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Article

Eco Concrete Blocks Using Marble Powder and Rice Husk Ash

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Abstract

The following research addresses two very recurring problems related to the construction industry, i.e. increase in the amount of waste production and carbon emissions. In the construction industry, the production of cement plays a major part in CO2 emissions therefore the need to replace the use of cement in concrete remains imminent, while on the other hand, harnessing waste materials to lower its global impact stays unchecked. Therefore, in this research we aim to utilize such waste materials by using the waste marble powder and rice husk ash as the partial replacement of the cement in the concrete blocks. Eco-Blocks are revolutionizing the construction industry by offering sustainable alternatives to traditional building materials. Made from recycled materials, these innovative blocks not only help reduce waste but also deliver enhanced strength, durability, and cost-effectiveness. This research includes the making of the eco-friendly concrete blocks by replacing cement with rice husk ash (RHA) and waste marble powder (WMP) at 15% and 30%. Compressive and tensile strength tests for the concrete with a mix ratio of 1:1.5:4 and w/c ratio of 0.45 were carried out after curing at 7,14 and 28 days. In comparison with the conventional concrete the results depicted that the 15% WMP mix outperformed traditional concrete, delivering a 25% increase in compressive strength and a 34% increase in tensile strength. This increase in the durability properties of concrete enables that can be cast as the concrete blocks. The concrete block can further be used as partition and boundary wall while contributing to the reduction of the global carbon footprint.

Keywords: WMP (Waste Marble Powder); RHA (rice husk ash); Compressive Strength; Eco Concrete Blocks; Tensile Strength; CO2 emissions

1. Introduction

Portland cement is a major issue for global CO2 emissions and environmental degradation, owing to high energy consumption and chemical processes involved. Use of conventional concrete ultimately involves a major issue of global increase of carbon footprint, which has motivated the search for a cleaner and greener alternative which will benefit the environment and hence be a good option for construction industry to adopt. This also leaves a window open for the use of agricultural products that can benefit the strength of concrete and remain a sustainable and a clean source of concrete with re-use of other materials that benefit the environment too.

One approach is to add waste marble powder, that is the byproduct of the process that is involved in marble cutting and the addition of rice husk ash that will benefit concrete too as it's also a byproduct of agricultural industry furthermore with addition of supplementary material such as fly ash with partial replacement of concrete. Research shows that addition of both materials with partial replacement offers improved mechanical and durability of concrete. Which also significantly offers reduced clinker usage with lesser CO2 emissions[1]. Similarly, WMP and other waste materials have been demonstrated to act as fillers or supplementary cementitious materials (SCMs), improving microstructure, reducing porosity, and in some cases enhancing compressive strength when optimized [2].

However, despite the individual advantages of waste marble powder, rice husk ash, and fly ash, there is still a lack of clear comparison on how these materials perform when used together in different combinations as partial replacements of cement. This creates a need to study how each of these waste materials influences the overall strength, workability, and durability of concrete, and whether they can serve as a reliable and cleaner substitute for traditional mixes. By evaluating their performance side by side, it becomes possible to understand which material or blend can offer the best improvement in strength while still reducing the carbon footprint linked with cement production. The purpose of this study is to explore and compare the effects of waste marble powder, rice husk ash, and fly ash on concrete strength and sustainability, with the aim of developing an eco-friendly concrete mix that reduces dependence on cement. Through this approach, the goal is to create a cleaner alternative that supports environmental protection, lowers CO_2 emissions, and still maintains or even enhances the strength characteristics expected from conventional concrete.

2. Literature Review

2.1. Introduction:

The conventional concrete has negative impact on environment due to high CO_2 emissions from cement production [3]. Because of this, the construction industry is searching for greener alternatives. The research consistently shows that cement is partially replaced by waste materials such as Rice Husk Ash (RHA) and Waste Marble Powder (WMP). These materials help reduce pollution and turn waste into useful construction products. The research reviews highlights that RHA and WMP can be used to produce eco-friendly blocks with adequate compressive strength and durability [4].

2.2. Composition and Strength Mechanism

2.2.1. Rice Husk Ash (RHA)

RHA is obtained from burning rice husks and is rich in silica (SiO_2). When mixed with concrete, RHA reacts with calcium hydroxide through a pozzolanic reaction to produce calcium silicate hydrate (C-S-H) gel. This gel increases the strength of concrete and fills small pores in the mix [5]. This explained that fine grinding of RHA is essential because finer particles react better and improve the concrete structure [6].

2.2.2. Waste Marble Powder (WMP)

WMP is produced as waste during marble cutting. It contains high amounts of calcium oxide (CaO) and mainly works as a micro-filler [4]. WMP fills tiny voids inside the concrete, making the mix denser and less porous. This results in improved compressive strength and durability [7].

2.3. *Replacement Levels*

Previous studies have found an optimal replacement range of about 5% to 15%, where compressive strength is highest and workability remains acceptable [6].The previous research showed that up to 20% RHA can be used if the ash is properly ground [5]. Most researchers agree that 10–15% replacement gives the best balance of strength and sustainability, while increasing replacement to around 30% requires careful mix design to prevent loss of strength and reduced workability [8].

2.4. *Research Gap*

Most available studies focus on using RHA or WMP replacement and usually test them in standard concrete elements such as beams or columns. Very few studies directly compare RHA and WMP at higher replacement levels (15% and 30%) in the production of concrete blocks, especially those used for partition and boundary walls.

To fulfill this gap, we need to apply a mix proportion of 1:1.5:4 to examine the use of higher cement replacement levels that can produce affordable, and eco-friendly concrete blocks that meet construction standards.

3. Material Used

3.1. *Cement*

Ordinary Portland cement was used as the main constituent of concrete mix. The role of cement is to hydrate with water and form the cementitious matrix that bonds aggregates and other supplementary materials together. OPC provides initial settings, long term strength and overall structural integrity of the concrete [9].

3.1. *Fine Aggregate*

Fine aggregate fills voids, enhances workability, make bonds and provide concrete stability. The fine aggregate consists of the fine particles that can pass through the 4.75 mm sieve according to the standard specifications. The fineness modulus of the fine aggregate used was 2.32.

3.2. *Coarse Aggregate*

Coarse aggregate refers to stone particles that form the load bearing skeleton of concrete. It interlocking nature reduces shrinkage and enhances the overall durability of the hardened mix [10]. The fineness modulus of the coarse aggregate used was 6.53.

3.3. *Waste Marble Powder*

When marbles are cut and polished there is some resulting fine marble dust primarily contains calcium carbonate with particle sizes significantly finer than cement known as marble powder. In concrete, WMP does not act as a binder but functions as an inert micro-filler that improves particle packing, reduces voids and make the matrix denser [2].

Figure 1. Waste Marble Powder

3.4. Rice Husk Ash

Rice husk ash (RHA) is produced by controlling burning rice husk waste and sieved to remove unburnt fibers. Based on studies RHA is rich in amorphous silica and behaves as a pozzolanic material. It needs cement to combine with and react with calcium hydroxide produced during hydration to form cementitious material. It enhances durability, refine pore structure and increases strength of concrete when used at optimal amount [11].

Figure 2. Rice Husk Ash

4. Methodology

The project methodology focuses on producing eco-concrete blocks by partially replacing cement with waste materials and how these substitutions influence strength, workability and overall performance.

4.1. Selection of Materials

The two main supplementary materials incorporated in the mix were Waste Marble Powder (WMP) and Rice Husk Ash (RHA). Their selection was guided by factors including local availability, environmental sustainability, cost effectiveness and their proven potential to enhance concrete strength and durability.

4.2. Mix Design

The mix design ratio of eco-concrete blocks was developed using a nominal ratio by weight of 1:1.5:4 showing cement, fine aggregate and coarse aggregate respectively. The estimated design compressive strength is approximately 20 MPa, which aligns with typical strength as per ACI guidelines. The water-cement ratio is used as "0.45" to achieve workable consistency and workability for handle casting effectively. This ratio differs from typical masonry where usually higher quantity of sand is used with little coarse aggregate. Our mix design incorporates coarse aggregate for high compressive strength and durability that allows partial substitution of cement.

4.3. Sample Preparation

Different samples are prepared as control mix and with partial replacement for cement with two different percentages as explained below:

4.4. Control Mix

The control mix consisted of cement, sand and coarse aggregate without any supplementary materials. Conventional concrete was prepared using cement from Bestway Cement purchased by local retailer in Westridge, Rawalpindi. Lawrencepur natural sand was used as fine aggregate, it was washed and free from organic impurities with particle size passing the 4.75 mm sieve in accordance with standards (IS 383-1970 and ASTM C33). Crushed stone sourced from Hasan Abdal purchased from local retailer in I-12, Islamabad. served as the coarse aggregate for the mix. The particles were uniformly graded to ensure proper compaction, minimize voids and provide a stable load bearing structures for hardened matrix.

4.5. Waste Marble Powder

Waste marble powder (WMP) was obtained from local marble processing workshops in Westridge, Rawalpindi. For experiment mixes, cement was partially replaced with waste marble powder at 15% and 30% by weight while keeping sand, coarse aggregate and w/c ratio identical to the control mix. WMP was selected due to its fine particle size and high calcium carbonate that improves particle packing and reduces voids. The replacement percentages were selected based on published research, which indicates that in 15-30% replacement achieves a balance result in term of strength and workability while higher substitution tends to reduce strength. [2][4]. The grain size of the particles of the marble powder were less than 75 microns (0.075 mm).The was concluded when all the samples was passed through the 75-micron sieve.

4.6. Rice Husk Ash

Keeping fine aggregate, coarse aggregate and w/c ratio same as control mix, cement is partially replaced by Rice Husk Ash (RHA). The amount taken to replace cement is 15 and 30% respectively showing the optimal balance as in previous studies. Literature shows that for effective balance of strength, durability and workability 10-15% partial replacement is sufficient with higher substitution reduces strength [4][11]. The grain size of the rice husk ash used was 10 to 45 microns.

4.7. Casting

As mentioned, three types of samples were cast i.e. control, waste marble powder, rice husk ash.

Table 1. Mix Calculation

Mix Type	Sample Type	Quantity per Mix	Dimensions	Cement	Fine Aggregate	Coarse Aggregate	WMP / RHA	Water
			in	kg	kg	kg	kg	kg
Control	Block	3	8 × 6 × 4	3.21	5.4	13	-	1.44
	Cylinder	3	4 × 8	0.84	1.41	3.39	-	0.375
WMP 15%	Block	3	8 × 6 × 4	2.7	5.4	13	0.48	1.44
	Cylinder	3	4 × 8	0.72	1.41	3.39	0.126	0.375
WMP 30%	Block	3	8 × 6 × 4	2.25	5.4	13	0.96	1.44
	Cylinder	3	4 × 8	0.585	1.41	3.39	0.255	0.375
RHA 15%	Block	3	8 × 6 × 4	2.73	5.4	13	0.48	1.44
	Cylinder	3	4 × 8	0.72	1.41	3.39	0.126	0.375
RHA 30%	Block	3	8 × 6 × 4	2.25	5.4	13	0.96	1.44
	Cylinder	3	4 × 8	0.585	1.41	3.39	0.255	0.375

Blocks with dimensions 8″×6″×4″ and cylinder with 4″ Dia and 8″ depth were cast as per ASTM standard for compressive and split tensile strength respectively. Mix ratio used for the control samples was 1:1.5:4.

All materials were weighed accurately and mixed thoroughly to ensure uniform distribution of cement, aggregates and supplementary materials. The details are given:

Figure 3. Samples Casted

4.8. *Curing and Testing of Samples*

After casting, all blocks and cylinders were demolded after 24 hours and were transferred to a curing tank with clean water at normal temperature for 14 days curing period, in accordance with ASTM C192. Curing ensured proper hydration of cement and supplementary materials allowing the pozzolanic reactions and particle packing effects to fully develop and achieve maximum strength.

Following curing, two types of tests were conducted of samples to evaluate their performance:

- **Compressive strength**

Cylinders were tested under axial compression using a universal testing machine as per ASTM C39.

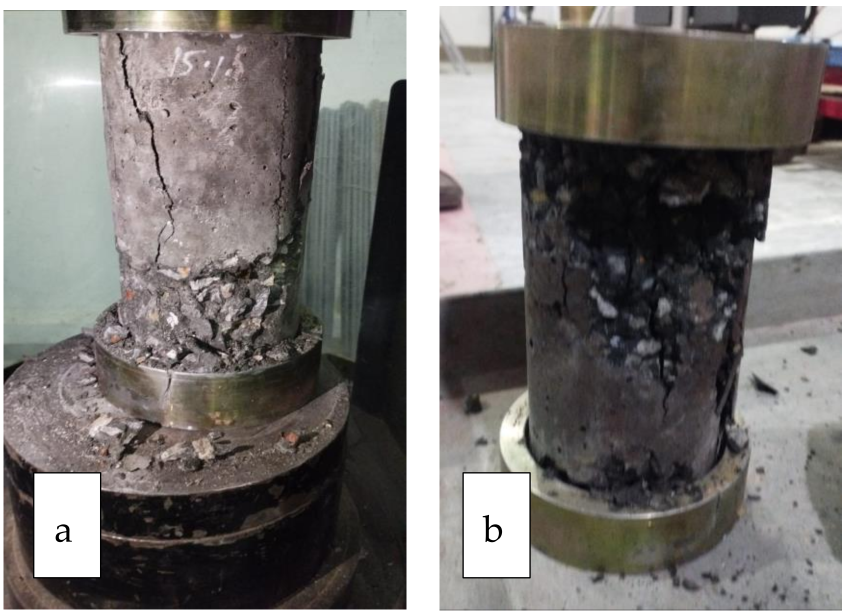

Figure 4. (a) Marble Powder Sample and **(b)** Rice Husk Sample under Compressive Loading

- **Split tensile strength**

Cylinders were subjected to diametral compression according to ASTM C496 to assess tensile capacity of samples.

Figure 5. Sample Under Spilt Tensile Test

5. Results

5.1. Comparison of Mechanical Properties.

The compressive and split tensile strength of the concrete mix with rice husk ash (RHA) and waste marble powder (WMP) as partial cement replacements were compared with those of the conventional control mix after a curing period of 28 days.

Table 2. Showing Strength Comparison

Mix Type	Compressive Strength (MPa)	Split Tensile Strength (MPa)
Control	19.53	2.4
15-RHA	9.67	1.37
30-RHA	6.87	1.12
15-WMP	24.48	3.21
30-WMP	12.68	1.89

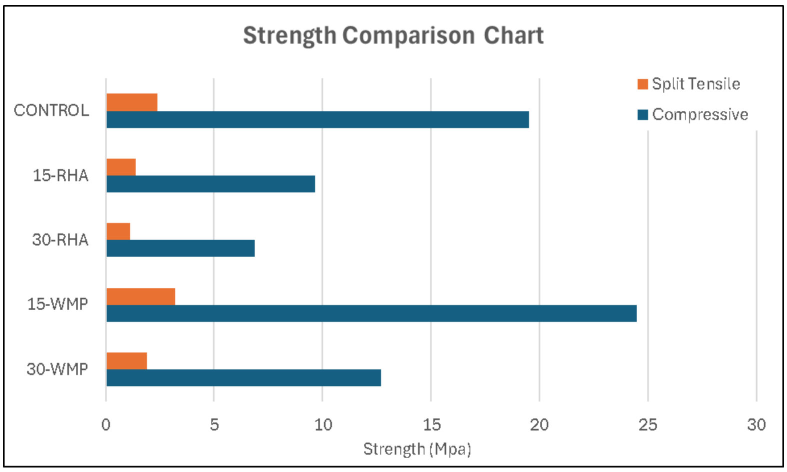

Figure 6. Graphical Representation of Result

5.2. Compressive Strength

The compressive strength of the control specimens was 19.53 Mpa. The compressive strength for 15-RHA decreased strength by 50.5 %, and for 30-RHA it decreased by 64.8%

In contrast, 15-WMP achieved a 25.4% increase in compressive strength, which was the largest increase that was found in all modified specimens that were investigated. Nevertheless, the compressive strength of the 30-WMP decreased by 35.1% when compared to the control mix.

5.3. Split Tensile Strength

The control specimens provided a split tensile strength of 2.40Mpa. The addition of RHA decreased the tensile performance by 42.9% and 53.3% for 15-RHA and 30-RHA, respectively. On the contrary, 15 % of WMP specimens were the strongest as their tensile strength increased by 33.8% over the control specimens. However, the tensile strength of 30% WMP mix reduced by 21.3%

6. Discussion & Conclusion

- The current experimental studies demonstrate quite different effects of waste marble powder (WMP) and rice husk ash (RHA) as partial cement substitutes in environment friendly blocks of concrete. The results highlight the importance of the fact that the material type and replacement proportion are the primary factors that dictate the mechanical performance of the resulting concrete.
- It is worth noting that the compressive strength results show that WMP has better results when compared to RHA at the lower replacement level. Compressive strength of the 15% WMP mix showed significant increment against that of the control. The explanation of this increment can be found in the micro-filler effect of WMP that results in better packing of the particles, reduction of internal voids, and an increase in the density of a concrete matrix. Moreover, WMP has high calcium carbonate level, and this compound enhances interfacial bond between aggregates and the cementitious paste. Nevertheless, at a substitution level of 30%, compressive strength was found to decline, likely due to the over dilution of the cementitious matrix resulting in a decrease in the supply of hydration products.
- On the other hand, compressive strength of both RHA-modified concrete showed a steep fall. This reduction is probably due to inadequate pozzolanic action at the selected curing time and replacement volumes together with increased water requirement and porosity of RHA. Higher substitution levels inevitably limit the availability of calcium hydroxide in the reduced cement content, thus limiting proper pozzolanic reactions resulting in a weaker matrix.
- The trends in compressive strength are also reflected in the split-tensile tests. The 15% WMP blend showed the maximum tensile strength of all the formulations tested indicating increased resistance to crack propagation and initiation. The observation supports the effectiveness of WMP in enhancing favorable internal stress distribution and reducing the development of micro-cracks. Conversely, tensile strength was lower with the addition of RHA especially at 30% replacement and this can be explained by the fact that RHA increased porosity and weakened bonding between the matrix.
- Overall, the evidence supports the utilization of waste marble powder as a partial cement replacement in concrete blocks in comparison to the rice husk ash, particularly in

the range of 15 %. or so. At this ratio, WMP does not only increase compressive as well as tensile strength, but also facilitates the use of waste as well as lessening the use of cement. Despite lower levels of substitution and RHA-based mixes having reduced strength, they can still be used in non-structural elements where low strength levels can be tolerated. These findings support the potential use of WMP-based eco-concrete blocks for partition and boundary walls, contributing to sustainable construction practices with reduced environmental impact.

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