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Effect of binders coating to improve the impermeability of Concrete

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Abstract. This research explores the application of sawdust ash, sugarcane bagasse ash, and paper sludge ash as binder coatings to improve the impermeability of concrete surfaces. Concrete permeability is a crucial factor affecting the lifespan and integrity of concrete structures. It essentially refers to how easily liquids and gases can pass through the concrete. Concrete water permeability is vital for durability, as it determines water ingress resistance, impacting long-term structural integrity. Most deterioration actions affecting the durability of concrete structures are related to the penetration of aggressive agents from the environment into the concrete (Robert J. Torent, et al, 2021). Highly permeable concrete allows water to seep in. This water can cause corrosion of the steel reinforcement within the concrete, leading to cracks and weakening the structure. These ashes were applied separately and in combination on 6" x 6" x 6" concrete cubes. The best ash mixture is 10% replacement combined with 30% replacement of cement by paper sludge ash and sugarcane bagasse ash respectively, increased impermeability about 72% when compared to uncoated and individually ash-coated surfaces, according to the results. This study emphasizes the possibility of recycling waste materials from agriculture and industry as environmentally friendly coatings to increase the durability of concrete and support sustainable building methods.

Keywords: Impermeability, Paper Sludge Ash, Saw Dust Ash, Sugarcane Bagasse Ash, Concrete Water Absorption.

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1. Introduction

Water can seep through permeable concrete, causing leaks. This may result in water loss, lowering the tank's capacity and possibly causing nearby regions to become moist or flooded. Dashtibadafridi (2017) stated that concrete become weakened by water seepage. Since, water has the ability to dissolve minerals and release calcium hydroxide, which is essential to the strength of concrete, as it permeates. This may cause the tank's structural integrity to be compromised and result in cracking and flaking. Corrosion may result from water seeping through the concrete and reaching the steel reinforcement bars inside. This may lead to structural failure by weakening the reinforcement. There low permeability concrete should be preferred for water tanks. According to Dashtibadfarid (2017) Low-Permeability Concrete reduces water seepage and guarantees the tank retains water efficiently. Where, the building water tanks that waterproof requires an in depth understanding of the concrete permeability.

Numerous studies in this field have shown that industrial wastes can function as efficient substitutes for conventional cementitious materials. The permeability and water absorption of the mortar are affected by the addition of industrial ashes. Since, these industrial by-products have pozzolanic qualities, therefore, they can improve the final cement paste's quality and enable to give fruitful results according to requirement, which can save money and energy (Dixit, 2020).

This study's primary goal is to investigate the impermeability of mortar cubes in water while taking various ash kinds into account.

2. Literature Review

Growing environmental consciousness has led to a rise in the use of industrial wastes as a partial replacement in concrete. Many researches are being conducted in the area of utilization of industrial wastes as a substitute for cementitious materials. The slump, water absorption, and strength characteristics of concrete are impacted by the addition of industrial ashes; yet, the partial replacements give reasonably acceptable results to justify the usage of the ashes as a partial replacement (Dixit, 2020).

2.1 Paper sludge Ash

Pakistan produces roughly 5,500 tons of paper waste per day, out of an estimated 55,000 tons of solid waste per day, of which 10% is estimated to be paper waste. This significant amount of paper waste emphasizes the need for efficient waste management strategies to minimize the impact on the environment and preserve landfill space (Pakistan Environmental Protection Agency, 2024).

Paper sludge is one of the major types of waste produced in Malaysia, alongside food and plastic waste, with Malaysians generating approximately 3,247 tons of paper waste daily. Repurposing non-recyclable paper can significantly reduce paper sludge waste in Malaysia, decrease the need for landfill space, and minimize environmental pollution. The composition of Paper Sludge Ash is shown in the given figure 1.

2.2 Sugar Cane Bagasse Ash

The main byproduct of the sugar business is bagasse. It is the fibrous residue left behind after the juice is extracted and the sugar cane is crushed. The same industry that produces sugar typically uses the bagasse generated as a power source. Because it reduces disposal-related concerns, using sugarcane bagasse ash as a pozzolanic ingredient in mortar mixtures or concrete as a partial substitute for cement leads to an optimistic attitude to environmental issues. Bagasse ash has a high-quality amount of amorphous silica in its chemical makeup, which makes it suitable as an additional cementitious material. The graphical depiction of Sugar Cane Bagasse Ash's chemical composition is presented in Figure 2.

After 28 days of curing, Praveenkumar (2019) discovered water permeability using a cylindrical mortar specimen. The findings indicate that the control mix specimen's water permeability was $1.157\times (10)^4$ cm/s and that this coefficient gradually decreased as the amount of bagasse ash added increased. At the 30% bagasse ash content, it displays a significant $0.159\times (10)^4$ cm/s reduction in water permeability. The bagasse ash particles that are filler material are assumed to occupy the spaces and reduce the water permeability. Therefore, the restriction of permeability caused by the filler action of bagasse ash aids in the creation of the dense mix.

2.3 Saw Dust Ash

As a byproduct of mechanically milling wood into different sizes, sawdust is produced. It keeps piling up, harming the environment in the process. For this reason, it is necessary to properly dispose of this agricultural residue. The use of sawdust ash (SDA) as a pozzolanic additive to partially substitute ordinary Portland cement (OPC) in mortar and concrete has been the subject of numerous investigations. At the construction site, SDA was mixed into the mortar or concrete. Concrete has been demonstrated to benefit from the use of SDA in cement in terms of low heat of hydration and strength growth at later curing ages. This study examines the process of producing blended cement using ordinary. Water Absorption of SDA of different days and their grades are shown in figure 4 (Marthong, 2012).

Figure 1: Graphical Representation of oxides percentages in WSA

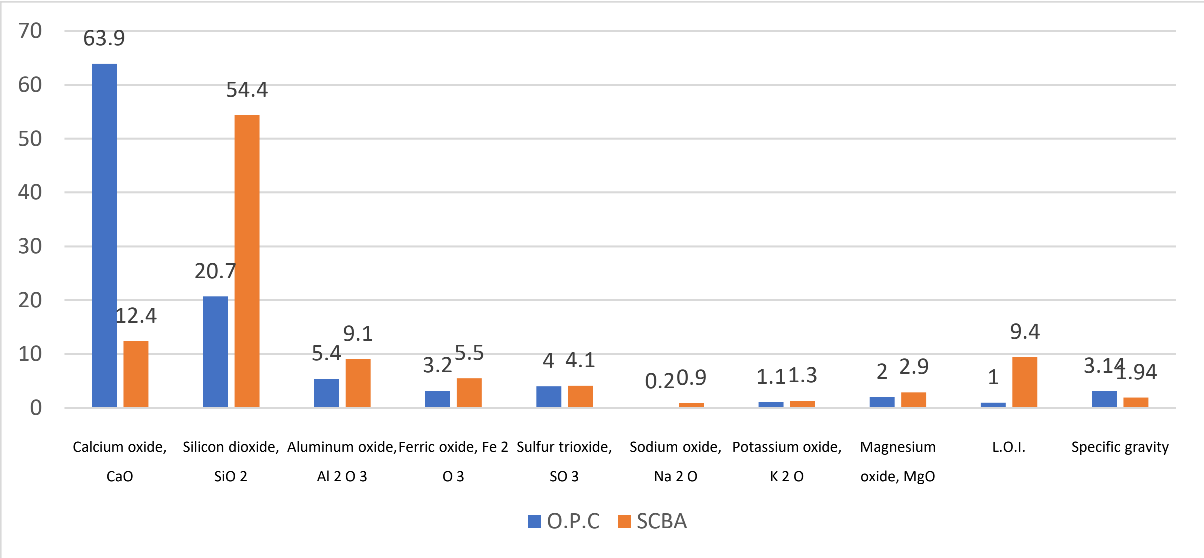


Figure 2: Chemical Composition of O.P.C and SCBA *(Chi, 2012)*

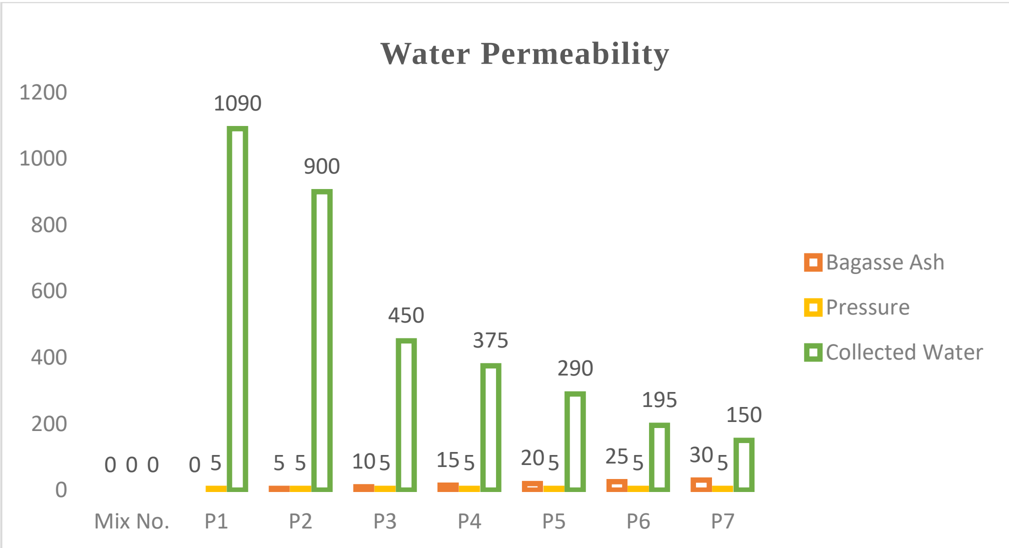


Figure 3: Water Permeability of Bagasse Ash

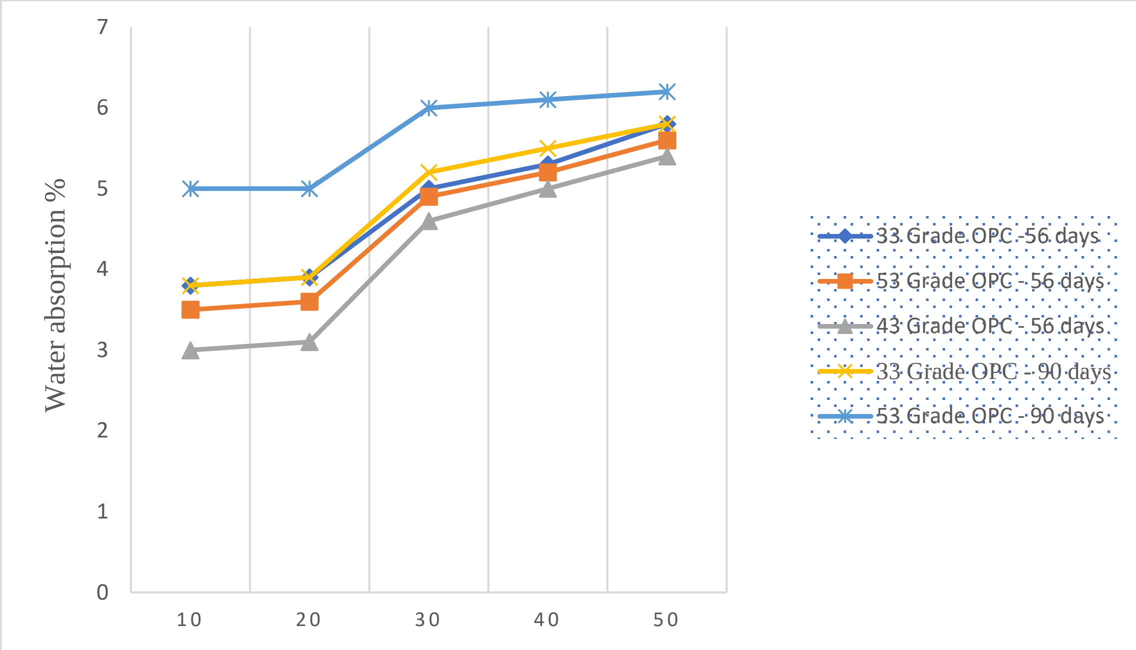


Figure 4: Graphical Representation of Water Absorption of SDA of different days and their grades (C.Marthong, 2012)

3. Methodology

3.1 Material

3.1.1 Paper Sludge Ash

Paper Sludge collected from industry as a raw material from SOHAIB PAPER MILL, Multan Industrial State, Multan, Pakistan. Paper sludge usually has some moisture in it. To lower the moisture level of the collected sludge, start by drying it. Dry the Paper Sludge about two weeks and then converted into ash.

3.1.2 Saw Dust Ash

Sawdust is produced as a byproduct of mechanically milling wood into different sizes. Saw Dust easily available material in timber market.

Saw Dust was collected from timber market, Multan, Pakistan. Then drying the saw dust for about 7 days. After drying converted the Saw dust into Saw Dust Ash. Then ash sieved from 45μm.

3.1.3 Sugar Cane Bagasse Ash

Bagasse is the waste product of Sugar Industry. Bagasse collected from drink corners and then drying it for about two weeks. After drying converted it in to ash. After making ash passing it from 45μm sieve.

3.1.4 Mixture and Specimen Preparation

1:2:4 concrete cubes were casted with size of 6”x6”x6” as shown in figure 7. Seven Days of curing was done. Then these samples were coated with CS mortar 1:3 with cement replacement according to figure 6.

3.2 Testing

3.2.1 Water Absorption of Uncoated Cube

Samples were casted with the 1:2:4 concrete. After completing the curing process of seven days, and then placed the samples in Oven at 105 ± 5°C for at least 24 hours for drying.

After oven dried place samples for air dried. Note the weight of oven dried samples. Submerged the dried samples in water and noted the weight for 30minutes, 24hours and 72hours. Calculate the water absorption for each sample from the formula which is given below.

Water Absorption %=(W_s-W_d)/W_d

Ws is the saturated surface dried weight

Wd is the oven dried weight

3.2.2 Water Absorption of Coated Cubes

After calculating the water absorption of uncoated samples dried the samples in oven at 105 ± 5°C for at least 24 hours. Coated the dried samples with 1:3 cement mortar with replacement of cement with ashes individually and with combinations of each other which are mentioned in table 1, 2, and 3. And calculate the water absorption which is done for uncoated samples.

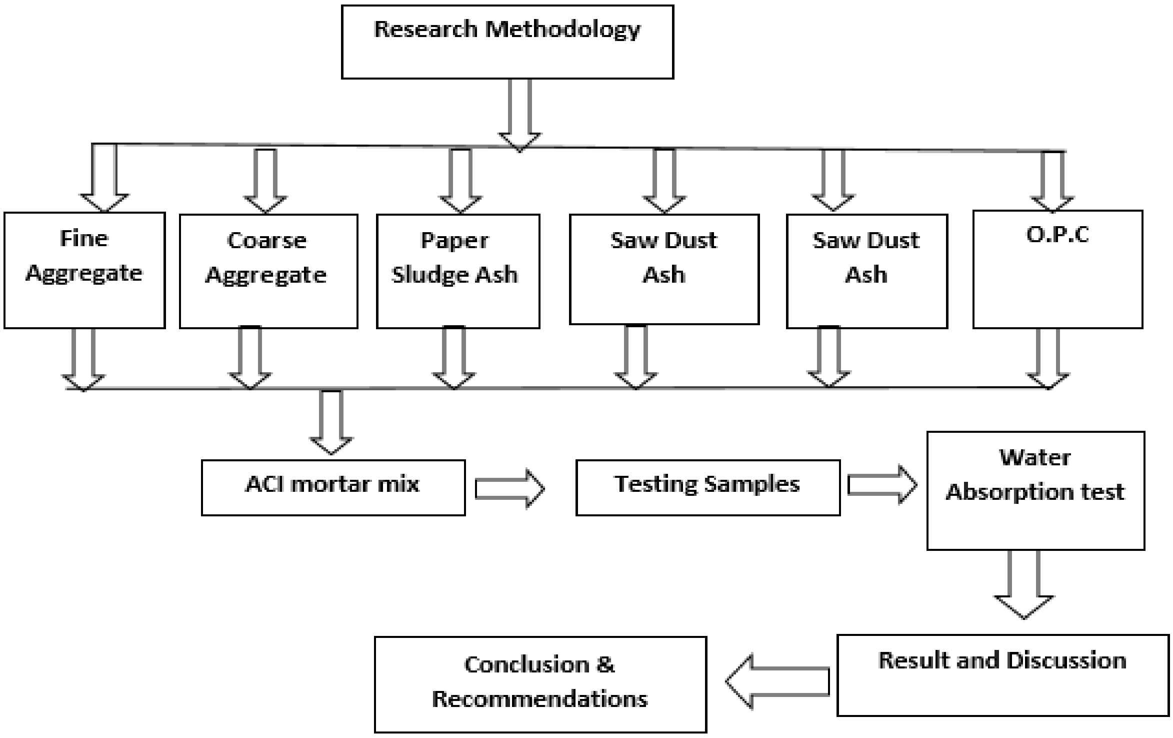


Figure 05: Research Methodology

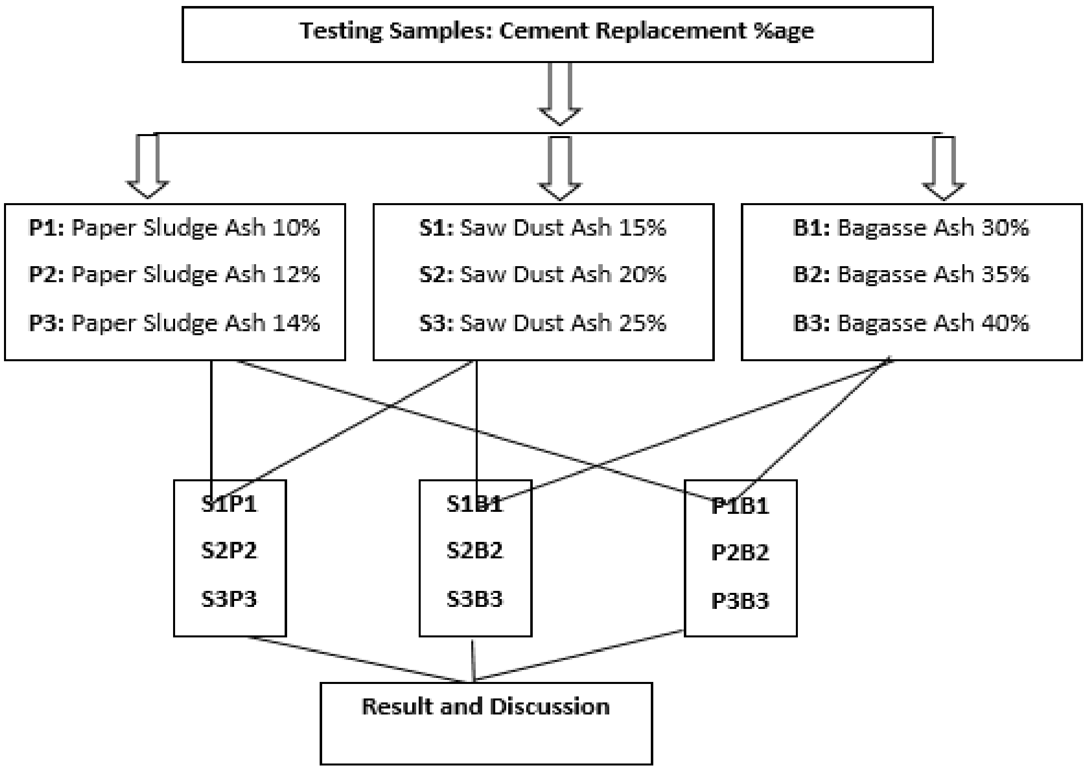


Figure 6: Testing Samples

Figure 7: Paper Sludge Ash

Figure 8: Saw Dust Ash

Figure 9: Sugar Cane Bagasse Ash

Figure 10: Cube 6”x6”x6”

Figure 10: Oven Dried Sample

Figure 11: Cubes Weight

Figure 12: Saturated Cube

4. Results and Discussion

- Cubes coated with 1:3 CS mortar with partial replacement of cement by ash resulted in reduction in water absorption up to 70%.
- Samples P-1, P-2, and P-3 show cement with 10%, 12%, and 15% substitution for paper sludge ash was done.
- Out of the P-1, P-2, and P-3 samples, P-1 exhibits the best results in terms of water absorption after 30 minutes.
- S-1, S-2 and S-3 are the samples of Saw Dust ash replacement with cement with 25, 30% and 35%.
- S-2 sample give the best of water absorption at 30minutes from the S-1, S-2 and S-3 samples.
- The cement replacement samples with 25, 30%, and 35% bagasse ash are B-1, B-2, and B-3.
- Compared to the B-1, B-2, and B-3 samples, the B-3 sample exhibits the best reduction in water absorption after 30 minutes.
- Sample S1P1 exhibits the greatest reduction in water absorption between the P.S.A. and S.D.A. combination at 30 minutes.
- After 30 minutes, Sample S1B1 produces the best results of reduction in water absorption when S.D.A. and B.A. are combined.
- Sample P1B1 yields the best results in reduction of water absorption after 30 minutes when comparing the two combinations of P.S.A. and B.A.

Table 1: Water Absorption at 30min

Ash / Ash Combination	% age replacement of cement	Water Absorption		%age Reduction in Water Absorption
		Before Coating	After Coating	
Paper Sludge Ash (PSA)	P1: PSA 10%	4.00%	1.15%	71.25%
	P2: PSA 12%	3.99%	1.85%	53.63%
	P3: PSA 15%	4.10%	1.45%	64.63%
Saw Dust Ash (SDA)	S1: SDA 25%	4.89%	2.30%	52.97%
	S2: SDA 30%	4.79%	1.85%	61.38%
	S3: SDA 35%	4.65%	1.85%	60.22%
Bagasse Ash (BA)	B1: BA 30%	5.90%	2.93%	50.34%
	B2: BA 35%	5.65%	2.79%	50.62%
	B3: BA 40%	6.30%	3.10%	50.79%
$PSA \times SDA$	S1P1	6.70%	1.97%	70.60%
	S2P2	5.90%	1.99%	66.27%
	S3P3	5.95%	1.85%	68.91%
$SDA \times BA$	S1B1	6.71%	2.68%	60.06%
	S2B2	6.45%	2.66%	58.76%
	S3B3	6.23%	2.59%	58.43%
$PSA \times BA$	P1B1	6.65%	1.90%	71.43%
	P2B2	6.65%	2.10%	68.42%
	P3B3	6.02%	2.32%	61.46%

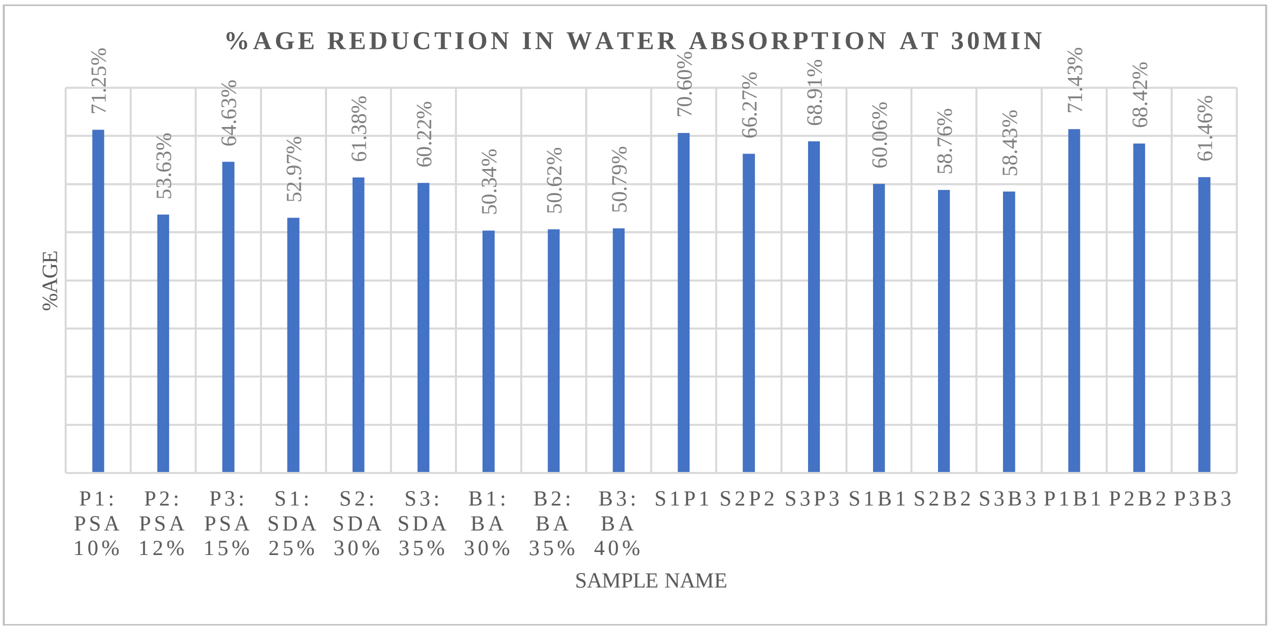


Table 1: Water Absorption at 24 hours

Ash / Ash Combination	**% age replacement of cement**	**Water Absorption**		**%age Reduction in Water Absorption**
		Before Coating	**After Coating**	
Paper Sludge Ash (PSA)	P1: PSA 10%	4.20%	2.60%	38.10%
	P2: PSA 12%	4.05%	2.55%	37.04%
	P3: PSA 15%	3.91%	2.35%	39.90%
Saw Dust Ash (SDA)	S1: SDA 25%	3.95%	3.00%	24.05%
	S2: SDA 30%	4.20%	2.85%	32.14%
	S3: SDA 35%	4.43%	2.75%	37.92%
Bagasse Ash (BA)	B1: BA 30%	6.70%	3.73%	44.33%
	B2: BA 35%	5.85%	3.99%	31.79%
	B3: BA 40%	6.20%	4.05%	34.68%
$PSA \times SDA$	S1P1	4.87%	2.87%	41.07%
	S2P2	5.40%	2.95%	45.37%
	S3P3	5.10%	2.70%	47.06%
$SDA \times BA$	S1B1	5.89%	3.38%	42.61%
	S2B2	6.30%	3.46%	45.08%

	S3B3	6.30%	3.39%	46.19%
$PSA \times BA$	P1B1	6.25%	2.88%	53.92%
	P2B2	6.80%	3.01%	55.74%
	P3B3	5.85%	3.07%	47.52%

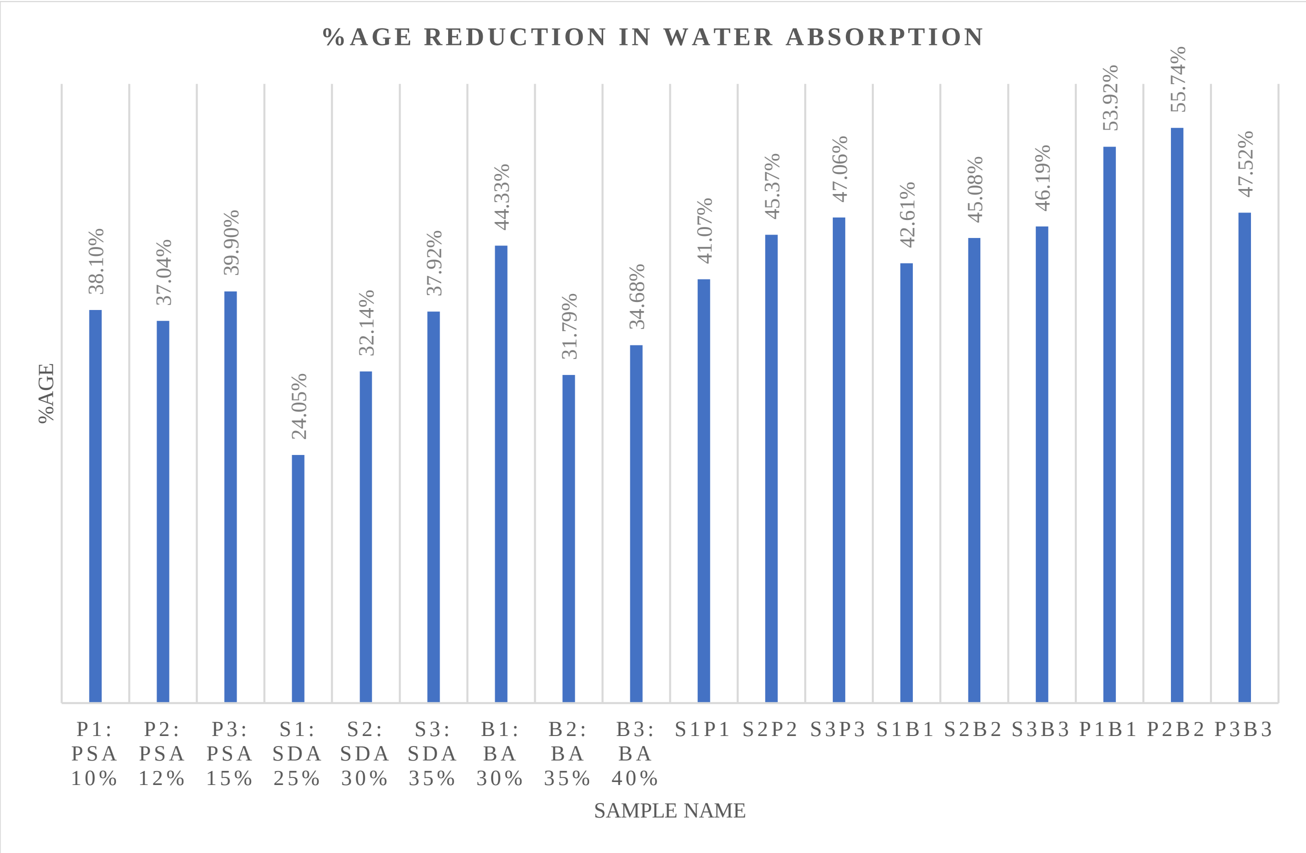
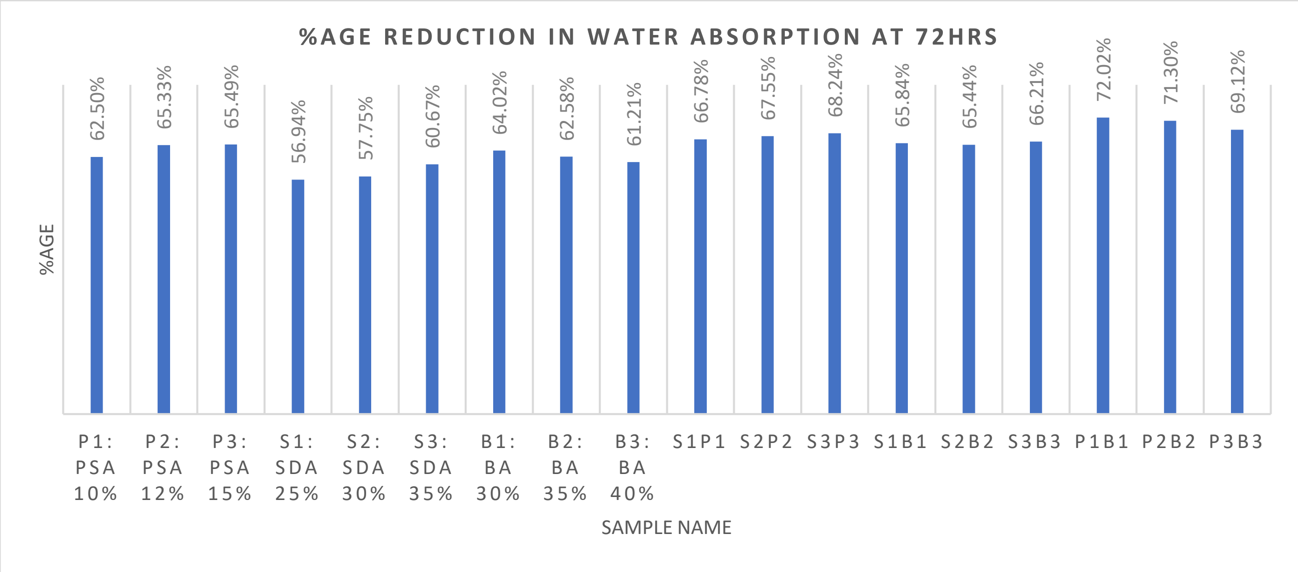


Table 3: Water Absorption at 72 hours

Ash / Ash Combination	% age replacement of cement	Water Absorption		%age Reduction in Water Absorption
		Before Coating	After Coating	
Paper Sludge Ash (PSA)	P1: PSA 10%	7.2%	2.7%	62.50%
	P2: PSA 12%	7.5%	2.6%	65.33%
	P3: PSA 15%	7.1%	2.45%	65.49%
Saw Dust Ash (SDA)	S1: SDA 25%	7.2%	3.1%	56.94%
	S2: SDA 30%	7.1%	3.0%	57.75%
	S3: SDA 35%	7.5%	2.95%	60.67%
Bagasse Ash (BA)	B1: BA 30%	10.7%	3.85%	64.02%
	B2: BA 35%	10.85	4.06%	62.58%
	B3: BA 40%	10.7%	4.15%	61.21%
$PSA \times SDA$	S1P1	9.0%	2.99%	66.78%
	S2P2	9.4%	3.05%	67.55%
	S3P3	9.1%	2.89%	68.24%
$SDA \times BA$	S1B1	10.1%	3.45%	65.84%
	S2B2	10.3%	3.56%	65.44%
	S3B3	10.3%	3.48%	66.21%
$PSA \times BA$	P1B1	10.65%	2.98%	72.02%
	P2B2	10.8%	3.10%	71.30%
	P3B3	10.2%	3.15%	69.12%



5. Conclusion

Cement-sand mortar with partial ash replacements of cement reduced water absorption up to 70%. Among paper sludge ash (PSA) replacements (P-1: 10%, P-2: 12%, P-3: 15%), P-1 showed the best reduction 71% in water absorption. Sawdust ash (SDA) replacements (S-1: 25%, S-2: 30%, S-3: 35%) demonstrated S-2 as the most effective in reducing water absorption is 62%. Bagasse ash (BA) replacements (B-1: 25%, B-2: 30%, B-3: 35%) showed B-3 achieving the greatest reduction 64% in water absorption. Combining PSA with SDA in sample S1P1 exhibited the highest reduction 68% in water absorption. Sample S1B1, combining SDA with BA, achieved the best reduction 66% in water absorption. Sample P1B1, combining PSA 10% & BA 30% replacement of cement, demonstrated the highest 72% reduction in water absorption among all combinations tested.

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