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Enhancement of Mechanical Properties of Concrete Using Industrial Waste

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Abstract **-** In response to the evolving global landscape, there is a growing inclination towards embracing sustainable and environmentally conscious construction practices to meet the demand for more eco-friendly and climate-resilient built environments. In recent time several SCM (Supplementary Cementitious Material) had been employed in concrete for its property enhancement as well as reducing negative impact of waste on environment. Taking a step in the similar direction the present study employs Rice husk ash (RHA) and Waste marble powder (WMP) for strength enhancement of concrete. Varying percentage of Rice Husk Ash (0%, 2.5%, 5%, 10%, 12.5%, 15%&20%) and Waste Marble Powder (0%,2.5%,5%, 10%, 12.5%, 15% & 20%) were used as a replacement of cement in binder. Further a combined replacement of RHA and WMP was used to prepare data cases for replacement of cement in concrete. Five different cases were designed with keeping RHA percentage constant for single case while varying the WMP percentage for same. Case 0 with no replacement, Case 1 with 2.5% RHA along with varying percentage of WMP, Case 2 with 5% RHA along with varying percentage of WMP similarly Case 3 with 10% RHA along with varying percentage of WMP and Case 4 with 12.5% RHA along with varying percentage of WMP. The varied percentage of WMP were 5%, 10%, 15% and 20% for each case. This resulted in identification of combined effect of both materials on concrete strength

Keywords**:** Concrete, Rice husk ash, Waste marble powder, Mechanical properties of concrete

1. Introduction

In present scenario the carbon emission form construction industries are a major cause of concern. As reported by down to earth [1], materials for construction of building account for 37 % of global energy and process related emissions. Over the past year various researchers have tried to reduce the ill effect of emission by incorporating different waste from industries for production of concrete mix in turn improving its mechanical properties. To cut back the consumption of cement partial replacement of cement with some supplementary building materials is a viable option. The characteristics of prepared concrete depends upon the properties of constituent of material and their combined action.

Rice Husk Ash and Waste marble powder, both are waste generated from different industries and are responsible for environment degradation when dumbed in land landfills.

Rice husk is an agricultural waste material which is produced in about 100 million of tons. As estimated by studies 100 kgs of rice yields 20 kgs of rice husk [2] .Also the generated rice husk mostly contains organic substances. The combustion of this rice husk results into obtaining Rice Husk Ash (RHA). In present context India stands among the major rice producing country, where mostly the generated rice husk is employed as a fuel for boiler to process paddy by mean of direct combustion . As estimated, around 700 million tons of rice is produced every year which generate around 140 million tons of rice husk [2]. RHA produced is of greater environmental concern when dumped in landfills. Over the years several attempts have been made to reduce this ill effect of RHA and making its use commercially viable. Present study also focuses in similar direction by incorporating RHA as a supplementary material in cement. Amorphous phase content is determining property of RHA's pozzolanic activity . The reactivity properties of RHA as a pozzolanic material makes it a suitable for replacement of Portland cement. High silicon dioxide content of RHA comparatively to cement leads to dependence of its reactivity on two factors, namely non-crystalline silica content along with its specific surface [3]. From past many years different researchers studied various properties of RHA, similar research conducted in 1973 presented the effect of pyro-processing on pozzolanic reactivity of RHA [4]. These over the year resulted in improving various properties of concrete. In this report, RHA obtained by uncontrolled combustion was added to concrete. The binder samples were tested at 7 and 28 days of age to determine effective combination percentage with WMP.

Marble is a metamorphic rock that will be foliated or non- foliated, composed of recrystallized carbonate minerals, most typically calcite or dolomite. The marble has been normally used as a construction material since past. With recent increasing use of marble, the problem of WMP disposal is causing a greater environmental concern . During this work, a marble powder, obtained as a byproduct of marble sawing and shaping, was characterized from a physical and chemical point of view for evaluating possibility of utilizing it in mortar and concrete production. Throughout the cutting process total 25% marble is resulted in dust [5]. As estimated by studies several marble process enterprises produce large amount of marble waste, as quoted Rajasthan marble process enterprise produces marble waste of 4500 tons annually [6]. Recycling marble waste powder in substitution of sand also indirectly will reduce environmental problem related with sand production.

Locally produced RHA were used to replace cement by 2.5%, 5%,7.5%,10%, 12.5&15 of its weight in the binder. Mixture proportioning was performed to reduce high workability RHA mixture (200 240 mm slump) with target strength of 40MPa. Partial replacement of RHA with cement resulted in variation of water-cement ratio along with providing similar mechanical properties with finer RHA giving improved variation . Micro fine particles of RHA provide highest shrinkage volume due to reduced particle size.

2. Materials and Method

Effective selection of materials along with proper mixing and incorporation of nano materials helps in attaining the desired results. Moreover, the obtained result is widely varied based on the incorporation technique employed. Different materials were used in the current study to evaluate the effect of RHA and WMP in concrete mix. In the present study the Ordinary Portland cement (OPC 53) produced by Ultratech Pvt. Ltd. confirming to international quality standards ISO 9001 was used. Graded fine (sieve no. 4 = 4.75 mm) and coarse aggregate were purchased from Sand Sure Enterprise, Gandhinagar, India. The different composition of OPC, RHA and WMP is presented in table 1.

Table 1: Chemical composition of cement, RHA and WMP

Oxides(%)	OPC	RHA	WMP
CaO	63.48	0.22	52.5
SiO2	18.93	88.90	2.79
Al2O3	5.22	2.50	0.68
Fe2O3	3.42	2.19	0.08
MgO	1.76	0.33	0.62
SO2	2.69	0.16	0.09
Na2O	0.45	0.11	0.12
K2O	0.71	1.33	0.22

2.1 Method of Incorporation

Combined incorporation of both materials in concrete is presented below in Figure 1

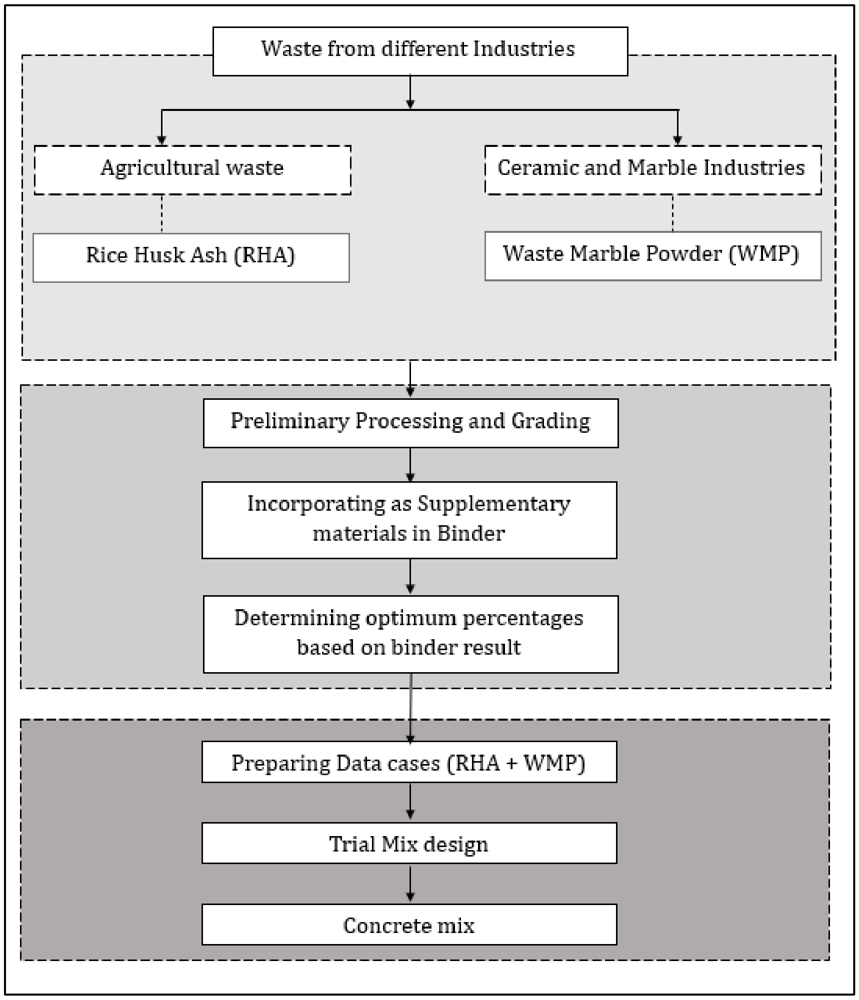

Figure 1: Method of combined incorporation of RHA and WMP in concrete

Rice husk ash and Waste Marble powder was individually incorporated in binder based on different percentage. These percentage include 0%, 2.5%, 5%, 10%, 12.5%, 15% & 20% for Rice husk ash and 0%, 2.5%, 5%, 10%, 12.5%, 15% & 20% for Waste marble powder by weight of the cement. Cube of size 5 x 5 x 5 cm were prepared and tested for 7 and 28 days respectively after controlled curing. Based on the obtained result data cases were prepared to report the optimum percentage combined replacement of both in cement. Data cases prepared is presented below in Table 2

Table 2: Data cases for combined incorporation of RHA and WMP in concrete

DATA CASES	SAMPLES	COMBINED PERCENTGE	Weight per cubic meter (in kg)		
			OPC	RHA	WMP
Case 0	SC-0	0%RHA+0%WMP	500	0	0
Case 1	SC-1.1	2.5%RHA+5%WMP	463	12.5	25
	SC-1.2	2.5%RHA+10%WMP	437.5	12.5	50
	SC-1.3	2.5%RHA+15%WMP	412.5	12.5	75
	SC-1.4	2.5%RHA+20%WMP	387.5	12.5	100
Case 2	SC-2.1	5%RHA+5%WMP	450	25	25
	SC-2.2	5%RHA+10%WMP	425	25	50

	SC-2.3	5%RHA+15%WMP	400	25	75
	SC-2.4	5%RHA+20%WMP	375	25	100
Case 3	SC-3.1	10%RHA+5%WMP	425	50	25
	SC-3.2	10%RHA+10%WMP	400	50	50
	SC-3.3	10%RHA+15%WMP	375	50	75
	SC-3.4	10%RHA+20%WMP	350	50	100
Case 4	SC-4.1	12.5%RHA+5%WMP	412.5	62.5	25
	SC-4.2	12.5%RHA+10%WMP	387.5	62.5	50
	SC-4.3	12.5%RHA+15%WMP	365.5	62.5	75
	SC-4.4	12.5%RHA+20%WMP	338.5	62.5	100

The concrete mix design of grade M30 have been done as per of the recommended guidelines of IS: 10262-2009.The weight ratio of mix proportion is 1:1.11:2.26 (Cement: Fine aggregate: Coarse aggregate-Ratio by Weight) keeping water-cement ratio as 0.37.To investigate the mechanical properties of M30grade concrete, cast with partial replacement of cement with 0%, 2.5%,5%, 10%, 15%, 20% of marble powder and rice husk ash, both supplementary materials also combined replacement through the work in all mix.

3. Result and Discussion

3.1 Binder results

The binder cube of both RHA and WMP were tested under compression testing machine at the interval of 7, 14 and 28 days . The results obtained are discussed as

3.1.1 Binder Incorporated with RHA

The binder of different percentage (0, 2.5, 5, 10, 12.5, 15 and 20%) were tested for specified period. The result obtained is presented below in Figure 2

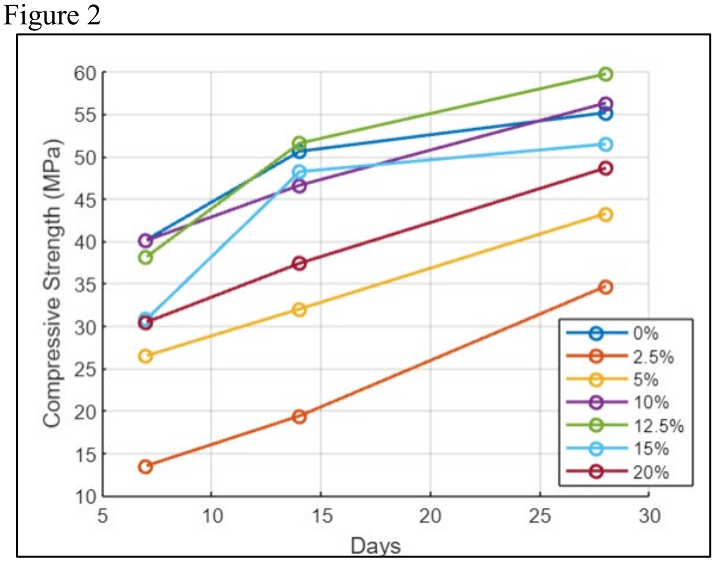

Figure 2: Compressive strength of binder incorporated with RHA for 7, 14 and 28 days

It was observed that the peak strength increment was obtained for binder sample incorporated with 12.5 % of rice husk as replacement of cement by weight. The compressive strength obtained by different researchers over the time varied because of adopted RHA which in turn depends upon its manufacturing process. Moreover, different studies conducted [7],[8]agreed to increase of strength of concrete up to an optimum level when incorporated with RHA. Further increase in percentage of RHA resulted in decrease in compressive strength of the samples. As explained by other studies [9],[10] increased percentage of RHA can result in significant loss of strength due to presence of large pores of in bulk

RHA which leads to reduction of C-S-H gel produced which in turn negatively affect the strength. Also, RHA particles in large quantity vary the water biner ration thus result effective bonding.

3.1.2 Binder Incorporated with WMP

Use of WMP also displayed similar behaviours of increased compressive strength up to optimum percentage after which a decline in strength was noted. The results obtained from compressive strength test are presented in Figure 3.

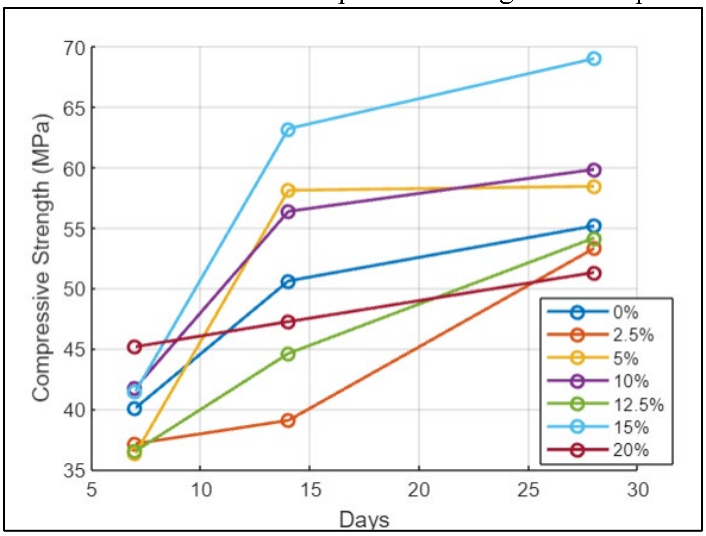

Figure 3: Compressive strength of binder incorporated with WMP for 7, 14 and 28 days

As noted in the present study in confirmation to Ashish (2018), compressive strength was decreased, this can be accounted due to drop of tricalcium silicate (C3S) and dicalcium silicate (C2S) cementing materials which are important in providing strength to concrete. The maximum strength was obtained till 15% replacement of WMP with cement as studied by existing researcher [11],[12]. This increase in strength is a result of pore filling effect of WMP in transition zone surrounding aggregates.

3.2 Combined Incorporation

Concrete samples were casted using trial and error data sets with varying percentage of RHA and WMP in moulds of 150 x 150 x 150 mm cubes tested under compressive strength for 7 and 28 days cured using conventional method. Case 0 depicts the conventional concrete mix with 0% of RHA and 0% of WMP, thus samples SC-0 is used as a reference to study the strength enhancement of incorporated concrete.

3.2.1 Case 1

Case 1 consist of four samples (SC-1.1, SC-1.2, SC-1.3 AND SC-1.4) with 2.5% of RHA and varying percentage of WMP for individual sample. The compressive strength results obtained are presented in Figure 4.

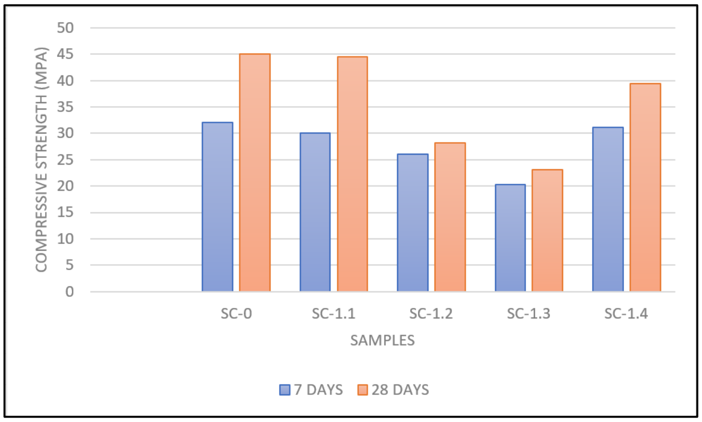

Figure 4: Case 1 Compressive strength for 7 and 28 days

The minimum combined replacement for sample SC-1.1 (2.5% RHA and 5% WMP) depicted similar strength increment to that of cement and further increase of WMP in samples with keeping the RHA percentage constant leads to decrease in strength which is due to decrease silica content and comparatively similar calcium oxide presence compared to cement with increase percentage of WMP replacement.

3.2.2 Case 2

Case 2 can also be referred as 5% RHA constant case consisting four samples (SC-2.1, SC-2.2, SC-2.3 and SC-2.4) with varying WMP percentage. The obtained result of compressive testing is represented as bar chart in Figure 5

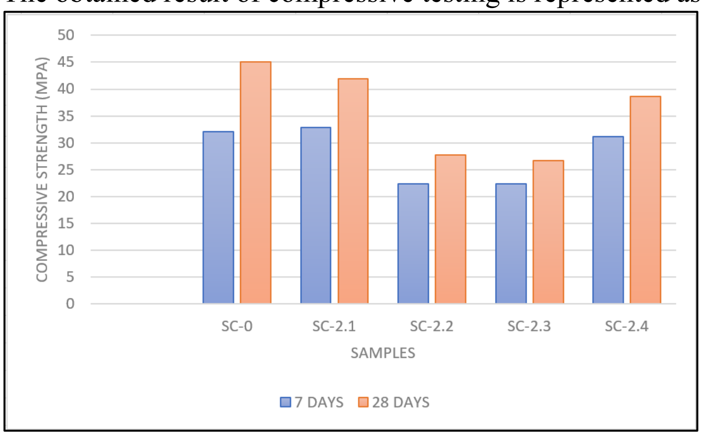

Figure 5: Case 2 Compressive strength for 7 and 28 days

This case also provides nearly similar behaviour of strength increment as of Case 1 with minimal decrease in strength due increased RHA percentage which in turn effect the water demand. The maximum strength for case 2 is obtained for sample SC-2.1 which is minimum replacement percentage (5% RHA and 5% WMP) with nearly similar strength to conventional concrete.

3.2.3 Case 3

Like previous two cases case 3 consist of four samples (SC-3.1, SC-3.2, SC-3.3 and SC-3.4) with 10% constant RHA along with varying percentage of WMP. Figure 6 represent the obtained result in form of bar chart

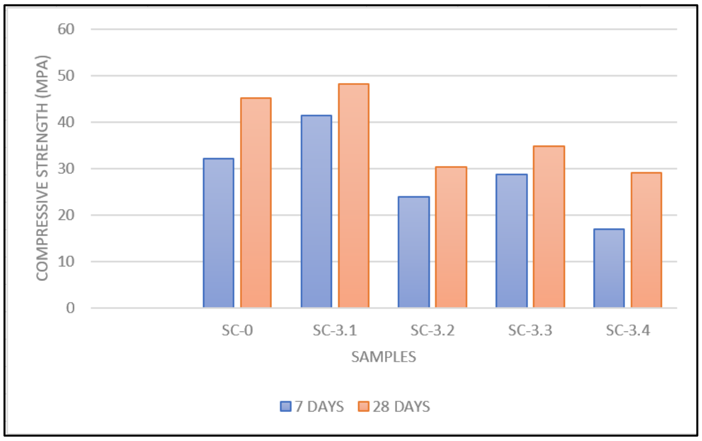

Figure 6: Case 3 Compressive strength for 7 and 28 days

Sample SC-3.1 depict the maximum strength increment compared to entire data case with optimum percentages of RHA and WMP. Further increase in WMP percentage accounted for decreased strength.

3.2.4 Case 4

Similar to all other case data set, case four consist of four samples (SC-4.1, SC-4.2, SC-4.3 and SC-4.4) with a constant percentage of 12.5% RHA and varying percentage of WMP. Results obtained are plotted below as Figure 7.

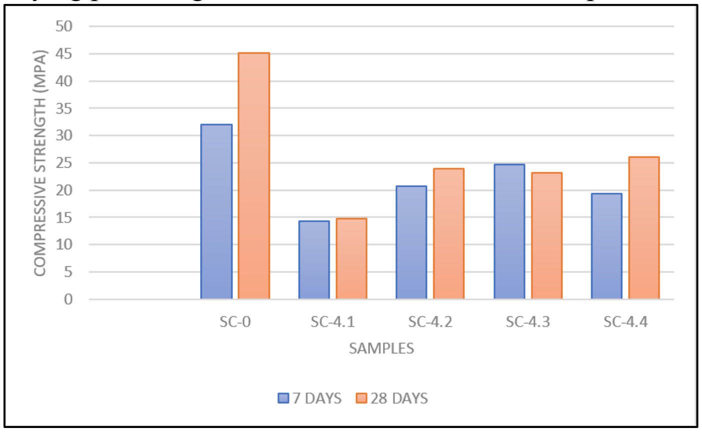

Figure 7: Case 4 Compressive strength for 7 and 28 days

All four samples in case 4 represented decreased strength due to high replacement percentage of cement, maximum reaching to 12% RHA and 20% WMP. This decrease strength is due to highly variable water demand along with decreased silica content due to large percentage of WMP.

4 Conclusion

The following conclusions was obtained from the study

- RHA in binder yield the maximum strength for partial replacement of cement up to 12.5% which was 10.8% when compared to conventional sample. Further increase in RHA percentage resulted in decreased value of strength due to decreased C-S-H gel production and increased water demand.
- WMP yield maximum strength at 15% which was in confirmation to various researches. Further increase in percentage of WMP for partial replacement of cement resulted in decreased strength due to drop of tricalcium silicate (C3S) and dicalcium silicate (C2S) cementing materials

- Sample SC-3.1 for case 3 of combined replacement of cement by RHA and WMP consisting of 10% RHA and 5%WMP yielded maximum strength increment. A total strength gain of 28.6% was noted at initial tests of 7 days. Further addition of RHA and WMP resulted in decreased strength due to varied water demand and drop of tricalcium silicate (C3S) and dicalcium silicate (C2S) because of decreased silica content with increased WMP percentage.
- Studies in future can be done toward direction to overcome this defect of decreased silica content with incorporation of additional materials.

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