

DEVELOPMENT OF INTERLOCKING BLOCKS FOR CONSTRUCTION IN SALINE AREAS

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Abstract

This research focuses on developing interlocking blocks for construction in saline environments, which present challenges due to the corrosive effects of salt on conventional building materials. The study aims to improve the durability and compressive strength of interlocking blocks by optimizing ratios of Type 1 and Type 5 portland cement, combined with laterite soil and water. Tests were conducted to evaluate the blocks' performance, particularly their resistance to saline soil and compressive strength, across 7, 14, 21, and 28 days. The findings reveal that blocks with higher proportions of Type 5 cement exhibited enhanced resistance to salinity, while Type 1 cement contributed to greater compressive strength. The optimal mix (2.5:2.5 ratio of Type 1 and Type 5 cement) provided both high compressive strength and superior salinity resistance, making it suitable for construction in saline environments. The study emphasizes the potential of these improved interlocking blocks for sustainable use in regions with saline soil, extending the lifespan of structures built in such areas.

Keywords: Compressive Strength; Construction Materials; Interlocking Blocks; Saline Soil

Introduction

The growing demand in the tourism and real estate sectors, both key sources of income for Thailand, has driven to the expansion of construction projects, including hotels, resorts, residential houses, and condominiums in both urban centers and major tourist destinations. This expansion has caused a rise in the demand for construction and decorative materials. Interlocking blocks have become an attractive option due to their affordability, natural aesthetic appeal, and the ability to reduce the use of other construction materials. Interlocking blocks are composed of laterite soil and cement, resulting in

structures that are both durable and visually appealing.

However, interlocking blocks have limitations in terms of durability, especially in areas with saline soil, such as the northeastern region and coastal areas of eastern and southern Thailand, where saline soil conditions reduce the lifespan of these blocks. Saline soil in the northeastern region of Thailand presents a significant challenge for construction work, as sulfates in the soil can react with construction materials such as cement and concrete, potentially causing material degradation and

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reducing the lifespan of structures. To address this issue, Type 5 portland Cement has been used due to its excellent sulfate resistance. This type of cement is specifically designed for use in high-sulfate environments, such as saline soils and coastal areas. This cement helps reduce the likelihood of reactions between sulfates in the soil and the hydration products in cement, which typically lead to the expansion and cracking of construction materials. The combination of Type 5 cement with laterite soil and Type 1 cement presents a promising approach for producing interlocking blocks that are both strong and resistant to saline soil conditions. This study aims to enhance the strength and salinity resistance of interlocking blocks by using soil from Ban Nong Sano, Chok Chai District, Nakhon Ratchasima Province, where such blocks are already produced. The researcher tested various formulations of Type 1 and Type 5 portland cement, refining the ratios of laterite soil and water to produce interlocking blocks with high compressive strength and improved resistance to saline soil conditions. This study will help extend the lifespan of interlocking blocks and promote their sustainable use in areas with saline soil conditions.

Materials and Methods

Standard Materials and Production Methods for Interlocking Blocks

Currently, the development of efficient and environmentally friendly construction materials is gaining significant attention. One widely adopted innovation is the interlocking block a construction material primarily composed of Type 1 portland cement, laterite soil, and clean water. While the components are simple, they have proven highly effective in construction.

This innovation was first developed by the Thailand Institute of Scientific and Technological Research (TISTR) and was used in the construction of an agricultural station in Nakhon Ratchasima Province in 1968. Since then, the technology has continued to evolve and has been widely accepted in the construction industry (TISTR, Interlocking Block Technology).

Interlocking blocks have been developed in compliance with the community product standard CPAC 602/2547, which specifies appropriate compressive strength values based on mixing ratios. The production process begins with selecting laterite soil that has been finely filtered to remove impurities or unwanted materials. The optimal mixing ratio consists of 5 kg of cement, 35 kg of laterite soil, and 0.5 liters of clean water. This allows the production of strong, durable blocks. After

compression, the blocks are left to dry in a well-ventilated area, which further enhances their strength and durability. Mechanical properties of the blocks were tested at intervals of 7, 14, and 28 days to assess quality before actual use.

Currently, geopolymer interlocking bricks incorporating rubber are being developed. This process involves recycling used rubber by crushing it and substituting it for fine aggregates in the production of interlocking bricks. Mohammed *et al.* (2018) studied the physical properties of interlocking bricks mixed with rubber. As a form of discarded material, rubber waste offers a sustainable alternative to conventional aggregates. Al-Fakih *et al.* (2018) investigated the relationship between the compressive strength and the specific characteristics of rubber-mixed interlocking brick walls plastered with mortar. The study focused on interlocking bricks mixed with crumb rubber and fly ash as substitutes for sand. Al-Fakih *et al.* (2020) examined the mechanical and thermal properties of interlocking bricks made from waste polyethylene terephthalate (PET) bottles, a non-biodegradable material. Alaloul *et al.* (2020) explored the seismic response of unreinforced interlocking brick walls under earthquake forces, focusing on mortarless construction using interlocking bricks. Xie *et al.* (2022) analyzed the composition of rubber-reinforced interlocking bricks under vertical loads, with fine aggregates and cement replaced by crumb rubber and fly ash. Al-Fakih and Al-Osta, (2022) conducted an experimental investigation of clay-cement interlocking bricks reinforced with CFRP and cement-sand mortar. Building on this line of research, Joyklad *et al.* (2023) contributed further insights through complementary studies. Aiamsri, (2021) investigated the engineering properties of cement-stabilized soil improved with natural rubber latex and additives, focusing on the effects of varying temperatures on the properties of cement-stabilized soil for use in base and subbase construction. The study compared the engineering properties of rubber latex-modified cement-stabilized soil with conventional cement-stabilized soil by examining unconfined compressive strength, indirect tensile strength, resilient modulus, and fatigue resistance. Different proportions of rubber latex combined with additives were tested under varying temperature conditions to simulate real-world road environments. The results indicated that rubber latex-modified cement-stabilized soil exhibits increased ductility and longer service life, offering cost-effective construction compared to conventional cement-stabilized soil. This research supports the development and promotion of rubber latex in construction, aligning with national policies aimed at encouraging domestic production and

reducing dependence on costly chemical materials. Chaiyaphanna and Hemathulin, (2022) investigated the improvement of Nong Han soil using natural rubber and cement, making it suitable for use as highway construction material. Korking, (2019) studied the construction process and embodied energy of rammed earth buildings.

The results indicate that cement-stabilized soil enhanced with natural rubber latex exhibits greater ductility, an extended service life, and more cost-effective construction compared to conventional cement-stabilized soil. This research aims to develop and promote the use of natural rubber latex in construction projects, aligning with policies to support domestic production and reduce reliance on expensive chemical materials.

A review of the related literature reveals a lack of studies on the salt resistance properties of interlocking blocks. This research, therefore aims to investigate and develop these properties.

The Compressive Strength Test

Interlocking blocks do not yet have an industrial product standard (TISI) but have been established as a community product standard (CPAC), specifically CPAC 602/2547, the community product standard for interlocking blocks. According to the standard, the compressive strength of load-bearing interlocking blocks must not be less than 70 kg/cm². It also defines the maximum water absorption value, which ranges from 208-288 kg/m³, depending on the unit weight of the interlocking blocks. The standard size for interlocking blocks is 12.5 × 25 × 10 cm, and the approximate weight of an interlocking block is 5.5 kg per block (Ruengrutch Cheerarot), as shown in Figure 1.

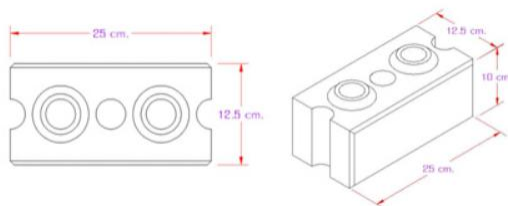


Figure 1. Standard block size

Water Absorption Testing

Testing the water absorption values of interlocking blocks aged 7, 14, and 28 days is conducted with the following steps:

Measure the dimensions (width × length × height) of the prepared interlocking block samples.

Place the interlocking blocks in an oven for 24 hours, then allow them to cool at room temperature for at least four hours. Weigh each interlocking

block individually, reading the weight to a precision of 0.01 grams, and record the dry weight of the interlocking blocks.

Submerge the interlocking blocks in water for 24 hours. Afterward, remove the blocks and use a cloth to absorb water from the surface of each block, weighing them within 3 minutes. Record the weight of the water-absorbed interlocking blocks (Reuang Ruchdi Chearaj).

Calculate the percentage of water absorption using the following formula:

$$\text{water absorption} = \frac{(W_2 - W_1)}{(W_1)} \times 100 \quad (1)$$

Where:

W_1 = weight of the dry interlocking block

W_2 = weight of the water-absorbed interlocking block

Testing for Salinity

Method

Soil: Water Ratio 1:5. Weigh 4 g of soil and place it in a 50 ml beaker. Measure 20 ml of water, add it, and stir until homogeneous using a glass rod. Let it sit for about 30 minutes, stir again, and then measure the EC value using an Electrical Conductivity Meter (OAKTON).

pH Measurement Method: Take a soil sample and measure 10 ml using a standard measuring tool. Add this to a 50 ml beaker. Then add 10 ml of distilled water (with a soil-to-water ratio of 1:1 by volume). Use a glass rod to mix the soil and water thoroughly. Let it sit for 30 minutes before measuring the pH with a pH meter. Before measuring, stir the sample with a glass rod again (Department of Land Development, Nakhon Ratchasima).

Salinity of Water: Salinity results from various salts dissolved in water. The definition of salinity is the amount in grams of inorganic salts present in one kilogram of seawater when all carbonate ions are converted to oxides, all bromide ions are replaced with chloride ions, and all organic matter is oxidized (Manuwadee, 1989). Salinity can be measured by evaporating seawater to dryness and weighing the remaining salt. Subsequent findings revealed that salinity is closely related to the main components of seawater. William Dittmar proposed using the concentration of chloride or bromide to estimate salinity, with chlorinity defined as the total amount of halogen ions (in grams per kilogram of seawater) after all halogens are chemically replaced by an equivalent amount of chloride. The empirical relationship between salinity and chlorinity is expressed as:

$$S = 0.03 + 1.805Cl$$

Salinity measured using this method is expressed in parts per thousand (ppt) or represented by the symbol ‰. This equation was used for approximately 65 years; however, it was later discovered that when chlorinity is zero, the equation yields a salinity value of 0.03. This inconsistency indicates a measurement issue, likely due to the original equation being based on only nine water samples. In 1965, the Joint Committee on Oceanography of UNESCO revised the equation to improve the relationship between salinity and chloride concentration.

Subsequently, the definition of salinity was re-evaluated with the development of techniques for measuring salinity based on electrical conductivity, temperature, and pressure. The Practical Salinity Scale of 1978 referred to the new salinity as practical salinity, which indicates the ratio of the electrical conductivity of seawater to that of a standard potassium chloride solution (Segar, 1998). According to this definition, the symbol ppt is no longer used as a unit of water salinity; instead, the practical salinity unit (psu) is used to represent the measured salinity value. Nevertheless, a salinity value of 35 practical salinity units (psu) corresponds to 35. Measuring salinity based on electrical conductivity is accurate and widely used today (Segar, 1998). Water from different sources varies in salinity. Ocean water typically has a stable salinity averaging 35 psu, while salinity in coastal waters is lower and highly variable, especially in estuary regions. The salinity of water in estuaries depends on the amount of freshwater from rivers and seawater. Therefore, salinity in estuaries varies both over time and distance from the sea. The types of water based on salinity levels are as follows: freshwater has salinity ranging from 0.0 to 0.21 psu, brackish water ranges from 0.21 to 3.0 psu, and seawater has a salinity greater than 3.0 psu. Salinity is crucial for the survival of aquatic animals, as it affects the regulation of water balance within their bodies (Institute for the Promotion of Science and Technology).

Testing Compressive Strength

Testing the compressive strength of interlocking blocks aged 7, 14, 21, and 28 days, with the blocks placed edge-wise (with the edges up). The testing procedure is as follows:

Measure the dimensions of the interlocking block in millimeters (width × length × thickness) and weigh it, reading the value to an accuracy of 0.05 grams.

Place the block in a testing machine to determine its compressive strength, applying a load

rate of approximately 100 kilograms per square centimeter until the block fails, then record the maximum compressive load.

Calculate the compressive strength using the formula:

$$\sigma = \frac{P}{A} \quad (2)$$

Where:

σ = compressive strength (kilograms per square centimeter)

P = load causing the specimen to fail (kilograms)

A = area subjected to the compressive load (square centimeters)

Method of Mixing and Molding Interlocking Blocks

In this research, Type 5 portland cement was used as one of the main materials due to its special property of high sulfate resistance, making it suitable for use in areas with saline soil. This type of cement has a C3A content of less than 5%, which reduces the likelihood of reactions between sulfate in the soil and the cement's hydration products, a key factor in material degradation.

In the block manufacturing process, Type 5 cement was tested in various proportions, combined with Type 1 cement, to find the optimal mix design. The mixing process began with selecting finely screened gravel to reduce impurities, followed by adding both types of cement in the specified ratios 5:0, 4:1, 3:2, 2.5:2.5, etc.

During the mixing process, water was added in appropriate amounts, and a concrete mixer was used to ensure the uniform blending of all materials. The mixture was then subjected to the molding process in an interlocking block press machine at a pressure of 75 kilograms per square centimeter. The blocks were then cured in a shaded area to ensure complete hydration.

The role of Type 5 cement in the mix: In mixes with higher proportions of Type 5 cement, the resulting material exhibited better resistance to sulfate corrosion from saline soil. Type 5 cement reduced water absorption in the interlocking blocks, contributing to improved long-term durability.

The mix with a 2.5:2.5 ratio of Type 5 to Type 1 cement showed the best results in terms of strength and resistance to saline soil.

This study and the development of this mix are crucial for producing construction materials suitable for the saline soil conditions in Thailand, particularly in the northeastern region and coastal areas.

The steps in this research.

1. Take the prepared soil sample according to the specified mixing ratio (as shown in Table 1), then pour cement into a concrete mixer and mix thoroughly.

2. Add the prepared water into the concrete mixer (as shown in Table 1). Water should be added gradually by stopping the mixer intermittently and scraping off the cement that sticks to the sides of the mixer. Continue adding water until the required amount is reached, then run the concrete mixer for 7-10 minutes.

3. Take the well-mixed components and press them in the interlocking block press machine. Each block should be pressed with the mixture at a pressure of 75 kilograms per square centimeter.

4. Once the pressing is done, remove the interlocking blocks from the machine and arrange them neatly. Do not stack more than 3 layers to prevent deformation of the blocks.

5. After 5 days, move the interlocking blocks to a well-ventilated area. Do not expose the blocks to direct sunlight, as it may affect the hydration reaction and weaken the compressive strength of the blocks. After 7, 14, 21 and 28 days, conduct mechanical property tests on the blocks.

Results and Discussion

Based on the results of testing various mixture formulas of portland cement Type 1 and Type 5, an optimal ratio for mixing laterite soil and water was developed to produce interlocking blocks with high compressive strength and resistance to saline soil conditions. This was compared to market-available interlocking blocks following community product standards (CPAC), specifically CPAC 602/2547, which sets the standard for interlocking blocks. According to the standard, the compressive strength for load-bearing types must not be less than 70 kg/cm², and the maximum water absorption rate must be between 208-288 kg/m³, depending on the unit weight of the standard interlocking block with dimensions of 12.5 × 25 × 10 cm.

It was found that the compressive strength of all interlocking block formulas exceeded the community product standard. Formulas with a higher proportion of portland cement Type 1, such as the 5:0 formula (Type 1 cement to Type 5), showed the best compressive strength, with a 28-day compressive strength of 179.734 kg/cm². In contrast, formulas with a higher proportion of Type 5 cement, such as the 0:5 formula, had lower

Table 1. Mixing ratio portland cement Type 1 and Type 5 mixed with 35 kilograms of lateritic soil and 0.5 liters of water

Mixing ratio	Portland cement Type 1 (kg.)	Portland cement Type 5 (kg.)	Number of sample blocks tested (blocks)
Interlocking blocks available in the market	5	0	8
7 days	4	1	8
	3	2	8
	2.5	2.5	8
	2	3	8
	1	4	8
	0	5	8
14 days	4	1	8
	3	2	8
	2.5	2.5	8
	2	3	8
	1	4	8
	0	5	8
21 days	4	1	8
	3	2	8
	2.5	2.5	8
	2	3	8
	1	4	8
	0	5	8
28 days	4	1	8
	3	2	8
	2.5	2.5	8
	2	3	8
	1	4	8
	0	5	8
Total number of sample blocks			200

compressive strength at 136.302 kg/cm², as shown in Figure 2. s community product standards have yet to define specifications for the density and moisture content of interlocking blocks, this study also measured these properties, as shown in Figures 3 and 4. Additionally, it was found that using a higher proportion of Type 5 cement improved the block's resistance to salinity. However, the mixture with a balanced ratio between Type 1 and Type 5 cement (1:4) provided the best resistance to salinity (3.97 dsm.). Although the mixing ratio of (2.5:2.5) had slightly lower salt resistance (4.15 dsm.) compared to the 1:4 ratio, it exhibited higher compressive strength, measuring 175.879 kg/cm², which is close to the (5:0) mixing ratio, as shown in Table 2, while still maintaining optimal compressive strength.

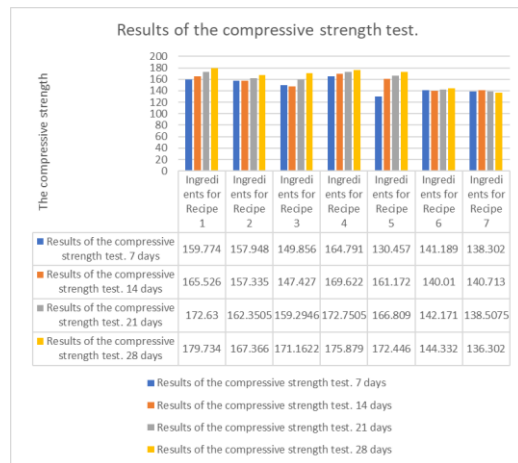


Figure 2. Comparison of compressive strength

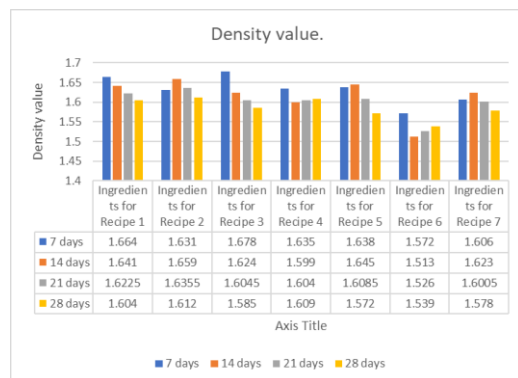


Figure 3. Density value

Figure 2 shows that the mixing ratio of Type 1 and Type 5 portland cement affects the compressive strength of interlocking blocks. Specifically, the ratio of 5:0 (Type 1:Type 5 cement) provides the highest compressive strength of 179.734 kg/cm² after 28 days of curing, which exceeds the community product standard value of 70 kg/cm². On the other hand, the 1:4 ratio yields lower

compressive strength but offers better resistance to saline soil conditions, the mixing ratio of (2.5:2.5) had slightly lower salt resistance (4.15 dsm.) compared to the 1:4 ratio, it exhibited higher compressive strength, measuring 175.879 kg/cm² (see details in Table 2). Figures 3 and 4 illustrate the density and moisture values, respectively, showing that higher proportions of Type 5 cement enhance water absorption resistance and reduce moisture in the blocks, making them suitable for use in saline environments.

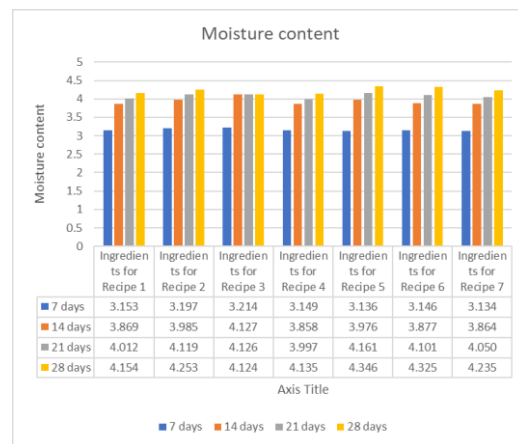


Figure 4. Moisture content

Table 2. Mixing ratio portland cement Type 1 and Type 5 mixed with 35 kilograms of lateritic soil and 0.5 liters of water

No.	Interlocking block example	(dsm.)
1	Ingredients for Recipe 1 5:0	5.17
2	Ingredients for Recipe 2 4:1	4.86
3	Ingredients for Recipe 3 3:2	4.48
4	Ingredients for Recipe 4 2.5:2.5	4.15
5	Ingredients for Recipe 5 2:3	4.18
6	Ingredients for Recipe 6 1:4	3.97
7	Ingredients for Recipe 7 0:5	4.02

Regarding the probability (p-value) for the compressive strength difference between the 5:0 and 2.5:2.5 ratios, the value is $p < 0.05$, confirming that the difference is statistically significant. Furthermore, the 95% confidence interval for the compressive strength of the 2.5:2.5 ratio ranges between 155-165 kg/cm², indicating consistency and reliability in the test results.

From the research findings, the optimal ratio of 2.5:2.5 not only increases durability in saline soil conditions but also maintains a suitable level of compressive strength. This demonstrates its potential application in construction in saline-prone areas, such as coastal regions or agricultural land with saline soils. Additionally, the use of Type 5 cement is cost-effective in reducing long-term maintenance. However, limitations such as the availability of Type 5 cement and potentially higher costs in certain areas should be taken into consideration.

Conclusions

This research aims to develop interlocking blocks with properties that resist salinity and are durable in salty environments, particularly in the northeastern region of Thailand, which faces significant problems with saline soils. The research tested interlocking blocks mixed with Type 1 and Type 5 portland cement to find the optimal ratio for improving the block's properties, including compressive strength and salt resistance, as well as water absorption. Various tests were conducted at different time intervals, such as at 7, 14, 21, and 28 days of block age. The results indicated that increasing the proportion of Type 5 cement enhanced salt resistance, although it had some effects on compressive strength in certain cases.

From the test results of interlocking blocks mixed with Type 1 and Type 5 cement, it was found that the use of Type 5 portland cement significantly improved salt resistance, especially in saline soil areas or near the sea. Additionally, interlocking blocks mixed with Type 5 cement exhibited good compressive strength, although it slightly decreased depending on the mixing ratio. The tests revealed that water absorption decreased with higher proportions of Type 5 cement, contributing to improved long-term durability of the blocks.

The experiment of mixing Type 1 and Type 5 cement in various ratios revealed that Type 5 cement plays a crucial role in enhancing the durability of interlocking blocks in environments with saline soil. The key findings are as follows:

1. **Resistance to saline soil:** The interlocking block mixed with Type 5 cement in a higher proportion (formula 1:4) exhibited the highest resistance to saline soil at 3.97 ds/m, indicating its ability to reduce the permeability of sulfate-containing chemicals, thus extending the block's lifespan in high-salinity environments.

However, the formula with equal proportions of Type 1 and Type 5 cement (2.5:2.5) provided a similar resistance to saline soil of 4.15 ds/m, while

balancing resistance to saline soil with the material's strength.

2. **Strength of interlocking blocks:** Formulas with a higher proportion of Type 1 cement (5:0 and 4:1) exhibited the highest strengths of 179.734 kg/cm² and 167.366 kg/cm², respectively, when cured for 28 days.

While increasing the proportion of Type 5 cement slightly reduced the strength, it still exceeded the minimum strength requirement set by the Community Product Standard (CPAC 602/2547), which specifies a minimum strength of 70 kg/cm².

3. **Water absorption:** Using Type 5 cement in higher proportions significantly reduced the water absorption in the interlocking blocks due to their dense structure, which helped protect against damage from moisture and salts.

This study demonstrates that Type 5 cement is critical in construction in saline soil areas. Increasing the proportion of Type 5 cement enhances resistance to saline soil, and while the strength of the blocks may decrease in some cases, it remains above the specified standard. A balanced mix of Type 1 and Type 5 cement, such as the 2.5:2.5 formula, effectively meets both strength and environmental durability requirements, making it the most suitable for use in saline soil areas.

Recommendations

1. The interlocking blocks should be tested in real environmental conditions where climate changes occur, such as areas with varying humidity and temperature, to assess long-term performance.

2. Using the developed interlocking blocks in actual construction projects in saline soil areas or near the sea would help in evaluating their economic feasibility.

3. Further research into the environmental impact and sustainability of interlocking blocks will deepen the understanding of resource-efficient construction practices.

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