Mechanical Properties of Binary Blended Concrete using Quarry Dust as a Partial Replacement with Sand

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Abstract: *Concrete is a key element of the structure. Construction expenses in today's market are high due to the use of materials like cement, fine aggregate and coarse aggregate. Manufacturing cement requires a lot of energy, which results in greenhouse gas emissions. To reduce emissions, various wastes produced from industries in the form of rice husk ash, fly ash, granite fines, quarry dust, etc. are used to replace cement. In current study, RHA and QD were used as partial replacement of cement and fine aggregate. Rice husk ash is the agricultural waste which produced by burning the outer shell of the paddy that comes out as a waste product during milling of rice. Quarry dust is obtained during crushing process of stones or rocks. The main purpose of present investigation is to study the partial replacement of fine aggregate by quarry dust of percentages 0%, 10%, 20%, 30%, 40%, 50% for M30 grade concrete cubes of size 100 mm. Optimum dosage of quarry dust was determined as 20 %. To the above optimized mix, cement is replaced by rice husk ash in certain proportions such as 0%, 2.5%, 5%, 7.5%, and 10% and concluded that maximum compressive strength obtained at 5% replacement.*

Keywords: Rice husk ash, Quarry dust, Compressive strength

1. INTRODUCTION

Rice husk ash (RHA) and quarry dust (QD) are two commonly available waste materials that can be used as partial replacements for cement and sand, respectively, in the production of concrete. The study of RHA and QD explores the potential of using these waste materials in construction by examining their physical and chemical properties and evaluating their effectiveness as partial replacements. The literature study evaluates the economic feasibility of using rice husk ash and quarry dust as partial replacements for cement and sand, respectively. The findings show that the use of these waste materials can lead to cost savings in the construction industry, which could help make construction more sustainable and environmentally friendly. Overall, the study suggests that the partial replacement of cement with rice husk ash and sand with quarry dust can be a promising strategy for sustainable construction practices. Padma Rao (2014) studied that 15% Rice Husk Ash as an admixture to an already replaced Cement with fly ash (Portland Pozzolana Cement) in Concrete, increase in compressive Strength and also the emission of greenhouse gases can be decreased to a greater extent by using rice husk ash. Satish (2016) studied that combination of 22.5% FA and 7.5% RHA concrete reduces the environmental effects, produces economical and eco-friendly concrete. Subramanian (2019) studied on comparative of fly ash (FA) and rice husk ash (RHA) as cement replacement and concluded that max compressive is at 5% RHA replacement concrete and 15% FA replacement concrete. Devendra (2019) studied that concrete with partial replacement of 22.5 % Fly Ash, 7.5 % RHA in cement and 45% Quarry Sand in Natural Sand increases Compressive, flexural strength and also workability of concrete increases with increase of Fly ash and decreases with increase of RHA& QS in concrete. Rinki (2014) studied that Compressive strength increases with the increase in the percentage of Fly ash and Rice Husk Ash up to 30 % replacement (22.5% FA and 7.5% RHA) and 60% of quarry sand. Siddika (2021) studied that the replacement of cement by the FA and RHA provides sustainability in the construction industry and waste management systems, and the replacement of natural sands by the stone dust (SD) can help saving natural resources and also studied that reduction in the water absorption capacity of the FA, RHA, and SD based concrete is a sign of improvement in durability. Sundara Kumar (2016) studied that 27 % increase in compressive strength by partially replacing cement with Fly ash (FA) and Rice husk ash (RHA) and complete replacement of sand with crusher dust as fine aggregate. Prakash (2018) studied that 20% QD and 15% RHA partial replacement in fine aggregate and cement not only increases strength of concrete by 7.71% than conventional concrete but also leads to considerable savings in cost of construction and considering RHA as a partial replacement of cement reduces the consumption of cement and CO_2 emissions and gives environmental benefits. Luqman (2022) studied that Replacement of conventional block materials such as cement and sand with rice husk ash and QD achieved compressive strength of 7.13 MPa. Dinesh Kumar (2022) studied that replacement of cement with quarry dust and rice husk ash as the percentage of replacement increases upto 35%, increases the compressive strength and workability of concrete were increased.

Zaidatul Syahida Adnan (2021) studied that 20% substitution of rice husk ash in cement boosted compressive strength and replacing 5% of the rice husk ash would increase flexural strength by 12%. Maurice (2012) studied the results of partial substitution of Ordinary Portland cement (OPC) with Rice Husk Ash (RHA) and concluded that adding RHA at levels of 5–10% will enhance strength, but adding RHA at levels of 15–25% will slightly reduce strength by 15%. Raman (2010) studied that 20 % quarry dust can be a viable partial substitute for sand to produce HSC with the combined utilization of superplasticizer and 10% RHA. Kartini (2012) suggested that the permeability of concrete can be reduced by the replacement of OPC with RHA; however concrete with 20% and 30% RHA replacement levels are 3-7 times less permeable than OPC Concrete. Arvind Kumar (2016) studied that the concrete with partial replacement of cement with rice husk ash and concluded that highest compressive strength is obtained at 20 % RHA replacement with 37.6 N/mm^2. Shaswat Kumar Das (2000) studied Rice Husk Ash (RHA), properties and potential to be used both as partial and full replacement of cement in concrete production and concluded that RHA has true potential to be used both in OPC and Geopolymer industries as a substitute of Portland cement hence saving economy and ecology. Mehta and Pirth (2000) studied the usage of RHA (Rice Husk Ash) to lower temperatures in high-strength mass concrete and concluded that 10% RHA replacement of cement in concrete are appropriate. Vijayalakshmi (2013) studied the effects of replacing river sand with granite powder and concluded that granite powder replacement upto 15% produce concrete with acceptable mechanical qualities. Singh (2016) studied that influence on concrete workability of replacing granite cutting waste for natural sand and concluded that maximum flexural strength is at 20%.

Ghannam (2016) studied the effects of substituting granite powder for river sand upto 10% resulted in concrete with acceptable mechanical characteristics. Bonavetti and irassar (1994) obtained maximum compressive strength with 5% replacement of granite dust with natural sand. Cordeiro (2016) investigated the effects of replacing natural sand with crushed granite, and concluded that compressive strength is greater at 50% replacement. Manoj (2017) studied the effect of substituting Quarry dust with cement and highest compressive strength of 41.5N/mm^2 was obtained at 25% replacement. Chetan (2020) studied the strength qualities of Robo Sand (RS) and rice husk ash (RHA) and concluded that the concrete with 50% more robo sand (RS) in the fine aggregate performs better than standard concrete. Mahalakshmi (2018) studied that M-sand concrete with 5% RHA have higher strength than the conventional concrete by increase in strength by 2%. Jayasree (2019) studied that 10% RHA and 100% of M- sand concrete exhibits good strength.
From the above research studies, the primary objective is to investigate the effects of partial replacement of cement with rice husk ash, and sand with quarry dust on the strength of concrete. The study was conducted through a series of laboratory experiments, including workability and compressive strength. The results showed an improvement in the compressive strength of concrete. This suggests that the use of these waste materials in concrete production can not only help reduce environmental waste but also improve the performance of concrete.

2. METHODOLOGY

The following methodology is used to determine the replacement percentage of cement and fine aggregate with rice husk ash and quarry dust of M30 grade as shown in flow chart. First step is to procure the materials like Cement, sand rice husk ash, quarry dust, coarse aggregate required for the replacement. Before using the materials in the mix, it is important to test their properties. The rice husk ash and quarry dust should be tested for their chemical and physical properties to ensure that they meet the required specifications. Once the materials have been tested, they can be mixed. In mix, the quarry dust is added to fine aggregate in proportions of 0%, 10%, 20%, 30%, 40%, 50% and casted the required number of cubes. After casting, the cubes are left in air temperature for 24 hours and then cured for 3,7, and 28. After curing age, the cubes were tested for compressive Strength. The optimum compressive strength obtained at 20 % replacement of quarry dust with Fine aggregate. By keeping this 20% replacement of quarry dust as constant, rice husk ash is added to the Cement in proportions of 2.5%, 5%, 7.5%, 10% and casted cubes of required numbers and cured for 3, 7 and 28 days. Finally, after curing period, the cubes should be tested to ensure that at which percentage replacement it meets the required specification and give optimum compressive Strength.

2.0 Materials used:

2.1 Cement

A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Ordinary Portland cement (OPC) is the most widely used type of cement manufactured and used worldwide. The cement used in this study was OPC 43 grade conforming to IS 12269.

Table.1 Physical properties of cement

S. No.	Property	Test results
1	Specific gravity	3.05
2	Fineness	93%
3	Consistency	27%
4	Setting time Initial Final	 128 mins 6 hrs

2.2 Fine aggregate

Sand is a naturally occurring granular material that is made up of finely divided rock and mineral particles. Sand can be made up of a variety of minerals, including quartz, feldspar, mica, and shell fragments. Sand is often sorted by size and shape, with different sizes of sand being used for different purposes. The fine aggregate used in this study was river sand conforming to grading zone II Table 1 of IS 383.

Table. 2 Physical properties of fine aggregate

S. No.	Property	Test results
1.	Specific gravity	2.51
2.	Fineness modulus	2.56

2.3 Coarse aggregate

The coarse aggregate used in this study is of angular in shape and the maximum nominal size of coarse aggregate is 20 mm and it is Conforming to Table 2 of IS 383. Aggregates retained on 4.75mm is sieve is called as coarse aggregate. The properties of coarse aggregate vary depending on the type of rock from which it is derived. Typically, coarse aggregate is made up of crushed stone, gravel, or recycled concrete.

Table.3 Physical properties of coarse aggregate		
S. No.	**Property**	**Test results**
1	Specific gravity	2.923
2	Fineness modulus	7.21%

2.4 Water:

The water-cement ratio is a key factor in determining the quality of the concrete, as it affects the density and strength of the mix. Water used for mixing and curing shall be clean and free from injurious amount of oils, acids, alkalis, salts, sugar and organic materials. Potable water is generally considered satisfactory for mixing concrete. Mixing and curing with sea water shall not be permitted. The p^H value shall not be less than 6. Hydration is a complex process but in simple terms is the reaction between water and the cement in the mix.

2.5 Quarry dust

Quarry dust, also known as stone dust or crusher dust, is a byproduct of the crushing process in quarries. It is a fine, grayish powder composed mostly of small rock particles and stone fines. Quarry dust is commonly used as a substitute for sand in construction projects, particularly in the production of concrete and masonry works. Its main advantage is its availability and affordability, as it can be obtained at a lower cost compared to natural sand. Moreover, quarry dust possesses good compaction and binding properties, making it useful for filling voids, stabilizing soil, and enhancing the strength and durability of concrete structures. However, it is important to consider the appropriate usage and proportions of quarry dust to maintain the desired structural integrity and performance of the construction materials.

Table. 4 Physical properties of quarry dust		
S. No.	**Property**	**Test results**
1	Specific gravity	2.261
2	Fineness modulus	2.43
3	Particle size	0.05-5 mm
4	Colour	Grey
5	Shape texture	Irregular

2.6 Rice husk ash:

Rice husk ash is a byproduct of burning rice husks, which are the outermost layer of rice grains. It contains high levels of silica (90- 95%) and small amounts of other minerals such as potassium, calcium, and magnesium. Rice husk ash is also an important material in the construction industry, where it is used as a supplementary cementitious material. When mixed with cement, it improves the strength and durability of the finished product and can help to reduce the amount of cement required in a mix. This not only reduces the cost of the mix, but also reduces the carbon footprint of the construction industry.

3. MIX DESIGN:

Concrete mix design is the process of finding right proportions of cement, sand and aggregates for concrete to achieve target strength in structures. So, concrete mix design can be stated as Concrete Mix = Cement: Sand: Aggregates. In this paper mix design is done for M30 based on Indian standard recommended method of concrete mix design IS 10262 - 1982. Mix design involves calculations and laboratory tests to find the right proportion.

Table. 5 Physical properties of rice husk ash

S. No.	Property	Test results
1	Specific gravity	2.36
2	Fineness modulus	5.6
3	Particle size	<45 microns
4	Colour	Grey
5	Shape texture	Irregular

METHODOLOGY CHART

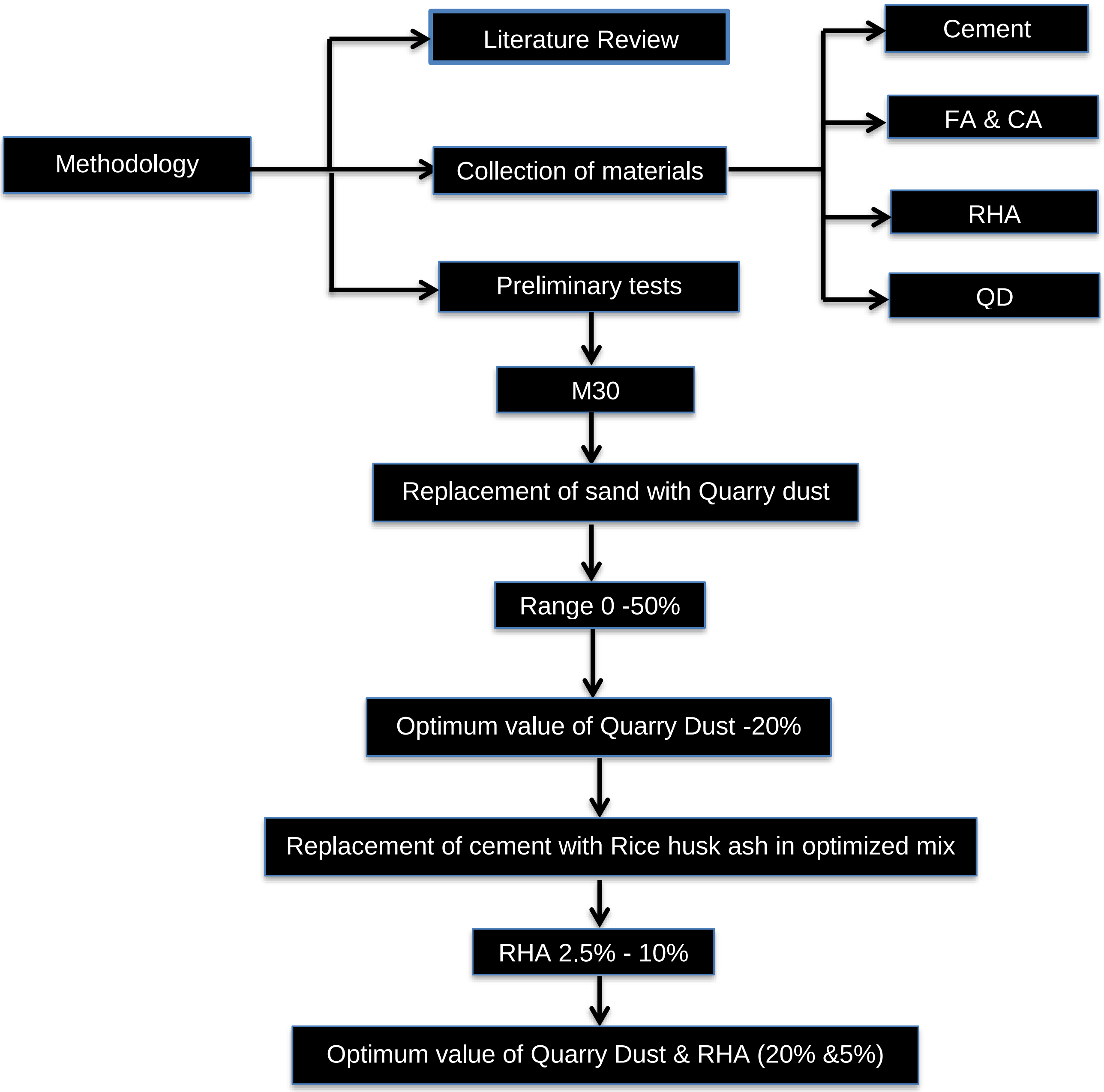


Table. 6 Test data for materials	
Mix design	M30(1: 1:2)
Cement	OPC 43
Aggregate maximum size	20mm
w/c ratio	0.45
Sand correspond to zone	Zone -2
Target strength	38.25

Table. 7 Details of Mix design			
Water	Cement	Fine aggregate	Coarse aggregate
136 liters	414kg/m³	641 kg	1091kg
0.45	1	1.54	2.63

4.1 Workability-Slump cone test (Fresh concrete test):

Concrete slump test or slump cone test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work.

Clean the internal surface of the mould, apply grease, and Place the mould on a smooth horizontal non- porous base plate. Fill the mould with fresh concrete mix, which is prepared according to the mix proportion 4 in 4 layers by tamping each layer by 25 strokes. By using trowel remove the excess concrete on top surface and level the surface. Raise the mould from the concrete immediately and slowly in vertical direction. The difference between the height of the mould and that of height point of the specimen being tested is the slump value for given sample.

4.2 Compressive Strength of concrete:

Compressive Strength of concrete can be defined as the maximum resistance of a concrete to axial loading. Compression test is conducted on cubes of size 100 mm for 3, 7, and 28 days by using compression-testing machine.

No. Of specimens and size: 90 cubes and 100 mm size

Casting and testing of concrete cubes

First, according to the above mix proportion, fill the cubes of size 100 mm with concrete mix in 3 layers by giving 25 strokes at each layer and compact the top surface with trowel and leave the specimens in moist air for 24hrs. After that, cure the cubes for 3 days, 7 days and 28 days in clean and fresh water. Remove the specimens from water after specified curing time and wipe excess water from the surface. Place the specimen in the compression-testing machine and apply the load at the rate of $140kg/cm^2/min$ till the specimen fails. Record the maximum load.

Compressive Strength= Load / cross sectional area

Fig. 1 Casting of specimens

Fig. 2 Curing of specimens

Fig. 3 Testing of specimens on CTM

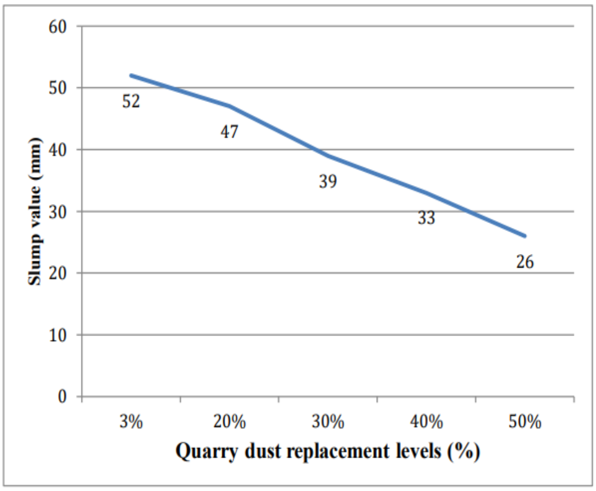
Fig. 4 Failure pattern of specimens

5. RESULTS AND DISCUSSION

Workability of concrete decreases with increase in replacement levels of Quarry dust. Replacement of quarry dust upto 20% is acceptable. Above 20% replacement of Quarry dust with fine aggregate decreases the compressive strength of concrete. Maximum compressive strength of 31 N/mm² at 7 days and 42 n/mm² at 28 days is obtained at 20% replacement of Quarry dust with fine agreement. Workability of concrete decreases with increase in rice husk ash replacement levels. At 20% quarry dust and 5% rice husk ash replacement with fine aggregate and cement gives maximum compressive strength of 24.5N/mm²,33.5N/mm2, 43 N/mm² at 3days,7days and 28 days respectively. Rice husk ash replacement levels above 5% decreases the strength of concrete.

Table. 8 Compressive Strength of cube when sand replaced with quarry dust			
% replacement of quarry dust	Average Compressive Strength (N/mm^2) for		
	3 days	7 days	28days
0 %	27	36.3	41.3
10 %	15.5	25.5	39.5
20 %	18	31	42
30 %	21	26.5	36
40 %	136.5	22.5	33.5
50 %	14	19	30.5

Table. 9 Compressive Strength of cube when cement replaced with of RHA in optimized quarry dust mix			
% replacement of RHA	Average Compressive Strength (N/mm^2) for		
	3 days	7 days	28days
0 %	18	31	42
2.5 %	15.5	23.5	37.5
5 %	24.5	33.5	43
7.5 %	13.5	19.5	36.5
10 %	11	17.5	34



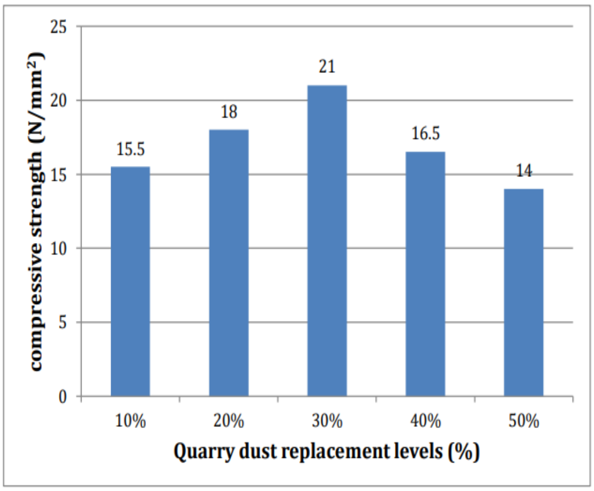


Fig. 5. Workability for concrete mix with **Fig. 6.** Three days compressive strength of

different Quarry dust replacement levels

concrete cube when river sand replaced with quarry dust

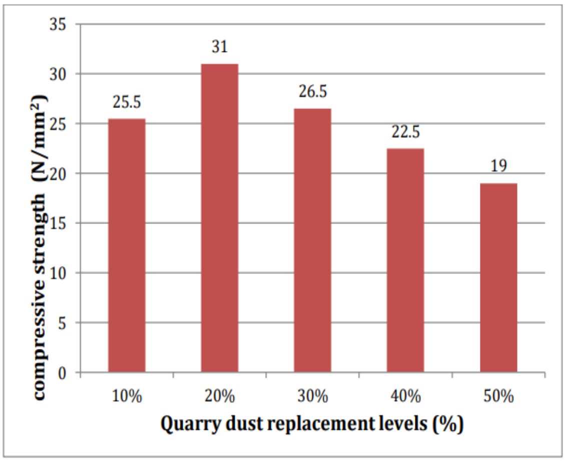


Fig. 7. Seven days compressive strength of concrete cube when river sand replaced with quarry dust

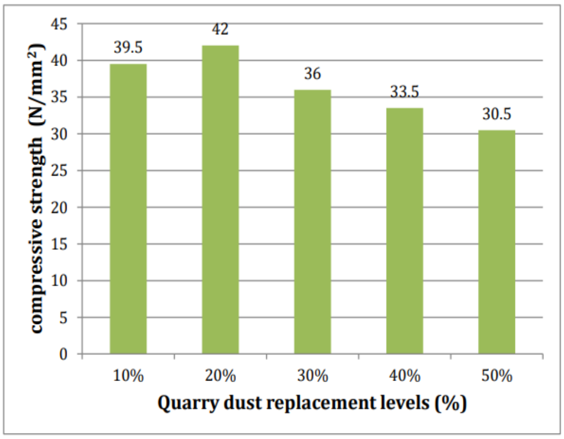


Fig. 8. Twenty-eight days compressive strength of concrete cube when river sand replaced with quarry dust

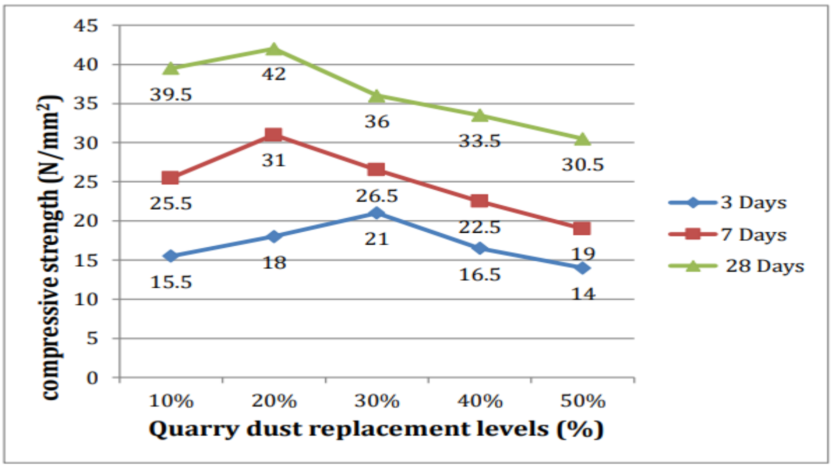


Fig. 9. Compressive strength of concrete cube when river sand replaced with quarry dust

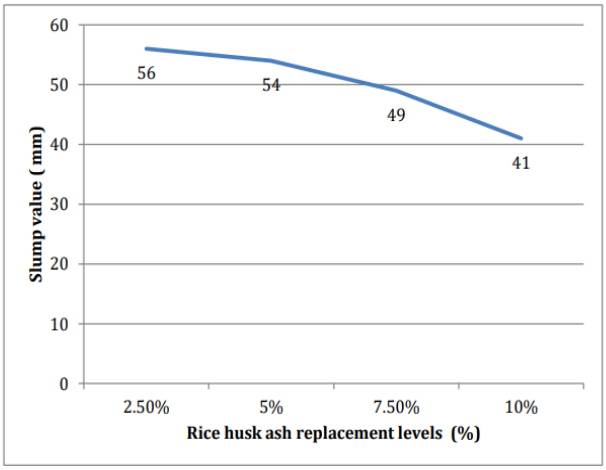


Fig. 10. Workability for concrete mix with different Rice husk ash replacement levels

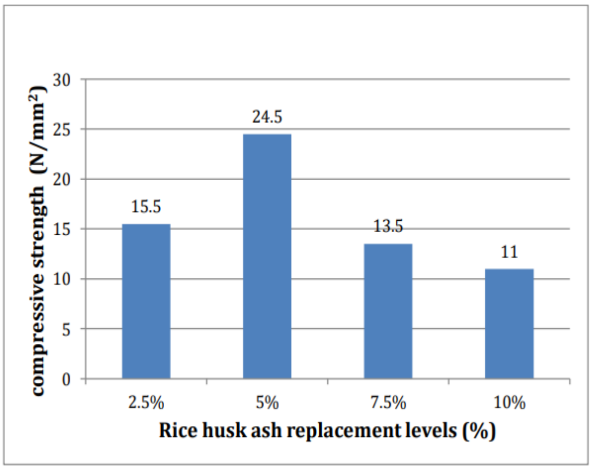


Fig. 11. Three days compressive strength of concrete cube when cement replaced with rice husk ash

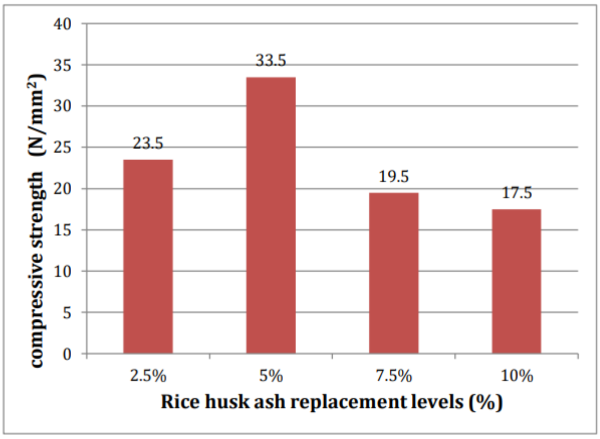


Fig. 12. Seven days compressive strength of concrete cube when cement replaced with rice husk ash

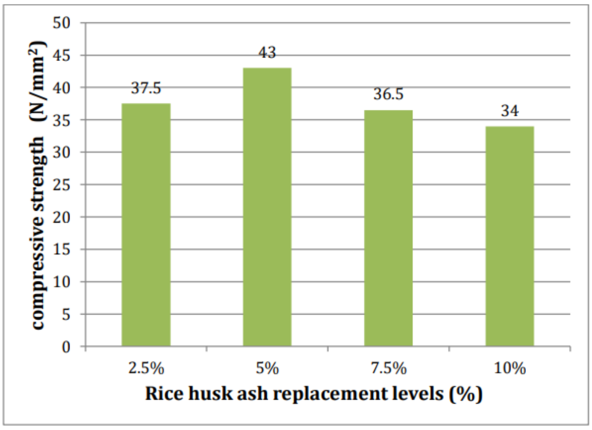


Fig. 13. Twenty-eight days compressive strength of concrete cube when cement replaced with rice husk ash

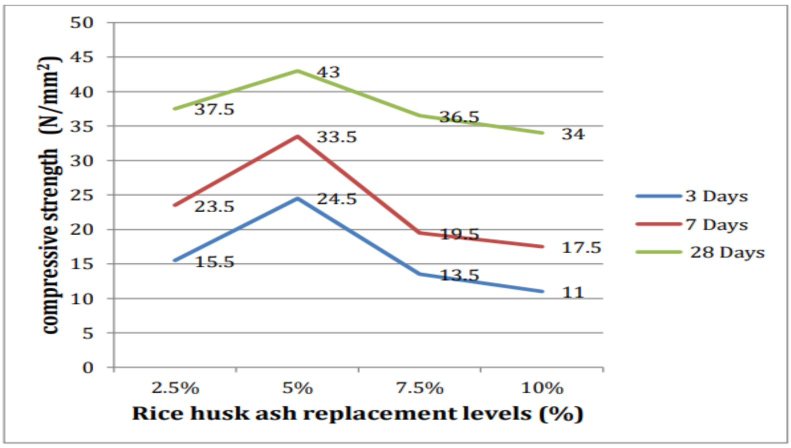


Fig. 14. Compressive strength of concrete cube when cement replaced with rice husk ash

6. CONCLUSIONS

The use of alternative materials in construction can help reduce environmental impact and lower costs. In this study, the partial replacement of cement with rice husk ash and sand with quarry dust was investigated. The results showed that the partial replacement of cement with rice husk ash up to 5% and sand with quarry dust up to 20% can lead to improved compressive strength and reduced water absorption. However, the use of higher percentages of these alternative materials resulted in a decrease in strength and an increase in water absorption. Therefore, it can be concluded that the partial replacement of cement with rice husk ash and sand with quarry dust can be a viable option for sustainable construction, but it is important to carefully consider the percentages used to ensure optimal results. Further research is needed to investigate the long-term durability and sustainability of these materials.

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