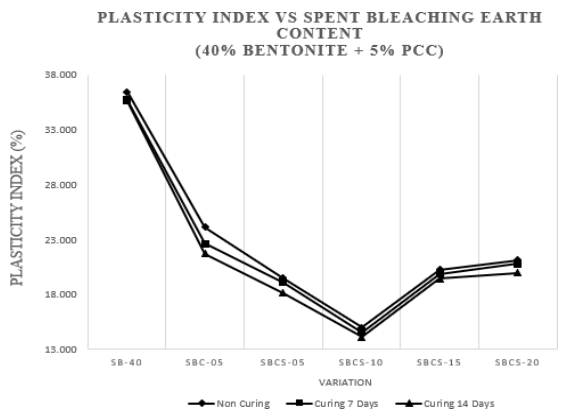

Figure 3. Graph of Analysis Results of Plasticity Index with Variations in Spent Bleaching Earth Content and Curing Time

Based on **Table 4** and Figure 3, soil mixed with 40% bentonite has the highest plasticity index, while soil mixed with 40% bentonite, 5% PCC, and 10% Spent Bleaching Earth during a curing time of 14 days has the lowest plasticity index. Therefore, it can be concluded that the plasticity index decreases with the addition of 10% Spent Bleaching Earth in the mixture and with longer curing time.

3.4 Soil Classification Test Results

Table 5. Classification Test Results According to USDA[4]

Code	USDA		
	0	7	14
S	Lempung Berlananu	Lempung Berlananu	Lempung Berlananu
SC-05	Tanah Liat Berlanau	Tanah Liat Berlanau	Tanah Liat Berlanau
SB-40	Lempung Berlanau	Lempung Berlanau	Lempung Berlanau
SBC-05	Tanah Liat Berlanau	Tanah Liat Berlanau	Tanah Liat Berlanau
SBCS-05	Tanah Liat	Tanah Liat Berpasir	Tanah Liat Berpasir
SBCS-10	Tanah Liat Berlanau	Tanah Liat Berpasir	Tanah Liat Berpasir
SBCS-15	Tanah Liat Berlanau	Tanah Liat Berlanau	Tanah Liat Berlanau
SBCS-20	Tanah Liat Berlanau	Tanah Liat Berlanau	Tanah Liat Berlanau

Table 6. Classification Test Results According to USCS[4]

Code	USCS		
	0	7	14
S	MH	MH	MH
SC-05	OL	OL	OL
SB-40	MH	MH	MH
SBC-05	MH	MH	MH
SBCS-05	MH	MH	MH
SBCS-10	OL	OL	OL
SBCS-15	MH	MH	MH
SBCS-20	MH	MH	MH

Table 7. Classification Test Results According to AASTHO[4]

Code	AASTHO		
	0	7	14
S	A-7-6	A-7-6	A-7-6
SC-05	A-7-6	A-7-5	A-7-5
SB-40	A-7-6	A-7-6	A-7-7
SBC-05	A-7-5	A-7-5	A-7-5
SBCS-05	A-7-5	A-7-5	A-7-5
SBCS-10	A-7-5	A-7-5	A-7-5
SBCS-15	A-7-5	A-7-5	A-7-5
SBCS-20	A-7-5	A-7-5	A-7-5

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3.5 Activity Results

Table 8. Activity Analysis Results

Code	Activity		
	0	7	14
S	0,225	0,223	0,210
SC-05	0,186	0,190	0,190
SB-40	0,369	0,363	0,362
SBC-05	0,290	0,273	0,264
SBCS-05	0,272	0,266	0,258
SBCS-10	0,228	0,223	0,220
SBCS-15	0,259	0,256	0,251
SBCS-20	0,266	0,264	0,256

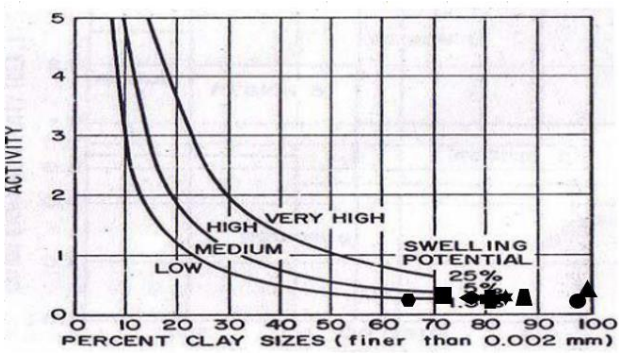

Figure 4. Graph of Activity Analysis Results with Variations in SBE Content and Non Curing [9]

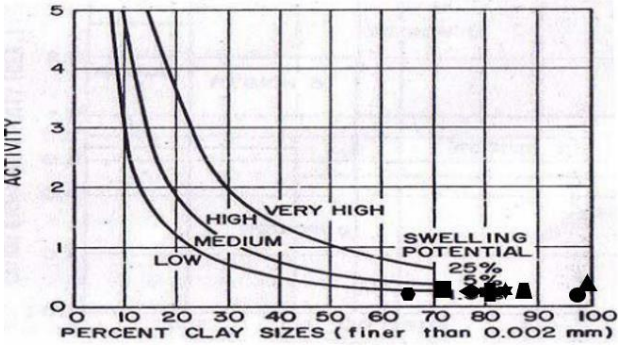

Figure 5. Graph of Activity Analysis Results with Variations in SBE Content and Curing 7 Days [9]

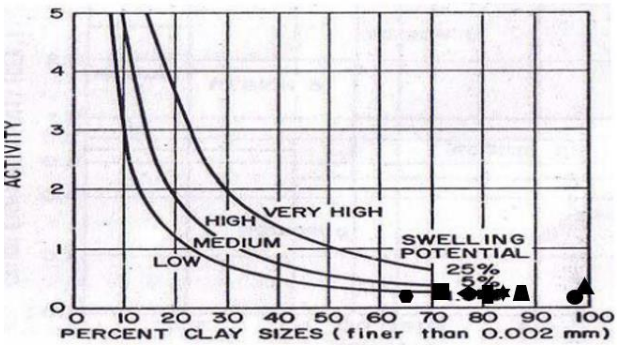

Figure 6. Graph of Activity Analysis Results with Variations in SBE Content and Curing 14 Days [9]

S	●
SC-05	▲
SB-40	▲
SBC-05	★
SBCS-05	■
SBCS-10	⬢
SBCS-15	■
SBCS-20	◆

Based on **Table 8**, soil mixed with 40% bentonite has the highest activity, while soil mixed with 40% bentonite, 5% PCC, and 10% spent bleaching earth during a curing time of 14 days has the lowest activity. Therefore, it can be concluded that the activity will decrease with the lowest results when adding 10% spent bleaching earth (SBE) in the mixture and with a longer curing time, thereby reducing the soil's potential for swelling.

3.6 Swelling Test (CBR Soaked)

Tabel 9. Swelling Test Results

Code	Swelling (%)		
	0	7	14
S	2,653	2,574	2,606
SC-05	2,598	1,905	1,588
SB-40	5,533	5,452	5,363
SBC-05	4,590	3,247	3,197
SBCS-05	2,178	2,152	2,062
SBCS-10	1,464	1,299	1,178
SBCS-15	2,209	2,166	2,104
SBCS-20	2,470	2,332	2,287

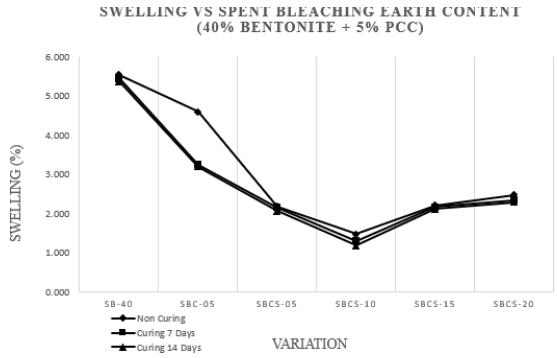

Figure 7. Graph of Swelling Results with Variations in SBE Content and Curing Time

Based on Table 9 and Figure 5, soil mixed with 40% bentonite has the highest swelling, while soil mixed with 40% bentonite, 5% PCC, and 10% spent bleaching earth with a curing time of 14 days has the lowest swelling. Therefore, it can be concluded that swelling decreases with the addition of spent bleaching earth in the mixture and with longer curing time.

3.7 Swelling Pressure Test

Tabel 10. Swelling Pressure Test Results

Code	Swelling Pressure (Kg/Cm^2)		
	0	7	14
S	2,427	2,335	2,257
SC-05	2,230	2,125	2,020
SB-40	4,133	4,054	4,028
SBC-05	3,674	3,411	2,952
SBCS-05	2,230	2,152	2,099
SBCS-10	1,916	1,863	1,706
SBCS-15	2,401	2,335	2,191
SBCS-20	2,493	2,348	2,217

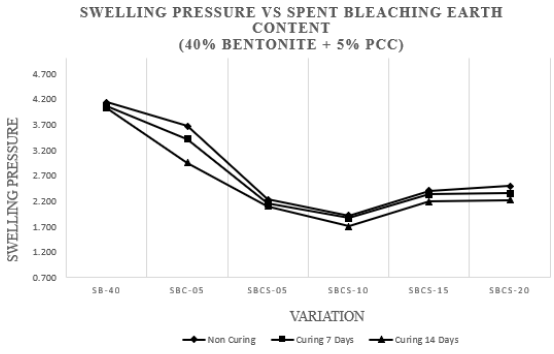

Figure 8. Graph of Swelling Pressure Results with Variations in SBE Content and Curing Time

Based on Table 10 and Figure 6 soil with 40% bentonite mixture has the highest swelling pressure and soil with 40% bentonite mixture, 5% PCC and 10% spent bleaching earth with 14 days curing period has the lowest swelling pressure. Therefore, it can be concluded that swelling decreases with the addition of spent bleaching earth in the mixture and with longer curing time.

3.8 Free Swelling Index

Tabel 11. Free Swelling Index Result

Code	Free Swelling Index (%)		
	0	7	14
S	26,667	26,667	25,000
SC-05	25,000	21,429	20,000
SB-40	45,455	45,455	41,667
SBC-05	33,333	30,769	28,571
SBCS-05	30,769	25	23,077
SBCS-10	16,667	14,286	13,333
SBCS-15	33,333	30,769	27,273
SBCS-20	36,364	33,333	30,769

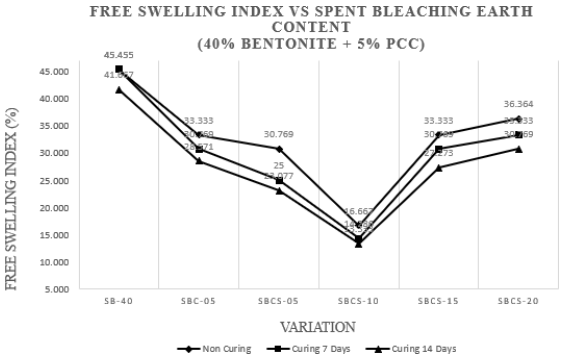

Figure 9. Graph of Free Swelling Index Results with Variations in SBE Content and Curing Time

Based on **Table 11** and **Figure 7**, it can be observed that the soil mixed with 40% bentonite exhibits the highest free swelling index, while the soil mixed with 40% bentonite, 5% PCC, and 10% spent bleaching earth with a curing time of 14 days demonstrates the lowest free swelling index.

4. Conclusion

Based on the compaction test results with 5% portland cement and variations in Spent Bleaching Earth (SBE) levels of 5%, 10%, 15% and 20% it was found that the maximum soil density (MDD) value would increase from modified soil with optimum levels of SBE 10 %. However, the optimum moisture content (OMC) in the soil will increase with increasing percentage of SBE content. Based on the results of the swelling test using CBR, FSI, and disturbed soil Geonor added bentonite increased the swelling pressure value and increased the potential development category to high swelling potential. Based on test results for developing soil with 5% portland cement and variations in SBE content of 5%, 10%, 15% and 20% it was found that the development of soil with 40% bentonite would decrease with the optimum decrease at 10% SBE content.

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