



Effect of Addition of Red Brick Powder and Salt on CBR Value in Clay Soil Stability

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ABSTRACT

Soil acts as the main support in building construction, including foundations. The type of clay soil that has high cohesion and plasticity properties often causes damage to building structures. This happened to the tourism development in Sampih Village, which experienced cracks in the walls and foundations due to the clay subgrade. This research aims to improve the quality of the soil with a stabilization method using a mixture of red brick powder and salt, which was tested using the California Bearing Ratio (CBR) method. Tests were conducted in the laboratory with a variety of mixtures: 10% salt; 10% red brick powder (SBM); 5% salt + 10% SBM; 10% salt + 5% SBM; 5% salt + 5% SBM; and 10% salt + 10% SBM. The test results show that the CBR value of the original soil is about 9.4% (CBR without soaking), which belongs to the low bearing capacity category. After stabilization, the 5% salt + 10% red brick powder mixture variation gave an increase in CBR value up to 24.10%, higher than the other variations. The study implies that the combination of salt and red brick powder can significantly increase the bearing capacity of the soil, which has implications for improving foundation stability for construction in areas with clay soils.

Keywords: Stabilization, Clay, CBR.

INTRODUCTION

A building is a structure that sits on the ground. Soil is very important because it supports the foundation of a building, where the soil plays a role in distributing the load of a construction; if the subgrade is clay soil, which has cohesive and plastic properties, it has high shrinkage and low bearing capacity (Nayoan, 2016). Clays with high shrinkage expansion fluctuations are called expansive clays (Lestari & Lestari, 2014). This expansive soil often causes damage to buildings by cracking walls and lifting foundations (Dharmawan et al., 2017). This also happened to the condition of tourist buildings in Sampih village, which experienced the same thing: cracking walls and foundations in the area.

To overcome these problems, one way can be to use methods to improve the quality of the original soil or soil stability. Soil stabilization is mixing soil with specific materials to improve the soil's technical properties (Firoozi et al., 2017). The selected mixing materials are table salt and red brick powder. Salt is one of the materials that can be used for soil improvement because it has mineral adhesives that have better properties than organic adhesives because they cannot cause pollution of air, soil, or water (Landangkasiang et al., 2020). According to (Azza et al., 2019) in their article entitled "Comparison of the Use of Cement and Salt for Subgrade Stabilization," the salt solution is an electrolyte that has a brown motion on the surface that is greater than pure water so that it can lower the water. This solution adds cohesion forces to the particles, making them tighter (Sutrisno, 2020). In addition, the salt solution can facilitate soil compaction, so the stabilization of clay soil with the addition of Saltsalt is expected to improve the physical and mechanical properties of clay soil to meet the predetermined strength requirements. (Musianirudin & Mindiastiwi, 2022). Similarly, brick powder is a type of pozzolan that contains a lot of silica and alumina compounds in a fine form, and there are water compounds that will react with calcium hydroxide at normal temperatures, which have a reasonably low solubility number (Aziz et al., 2022).

According to previous research by (Cahyadi & Puspasari, 2017) on "Utilization of Salt as a Stabilization Material for Clay in Central Kalimantan", the addition of salt proved to be very effective in improving the stability of clay soil. Based on this, this study introduces a new approach by incorporating red brick powder as an additional stabilization material along with salt. This combination utilizes the complementary properties of both materials to further improve soil stability. The main novelty of this research lies in exploring the synergistic effect of red brick powder and salt on clay stabilization, which has not been thoroughly investigated in previous studies.

Based on the above background, the main objective of this research is to determine the optimal levels of salt and red brick powder to stabilize clay soils, especially in areas with soft soils that are prone to structural changes. By identifying the best combination, this research aims to develop better stabilization methods that are effective and economical. In addition, this research also highlights the use of locally available and environmentally friendly materials as alternatives to conventional chemical stabilizers, to address sustainability issues in construction practices.

The findings of this research are expected to benefit from contributing new insights in soil stabilization technology by demonstrating the potential of locally sourced materials to improve soil properties. These insights can serve as references for practical applications in construction, especially in areas with similar clay soil conditions. In addition, this approach supports the development of cost-effective and sustainable engineering solutions, expanding the applicability of soil stabilization methods in resource-constrained environments.

RESEARCH METHOD

The research methodology carried out in this study uses experimental methods in the Swadaya Gunung Jati University Laboratory and also in the PT Perwita Karya Konstruksi Laboratory. In the Swadaya Gunung Jati University research, researchers conducted research on the original soil index properties test, Water content test, soil specific gravity test, and Atterberg value test (consistency limits). Whereas in the testing at the PT Perwita Karya Konstruksi Laboratory, the Compaction Test was carried out in the form of compaction of original soil samples and modified samples before testing, and laboratory CBR tests, with the CBR method without soaking (Unsoaked). The research was conducted using original soil samples and soil samples that had been added with table salt and red brick powder. With variations: 100% native soil, 90% native soil + 10% kitchen salt, 90% native soil + 10% red brick powder, 90% native soil + 5% red brick powder + 5% kitchen salt, 80% native soil + 10% red brick powder + 10% kitchen salt, 85% native soil + 5% red brick powder + 10% kitchen salt, and 85% native soil + 10% red brick powder + 5% kitchen salt,

Preparatory Work

The preparations carried out in this study are:

1. The preliminary stage begins with a literature study, which includes collecting and studying literature related to this research.
2. Determine sampling locations and conduct sampling by handboring.
3. The samples taken and used in this test are clay soil from Sampih Village, Pahing Block, Rt. 03, Susukan lebak, Cirebon Regency.
4. Preparation of tools related to this research.
5. Materials include table salt and red brick powder.

Making Test Objects

In this research, the manufacture of test objects is divided into two stages, namely the stage of determining the soil type and the stage of CBR testing without soaking (Unsoaked) with a mixture of red brick powder and kitchen salt.

Testing Implementation

This test was carried out as follows:

1. Test index properties of native soil viz: Moisture content test, Specific gravity test, Atterberg value test.
2. A compaction or proctor test is performed in the form of compaction of original soil samples and modified samples before the CBR test to determine the optimal water content before testing the CBR sample.
3. Laboratory CBR test: This test uses a method called CBR without soaking (Unsoaked).
Data analysis is carried out after all the data is collected, producing tables, graphs, and explanations based on the study results. The research flow chart can be seen in the figure below:

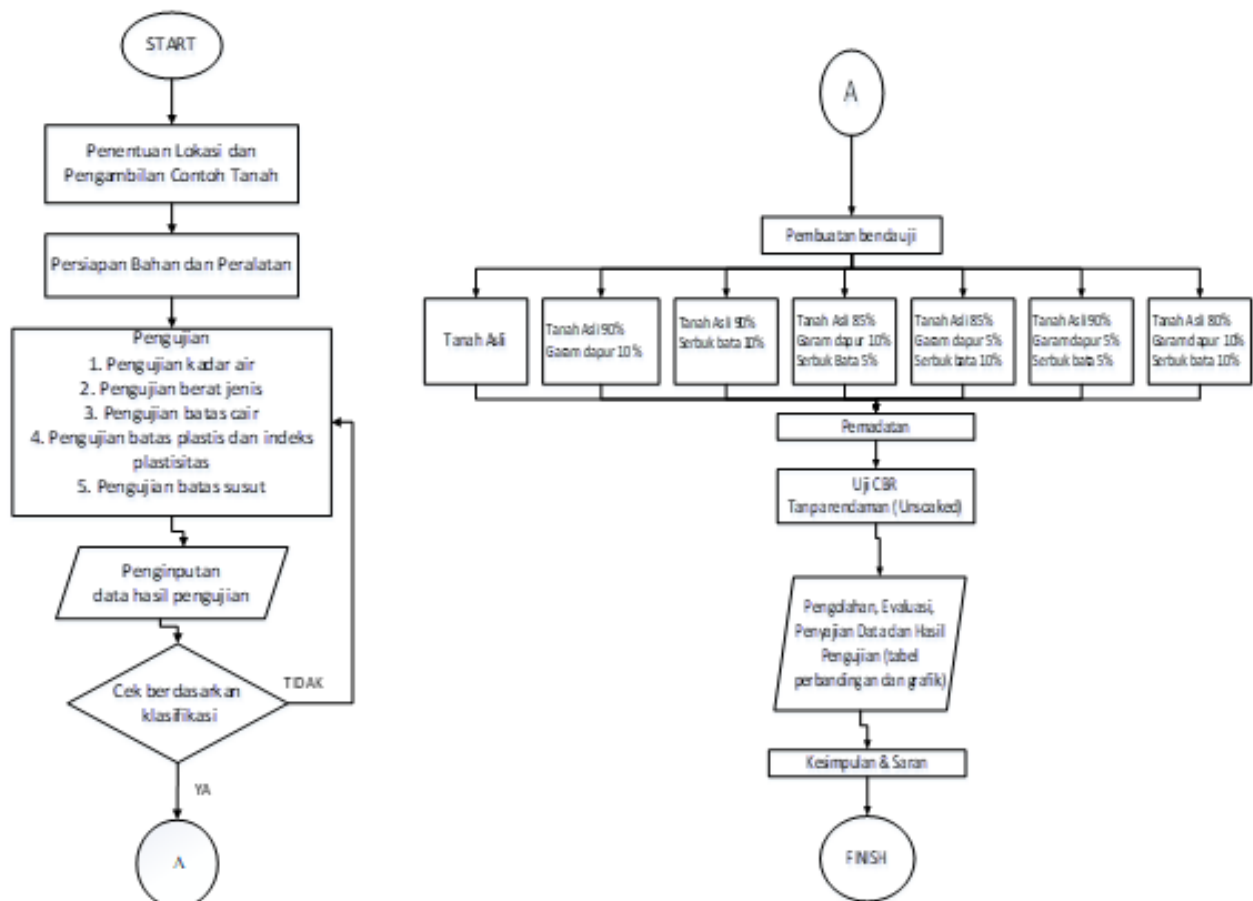


Figure 1. Research Flowchart

Data Processing

The data obtained from the results of research in the field in the form of Disturb (disturbed soil) and Undisturb (undisturbed soil) clay with Handboring work methods that refer to the equations and formulas of ASTM D 2113, which refer to SNI 2848: 2008 (Marpaung, 2013). Which is then processed in the laboratory to determine the testing of index properties such as:

- 1) Moisture content using Disturb (disturbed soil) and Undisturb (undisturbed soil) clay using equations and formulas ASTM D-2216-71 referring to SNI 1965: 2008 (Al Zakina et al., 2023).

Water Content Formula

$$W = \frac{M2 - M3}{M3 - M1} \times 100\%$$

Where:

W : Water Content (%)

M1 : Weight of empty cup (gram)

M2 : Weight of cup + wet soil (grams)

M3 : Weight of cup + dry soil (grams)

Table 1. Soil types based on moisture content

Land Type	State of Water in Saturation
Loose Sand with Uniform Grains	30
Dense Sand with Uniform Grains	16
Dense Silty Sand with Angular Grains	25
Loose Silty Sand with Angular Grains	15
Rigid Loam	21
Soft Loam	30-50
Land	25
Soft Organic Loam	90-120
Glcia Till	10

Source: Soil Mechanics Book

- 2) Specific gravity testing using Undistub soil using ASTM D 854 equations and formulas, which refer to SNI 19654: 2008, relates to the table of soil types based on Specific Gravity.

Water Volume Formula

$$V = \{((W2 - W1) + W4) - W3\}$$

Where:

V : Water volume

W1 : Weight of pycnometer

W2 : Weight of pycnometer + soil

W3 : Weight of pycnometer + water + soil

W4 : Weight of pycnometer + water

Specific Gravity Formula

$$Gs = \frac{\text{Soil Weight}}{\text{volume udara} \times K}$$

Where:

Gs : Specific Gravity

K : Temperature correction

Table 2. Classification of Soils Based on Specific Gravity

Soil Type	GS
Sand	2,65 - 2,67
Silty Sand	2,67 - 2,70
Organic Silty	2,70 - 2,80
Soi With Micas Or Iron	2,75 - 3,00
Organic Soil	< 2,00

Source: L.D.Wesley, Mektan, Mold IV Page 5

- 3) Atterberg limit testing consists of a liquid limit where the soil moisture content is at the boundary between the liquid and plastic states of the soil.

- 4) Plastic limit testing occurs when the water content at the lower and lower limits is in the plastic region of the soil. The plastic limit is determined by the formula.

Plastic limit formula

$$Plastic\ Limit = \frac{weight\ of\ water\ mass}{dry\ soil\ weight} \times 100\%$$

And to find the plasticity index (P.I.) is determined by the formula

PI Formula

$$PI = LL - PL$$

Where:

LL : Liquid Limit

PL : Plastic Limit

Table 3. Plasticity Index Values and Soil Types

PI	Nature	Soil Type	Cohesion
0	Non-Plastic	Sand	Non-cohesive
<7	Low plasticity	Silt	Partially Cohesive
7-17	Medium plasticity	Silty clay	Cohesive
>17	High plasticity	Clay	Cohesive

Source: Expansive Land Book by Hary Christady Hardiyatmo

- 5) Shrinkage limit testing is where the soil shrinks in dry soil conditions. This test uses ASTM D 2113, which refers to SNI 2848: 2008. The minimum value of CBR for Subgrade is according to Raharjo (1985).

Table 4. Minimum CBR Value According to Turnbull & Raharjo

Section	Materials	CBR Value (%)
Subgrade	Very good	20-30
	Good	10-20
	Medium	5-10
	Bad	< 5

- 6) Compaction or Proctor testing is where the optimum moisture content (OMC) is obtained at maximum density (MDD) (Rumissing et al., 2019). This test uses three types of impact, namely 10x, 30x, and 65x, with reference (ASTM 689, AASHTO T-99) SNI 03-1742-1989—both original and modified soil samples.

Water Content Formula

$$Water\ Content = \frac{weight\ of\ water}{weight\ of\ dry\ soil} \times 100$$

Wet Density Formula

$$\gamma_b = \frac{wet\ soil\ weight}{contents\ of\ the\ mold}$$

Where:

γ_b : Wet density

Dry Density Formula

$$\gamma_d = \frac{\gamma_b}{100 + w} \times 100$$

Where:

γ_d : Dry Density

γ_b : *Wet Density*

W : moisture content

- 7) CBR (California Bearing Ratio) testing where this test is to determine the bearing capacity of the subgrade soil (Katte et al., 2019). To obtain the appropriate CBR value, the soil is prepared and compacted in as many as 3 samples, where each sample is compacted as much as 10x, 30x, and 65x impact per layer. The compacted soil is the original soil, and the modified soil is after compaction testing with optimum moisture content conditions (Hu et al., 2020). This CBR test is carried out in 1 condition, namely unsoaked CBR conditions. This test uses AASHTO T - 193-73.

CBR formula at 0.1" penetration load:

$$\text{CBR} = \frac{\text{Burden } 0,1'}{3 \times 1000} \times 100\%$$

CBR formula at 0.2" penetration load

$$\text{CBR} = \frac{\text{Burden } 0,2'}{3 \times 1500} \times 100\%$$

RESULT AND DISCUSSION

Research Results Physical Properties of Clay Soil

Based on the tests that have been carried out, such as water content, soil content weight, and soil specific gravity (L.L. liquid limit), plastic limit (P.L.), and shrinkage limit (S.L.), The results of this test can be seen in Table 5 as follows:

Table 5. Results of Soil Physical Properties

No.	Testing	Results
1	Undisturb Moisture Content (%)	32,3
2	Disturb Moisture Content (%)	38,8
3	Specific gravity (gr/cm)	2,69
4	Liquid Limit	55
5	Plastic Limit	28,2
6	PI	27,3
7	Shrinkage Limit	12,5

Based on the results of testing the physical properties of the soil above, it is found that the soil is included in the clay category with an average undisturbed moisture content value of 32.3 Gs value of 2.69 and has high plasticity with a properties index value of 27.3.

Compaction Test Results

This test is a method used to determine the optimum moisture content in an experiment where the soil type will reach its maximum dry density (Agustina & Yatul, 2019). The results of this test can be seen in Table 6 as follows:

Table 6. Optimum moisture content & MDD results

Variations	Water Content (%)	MDD (%)
Original Land	28,44	1,261
Native Soil 90% + Salt 10%	30,16	1,296
Original Soil 90% + SBM 10%	31,54	1,268
Native Soil 85% + Salt 10% +SBM 5%	23,37	1,338
Native Soil 85% + Salt 5% +SBM 10%	31,33	1,26
Native Soil 90% + Salt 5% +SBM 5%	25,06	1,337
Native Soil 90% + Salt 10% +SBM 10%	26,25	1,359

These results suggest that the higher the percentage of Salt, the smaller the optimum W value will be, while the higher the percentage of SBM, the greater the optimum W value will be. The SBM mixture material can absorb more water in the proctor test to find the optimum W.

CBR (California Bearing Ratio) Testing Results

CBR testing compares the penetration load value of materials such as soil against standard materials with the same depth and speed (Muda, 2016). The results of this test are shown in Table 7.

1. UNSOAKED CBR

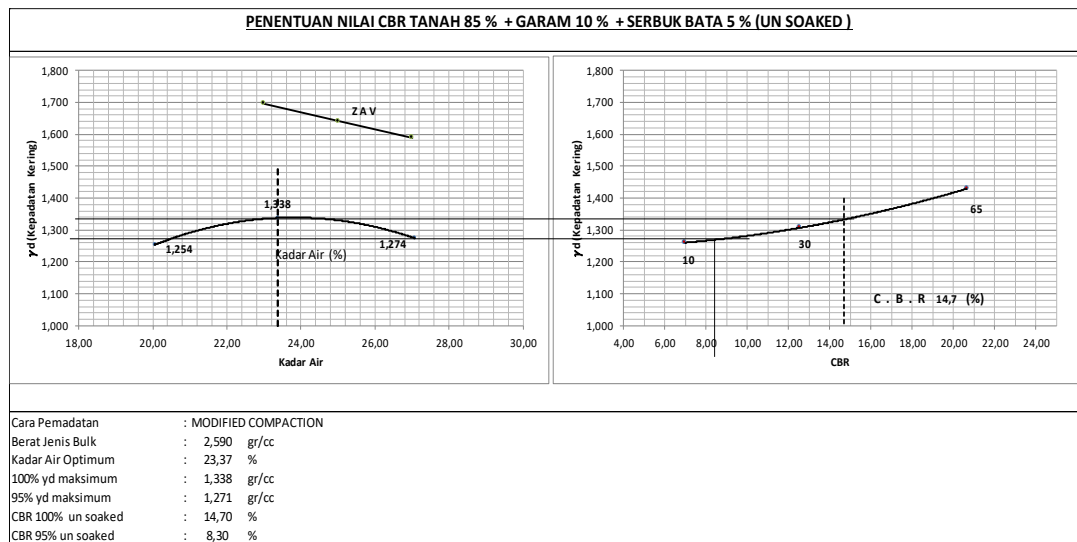
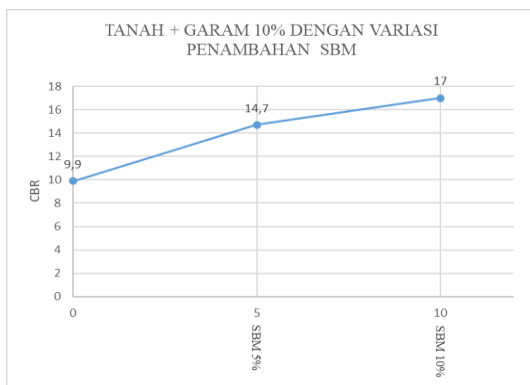


Figure 2. Example Graph of Determination of CBR Value of Original Soil + 10% Salt + 5% SBM Unsoaked

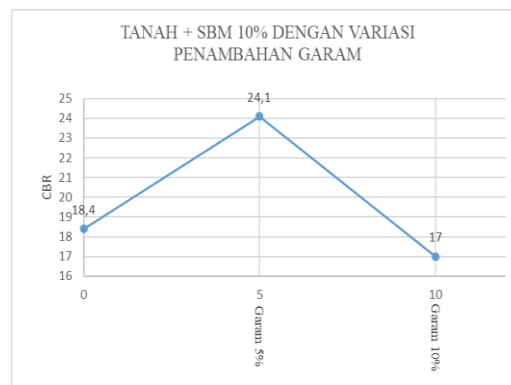
Table 7. Unsoaked CBR Results

No.	Mixture Variation	Unsoaked Recapitulation	
		Value CBR	Minimum CBR According to Tunbull (1968) and Raharjo (1985)
1	Land of Asu	9,40	Medium
2	Asu soil 90% + Salt 10%	9,90	Medium
3	Original Soil 90% + Sbm 10%	18,40	Good
4	Original Soil 85% + Salt 10% + Sbm 5%	14,70	Good
5	Original Soil 85% + Salt 5% +Sbm 10%	24,10	Very good
6	Native Soil 90% + Salt 5% +Sbm 5%	15,30	Good
7	Native Soil 90% + Salt 10% + Sbm 10%	17,00	Good

The results of the tests that have been carried out are presented in the graphs and tables above, where the graph results can be known as CBR results. Then, it will be determined again to find the best variation in clay stabilization.



**Figure 3. Comparison Chart of CBR
Combination of Soil Material + 10% Salt +
SBM**



**Figure 4. Comparison Chart of CBR
Combination of Soil Material + 10% SBM +
Salt**

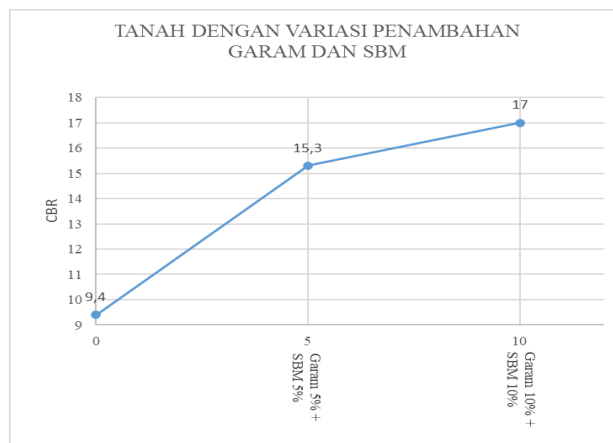


Figure 5. Comparison Chart of CBR Combination of Soil + Salt + SBM Materials

Based on the comparison data between the variations above, the addition of the variation of soil mixture + SBM 10% + salt 5% on clayey soil can increase the CBR value from the original CBR value of 9.40% to 24.1%. However, a smaller CBR value is obtained if the SBM addition percentage is more minor than salt addition.

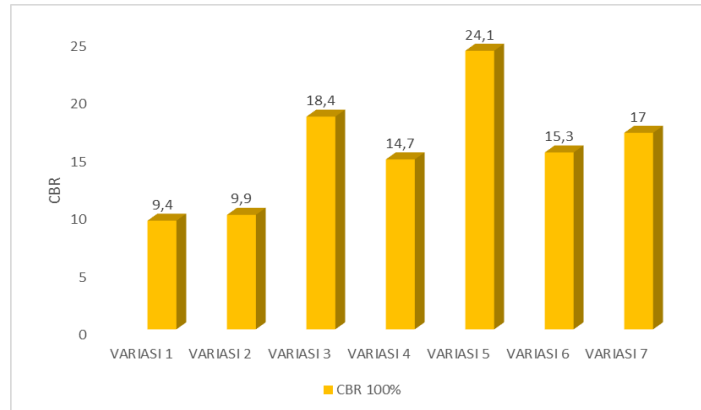


Figure 6. Unsoaked CBR graph

Notes:

- Variation 1 = Original Soil
- Variation 2 = Native Soil + 10% Salt
- Variation 3 = Original Soil + 10% SBM
- Variation 4 = Original Soil + 10% Salt + 5% SBM
- Variation 5 = Original Soil + 5% Salt + 10% SBM
- Variation 6 = Original Soil + 5% Salt + 5% SBM
- Variation 7 = Original Soil + 10% Salt + 10% SBM

CONCLUSION

The conclusion of this research is that the addition of salt and red brick powder significantly affects the CBR value in stabilizing clay soil in unsoaked condition. The soil, classified as clay with 38.8% moisture content, specific gravity of 2.69 g/cm³, and plasticity index of 27.3, showed increased stability in all variations. Among the tested combinations, variation 5 (native soil + 10% red brick powder) achieved the highest CBR value of 9.40, which showed an increase of 24.10% compared to the untreated soil. This research contributes to advancing soil stabilization techniques by introducing a cost-effective and environmentally friendly approach using locally available materials, such as salt and red brick powder. The findings provide a basis for further exploration of material combinations to improve soil stability in different regions with similar clay characteristics. Future research could build on these findings by investigating long-term durability, effects under varying moisture conditions, and scalability to larger construction projects. This research also highlights the potential for sustainable engineering solutions, which is in line with global efforts to minimize environmental impacts in infrastructure development.

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