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Utilization of Rice Husk Ash and Coconut Fibers to Enhance Pervious Concrete in Sustainable Pavement Systems

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ABSTRACT

This study examined the influence of rice husk ash and coconut fiber on the mechanical and durability performance of pervious concrete. The concrete mixes were prepared without fine aggregates to maintain high porosity, using a water-to-cement ratio of 0.30 and a coarse aggregate-to-cement ratio of 4.5:1. Rice husk ash replaced 10% or 12% of the cement by weight, while coconut fiber was added at 0.3% and 0.5% by volume. The results showed that both additives slightly reduced porosity and permeability, yet the compressive strength remained above the minimum threshold of 7 MPa. The mix containing 0.3% coconut fiber achieved the highest strength of 11.0 MPa. The most optimal mix combined 10% rice husk ash with 0.5% coconut fiber, producing a porosity of 21%, permeability of 3.8 mm/s, compressive strength of 10 MPa, and water absorption of 250 L/m^3. Durability also improved in fiber-containing mixes, as observed from reduced damage under wet-dry cycles. The addition of these natural materials contributed to enhanced mechanical performance and resistance to water-related degradation, making the mix suitable for sustainable pavement systems. Overall, the findings confirmed that rice husk ash and coconut fiber can be effectively utilized as partial replacements in pervious concrete without compromising structural integrity.

1. INTRODUCTION

Pervious concrete also known as porous concrete is a novel type of concrete that contains voids which permits water to flow through the concrete itself [1] It can be used for sidewalks, parking lots, roadways, and drainages in urban places where waters need to be channeled properly. [2] The importance of groundwater recharge and surface runoff reduction is significant in cities where green spaces are scarce and population is high, hence the importance of pervious concrete to let water infiltrate through its material Because of its ability to mitigate the urban heat island effect and help in lowering the temperature in densely populated cities, the application of pervious concrete in such areas is a necessity. [3].

Accordingly, the purpose of our research is for identifying when using coconut fiber and rice husk ash (RHA) to the concrete would improve its durability and strength. RHA is basically just ash from burning rice husks and contains a high concentration of silica. It can therefore partially replace cement in concrete. It conforms with SNI 03-6861.1-2002 and ASTM C618. [4] According to certain research, RHA can lower CO2 emissions and reinforce concrete. [5] However, when moisture or temperature changes take place, the strength and pliability of coconut fiber can assist keep cracks from forming. As a result, the concrete lasts longer. [6]

Concrete specimens will be tested following SNI 1974:2011 and ASTM C39 for compressive strength, [7] SNI 03-2461-2002 and ASTM C1701 for permeability, and ASTM C666 for freeze-thaw durability. [8]

Through combining organic materials like RHA and coconut fiber improve the quality of pervious concrete, recent construction projects have tried to determine measures to reduce difficulties [9] like RHA and coconut fiber to enhance the performance of pervious concrete. [10] During mixing concrete, rice husk ash (RHA), a natural filler derived from the rice processing business, states to be enhanced with silica, allowing to substitute for certain cement. [11].

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2. METHOD

The raw materials used in this study were carefully selected before the concrete was mixed by hand and machine. The main ingredients were pure water, crushed stone (5-10 mm) as coarse aggregate, and Type I Portland cement as a binder. RHA was used to replace 10%, and 12% of the cement, respectively, while coconut fiber made up 0.3% and 0.5% of the mixture's volume. To facilitate interaction with the mixture, a trace amount of superplasticizer (0.3% of the cement weight) was added.

The mix design had a water-to-cement ratio of 0.30 and a coarse aggregate-to-cement ratio of 4.5:1, excluding fine aggregates to preserve macro-porosity. It evaluated five alternative mix variations:

1. V0: Control mixture
2. V1: RHA of 10%
3. V2: 0.3% fiber from coconut
4. V4: 0.3% coconut fiber and 10% RHA
5. V5: 0.5% coconut fiber and 10% RHA

The following criteria were followed when conducting the tests:

1. Porosity: ASTM C1754
2. Permeability: Falling head method
3. Compressive Strength: ASTM C39 (28 days)
4. Durability: Simulation of a wet-dry cycle (10

3. RESULT AND DISCUSSION

Result

This chapter analyzes the results obtained from testing concrete samples with additives such as Rice Husk Ash (RHA) and coconut fibers. The primary concern is how these additives affect the porosity and permeability alongside compressive strength and durability of concrete.

The experiments conducted reveal how different mix designs influence performance characteristics including concrete density, water tightness, compressive strength, and sustained durability over time.

For every subsequence or subsection that includes the control mix, comparison of results from other mix designs is done to ascertain the best blend for improving concrete properties as well as verifying the porous, permeable, compressive, and durable aspects against the control mix. most effective mix for improving concrete properties

Discussion

The table depicts how the material performs when the mix is altered slightly. It considers factors such as its strength, porosity, ability to pass water, amount of water absorbed, and longevity. These features are important because they indicate how strong the material is, how it reacts to water, and how long it will last. All of this helps us determine if the material is suitable for specific construction or engineering applications.

Table 3. Material Property Analysis Across Variations

Variation	Compressive Strength (MPa)	Porosity (%)	Permeability (mm/s)	Water Absorption Volume (L/m^3)	Durability (Damage Score)
V0	10.0	23.0	4.5	270	3.0
V1	10.5	22.5	4.2	260	2.5
V2	11.0	22.0	4.1	265	2.0

V3	10.2	21.5	4.0	255	1.5
V4	10.1	21.0	3.8	250	1.0
V5	9.8	20.5	3.5	248	1.2

Looking at the table, you can see the numbers change depending on the mix. Stuff like strength and how it deals with water shifts when the mix changes. Seeing how those things vary helps us understand what happens when we tweak the material or change how it's made. That's useful when picking materials for different kinds of projects.

Concrete Testing Porosity

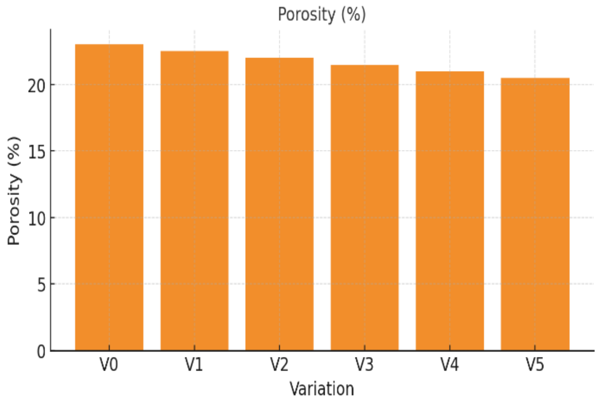

Figure 3.2. Testing Porosity

The concrete porosity test results based on various mix variations appear in Figure 3.1. The test result s showed that the control mix (V0) had the highest porosity value, at 23%. It indicate the porosity of concrete mixtures without additives is higher than that of mixtures with additives. To reduce the porosity, coconut fiber and rice husk ash (RHA) have been added to the concrete mixture. In completing the empty spaces (pores) between the coarse aggregates, the fine RHA and coconut fiber particles raise the concrete's density. Also in accordance to test results, the mix variation V5 had the lowest porosity value.

Concrete Permeability Testing

Figure 3.2 shows how water moves through different concrete mixes. Basically, it's a test to see how porous the material is how easily water can get through. If the permeability is low, that's usually a good sign; it means water doesn't pass through easily. But if the number's high, water can flow through more quickly, which could be a problem for durability

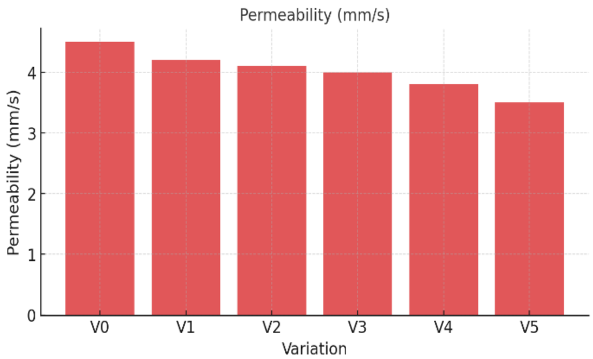

Figure 3.2. Permeability Testing

The control mix, which is labeled V0, ended up with the highest permeability at 4.5 mm/s.

That's the mix without any additives, so it makes sense it didn't have anything to help block the water. It just lets water through more easily.

Now, when additives were added—particularly in the V5 mix—the permeability dropped to around 3.5 mm/s. That drop isn't random; it matches what was seen earlier with the porosity results. Less porosity means fewer empty spaces inside the concrete, so there's not much room for water to move through.

Concrete Compressive Strength Testing

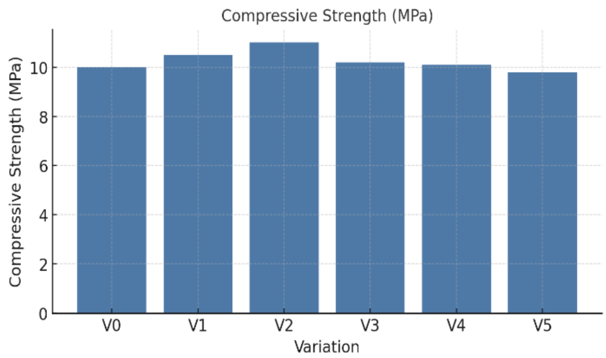

Figure 3.4. compressive strength test results

After 28 days of curing, the compressive strength results can be seen in Figure 3.3. Interestingly, every concrete mix tested showed values above 7 MPa, which is actually the minimum requirement for permeable concrete according to the standards. This shows that even with the addition of rice husk ash (RHA) and coconut fiber, the concrete still holds up well and in some cases, performs even better. One mix in particular, called V2, which had 0.3% coconut fiber, showed the highest strength at 11.0 MPa. That's a clear sign that the fiber played a role in making the mix stronger, most likely by holding off the formation of small cracks when the concrete is under pressure. Basically, the coconut fiber seems to help the concrete carry more weight and stay tougher over time by linking across cracks before they grow bigger.

Concrete Durability Testing

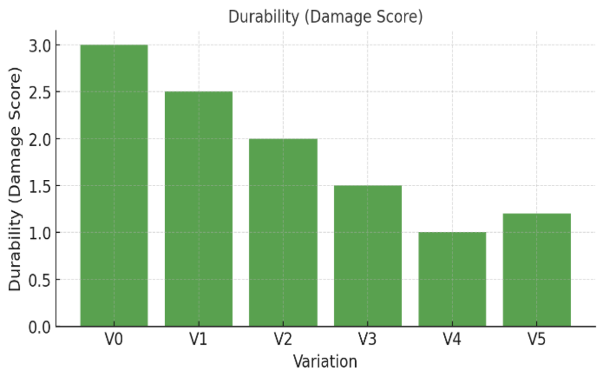

Figure 3.5. Durability Testing

In Figure 3.4, we can see how the concrete handled a durability test that involved getting wet and drying out over 10 cycles. The whole idea of this test is to see how the concrete reacts to being soaked and then dried repeatedly, which usually makes it expand and shrink. According to the results, the concrete mixed with coconut fiber did better than the one without it. The fiber seems to help by easing the internal stress that happens when the water content changes, which keeps cracks from forming or spreading. It basically helps the concrete deal with changes in volume and spreads out the stress more evenly, making it stronger overall.

Water Absorption Volume

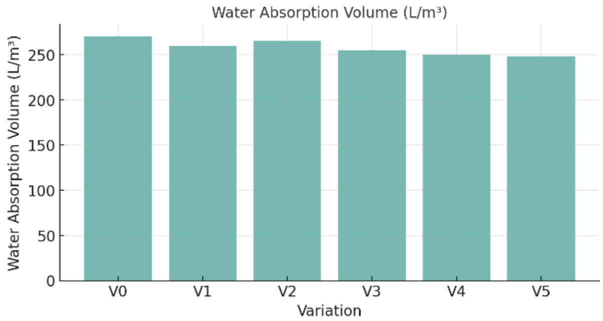

Figure 3.6. Water Absorptio Volume

when checked how much water the samples took in, it kinda made sense the ones that didn't soak up much seemed tougher. V5, for example, only took in about 248 liters per cubic meter. That's not a lot, and it seemed to hold up better. Now V0? That one absorbed around 270. And yeah, that could mean it's more likely to wear down or get weak quicker. Honestly, if a material doesn't pull in much water, chances are it'll last longer especially in wet places or places where moisture is a problem.

4. CONCLUSION

1. Adding RHA at up to 10% of the cement's weight seems to boost the overall performance of porous concrete while still keeping the water absorption volume above the minimum standard of 250 L/m^3. But once it hits 12%, the number drops slightly to 248 L/m^3, which is just under the required limit.
2. Using coconut fiber at 0.5% of the concrete's volume helps make the mix more resistant to cracking and still holds the compressive strength at around 10 MPa.
3. The best results show up in mix V4, where 10% RHA and 0.5% coconut fiber are used together. That mix ends up with a porosity of 21%, a permeability rate of 3.8 mm/s, compressive strength at 10 MPa, and water absorption right at the 250 L/m^3 mark.

All mixtures from V0 to V4 manage to meet the porous concrete standards, especially in terms of minimum water absorption. V5 is just barely below that line.

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