



Effect of Stabilized Spent Bleaching Earth Using Seashell on the Compressive Strength and Water-Blasting Resistance of Concrete

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Abstract

Palm Crude Oil (CPO) production generates substantial waste, including Spent Bleaching Earth (SBE), which is difficult to recycle. This research explores the stabilization of SBE using seashells for use in concrete mixtures. The goal is to enhance concrete's durability by utilizing the calcium content in stabilized SBE. In this study, we tested concrete with a design strength of 30 MPa. The tests included compressive strength on 150x300 mm cylinders, flexural strength on 600x150x150 mm beams after 28 days of curing, and water blasting resistance using two methods. The water blasting test assessed the concrete's resistance to water pressure on 500 x 350 x 50 mm samples over three consecutive days. The results showed that concrete with a 7.5% SBE variation achieved a compressive strength of 42.06 MPa, higher than the design strength. Flexural strength increased by 4.67% with a 10% variation in SBE. However, the water blasting tests revealed that both concrete variations exhibited greater damage than normal concrete, indicating that while SBE improves compressive and flexural strength, it may reduce the concrete's water resistance.

Keywords: Stabilization Material, Crude Palm Oil, Water Blast Testing, Recycle Materials

1. Introduction

The demand for palm oil continues to grow year after year. By August 2025, Crude Palm Oil (CPO) production is projected to hit 5,062 thousand tons [3]. To produce cooking oil from refined CPO, a material called Bleaching Earth, or bleaching flour, is needed [4]. Once it's used, Bleaching Earth is usually discarded in landfills or on unused land. This discarded material, known as Spent Bleaching Earth (SBE), is a waste product produced during the oil refining process.



Source: Garcya, 2023

Figure 1. SBE on Landfill

Researchers are exploring the potential of Spent Bleaching Earth (SBE) as a more sustainable solution to address the growing waste problem. When SBE is used as a replacement for cement in concrete, studies have found that increasing the substitution level reduces both compressive and flexural strength [4]. Further experiments have also tested SBE as a cement substitute combined with a superplasticizer, since SBE's powdery nature tends to absorb water, making the mixture dry and harder to work with and giving it a porous appearance. In this study, two different curing methods—seawater and freshwater—were applied. Surprisingly, concrete mixed with SBE showed better resistance to chloride attack than concrete cured with freshwater, without any loss in compressive strength, and even experienced a slight increase of around 4.86%. [5]

Previous studies have shown promising results with using Spent Bleaching Earth (SBE) in concrete mixtures, providing a strong foundation for further exploration. However, these studies have only used unstabilized SBE. The need to stabilize SBE stems from its inability to replace the calcium lost in cement, which is essential to concrete strength. Without sufficient calcium, concrete can become brittle over time, posing potential damage and safety risks. Therefore, addressing this issue is crucial to prevent such problems.

Bengkalis Regency is an island mainly covered by peatland, a type of soil rich in organic matter from decaying plant material. Research shows that the peat soil in Bengkalis spans over 82,129.73 hectares [1]. This soil is typically acidic, which can gradually degrade the concrete's outer surface. Additionally, because of its coastal location, materials in Bengkalis are constantly exposed to seawater, which is high in chloride, a major cause of corrosion in concrete reinforcement. The area's rainwater also accelerates the rusting of metal materials. Given these challenging conditions, it's crucial to design concrete structures with high durability to withstand harsh conditions and age without significant damage.

Material stabilization is one method to modify the properties and characteristics of materials using blood clam shells, which are known to have high calcium content, so this is one of the innovations to modify the properties and characteristics of SBE into a more useful material and has the potential to become a pozzolanic material that can be used as a cement substitute in concrete mixtures [6]. In concrete, using SBE stabilized with a 40% SBE and 60% shells mixture as a substitute for a 5% cement mixture, it showed an unexpected value of 40.47%, which is higher than normal concrete. So, it's quite surprising, and it can occur because the high calcium content in shells makes the concrete more durable under compressive force [7].

In coastal areas, concrete structures are often exposed to wave action, which can cause erosion over time. To simulate this effect, a water blasting method using an artificial water pump is needed to replicate the waves that erode the concrete core through gravitational acceleration. This method can then be compared with concrete samples subjected to natural wave conditions. Given this issue, further research is essential to explore the potential of using SBE stabilized with shells to enhance and maintain concrete durability. So, it's especially important for coastal construction materials that are directly exposed to both peat and seawater.

2. Methodology

2.1 Samples

This study used three concrete mixtures: SBE (40%) and Seashell (60%) as cement substitutes at 0%, 7.5%, and 10%. Further details are provided in Table 1 below.

Table 1. Total of Testing Samples in this Research

Variation	Compressive Strength	Flexure Strength	Water Blasting	Total
BN	9	2	4	15
BCK - 7.5%	9	2	4	15
BCK - 10%	9	2	4	15
Total				45 Samples

Source : Process Data, 2026

For compressive strength test specimens using curing ages of 7 days, 28 days, and 56 days in the form of cylinders with dimensions of 150 x 300 mm, while the test specimen for flexural strength uses a beam measuring 600 x 150 x 150 mm with a curing age of 28 days. For water blasting testing, it is ensured that the concrete has reached 28 days of age before testing is carried out, using a slab measuring 500 x 350 x 50 mm with 2 (two) test methods: pump simulation by gravity and simulation of natural sea waves.

2.2 Mixing Composition

Composition is crucial to concrete strength: the better the concrete mix, the more durable the concrete; conversely, the worse the concrete mix, the worse the concrete. The mix used in this study is shown in Table 2 below.

Table 2. Concrete Compositions in 1m³ of concrete mixture

Variation	Concrete (Kg)	Water (Kg)	Coarse Aggregate (Kg)	Fine Aggregate (Kg)	SBE (40%) (Kg)	Seashell (60%) (Kg)
BN	395.40	139.16	1165.18	682.29	0	0
BCK - 7.5%	365.74	139.16	1165.18	682.29	11.862	17.793
BCK - 10%	355.86	139.16	1165.18	682.29	15.81	23.72

Source: Process Data, 2026

2.3 Compressive Strength

To determine the quality of concrete, a concrete compressive strength test is carried out which measures the load the concrete can withstand per unit area [8].

$$\text{Compressive Strength (MPa)} = \frac{\text{Force (N)}}{\text{Area (mm}^2\text{)}} \quad (1)$$

When a compressive load is applied, a reaction occurs between the load and the concrete surface, causing the concrete to collapse slowly. When the concrete reaches its load-bearing limit, its ability to withstand that load is measured in N/mm² or MPa. The setup for the compressive strength tool is shown in Figure 2 below.



Source: Garcya et all, 2024

Figure 2. Compressive Strength Setup

2.4 Flexural Strength

The flexural strength test is a test carried out to measure the ability of concrete to withstand loads applied to concrete beam structures, particularly bending or bending forces. This test aims to determine the extent of flexibility or deformation in concrete under a specific load.

When flexural strength testing is carried out, the concrete being tested will experience deflection, namely a shift or bending in the concrete beam plane underload. This deflection occurs due to forces applied at the center of the beam or at certain points, causing the concrete to bend. The magnitude of the deflection indicates the extent to which the concrete can withstand bending without damage or structural failure.

Furthermore, this test is important for identifying the point at which concrete begins to deteriorate or fracture under excessive bending forces. The results of this flexural strength test can be used to assess concrete quality in construction and to design concrete structures that are safer and more durable under flexural loads. The flexural strength of concrete is determined by the location of failure in the test specimen [9]. The equation used to calculate the flexural strength of concrete is as follows:

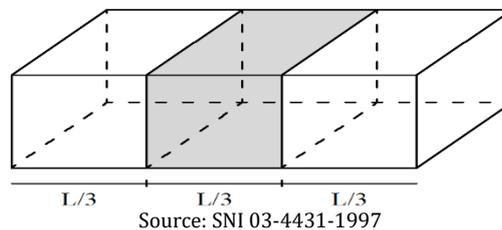


Figure 3. Concrete Flexural Failure Pattern

$$\text{Flexure Strength (MPa)} = f_r = \frac{PL}{bd^2} \quad (2)$$

with:

- f_r = Modulus of Rupture (MPa)
- P = Maximum Loads(P)
- L = Length (mm)
- b = Thickness of Sample (mm)
- d = Width of Sample (mm)

2.5 Water Blast Testing

The water blasting tests in this research were conducted to determine the extent of damage caused by seawater attack on concrete. Two different testing methods were employed: one based on the simulated wave impact with an artificial water pump, where water was dropped from a height of 1.5 meters at a flow rate of 35 liters per minute, and another adapted from general concrete durability testing methods. This approach was selected because it simulates the erosive effect of seawater with sufficient intensity to assess concrete durability in coastal areas. The first method employed a natural sea wave attack, placing the concrete directly near the beach so it remained continuously exposed to ocean waves. This method allowed researchers to observe and evaluate the extent of damage caused by direct interaction with seawater ocean waves.

The second method uses a pump mounted on a pedestal, with the pumped water allowed to pour onto the concrete from a height of 1.5 meters. The water is then directed to damage the top of the concrete for three consecutive days. The goal is to determine whether significant damage can occur from seawater exposure over a specified period. With both methods, it is hoped that a clearer picture of the impact of seawater attack on concrete structures, both those exposed to natural waves and those tested with the artificial pump

method, will be obtained. A sketch of this test pattern is shown in Figure 4 below, providing a visual overview of the setup and testing process.

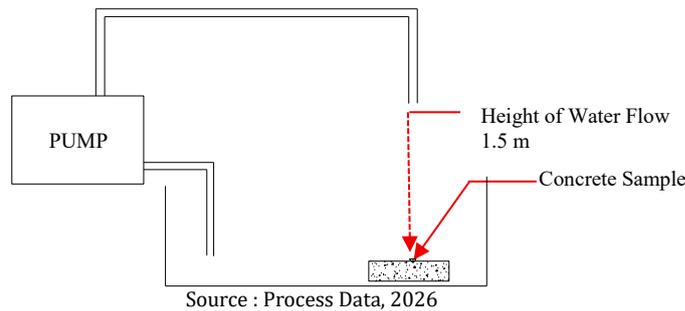
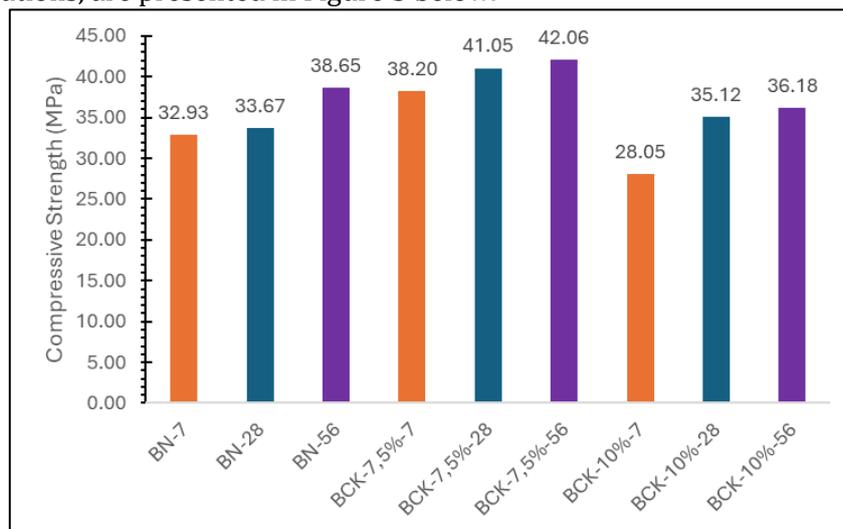


Figure 4. Water Blast Test Sketch with Pump

3. Results and Discussion

3.1. Compressive Strength

Compressive strength testing plays a crucial role in determining the methods for testing and compacting concrete during casting. The outcomes of these material property tests have a direct effect on the overall quality of the concrete. Since concrete has a higher compressive strength than steel [10], its quality is essential for ensuring it can effectively support the design load. The results of the compressive strength tests, along with comparisons to other variations, are presented in Figure 5 below.



Source: Process Data, 2026

Figure 5. Compressive Strength Value

Based on the results of the compressive strength test of several variations used with a concrete curing age of 7 days, 28 days and 56 days, quite interesting results are seen, namely at the age of 7 days it is seen that normal concrete reaches 32.92 MPa while with a mixture of BCK-7.5% substitution (40% SBE + 60% Seashells as much as 7.5% of cement) shows higher results reaching 38.20 MPa or 16% higher than normal concrete. Meanwhile, when using a mixture of BCK-10% (40% SBE + 60% Seashells as much as 10%) at the age of 7 days, it has the lowest value, which only reaches 28,05 MPa, which is 14.81% lower than normal concrete.

In the test when the concrete age reaches 28 and 56 days, it still shows the same thing as the 7-day linear test, only when the concrete reaches the age of 56 days, which is certain that the concrete reaches strength even more than 100% of BCK-7.5%, it shows more promising results, namely it can reach 42.06 MPa, exceeding the results that can be achieved by normal concrete. For more details, see Table 3 below

Table 3. Compressive Strength Testing Results

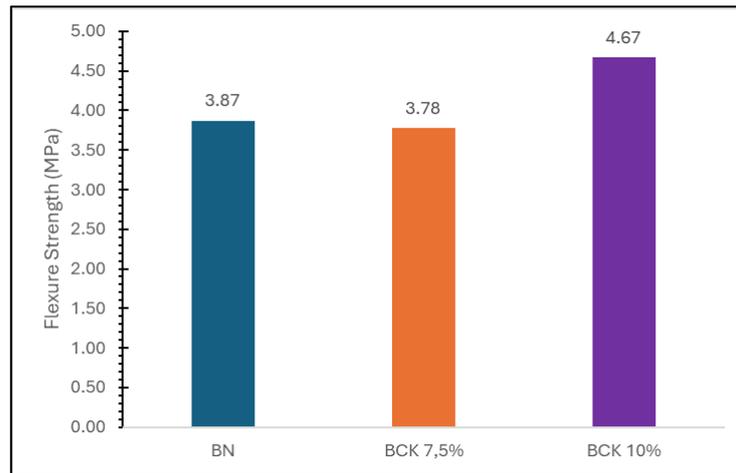
Variation	Sample	Age	D (mm)	H (mm)	Weight (gr)	Load (kN)	Area (mm ²)	Fc (MPa)	Mean	
BN	1	7	150	300	12837	585	17671.46	33.10	32.93	
	2	7	150	300	12056	583	17671.46	32.99		
	3	7	150	300	13172	578	17671.46	32.71		
	BN	1	28	150	300	12521	798	17671.46	45.16	33.67
		2	28	150	300	12116	643	17671.46	36.39	
		3	28	150	300	12844	344	17671.46	19.47	
	BN	1	56	150	300	11876	588	17671.46	33.27	38.65
		2	56	150	300	12039	766	17671.46	43.35	
		3	56	150	300	12219	695	17671.46	39.33	
BCK - 7.5%	1	7	150	300	12262	597	17671.46	33.78	38.20	
	2	7	150	300	12256	707	17671.46	40.01		
	3	7	150	300	12414	721	17671.46	40.80		
	BCK - 7.5%	1	28	150	300	12034	798	17671.46	45.16	41.05
		2	28	150	300	13037	627	17671.46	35.48	
		3	28	150	300	12200	751	17671.46	42.50	
	BCK - 7.5%	1	56	150	300	11942	634	17671.46	35.88	42.06
		2	56	150	300	12219	779	17671.46	44.08	
		3	56	150	300	11765	817	17671.46	46.23	
BCK - 10%	1	7	150	300	11978	549	17671.46	31.07	28.05	
	2	7	150	300	13538	412	17671.46	23.31		
	3	7	150	300	12414	526	17671.46	29.77		
	BCK - 10%	1	28	150	300	13227	725	17671.46	41.03	35.12
		2	28	150	300	11928	649	17671.46	36.73	
		3	28	150	300	12175	488	17671.46	27.62	
	BCK - 10%	1	56	150	300	13070	598	17671.46	33.84	36.18
		2	56	150	300	12214	673	17671.46	38.08	
		3	56	150	300	12439	647	17671.46	36.61	

Source: Process Data, 2026

As seen in Table 3 above, concrete with a BCK-7.5% as cement substitute at 7.5% shows better results than other variations, with compressive strength increasing with age. Under higher compressive-strength conditions, it is expected that concrete durability will also increase. It can happen because, in this test, the fresh water from Bengkalis Island has a non-standard pH (<7.0), which can erode the concrete surface over time. Based on this, it is hoped that shellfish shells can increase concrete durability by providing high calcium and SBE, which will help prevent acid from entering the concrete core, enabling it to withstand better the environment in which it is applied.

3.2. Flexure Strength

Concrete flexural strength testing is performed only after 28 days, as concrete has reached optimal hardening conditions. This test was carried out with 3 (three) variations used to see how the results were in response to the force applied. The results of the flexural strength test are shown in Figure 6 below.



Source: Process Data, 2026

Figure 6. Flexure Strength Value

Based on the results of the compressive strength test of several variations used with a concrete curing age of 28 days, quite interesting results are seen, namely at the age of 28 days it is seen that normal concrete reaches 3.87 MPa while with a mixture of BCK-7.5% substitution (40% SBE + 60% Seashells as much as 10% of cement) shows higher results reaching 4.67 MPa or 20.6% higher than normal concrete. Meanwhile, when using a mixture of BCK-7.5% (40% SBE + 60% Seashells as much as 10%) at the age of 28 days, it has the lowest value, which only reaches 3.78 MPa, which is 2.3% lower than normal concrete. For more details, see Table 4 below.

Table 4. Flexure Strength Testing Results

Variation	Sample	Age	L (mm)	W (mm)	H (mm)	Loads (kN)	Fr (MPa)	Mean
BN	1	28	450	150	150	30.1	4.01	3.87
	2	28	450	150	150	28	3.73	
BCK - 7.5%	1	28	450	150	150	29.4	3.92	3.78
	2	28	450	150	150	27.3	3.64	
BCK - 10%	1	28	450	150	150	35	4.67	4.67
	2	56	450	150	150	35	4.67	

Source: Process Data, 2026

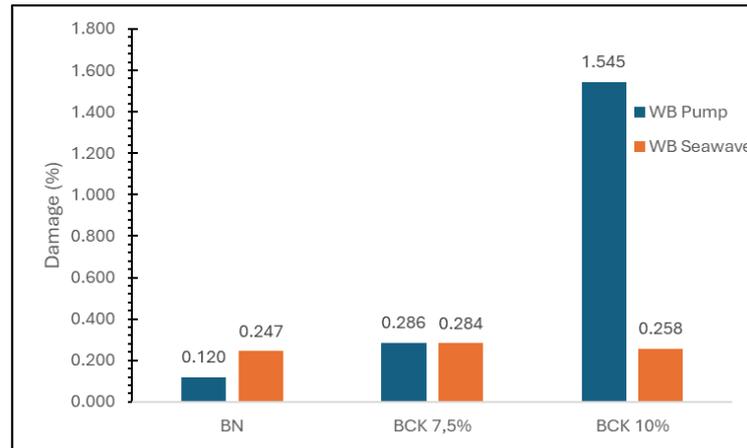
As seen in the table above, concrete with a 10% BCK mixture as a cement substitute shows higher flexural strength than other variations, with increasing age. The result of this test is quite surprising, as it does not align with the compressive strength tests conducted. It could occur due to several factors, such as reduced concrete elasticity, which affects its flexibility through the shells and SBE it contains. Based on this, it is hoped that shells can increase concrete's flexural strength and are suitable for use in elements that require high flexural performance.

3.3. Water Blasting Testing

The water-blasting test in this study aims to determine the extent of damage caused by seawater attack on concrete. Two different testing methods were used: the first, a simulated wave impact test using a custom-made water pump, in which water was dropped from a height of 1.5 meters at a flow rate of 35 liters per minute; and the second, a method adapted from general concrete durability testing. This approach was chosen because it can simulate the effects of seawater erosion with sufficient intensity to assess concrete durability in coastal areas.

In the test using a pump, water was dropped from a height of 1.5 meters and flowed at a speed of 35 liters per minute for 3 (three) consecutive days. However, in this research, the water pressure generated by the pump was not specifically calculated because the main focus was on the height of the waterfall and the rate of its flow, which aimed to simulate the intensity of seawater attacks. So, the calculation or measurement of water pressure is not part of the method applied in this research. Therefore, the absence of water pressure measurements should be noted as a limitation of this study.

In comparison, testing with natural seawater attacks originating from direct waves provides more natural results and is closer to field conditions. While the two methods differ, pump testing yields more controlled results, and wave testing provides a more realistic picture of the impact of natural erosion. The results of this test are shown in Figure 7 below.



Source: Process Data, 2026

Figure 7. Water Blasting Damage Value

Based on the results of water blasting tests of several variations used with a concrete curing age of 28 days and tested for 3 (three) consecutive days using natural waves, quite interesting results were seen, namely that normal concrete showed damage of 0.247%, while with a substitution mixture of BCK-7.5% (40% SBE + 60% Seashells as much as 7.5% of cement) showed higher results reaching 0.284% which is higher than normal concrete. On the other hand, when using a mixture of BCK-10% (40% SBE + 60% Seashells), the value is not far from that of normal concrete, as it experiences damage of around 0.258%.

Meanwhile, in tests using a water pump, very significant results were seen. The BCK-10% (40% SBE + 60% Seashells) mixture had the highest value of the two, experiencing approximately 1.545% damage. The second-highest damage rate was BCK-7.5% (40% SBE + 60% Seashells) with 0.286% damage, and normal concrete with 0.120%.

Based on these test results, it appears that concrete with a BCK + SBE mixture exhibits stronger compressive and flexural strength. Still, some aspects are reduced, including the concrete's watertightness against direct water intrusion into the concrete core. Therefore, before using this mixture, a thorough assessment of the concrete's compressive strength for the intended application is necessary, as this affects the concrete's watertightness.

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