Eco-Friendly Concrete: Sustainable Integration of Plastic Waste and Rice Husk Ash for Enhanced Strength and Durability

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ABSTRACT

Concrete is one of the most widely used construction materials, playing a crucial role in infrastructure development. However, with the rapid increase in population and urbanization, the demand for cement production has risen significantly, reaching approximately 4.1 billion metric tons annually. This large-scale production leads to the depletion of natural resources and poses severe environmental challenges, including carbon emissions and ecological degradation. Simultaneously, industrial and agricultural by-products such as fly ash, silica fume, mineral slag, and rice husk ash (RHA) are generated in large quantities. Among these, RHA is a highly reactive pozzolanic material obtained from rice mills, where rice husk is burned at high temperatures. Due to its lightweight and high silica content, RHA has potential applications as a supplementary cementitious material. On the other hand, plastic waste is one of the most pressing environmental concerns due to its non-biodegradable nature. The improper disposal of plastic negatively affects soil fertility, pollutes water bodies, and poses significant threats to human health. Given its durability, lightweight properties, and moldability, plastic can be repurposed in construction materials rather than discarded as waste. This study focuses on the sustainable incorporation of plastic waste and RHA in concrete to address both environmental pollution and resource conservation. The objective of this research is to investigate the optimal replacement ratio of natural coarse aggregate with plastic aggregates and cement with RHA while maintaining or enhancing the strength characteristics of conventional concrete. Experimental studies were conducted with varying replacement percentages, where natural coarse aggregates were partially replaced with plastic aggregates (ranging from 0% to 25%), and cement was partially replaced with 5% RHA. Key mechanical properties such as compressive strength, split tensile strength, and workability were analyzed for different curing periods. The findings of this research indicate that concrete incorporating plastic aggregates and RHA can achieve comparable or improved strength characteristics when compared to conventional concrete. This sustainable approach not only reduces the dependency on natural resources but also provides an effective solution for managing plastic waste and utilizing industrial by-products. The successful implementation of such eco-friendly concrete can significantly contribute to sustainable construction practices and environmental conservation.

Key words: RHA (rice husk ash), plastic aggregate, compressive strength, split tensile strength.

1. INTRODUCTION

Today concrete has become an unavoidable construction material in the construction industry. Cement is the main ingredient in concrete and its production increases global warming by releasing huge amount of carbon dioxide into the atmosphere which is one of the main threats to the environment. To address this problem, Supplementary Cementitious Materials (SCMs) are used in concrete to reduce the use of high amount of cement content. SCMs such as Fly Ash, Rice Husk Ash, Ground Granulated Blast

Furnace Slag, Silica Fume and Metakaolin play a vital role in concrete industry. It has not only economic and environmental benefits but also enhanced concrete properties. Since most of the SCMs are by-product materials of industrial and agricultural sectors, their utilization in concrete has become an efficient alternative to disposal of the same.

2. LITERATURE REVIEW

Saand et.al., (2019) studied the effect of partial replacement of cement with rice husk ash at different percentage i.e., 0%,2.5%,5%,7.5%,10%,12.5% and 15%. It was found that up to 10% replacement of cement with rice husk ash the compressive strength and split tensile strength will get increased but further increase in the percentage of rice husk ash beyond 10% the strength starts decreasing. The maximum value of compressive strength and split tensile strength for 10% of cement replacement with RHA obtained is 4.4MPa and 0.53MPa respectively.

Fabien et.al., (2019) have done experimental work on the replacement of sand with recycling waste perlite and pure perlite. Pure perlite sand and waste perlite sand (30% +30%), which is used to replace sand is characterised by low density, which makes the concrete expand under non-autoclaved condition. The presence of these waste products reduces mechanical strength but improve thermal insulation. It is found that increasing the cement by 2%, we can increase the mechanical strength by 21%. A 100% expended material with thermal conductivity of 0.176w/. k was obtained. Therefore, non-autoclaved swelling solutions have promoted the development of thermal insulation material based on recycled product.

Kunchariyakun et.al., (2018) had done an experimental investigation on replacement of sand with two agricultural waste i.e., rice husk ash and bagasse ash in preparation of AAC blocks. These samples are autoclaved at different autoclaving temperature (140oc, 160oc and 180oc) and different time period (4h, 8h and 12h). It was found that the effect of the increase in autoclaving temperature and time is directly related to the increase in strength and microstructural properties. But at 180oc it was found that there is no significant increase in strength with increase in time. The reason for no significant increase in strength is because Si ions from the sand reach its maximum dissolution.

Karolina R. And Muhammad F. (2017) concluded that fly ash and bottom ash can be used in the manufacturing of lightweight concrete to minimize the use of cement and sand. In normal NAAC lightweight concrete, the water absorption is found to be 5.66% which is greater absorption in the study and 2.76% is the smallest absorption by adding 30% fly ash in concrete. For normal NAAC the compressive strength is 8.891Mpa that is the lowest compressive strength in the study and the highest compressive strength is 12.687Mpa using fly ash. The researcher also concluded that the addition of 30% fly ash in concrete gives the highest tensile strength i.e., 1.540Mpa while NAAC gives the lowest tensile strength i.e., 0.801Mpa.

Wahane A. (2017) compared the AAC blocks with red bricks. The researcher concluded that these blocks are more earthquake resistant and safer than red bricks because of the lightweight of AAC blocks. Compared with red bricks, the weight of AAC blocks is almost reduced by about 80% which will lead to reducing a dead load of the structure. Also, it is found that these blocks have an attractive appearance and are easy to adapt to any style of building.

Some of the literatures were explained the use of waste plastic in concrete like, concrete produced by mixing at partial replacement of plastic aggregates that is plastic waste aggregates are resulted from shredding (cut in to small pieces) used pet bottles and are of three types a,b,c based on their size and concrete produced by 7.5% replacement and 15% replacement to natural aggregates these 7.5% and 15% are replaced by three different types of plastic as categorized based on the shapes that is lamellar (Pc), irregular (Pf) and regular cylindrical granular (Pp) shaped aggregates are maintained nearer to target strength of concrete made by natural aggregates only. This research is about the study of curing conditions on the mechanical performance of concrete with the replacement of plastic aggregates to the natural aggregates.

To minimize the plastic waste in the environment another test conducted by the Fahed K Alqhatani and other three, the research work based on the plastic waste of the type manufactured by mixing 30% of recycled plastic and 70% of red dune sand filter, these two proportions mixed homogeneously and followed by compressing and heating the mix using compression molding press techniques to turn it in to solid sheets or slabs, which were used then manufactured plastic aggregates. Test conducted at a minimum slump of 100mm and a minimum compressive strength of 30MPa, replaced the plastic aggregates so obtained at a replacement level to 25, 50, 75 and 100%. This paper concludes slump values decreased by 11% to 23% (25mm-50mm) compared to light weight aggregates concrete with the increase in replacement level from 25 to 100%. The influence of replacement level on the fresh, hardened and microstructure properties of concrete was investigated. Here, compressive strength decreases with increase in replacement plastic aggregates.

Another study by F. Iucolano, B. Liguori D. Caputo, F. Colangelo, R. Cioffi on waste plastic to be utilized in concrete that is as a fine aggregates replacement. Tests conducted on the effect of recycled plastic aggregates on the Chemico-Physical and functional properties of manufactured hydraulic composite mortars. Tests have been conducted on density, porosity, compressive and flexural behavior and water vapor permeability. Here fine aggregates are the plastic waste, which has been manufactured at the industry and supplied with the standard fraction of particle size and with some chemical composition.

The PET bottles were shredded and then melted in the oven at a temperature of 280-320^{0}C. The molten plastic was then collected and cooled to get a solidified PET. Finally, it was crushed in the crushing machine and an angular aggregate with smooth surface was obtained. A volume replacement of 0%, 20%, 40% and 50% was taken for the experiment.

Faaeza Ahmed Abd Ul-Kareem concluded that Incinerating solid wastes is an efficient method compared with land filling to reduce the non-recyclable waste amount; the waste reduced by incineration is less than 30 % of original mass and the volume decrease is about 10 %. The pozzolanic activity of the mortars decreases as the percentage of solid ash used increases. However, with 5% and 10% replacement of cement by solid ash. The is aslight decrease in the initial and final setting times with an increase in the amount of replaced by solid west ash. Solid waste ash concretes showed significant reduction in drying shrinkage at all age compared to reference concrete. The concrete which has fly ash is an effective technique for the frost resistance. The high percent fly ash without any accompanied loss of concrete properties possible only when the fly ash is treated by using vitrification method. Where in such case there is arise additional costs suppressing the MSWI ashes utilization attractiveness for building industry. Solid waste ash concretes exhibit a slight improvement in workability relative to their reference concrete.

3. PROPOSED SYSTEM

3.1 Objective

The main objective of this research is to explore the possibility of using waste plastics as coarse aggregate and rice husk ash as cement in concrete preparation and to reduce the problems associated to plastic wastes and rice husk ash disposal.

Other objectives of the research are as follows:

- To obtain optimum percentage of aggregate replacement.
- Study on strength characteristics of M25 grade concrete with replacement of 5% cement by RHA and replacement of 0%, 5%, 10%, 15%, 20% and 25% coarse aggregate by plastic aggregates.
- To determine the fresh properties of concrete by slump cone test.
- To determine the harden properties of concrete by compressive and tensile strength test.

3.2 Methodology

(a) Methodology of Plastic aggregates preparation:

The methodology adopted for this study is given below:

1. Literature study was done on the available data on use of plastic in concrete.
2. Plastic was collected from the waste material.
3. Plastic was cleaned for the removal of any foreign material, dust etc.
4. It was then sundried for few hours and then melted in container.
5. The melted plastic was the drawn into sheets by pouring it on flat surface, and then allowed to cool down and get hard.
6. Cooled and hard plastic sheets were then broken into smaller particles by hammering the sheets.
7. Test related to properties of cement and aggregates were performed.
8. Proportion of plastic coarse aggregates (PCA) in different mixes was selected on the basis of available literature.
9. Mix design for different proportions of concrete was decided and tests were performed to obtain the mechanical properties of different mixes.
10. Based on the literature survey and optimum quantities of plastic, the following combinations were adopted.

(b) Methodology of Rice husk ash preparation:

Rice husk is incinerated manually up-to ash form. The final ash sieved with 75microns and used as partially replacement of cement.

(c) Preparation of concrete with RHA – Plastic aggregates

1. Initially find-out the physical properties of RHA, plastic aggregate, Cement, coarse aggregate and cement.
2. Find-out the M25 grade mix proportions as per IS10262-2019 and IS456-2000 code books.
3. Based on the mix design, the replacement of RHA and plastic aggregate find outed. The 5% of RHA by cement and varying percentages of Plastic aggregate (0% - 25%) by coarse aggregate in the preparation of concrete.
4. By Freshly prepared concrete, slump cone test will find out.

5. By Harden concrete, compressive and tensile strengths tests will find out.
6. Based on the test results optimum dosage of plastic aggregate replacement in concrete preparation.

4. RESULTS AND DISCUSSIONS

As per experimental programme results for different experiments were obtained. They are shown in table format and graph format, which is to be presented in this chapter.

4.1 Fresh properties of concrete (Workability Test)

4.1.1 Slump Test

The Slump test was performed on the Rice husk ash – Plastic aggregate based concrete to check the workability of it at different replacements viz. 0 % - 0%, 5% - 0%, 5% - 10%, 5% - 15%, 5% - 20%, 5% - 25% and the following results were obtained, according to which it can be concluded that with the increase in % of Rice husk ash – Fly ash from M0 to M4, workability increases. The results obtained for Slump test are shown below in Table 5.1.

Table 4.1: Results of Slump test

MIX	RHA % - Plastic aggregate %	Slump (mm)
M0	0 - 0	120
M1	5 - 0	125
M2	5 - 5	128
M3	5 - 10	132
M4	5 - 15	135
M5	5 - 20	123
M6	5 - 25	110

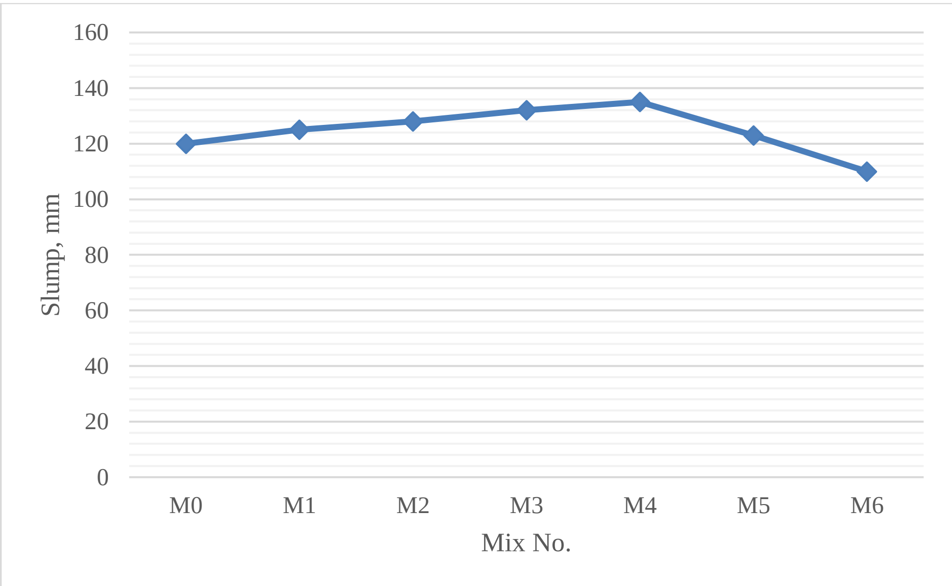

Fig 4.1: Slump test results

The above figure 5.1 shows the slump results. It was observed that, the slumps increased from M0 to M4 mix with increased after that decreases in RHA –plastic aggregate based concrete. It was Medium Workability.

4.2 Harden properties of concrete

4.2.1 Compressive Strength Test

The compressive strength test was performed on the cubes of size 15 cm x 15 cm x 15 cm on the Rice husk ash – Plastic aggregate based concrete to check the compressive strength of it at different replacements viz. 0 % - 0%, 5% - 0%, 5% - 10%, 5% - 15%, 5% - 20%, 5% - 25% and the following results were obtained, according to which it can be concluded that with the increase in % of Rice husk ash – Fly ash from M0 to M4, compressive strength increases. The results obtained for Slump test are shown below in Table 5.2.

Table 4.2: Results of compressive strength test

MIX	RHA % - Plastic aggregate %	Compressive strength of cubes (N/mm^2)		
		7 days	14 days	28 days
M0	0 - 0	17.1	21.98	24.8
M1	5 - 0	18.98	23	26.3
M2	5 - 5	20	24.87	28.2
M3	5 - 10	21.2	25.1	28.9
M4	5 - 15	21.9	25.7	30.12
M5	5 - 20	19.6	22.6	28.1
M6	5 - 25	18.5	22	26

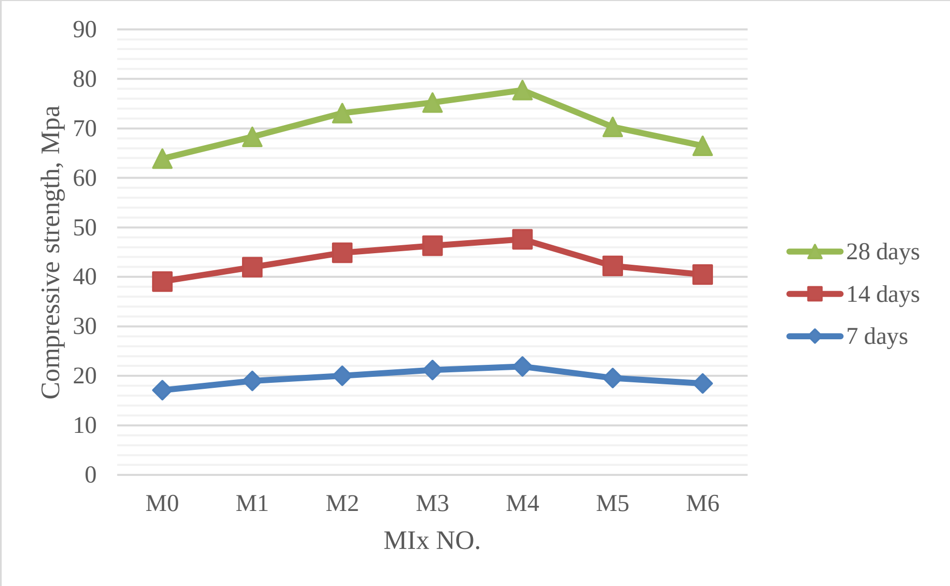

Fig 4.2: Compressive strength test result graph

The above figure 4.2 shows the compressive strength results. It was observed that, the compressive strength increased from M0 to M4 mix with increased after that decreases in RHA –plastic aggregate based concrete. The optimum dosage suggested from this study was (M4 mix) 5% RHA – 15% plastic aggregate.

4.2.2 Tensile Strength Test

The Tensile test was performed on the beams of size 300mm height x 150 diameter mm to check the Tensile strength of the concrete and the results obtained while performing the Tensile test on CTM are given in Table 5.3.

Table 4.3: Results of Tensile strength

MIX	**RHA % - Plastic aggregate %**	**Tensile strength (N/mm^2)**
M0	0 - 0	2.51
M1	5 - 0	2.67
M2	5 - 5	2.9
M3	5 - 10	2.93
M4	5 - 15	3.05
M5	5 - 20	2.87
M6	5 - 25	2.62

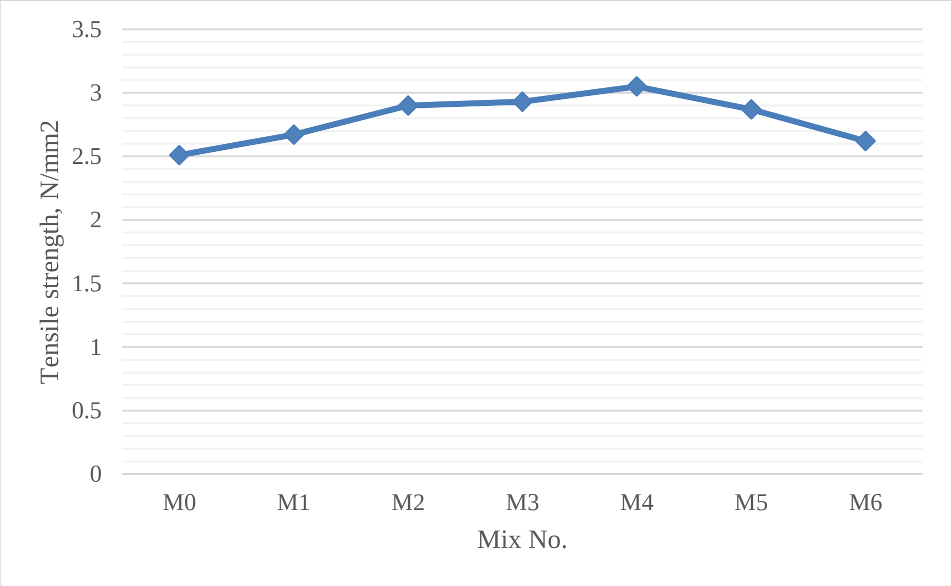

Fig 4.3: Tensile strength graph

The above figure 5.2 shows the tensile strength results. It was observed that, the tensile strength increased from M0 to M4 mix with increased after that decreases in RHA –plastic aggregate based concrete. The optimum dosage suggested from this study was (M4 mix) 5% RHA – 15% plastic aggregate.

4.3 Discussions

The workability was increasing with increasing up to M4 mix in RHA – plastic aggregate replacement in the concrete. The compressive and tensile strengths for RHA – plastic aggregate replacement in the concrete, was more than control mix. The strength increment percentages were mentioned below Table 5.4. The maximum or highest strength was gained for 5% RHA replacing with cement and 15% plastic aggregate replacing with coarse aggregate.

Table 4.4: Comparison of strengths

Mix	RHA % - Plastic aggregate %	28days compressive strength (Mpa)	Increment (%)	28days Tensile strength (Mpa)	Increment (%)
M0	0 – 0	24.8	-	2.51	-
M4	5 – 15	30.12	21.45	3.05	21.51
M6	5 -25	26	4.838	2.62	4.38

5. CONCLUSIONS

This experimental investigation examines the impact of incorporating rice husk ash (RHA) and plastic aggregates into control concrete, focusing on the tensile behavior of concrete cylinders and the compressive behavior of concrete cubes. The results were compared with conventional concrete to evaluate performance differences. The study revealed that workability improved with the replacement of natural coarse aggregate by plastic aggregate up to 15%, after which it started to decline. The highest compressive and tensile strength gains were observed when 5% of cement was replaced with RHA and 15% of coarse aggregate was replaced with plastic aggregate. Specifically, at this optimal mix, compressive strength increased by 21.45%, while tensile strength improved by 21.51% compared to conventional concrete. Additionally, the use of Supplementary Cementitious Materials (SCMs) such as RHA, along with plastic aggregate, contributed to cost reduction and helped mitigate the disposal issues associated with agricultural and industrial waste. This sustainable approach not only enhances concrete properties but also promotes environmental conservation by efficiently utilizing waste materials in construction.

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