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AN STUDY ON ACHIEVING THE COMPRESSIVE STRENGTH OF M-35 GRADE CONCRETE USING M30 GRADE CONCRETE WITH POLY PROPENE FIBER AND RICE HUSK ASH

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ABSTRACT:

Cement manufacturing now generates a lot of carbon dioxide (CO2), therefore finding environmentally acceptable, long-lasting alternatives to cement as a binder is becoming increasingly important. The purpose of this investigation was to examine the effects of adding rice husk ash (RHA) as a supplemental cementitious material on the compressive and flexural strengths of concrete. RHA's pozzolanic nature makes it a promising alternative binder, but it can only partially replace cement up to a certain percentage; beyond that, the concrete's strength drops, making it less desirable. Thus, Polypropylene (PP) fibers were employed to reinforce RHA-based eco-friendly concrete. After analyzing the data, it was found that while 5% RHA was stronger than the control sample, increasing the RHA level beyond that point significantly reduced the strength. When PP fibres were added to concrete that had 10% RHA and had decreased strength, the concrete's strength increased.

KEYWORDS: Supplementary Cementitious Materials, Polypropylene Fibres, Rice Husk Ash, Fibre Reinforced Concrete, Sustainable Concrete

I. INTRODUCTION

One of the fastest-growing sectors worldwide, the construction industry is crucial to every country's economic development (Sohu et al., 2018). Cement, aggregates, and water make up concrete, the synthetic material most frequently employed in the construction sector. Cement is the most crucial component of concrete since it binds the material together, making it suitable for a wide range of construction projects, from modest homes to enormous skyscrapers (Sandhu et al., 2019). Buildings and infrastructures are being constructed at a record rate worldwide, driving up the demand for concrete and cement and leading to a corresponding rise in cement output. To produce cement, the cement industry releases a significant amount of carbon dioxide (CO2), both directly and indirectly (Suhendro, 2014).

Rising cement output correlates with increased emissions of greenhouse gases like carbon dioxide, which deplete the ozone layer and speed up global warming. Cement's use of natural resources like clay and limestone is another drawback; with cement's ubiquitous presence in the building industry as the primary binder material, these resources are being depleted at an alarming rate to keep up with the industry's insatiable demand. Waste production has skyrocketed with urbanization (Abdel-Shafy et al., 2018) and industrialization; however, much of this garbage is just dumped in landfills without being properly processed, which has serious consequences for human health and the environment. In an effort to lessen cement production's and concrete manufacturing's harmful effects on the environment, scientists have experimented with replacing some of the cement with other materials. Cement may be used in less quantities thanks to this partial substitution, and the waste materials can be put to good use. Research has been going on for decades to develop sustainable concrete with different supplementary cementitious materials (SCMs) (Ramadhansyah et al., 2020; Ashish 2019; Gettu et al., 2019; Jhatial et al., 2019a; Juenger et al., 2019; Martirena & Monzó, 2018), so the idea of using waste materials in concrete is not new. In this experiment, an agro-industrial byproduct called Rice Husk Ash (RHA) is used to partially substitute for cement. RHA is produced as a byproduct of rice, a staple food for half the global population. However, only around 10% of the world's fertile land is used to cultivate rice (Koushkbaghi et al., 2019).

It is anticipated that 600 million tonnes of rice paddy are generated every year (Krishna et al., 2016), and the average rice paddy comprises of 25% husk, 10% barn and germ, and the balance is rice. Rice mills use the husks as fuel in the boiler to create power, resulting in the generation of RHA, a type of solid waste seen in Figure 1. The rice mills have no practical use for this powder, so it is dumped in the open air, where it poses serious health risks to the local population..

Figure 1. Sample of Rice Husk and Rice Husk Ash (Jhatial et al.,2019b)

Because it contains more silica than any other plant waste, RHA is an efficient pozzolanic-based SCM. Because of its pozzolanic properties, it may be used as a cementitious material after being finely powdered. Using RHA as a cement replacement would save construction costs, assist the environment, and make sustainable building possible. The building industry's possible use of waste materials has further implications for limiting the growth of landfills.

Studies have shown that RHA may be used to replace cement content up to a specific limit (Hussain et al., 2019; Kachwala et al., 2015; Rahim et al., 2014; Chao-Lung et al., 2011; Kishore et al., 2011) without reducing the strength of concrete. Strength often decreases as RHA concentration is increased past this point. It is common knowledge that concrete is a fragile material that performs well in compression but poorly in tension. When a greater proportion of RHA is utilised to replace cement, the material becomes more brittle and weaker than it would be otherwise. Concrete has relatively low flexural strength because it tends to collapse suddenly and without notice.

As can be seen in Figure 1, incorporating fibre reinforcement into concrete helps mitigate the material's brittleness, effectively transforming it into a ductile material.

By altering its behaviour in this way, concrete is able to improve its flexural strength by being less prone to breaking. Fibres added to concrete not only make it stronger (Nair et al., 2018), but they also make it last longer..

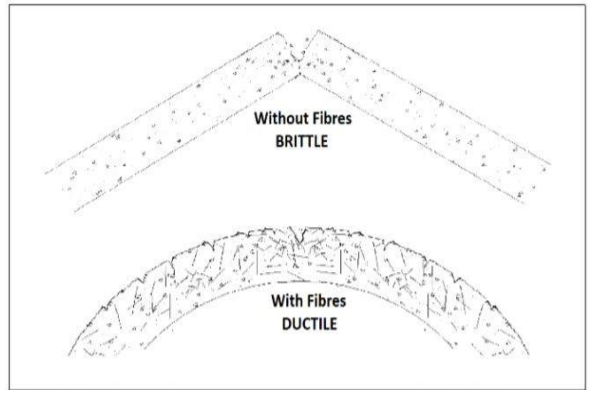

Figure 2. Behaviour change of concrete due to fibres (Jhatial etal., 2018a)

Fibers made from polymerized propylene, a byproduct of petroleum processing, are known as polypropylene (PP) (Jhatial et al., 2018b). When stress is applied to concrete, fractures form and spread fast, eventually leading to the material's failure. When used in concrete, PP fibres provide a bridging mechanism inside the matrix, increasing the material's strength, toughness, and deformation properties to the point where it may withstand failure.

Since the 1970s, PP fibres have been used to strengthen concrete. Recent research have revealed that PP fibres tend to lower the thermal conductivity value of concrete, despite previous reports that they increase the strength of concrete (Memon et al., 2018; Ibrahm and Abbas, 2017; Jhatial et al., 2018c; Mohod, 2015; Singh, 2014; Bagherzadeh et al., 2012). (Jhatial et al., 2020).

Therefore, the purpose of this study is to evaluate the durability of RHA-reinforced concrete made with PP fibres.

II. RESEARCH METHODOLOGY

This research was done to find out what happens to the concrete's strength when different percentages of RHA are used as a partial cement replacement and different percentages of PP fibres are added to the mix (0%, 0.10%, 0.20%, and 0.30%).

2.1 Materials and Mixes

This experimental endeavour employs a single batch of 53 Grade ordinary Portland cement (OPC). We took the necessary precautions to seal and store the cement bags away from the elements and any other agents that may cause them harm. For these experiments, local fine and coarse aggregates were sourced; their respective qualities are listed in Table 1. To make concrete of grade M30, the quantities shown in Table 2 were used.

Table 1. Properties of Aggregates

Property	Coarse Aggregates	Fine Aggregate
Water Absorption	1 %	2.2 %
Bulking Density	1.610 gm/cc	1.542 gm/cc
Specific Gravity	2.74 (for 20 mm aggregates)	2.62
Fineness Modulus	7.17	2.74

Table 2. Mix proportions of Concrete

Mix Designation	Cement (%)	RHA (%)	PP Fibres(%)
M0	100%	0%	---
M1	95%	5%	---
M2	90%	10%	---
M3	85%	15%	---
M4	90%	10%	0.10%
M5	90%	10%	0.20%
M6	90%	10%	0.30%

2.2 Experimental Work

There were two phases to the experimentation. The first step is to make concrete samples with different percentages of RHA used to substitute cement (5%, 10%, and 15% by weight of cement). Compression and flexural tensile bending strength tests were then performed on the cube and beam specimens.

After analyzing the first-stage data, the optimal RHA concentration was proposed, which plays a key role in the concrete's impressive strength. To test if PP fibers on concrete integrating RHA above ideal content may provide better results, we picked a concrete mix with a little greater percentage of RHA than the optimum mix and reinforced it with 0.1%, 0.20%, and 0.30% PP fibers. Before any of the mixtures were made, the ingredients were weighed. Before adding the corresponding PP fibers, the sand, coarse aggregates, and binders (OPC and RHA) were vigorously mixed for around 3-5 minutes to achieve equal dispersion of RHA in the mix.

Water was injected gradually into the concrete mixer so that it could be dispersed evenly over the dry mix, and the mixture was mixed for about 3 minutes to obtain the homogeneous mix. The standard-sized castings of the specified specimens were made. The samples were removed from the moulds after 24 hours and cured for 7 and 28 days.

Compressive strength tests were conducted in accordance with BS EN 12390- 3:2019, and flexural strength tests were conducted in accordance with BS EN 12390-5:2019, using a universal testing machine (UTM). Three cube-shaped specimens and three beams were made from each batch to evaluate the compressive and flexural strengths after 7 and 28 days, respectively.

III. RESULTS AND DISCUSSION

3.1 Workability

The slump test, as specified in BS EN 12350-2:2019, was used to evaluate the mix designs for their suitability as working concrete. Figure 3 depicts the slump values for each mixture as they were calculated. It was shown that the inclusion of RHA decreased the slump of the concrete mix, which may be related to the water absorption characteristic of RHA, but the absence of RHA or PP fibres (M0) resulted in a decent slump of 55 mm. In addition, mixes containing PP fibres had lower slump, possibly because the fibre content becomes more dense as the percentage of fibres added rises, making it more difficult for the other components of concrete to move and, in turn, decreasing its workability.

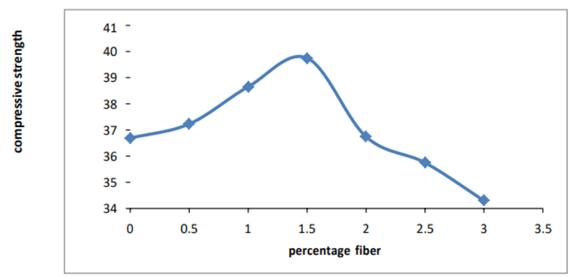

Figure 3. Slump Loss of Concrete

3.2 Compressive Strength

Table 2 lists the compressive strength of RHA-reinforced concrete. The table shows that M1, which had 5% RHA content substituted for cement, increased its strength by 6.34% after 7 days and by 12% after 28 days when compared to control M0 samples. However, the strength of the sample significantly decreased as compared to the control when the RHA level was increased beyond a certain point.

As a result of the pozzolanic reaction, this depletion occurred. Like I said before, RHA has the largest silica concentration and uses up the available Ca(OH)2 during the pozzolanic process.

Based on the findings, it can be concluded that a RHA concentration of 5% uses up the available Ca(OH)2 and generates extra C-S-H gel, both of which contribute to a greater overall strength. However, the available Ca(OH)2 content decreases when RHA levels rise, which has a negative impact on strength.

Table 3. Average Compressive Strength of Concrete Incorporating RHA

Days	RHA	% strength achieved (In the avg. range of)	
		75µ	150µ
7 days	12.5%	90-95%	50-55%
7 days	25%	75-80%	45-48%
7 days	37.5%	53-56%	15-18%
28 days	12.5%	80-85%	85-90%

Concrete with 10% RHA reinforced with PP fibers has an average compressive strength of the values shown in Table 3. Results were encouraging when PP fibers were added to 10% RHA concrete, with both 0.10% and 0.20% PP fibers increasing flexural strength.

The PP fibres' potential to improve bonding and serve as a reinforcing bridge suggests that this may be the case, slowing the spread of fractures. However, the flexural strength was diminished with increasing amounts of PP fiber. High-fiber mixes may not bind as well with concrete because fibers become clumped together.

Table 4. Average Compressive Strength of Concrete Incorporating RHA reinforced with PP Fibres

Testing	Mix	Compressive Strength (MPa)	Difference in Strength w.r.t M2 (%)
7 Days	M2	32.37	---
	M4	32.42	+ 0.15 %
	M5	35.53	+ 9.76 %
	M6	31.08	- 3.99 %
28 Days	M2	37.20	---
	M4	37.83	+ 1.69 %
	M5	40.75	+ 9.54 %
	M6	37.07	- 0.35 %

3.3 Flexural Strength

Table 4 displays the flexural strength of RHA-reinforced concrete. It was discovered that the flexural strength of concrete dramatically dropped as the RHA level increased, with a loss of 8.03% at 5% RHA content and a loss of 30.57% at 15% RHA content when compared to the control sample M0. Because less $Ca(OH)_2$ is available, the pozzolanic process is slowed, and the C-S-H gels that contribute to strength increase are not formed as quickly..

Table 5. Average Flexural Strength of Concrete IncorporatingRHA

Mix	Flexural Strength (MPa)	Difference in Strength w.r.t M0 (%)
M0	3.86	---
M1	3.55	- 8.03 %
M2	2.84	- 26.42 %
M3	2.68	- 30.57 %

As an added bonus, Table 5 lists the typical flexural strength of concrete reinforced with PP fibers and containing 10% RHA. Results were encouraging when PP fibers were added to 10% RHA concrete, with both 0.10% and 0.20% PP fibers increasing flexural strength. The ductile concrete owes its increased strength to the bridging mechanism of the fibers. As the percentage of fibers in a material rises, the fibers' ability to prevent fracture development, spread, and enlargement improves.

Table 6. Average Flexural Strength of Concrete Incorporating RHA reinforced with PP Fibres

Mix	C:S:A	w/c	% fiber added	Cement (kg/m^3)	Sand (kg/m^3)	Aggregate (kg/m^3)
M25	1:1.42:2.56	0.42	(0-3)	350	497	896
M30	1:1.3:2.5	0.43	(0-3)	350	455	875

IV. CONCLUSION

Reducing, rescuing, and recycling the solid agricultural and industrial waste, as well as lowering CO2 emission from various cement reactions, are all ways in which utilising rice husk ash and polypropylene fibres may contribute to the long-term development of concrete technology. The following are findings and insights gained from the actual work done:

1. One, the RHA's high surface area meant that it soaked up more water during mixing, which had a negative effect on the concrete's workability; as RHA concentration increased, slump values decreased.

2. Second, a replacement of 5% RHA was found to be the most effective after tests showed an increase in strength. However, a replacement rate of 10% RHA is recommended for buildings that will stand the test of time.

3. Incorporating PP fibres into concrete decreased its workability but increased its compressive and flexural strength. A mix of 10% RHA and 0.20% PP fibres was shown to be the most effective method of reinforcing the concrete.

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