International Journal of GEOMATE, Oct., 2025 Vol.29, Issue 134, pp.59-68
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2025.134.5017
Geotechnique, Construction Materials and Environment

UTILIZATION OF DREDGED SOIL-EPS MIXTURE AS A LIGHTWEIGHT MODULAR BLOCKS: A STUDY ON THE BEARING CAPACITY

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*Corresponding Author, Received: 17 April 2025, Revised: 17 July 2025, Accepted: 26 July 2025

ABSTRACT: The increasing demand for sustainable and lightweight construction materials has encouraged the exploration of alternative resources such as dredged soil. This study investigates the mechanical performance of Lightweight Modular Blocks (LMB) composed of dredged soil (DS), cement (C), and Expanded Polystyrene (EPS), with a focus on their applicability as subgrade materials. The research examines the effects of varying cement content (3%, 5%, 7%, and 9%), curing periods (7, 14, and 28 days), and EPS inclusion (0.5% and 0.75%) on the California Bearing Ratio (CBR) value under both unsoaked and soaked conditions. Specimen expansions were recorded at the end of the soaking period (96 hours). The results indicate that increasing cement content and extending the curing period significantly improve CBR values. Furthermore, these two variables exhibit an interdependent relationship, complementing each other in enhancing soil strength. In contrast, the inclusion of EPS reduces CBR values due to the reduced proportion of the soil-cement matrix and the formation of voids. However, increasing the EPS content proves beneficial in reducing specimen expansion and bulk density, achieving a weight reduction of up to 29%. The findings confirm that, with an optimized curing period, all tested compositions meet the minimum subgrade requirement specified by the Indonesian National Standard (SNI). Further analysis for the future development reveals that: 1) The optimal strength gain is observed in the C7%-14 days composition, 2) The inclusion of 0.5% EPS offers the best balance between strength and weight reduction, 3) For greater weight reduction, 0.75% EPS may be used, provided that a minimum of 7% cement and at least 14 days of curing are applied to maintain structural integrity.

Keywords: LMB, Dredged soil, EPS, California Bearing Ratio, Subgrade applications

1. INTRODUCTION

EPS geofoam is widely utilized in construction for its efficiency and practicality. It offers significant benefits, particularly in reducing lateral earth pressure and settlement in soft soil applications. Using EPS geofoam minimizes the need for extensive excavation and compaction, making it advantageous for construction on problematic soils [1], [2]. A case study on the Canaveral Port construction project in Florida demonstrated that geofoam is a more cost-effective solution than conventional backfill [3]. This cost efficiency was attributed to the lighter backfill reducing steel walls' required grade and thickness and allowing for smaller tie-back anchor supports.

Previous geofoam studies have shown that the bearing capacity values for densities of 12, 15, and 20 kg/m³ were 0.87%, 1.67%, and 1.86%, respectively[4]. These values are significantly below the minimum requirement of 6% set by the Indonesian National Standard (SNI) for subgrade materials [5]. As a result of its low CBR values, geofoam is seldom used as a primary load-bearing material. Instead, its application is limited to areas where its lightweight properties are prioritized over its load-bearing capacity.

The concept of Lightweight soil-EPS was introduced as a modification of lightweight materials combining stabilized soil and EPS. This innovation leverages geofoam's lightweight characteristics and practicality with some improvement in its geotechnical properties. Lightweight soil-EPS combinations have been referred to by various names[6-13]. In this study, it is known as Lightweight Modular Block (LMB), a type of lightweight soil specifically designed in a practical block form. The primary material used in LMB is dredged soil sourced from the Bili-Bili Dam.

Dredged soil is a substitute for conventional soil and refers to sediment collected from annual dredging activities, which is disposed of in designated disposal areas, as presented in Figure 1. As the largest dam in South Sulawesi, Indonesia, the Bili-Bili dam faces significant sedimentation issues [14-16] . Consequently, dredging activities are routinely carried out to maintain the dam's operational efficiency and service life. Based on the data, the recorded volume of dredged material from the dam reached 82,000 m³ [17]. It represents only one year of dredging and does not account for cumulative volumes from previous years or the potential future volumes. Thus, dredged soil is considered to have great potential as an alternative construction material. Besides dredged soil, LMB uses EPS in beads form. While the inclusion of EPS generally reduces soil strength, cement helps enhance the mechanical properties of LMB, resulting in a lightweight material with significantly improved geotechnical characteristics.

Previous studies on LMB elements primarily focused on unconfined compressive strength and direct shear performance [18]. This paper extends the discussion by providing the California Bearing Ratio (CBR) Test results. Bearing capacity is a critical parameter that reflects the local shear strength of the soil. It plays substantial role in subgrade engineering applications [19], [20]. Therefore, studying this parameter is essential to provide a broader perspective. As discussed in previous research, LMB elements were prepared using a single-layer static compaction method. The bearing characteristics were evaluated under unsoaked and soaked conditions, with variations in cement content, curing time, and EPS percentage. The effects of these parameters on the CBR values and the behavior of the specimens are analyzed. Additionally, statistical analysis was conducted to provide a more accurate interpretation of the results.

2. RESEARCH SIGNIFICANCE

This study presents two main aspects: the utilization of dredged soil and its potential as a primary component in lightweight construction materials. This research brings valuable insights into transforming the abundant dredged soil from the Bili-Bili Dam into more functional and sustainable construction materials. Beyond serving as an alternative solution to reduce self-weight, this research provides an environmentally conscious strategy for managing the sedimentation issue at the dam. This research specifically investigated the mechanical properties of Lightweight Modular Blocks (LMB), which incorporate dredged soil, cement, and EPS beads. This study focuses on evaluating CBR value to analyze the feasibility of using LMB from the point of view of a subgrade material. The results of this study are expected to provide an understanding of the future development of LMB as a suitable lightweight material.

3. MATERIALS AND METHOD

3.1 Materials

The materials used for the development of Lightweight Modular Blocks (LMB) consisted of dredged soil (DS), cement (C), and EPS particles. The dredged soil was obtained from the disposal area of Bili-Bili Dam (Fig.1), located in South Sulawesi, Indonesia. The soil underwent a transformation process to improve its suitability for the laboratory experiment, as presented in Fig.2. Initially, it was collected in sludge form (Fig.2a) and sun-dried to achieve an air-dried condition (Fig.2b), followed by a crushing and sieving process using a #4 sieve (Fig.2c) The soil was subsequently stored in a container. Prior to each use, its initial moisture content was measured.

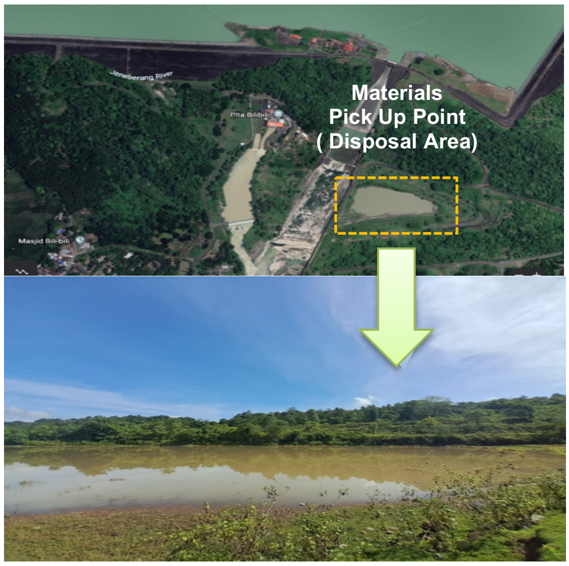

Fig. 1 Dredged soil pick up point [18]

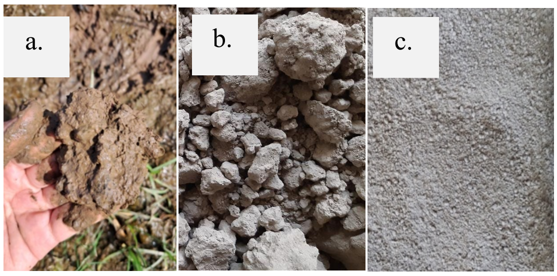

Fig.2 Dredged soil a) sludge form, b) boulder form, c) pass #4 sieve

Table 1. Dredged soil properties

Properties	Value
Specific Gravity, Gs	2.66
Consistency Limit	
Plasticity Index, PI (%)	6.50
Liquid Limit, LL (%)	38
Plastic Limit, PL (%)	32
Shrinkage Limit, SL (%)	27
Grain Size Analysis	
Sand (%)	9.20
Silt (%)	83.10
Clay (%)	7.50
USCS Classification	ML
Standard Proctor Test	
MDD (kN/m^3)	14.45
OMC (%)	27.20
CBR Value	
Unsoaked (%)	15.88%
Soaked (%)	6.37%

Overall the basic properties of this soil are presented in Table 1. The particle size distribution analysis indicated that most soil particles are classified as finer (90.6%), placing the material in the ML category according to the Unified Soil Classification System (USCS). EPS particles were used to enhance the lightweight properties of the mixture, with a bulk density are 0.034 g/cm^3. Meanwhile, the cement used in the study was Tonasa PCC [4], [21].Materials were carefully selected and prepared to ensure uniformity and reliability in the experimental analysis. The combination of dredged soil, EPS particles, and cement was chosen to focus the research development on dredged soil-EPS potency since cement is a well-known standardized stabilization material.

3.2 Experimental Design

Table 2. presents the laboratory experimental design of this research. This study conducted penetration tests on two types of mixtures: dredged soil-cement (DS + C) and LMB or dredged soil-cement with EPS inclusion (DS + C + EPS). Each specimen were subjected to curing treatment and tested under unsoaked or soaked conditions. All variables influencing this CBR investigation are systematically evaluated, including the expansion of soaked specimens after 96 hours of soaking were recorded and will be analyzed.

Table 2. Experimental design

Specimen	Cement (% by dry weight)	EPS (% by total mass)	Curing Period (days)	Condition
Dredged Soil - Cement *(DS +C)*	3, 5, 7, 9	-	7, 14, 28	Unsoaked
	3, 5, 7, 9	-	7, 14, 28	Soaked
Dredged Soil - Cement + EPS *(DS + C + EPS)*	3, 5, 7, 9	0.5, 0.75	7, 14, 28	Unsoaked
	3, 5, 7, 9	0.5, 0.75	7, 14, 28	Soaked

3.3. Specimen preparation and testing

The preparation phase were divided into four key stages: preparation, curing, soaking, and penetration test. The DS + C specimens were compacted with different compaction blows following ASTM D-1883-21, which are 10, 25, or 56 blows. Penetration tests were performed on each specimen. The output were graphs of density versus CBR values. The graphs were analyzed to determine the CBR values at the desired density.

The DS + C + EPS specimens were prepared using static compaction method. Static compaction method is not new and has been frequently used due to its effectiveness [23-25]s.A single-layer static compaction method, as developed in previous research was adopted [18]. The apparatus used for static compaction is illustrated in Figure 4. The single-layer compaction method was chosen to mitigate issues commonly associated with three-layer compaction, such as specimen rebound and surface cracking. Experimental observations revealed that cracks consistently formed at the top of each layer. In the three-layer compaction method, the specimen underwent repeated load–unload phases to accommodate the addition of subsequent layers.

Upon removal of the compaction load, the EPS particles exhibited swelling behavior, which disrupted the structure of the previously compacted soil-cement matrix. Moreover, three-layer compaction tends to be more time-consuming, raising concerns that the load-unload cycles may occur during the initial setting time of the soil–cement and cause separation. To address this, reducing the number of layers was evaluated. The results indicated improved specimen performance especially in cracks occurance.

The mixing process was considered the most critical step in the soil-EPS mixture, as improper mixing led to an uneven distribution of EPS. Uneven EPS distribution resulted in inconsistent specimen behavior, making it difficult to interpret the specimen's behavior accurately. The soil-cement-water needed to be thoroughly mixed to achieve a homogeneous state before adding EPS, as incomplete mixing could cause the beads to cluster in certain areas. Water generates capillary forces that effectively bond the EPS to the surface, leading to the accumulation of EPS in wet spots only [25]. Therefore, it is essential to ensure the soil-cement-water mixture is entirely homogeneous before adding EPS. Fundamentally, the interaction between EPS and water facilitates the integration of EPS into the mixture when the soil moisture is higher. In contrast, when the moisture content exceeds the optimum moisture content (OMC), the soil strength decreases significantly [27-29]. Therefore, the moisture content used was maintained at its OMC to optimize the strength.

Fig.4 Static compaction apparatus

Fig.5 CBR specimens preparation and testing

Upon completion of the specimen preparation, the specimens underwent curing for the durations specified in Table 2. After curing, the unsoaked specimens were immediately subjected to a penetration test, while the soaked specimens were immersed in water for 96 hours. Understanding the specimen's behavior in soaked conditions and assessing its long-term stability is important. The expansion was manually monitored using a dial gauge seated on a holder connected to the base plate. At the end of soaking, specimen expansion was observed. Overall, the scheme of these processes is presented in Figure 5.

4. RESULT AND DISCUSSION

4.1 Effect of Cement Content and Curing Period

The results of the penetration test are summarized in Figure 6. It was constructed using the data collected during the experiments. It can be seen that all graphs exhibit a positive linear correlation, indicating that the addition of cement increased the CBR values. The CBR values of natural soil were taken as a benchmark, which were 15.88% and 6.37% under unsoaked and soaked conditions, respectively. The effectiveness of each parameter was evaluated by comparing its CBR value to the natural soil.

To evaluate this positive linear correlation, R-squared (R^2) value are calculated. It shows the relationship between increasing cement content and CBR values in the regression model. It indicates how well the independent variable (cement content) explains the variance in the dependent variable (CBR values). The data in Table 3. show that R^2 values are close to 1 for all variations. It can be interpreted as a consistent and strong relationship between increasing cement content (3%, 5%, 7%, and 9%) and improving CBR values across all specimens. The results confirm that higher cement content reliably enhances the bearing capacity of the DS + C specimens, with peak value achieved at 9% cement.

The DS + C + EPS specimens observe a slightly different trend. The results show a linear relationship, although CBR values of 3% and 5% cement in some conditions are detected below the natural soil value, particularly at 0.75% EPS. It might caused by inadequate bonding of 3% and 5% cement content to compensate the strength reduction caused by the presence of EPS. However, specimens with more than 7 days of extended curing periods demonstrate improvement, suggesting that lower cement content requires longer curing time. In contrast, specimens with 7% and 9% cement content show remarkable improvements even with 7 days of curing.

The 5% cement specimen demonstrates better value after the curing period is extended from 7 to 14 days, as shown in Figure 6a. The CBR value increased from 12.87% to 26.37%. Further extension to 28 days increased the CBR to 55.1%, approximately 3.6 times that of the natural soil. Meanwhile, the 3% cement specimen results indicate the necessity of a minimum of 28 days of curing. However, the increased ratio calculated is still minimal (1.1), which barely contributes to the strength improvements.

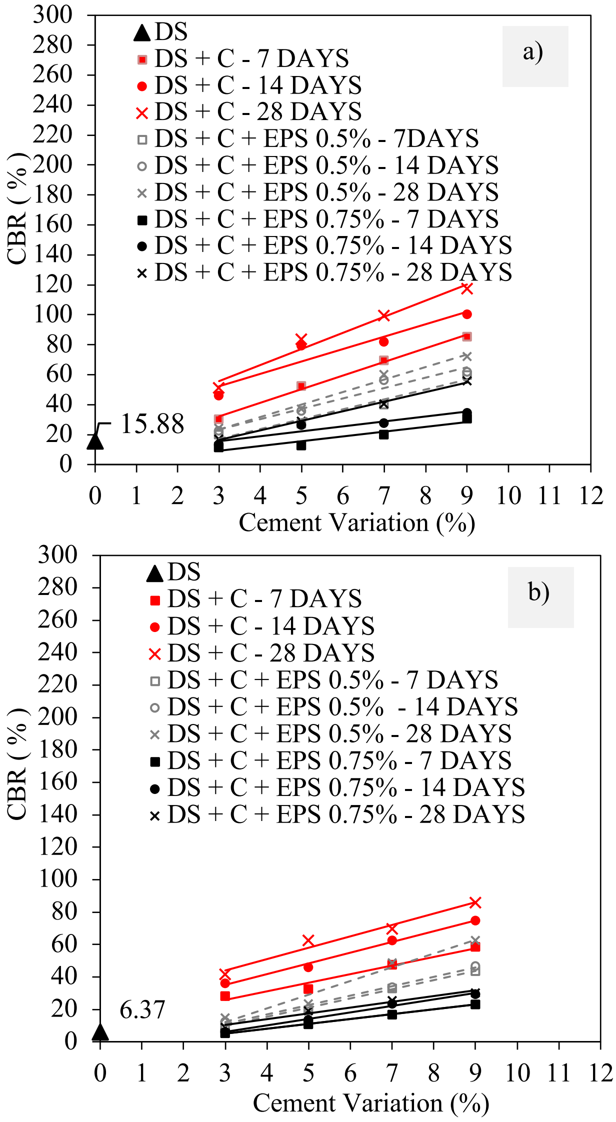

Fig.6 Summary of CBR values a) unsoaked condition, b) soaked condition

Table 3. R^2 value of the specimen

Unsoaked Condition	R^2	Soaked Condition	R^2
DS+C– 7 days	0.993	DS + C – 7 days	0.967
DS+C– 14 days	0.892	DS + C – 14 days	0.993
DS+C– 28 days	0.971	DS + C – 28 days	0.971
DS+C+EPS 0.5% –7 days	0.960	DS + C +EPS 0.5% – 7 days	0.996
DS+C+EPS 0.5% –14 days	0.958	DS + C + EPS 0.5% – 14 days	0.989
DS+C+EPS 0.5% – 28 days	0.985	DS + C + EPS 0.5% – 28 days	0.961
DS+C+EPS 0.75% – 7 days	0.905	DS + C + EPS 0.75% – 7 days	0.998
DS+C+EPS 0.75% –14 days	0.897	DS + C + EPS 0.75% – 14 days	0.993
DS+C+EPS 0.75% –28 days	0.995	DS + C + EPS 0.75% – 28 days	0.970

The observed phenomena suggest a positive correlation between increasing cement content and extending the curing period, leading to a remarkable improvement in CBR values. It was observed that cement addition and prolonged curing play critical and interdependent roles in enhancing the performance of the specimens. Cement strengthens the mixture through the hydration process, which occurs when cement reacts with water and produces calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H) compounds. These hydration products fill the voids between soil particles and act as binders, strengthening the soil matrix. Increasing the cement content from 3% to 9% increases the amount of hydration products, and more hydration products mean more binding compounds involved. Meanwhile, a longer curing time allows the hydration process to continue and become more complete over time, resulting in a stiffer and stronger structure. Therefore, these parameters complement each other and play a vital role in enhancing the CBR values. The increasing trend was not only evident in the CBR test results but also reflected in the findings from previous LMB element tests [18]. The unconfined compressive strength and shear strength parameters also exhibited similar behavior as cement content and curing time were increased. From these results, it can be concluded that cement is an approved binder for improving the mechanical properties of typical dredged soil material and is recommended for further investigation.

4.2 The Effect of EPS Addition

In addition to the effects of cement content and curing duration discussed in the previous section, Figure 7 presents data illustrating the impact of EPS addition on CBR values. The data provided serve as representative findings under unsoaked conditions, aiding in assessing how EPS influences the CBR values of the soil-cement mixture. Regardless of the cement content, the dataset shows a clear trend: as EPS content increases, CBR values consistently decrease. This phenomenon is likely attributed to two primary factors:

1.) The reduction of the soil-cement portion within the mixture due to increased EPS amount.

In DS + C + EPS specimens, EPS made a minimal contribution to the overall strength of the specimen, including its bearing capacity. Based on the data, the CBR values of geofoam with various densities range from 0% to 1% [4]. It shows that EPS material has minimal value in terms of bearing capacity. Therefore, the soil-cement portion is mainly responsible for bearing the penetration load, which determines the CBR value. In summary, as EPS replaces the soil cement in the mixture, the key structural components responsible for strength are reduced, leading to a lower CBR value.

2.) The presence of EPS creates voids.

The inclusion of EPS inherently increases voids in the mixture. Figure 8 further supports this by showing gaps and fractures around EPS particles. Fractures surrounding the EPS particles can be seen in both 0.5% EPS and 0.75% EPS. The fractures follow the shape of EPS. These findings align with Jiang et al. results [29], which reported an observed specimen with removed EPS traces. It left a spherical depression in the shape of EPS. It indicated EPS particles were not chemically reacted with the soil-cement portion. Since the properties of EPS and soil-cement are significantly different from each other. Therefore, the interfaces between them are weak. These weak interfaces reduce the cohesion of the mixture, making it prone to damage under stress.
While the CBR values decline with EPS inclusion, this does not negate its practical utility. The lightweight nature of the material is particularly beneficial in LMB. EPS inclusion is responsible for the material's lightweight properties. The impact of EPS inclusion on reducing the specimen's self-weight was significant. It was approximately 18%—29% lighter than the bulk density of DS + C specimens [18]. The bulk density of the mixtures ranged from 10.23 kN/m³ to 11.64 kN/m³.

3.) Expansion Analysis

Figure 6b presents the penetration test results after soaking specimens for 96 hours. When compared to specimens with the same compositions in Figure 6a, it is clear that soaking reduced CBR values. The corresponding expansion values are recorded in Table 4, ranging from 0.04 mm to 0.87 mm. The specimen had the highest expansion with 3% cement - 7 days - 0.5% EPS. Furthermore, the expansion values decreased with increasing cement content and curing duration, reaching nearly zero in the specimen with 9% cement- 28 days - 0.75% EPS. This trend indicates that both cement content and curing time significantly influence the strength and stabil[32-36]ity of the soil-cement mixture. Prolonged curing promotes a more extensive hydration, leading to a stiffer structure. This hardened matrix becomes less permeable and less susceptible to water absorption during soaking, thereby improving the material's resistance to swelling and loss of strength in saturated conditions.

Additionally, in contrast to its effect on CBR values, the addition of EPS demonstrates a positive impact in reducing specimen expansion. The data show specimens containing 0.75% EPS exhibited less expansion than those with 0.5% EPS. A similar observation was also reported in other studies , which explained that this behavior is influenced by the high compressibility of EPS, allowing it to function as a compressible inclusion to reduce subsequent swelling pressure.

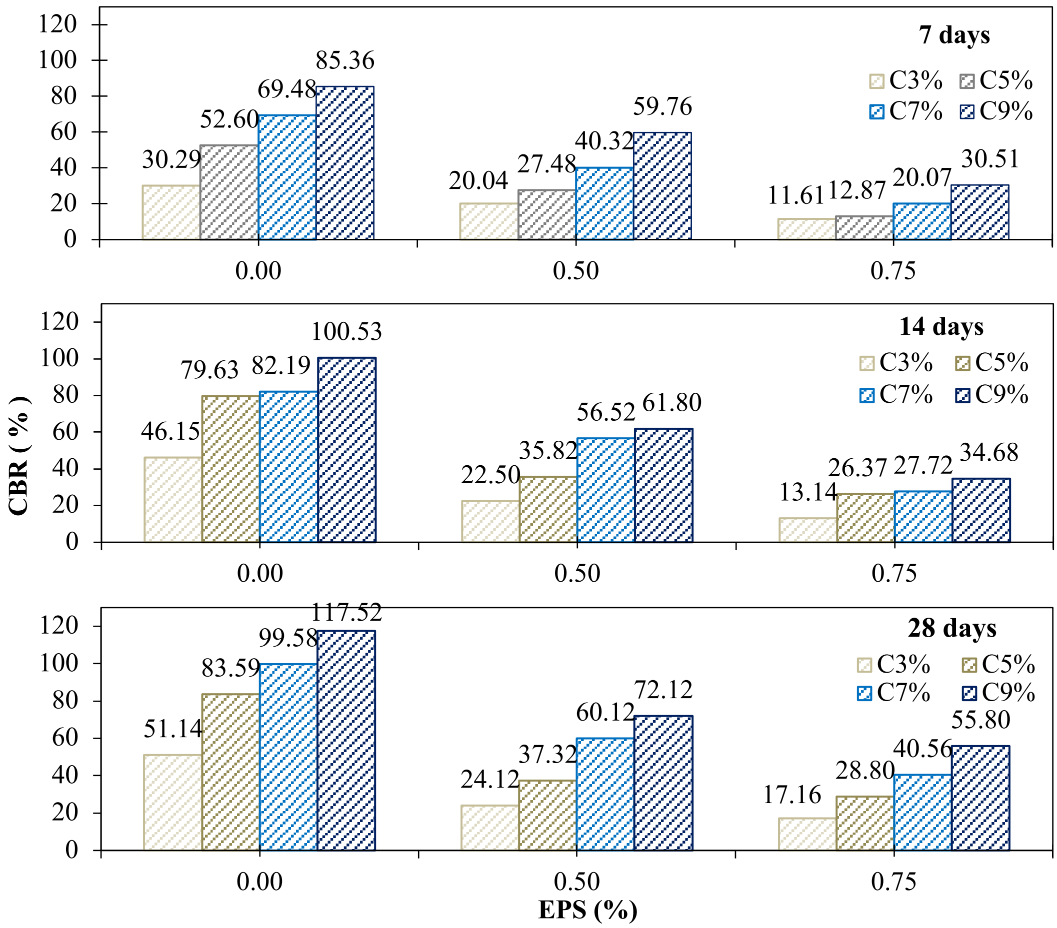

Fig.7 Correlation between EPS and CBR value of DS+C+EPS unsoaked condition

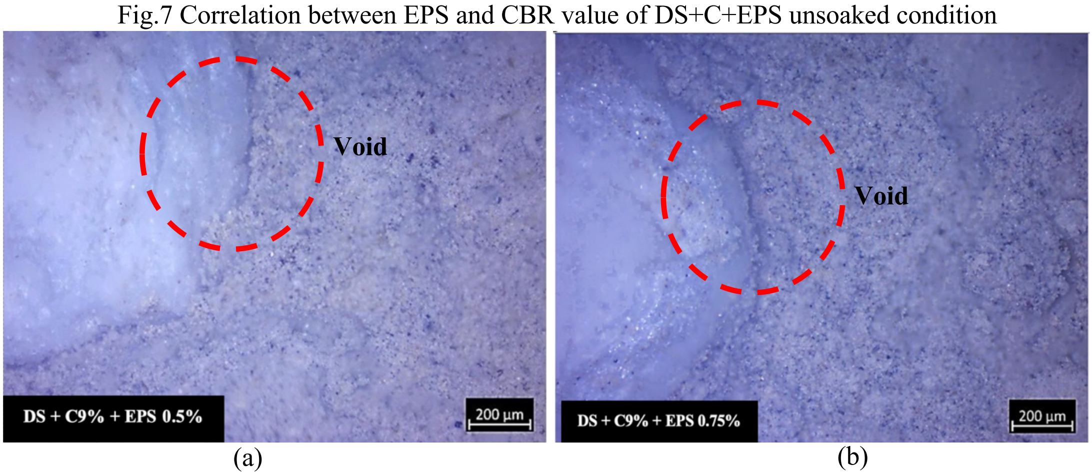

Fig.8 Optical microscope observation on (a) C9% + EPS 0.5%, (b) C9% + EPS 0.75%

Table 4. Expansion of DS+C+EPS

		Expansion (mm)		
EPS Content (%)	Cement Content(%)	Curing Period (days)		
		7	14	28
0.5	3	0.87	0.65	0.32
	5	0.70	0.56	0.20
	7	0.55	0.28	0.135
	9	0.42	0.155	0.10
0.75	3	0.76	0.44	0.26
	5	0.69	0.38	0.15
	7	0.48	0.13	0.07
	9	0.315	0.08	0.04

4.3. Analysis using Statistical Approach

Based on the discussion in Sections 4.1 and 4.2, increasing cement content and extending the curing period positively correlate with higher CBR values, whereas an increase in EPS content has the opposite effect. To optimize the performance of LMB, the EPS content must be carefully evaluated to achieve the optimal balance between density reduction and sufficient bearing capacity.

As an additional consideration, a statistical approach was conducted to accurately determine the impact of various variables on bearing capacity. Several T-test were conducted to analyze the independent effect of each variable. Three independent variables were examined: cement content, curing period, and EPS content, with CBR value as the dependent variable. The tests were conducted separately for unsoaked and soaked conditions. The results are considered statistically significant when the p-value is greater than 0.05.

Tables 5 and 6 illustrate the correlation between EPS content and CBR values under unsoaked and soaked conditions. Under unsoaked conditions, the mean CBR value without EPS is 74.84 ± 12.33, which decreases to 43.16 ± 9.46 by adding 0.5% EPS and further to 26.61 ± 5.56 at 0.75% EPS. These results demonstrate a significant difference between without EPS and 0.75% EPS specimens (p = 0.012). A similar trend was observed under soaked conditions, where the mean CBR value without EPS is 53.91 ± 8.15, decreasing to 30.90 ± 8.63 for 0.5% EPS and further dropping to 17.74 ± 4.55 for 0.75% EPS. It also indicates a significant difference between without EPS and 0.75% EPS (p = 0.008).

Table 5. CBR on different EPS content – unsoaked condition

EPS Content	CBR (Mean±SD)	p
Without EPS vs EPS 0.5%	74.84±12.33 43.16±9.46	0.088
Without EPS vs EPS 0.75%	74.84±12.33 26.61±5.56	0.012*
EPS 0.5% vs EPS 0.75%	43.16±9.46 26.61±5.56	0.182

Table 6. CBR on different EPS content – soaked condition

EPS Content	CBR (Mean±SD)	p
Without EPS vs EPS 0.5%	53.91±8.15 30.90±8.63	0.101
Without EPS vs EPS 0.75%	53.91±8.15 17.74±4.55	0.008*
EPS 0.5% vs EPS 0.75%	30.90±8.63 17.74±4.55	0.392

From the above data, it is observed that these findings give a consistent trend. It implies that more EPS amount added substantially reduces the bearing capacity. However, the reduction of CBR values when EPS content increased to 0.5% EPS is less pronounced. These statistical results suggest that maintaining EPS content at 0.5% may provide an optimal balance between strength and weight reduction. Beyond this percentage, the decrease in CBR values is significant and may limit the material's applicability.

Table 7. CBR on different cement content – unsoaked condition

Cement Content	CBR (Mean±SD)	p
3% vs 5%	26.24±8.49 42.72±14.94	0.392
3% vs 7%	26.24±8.49 55.17±15.74	0.181
3% vs 9%	26.24±8.49 68.68±17.67	0.096
5% vs 7%	42.72±14.94 55.17±15.74	0.597
5% vs 9%	42.72±14.94 68.68±17.67	0.325
7% vs 9%	55.17±15.74 68.68±17.67	0.599

Table 8. CBR on different cement content – soaked condition

Cement Content	CBR (Mean±SD)	p
3% vs 5%	18.27±8.73 27.61±9.92	0.519
3% vs 7%	18.27±8.73 40.19±11.01	0.194
3% vs 9%	18.27±8.73 50.66±13.11	0.109
5% vs 7%	27.61±9.92 40.19±11.01	0.444
5% vs 9%	27.61±9.92 50.66±13.11	0.234
7% vs 9%	40.19±11.01 50.66±13.11	0.575

*Note : * means statistically significant value*

Furthermore, Table 7 and 8 present the statistical analysis results of different cement content variations, comparing 3% and 5%, 3% and 7%, and 3% and 9%. The data show that all p-values are greater than 0.05. As previously discussed in Section 4.1, higher cement content contributes to an increase in bearing capacity, but apparently, the effect is not statistically significant.

However, from the results shown there is a threshold beyond which additional cement yields diminishing returns. It means that while the peak performance was observed at 9% cement addition, the most favorable increase in bearing capacity is already reached at 7% cement content.

Additionally, the effect of the curing period is analyzed in Table 9 and 10. The CBR values show a significant increase when the curing period is extended from 7 to 14 days (p = 0.001) and further improve with an extension to 28 days (p = 0.002). P-values are consistently below 0.05 in both unsoaked and soaked conditions, confirming the substantial impact of curing time on bearing improvement.

A comparative assessment of the two variables—cement content and curing time— demonstrates that the curing period plays a more dominant role in strength improvement than cement content alone. For instance, specimens with lower cement content (3% and 5%) show considerable strength improvement with prolonged curing, suggesting that adequate curing time can compensate for lower cement percentages. Conversely, higher cement content alone without sufficient curing yields suboptimal results. The results emphasize the importance of proper curing time.

Table 9. CBR on different curing periods – unsoaked condition

Curing Period	CBR (Mean±SD)	p
7 days vs 14 days	38.37±23.59 48.92±27.40	0.001*
7 days vs 28 days	38.37±23.59 57.32±31.01	<0.001*
14 days vs 28 days	48.92±27.40 57.32±31.01	0.002*

Table 10. CBR on different curing periods – soaked condition

Curing Period	CBR (Mean±SD)	p
7 days vs 14 days	27.50±16.35 33.85±20.83	0.003*
7 days vs 28 days	27.50±16.35 41.20±24.68	<0.001*
14 days vs 28 days	33.85±20.83 41.20±24.68	0.001*

4.4 Practical Implications, Limitations, and Recommendations

The findings of this study offer several practical implications for applying Lightweight Modular Blocks (LMB) composed of dredged soil, cement, and EPS in subgrade engineering. From a design perspective, LMB provides an opportunity to utilize locally available dredged material, contributing to environmental sustainability while offering lightweight and structurally adequate solutions.

The results suggest that a composition of 7% cement and 0.5% EPS, cured for 14 days, represents the most efficient balance between strength and weight reduction. This mixture fulfills the Indonesian National Standard (SNI) minimum subgrade requirements while reducing bulk density by approximately 20%, thereby improving constructability in soft soil areas. For scenarios requiring greater density reduction, 0.75% EPS may be employed. However, this must be accompanied by at least 7% cement and a curing period of no less than 14 days to maintain structural reliability.

Despite the promising results, several limitations must be acknowledged. First, the study focused on short-term laboratory evaluations under controlled curing and soaking conditions. Long-term durability under environmental conditions such as wet-dry or freeze-thaw cycles, chemical exposure, or repeated traffic loading was not assessed and remains a critical area for future investigation. Second, the interface behavior between EPS and soil cement matrix should be studied further, possibly through microscopic or interface shear strength analysis.

Regarding future research related to field applications, the construction and compaction process of LMB must ensure homogeneous mixing and effective placement at a large scale. Additional guidelines and admixture optimization should be investigated to enhance constructability and quality control in real-world projects. Finally, by providing limitations and future recommendations, this study is expected to contribute to transitioning LMB from laboratory innovation to practical engineering solutions.

5. CONCLUSIONS

This study investigated the use of dredged soil, cement, and EPS to develop Lightweight Modular Blocks (LMB) as a sustainable alternative for subgrade materials. The results demonstrate that LMB can provide adequate bearing capacity while reducing material weight and offering practical use for dredged sediment.

The key conclusions are as follows:

-Cement and Curing Period: Increasing cement content and extending the curing time improved CBR values. Among the two variables, the curing period has a stronger effect on strength development, showing that proper curing is essential even for mixtures with lower cement content. However, higher cement content without proper curing achieves suboptimal results.

- EPS Addition: Adding EPS reduces CBR values due to increased voids and reduced soil-cement bonding. However, it also reduces bulk density and expansion. 0.5% EPS provides a good balance between strength and weight reduction without significantly affecting bearing performance.

-Recommended Composition: The most effective combination is a mix containing 7% cement, 0.5% EPS, and 14 days of curing time. This composition meets the minimum strength requirement while reducing weight by around 20%. For applications requiring more weight reduction, 0.75% EPS can be used, provided that the cement content and curing time are increased.

- Practical Implications: This study highlights the potential of LMB for lightweight subgrade construction and the reuse of dredged soil in engineering applications. However, further studies are still needed to assess long-term durability, field performance, and cost estimations before large-scale implementation.

6. ACKNOWLEDGMENTS

The author would like to thank the Directorate General of Higher Education of the Ministry of Education and Culture for providing funding assistance through the PMDSU Scholarship.

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