



Effect of Superplasticizer on Strength and Durability of Rice Husk Ash Concrete

V. N. Kanthe*

Department of Civil Engineering, Guru Gobind Singh College of Engineering and Research Centre, Nashik, Maharashtra, India

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ABSTRACT

In this research work, the effect of rice husk ash (RHA) along with and without superplasticizer (SP) on the properties of concrete was investigated. The good workability and compaction is key parameter for strength and durability of concrete, and it may achieved by adding SP in to the concrete. In India RHA is available in huge quantity. It is byproduct of agriculture. In present research ordinary portland cement (OPC) was replaced by 10 to 50% RHA. The fresh properties as workability and hardened properties of concrete as compressive strength were examined. For durability test water absorption, acid attack and sulphate attack tests were conducted. The test results show that at 10% RHA with SP the maximum strength of concrete was attained with respect to control concrete mix (CM). The satisfactory test results were shown for durability and strength. Such kind of blend concrete is more efficient to enhance the properties of concrete which reduce the consumption of cement. The utilization of agricultural byproduct makes concrete sustainable and reduce environmental problems.

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INTRODUCTION

World wide, the concrete used in construction industries is huge quantities. The important ingredient of concrete is cement and it is widely utilized. In the manufacturing practice of ordinary portland cement (OPC) emits a huge quantity of CO₂ gas, and pollutes the environment [1]. The by-product such as fly ash (FA) [2, 3], Ground Granulated Blast Furnace Slag (GGBS) [4], and rice husk ash (RHA) [5, 6] are produced large amount in India and it causes the environmental issues due to its disposal problem. To overcome this problem one of the solution is to use such by-product in concrete as partial replacement of OPC [6, 7]. These types of by product were mostly in pozzolanic nature.

The RHA is obtainable from paddy rice. The annual global production of paddy rice in the year of 2018 was found 725.17 million tonnes and about 26.10 million tonnes of RHA [8]. RHA production in India is 5.88 million tonnes [8, 9]. Usually, the RHA may produce by burning rice husks in a controlled temperature at range of

600–800°C, which produce amorphous silica as reported by other researcher [10]. The presence of amorphous silica (SiO₂) in RHA is more functional to form hydration product such as C-S-H gel in concrete also reduce early age shrinkage of concrete [11, 12].

The use of RHA in concrete as partly replaced the cement which enhanced the properties of concrete such as strength of concrete and durability but reduces the workability of concrete [13–15]. The workability issue can be resolved by adding SP along with RHA in concrete. Very few research work were found related to RHA as partial replacement of OPC, with or without SP in concrete and most of them on self-compacting concrete (SCC) [16]. The major objective of this research is to study the effect of locally available RHA along with and without SP on compressive strength of concrete and durability of blended concrete. The main advantage of blended concrete was to achieve the dense particle packing in concrete microstructure and to enhance the mechanical and durability properties of concrete with the SP concrete can make dense and workable concrete [17–19].

*Corresponding Author Email: vishukanthe@gmail.com (V. N. Kanthe)

MATERIAL AND METHODS

The materials were used such as OPC 43 grade cement, river sand, coarse aggregate, water, RHA and SP. The cement, river sand and 20mm coarse aggregate with specific gravity of 3.13, 2.6 Zone II and 2.64 were used in mix design of concrete. The RHA is freely available in rice mills. The processed RHA were arranged from the local supplier. The chemical properties of the material are summarized in Table 1. The high range water reducing (HRWR) Superplasticizer (SP) was used based on the dosage required to enhance the performance of concrete mix. The specific gravity of SP was 1.26 conforming to IS 9103:1999. Figure 1 illustrates the particle size distribution. It shows that The average size of particles at D10 and D50 for OPC and RHA particles were $5\mu\text{m}$ & $32\mu\text{m}$ and, $3\mu\text{m}$, & $22\mu\text{m}$, respectively. From the presented information, it can be viewed as the RHA molecule is better than OPC. The concrete mix design was done as per the IS 10262- 2009 for 0.30 w/c ratio. The details of concrete mix design are given in Table 2. The mix (90C10R) was denoted the combination of 90%OPC and 10%RHA. The percentage variation of RHA were used as 10% to 50% [20, 21]. The percentage of aggregates were fixed for better comparison and compactability [20]. The fresh concrete property called workability. It was used to check the concrete flow ability by slump cone conforming to IS: 1199-1956. The 100x100x100mm size molds were used for casting of total 42 numbers of concrete cubes. After 24 hours cubes were removed from mold and placed it 7 and 28 days for water curing. The strength of concrete specimens was tested after required time of curing. The water absorption of concrete was examine by the guideline given in ASTM-C642-13 [22]. This test was performed for to check the permeability of concrete. The 100mm x 100mm x 100mm size cube specimen were selected to perform the water absorption test for all concrete at 28 days. The percentage of water absorption were determine by the given equation [23],

$$\text{Water absorption (\%)} = \left[\frac{(b-a)}{a} \right] * 100 \quad (1)$$

where, (a) denote the initial weight, (b) denote the weight after water absorption. Deterioration of concrete and reinforcement corrosion is very important for the durability of concrete and hence it is necessary to be studied. The concrete durability was tested by water absorption, acid attack and sulphate attack. For sulfuric acid (H_2SO_4) attack and sodium sulphate attack tests the specimens were completely immersed in violent sulfuric acid solution and sulphate solution with 5% concentration for duration of 8 weeks. Before immersion, the specimens were taken as initial weight. For acid and sulfate attack testing of concrete there is not any specified guideline given in the standard. However, ASTM C267-01, 2012 has given general recommendations for testing. After the

Table 1. Chemical properties of OPC and RHA

Elemental Contents (%)	(Si)	(Ca)	(Al)	(Fe)	(Mg)	(K)	(Na)
RHA	92.45	1.94	0.80	1.12	0.37	3.25	0.07
OPC	15.70	68.51	4.65	3.76	1.66	2.35	0.37

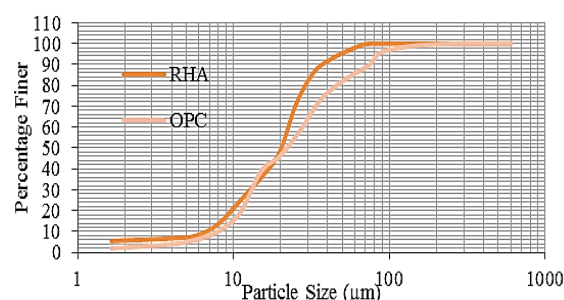


Figure 1. Particle size distributions of RHA, and OPC

Table 2. Concrete mix proportion (kg/m^3)

Mix	Cement	RHA	Coarse Agg.	Sand	Water	SP
100C0R	450	0	1210	598	152	0
100C0R	450	0	1210	598	152	3.9
90C10R	405	45	1210	598	152	3.9
80C20R	360	90	1210	598	152	3.9
70C30R	315	135	1210	598	152	3.9
60C40R	270	180	1210	598	152	3.9
50C50R	225	225	1210	598	152	3.9

specimens dipping in acidic solution, the specimens were cleaned by fresh water, and take weight (w_2). The weight loss (W) is determined from the following Equation (2),

$$W = [w_2 - w_1 / w_1] * 100\% \quad (2)$$

RESULT AND DISCUSSION

Workability of concrete

Figure 2 illustrates the slump cone test results. It shows that the slump was reduced but within the desired range (50 to 75mm) by increasing the RHA content with and without SP concrete mix it was due to the finer and porous structure of RHA. But the reduction in slump was resolved by addition of SP. The slump value increased when SP was included; because the SP break the water clots produced during mixing. The released water makes the cement past and coated all particles in the mix. Hence it resulting dense concrete mix formed and increased durability.

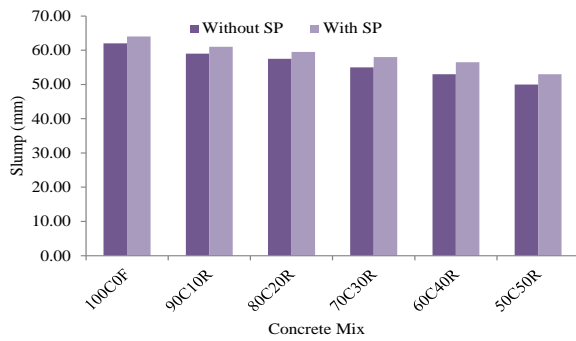
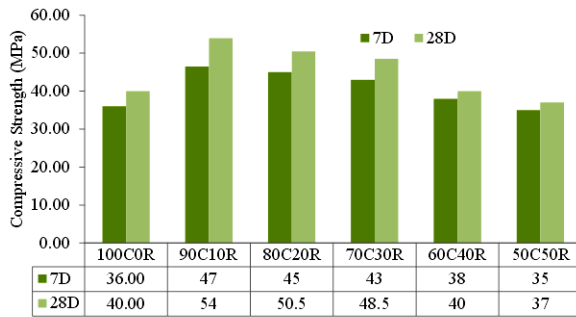


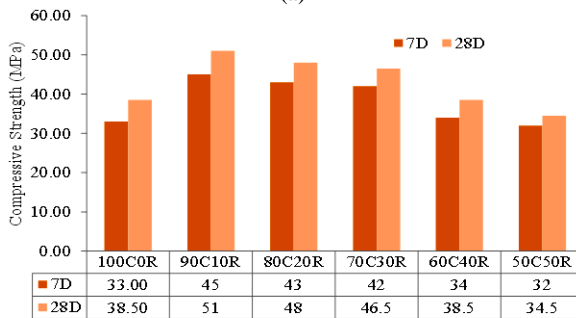
Figure 2. Slump test result of concrete mix

Compressive strength

The test results of compressive strength are shown in Figure 3 (a) and (b). It was shown that mix 90C10R with SP getting maximum strength by 5.56% than control concrete without SP. The concrete mix of 80C20R with SP improves the strength by 26.25% than the without SP combination of concrete. For samples with SP mix 30% cement replacement the strength improved by 4.12% with respect to the samples without SP mix at 28 days, it was because of the good particle packing of the matrix and due to the SP in concrete the cement paste spread on particles resulting dense particle packing. In addition it was due to the reactive RHA pozzolanic reaction. Whereas for samples with SP mix 50% the strength slightly reduced by 7.5% this may be because of after 40% replacement by



(a)



(b)

Figure 3. Compressive strength of concrete (a) with SP and (b) without SP

RHA it works as filler only and not took part forming CSH gel [23]. Hence it is evidence that samples with SP possess high strength of enhanced concrete.

Water absorption

Figure 4 illustrates the test results of water absorption. The results demonstrate that the percentages of water absorption of RHA concrete reduced around 6% than samples without SP. The content RHA increased the percentage of water absorption was reduced in both cases with and without SP concrete. Therefore, it may conclude that with an increase in the proportion of RHA along with SP in the concrete were able to reduce the micro pores. This was because of the high reactivity of RHA and SP spread cement paste completely over the aggregate particles. This resulting dense particle packing achieved and C-S-H gel which fills the micro pores.

Acid attack

The results related to weight loss after 28 days of dipping in the sulfuric acid solution of all concrete mix specimens are shown in Figure 5. It was found that the maximum weight loss was observed for the control concrete as 0.35% whereas less for combination of RHA with SP was 0.07%. The maximum weight loss was observed in control concrete, one of the possible reasons is that the conversion of anhydrate calcium content present which react with acid ion and reduced the forming of CSH gel which resulting the cracks and deterioration of the concrete. It was also noticed that the rise in RHA content the weight loss reduces. That was because of dense particle packing formed by the finer particle of RHA which filled the complete voids.

Sulphate attack

The variations in weight loss for all concrete mixes after 28 days of sulphate exposure condition are shown in Figure 6. It was noticed that the control concrete was more affected by the sulphate attack in terms of weight loss than the RHA concrete with SP. weight loss was observed for the control concrete as 0.28% whereas less

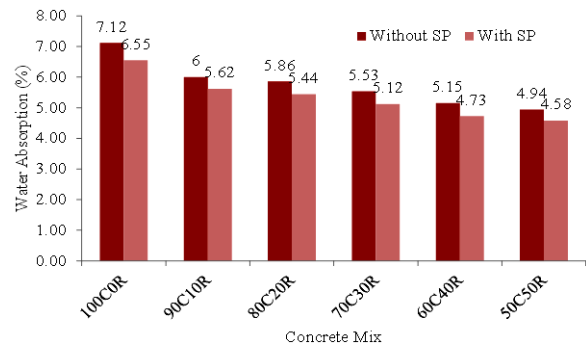


Figure 4. Water absorption test result

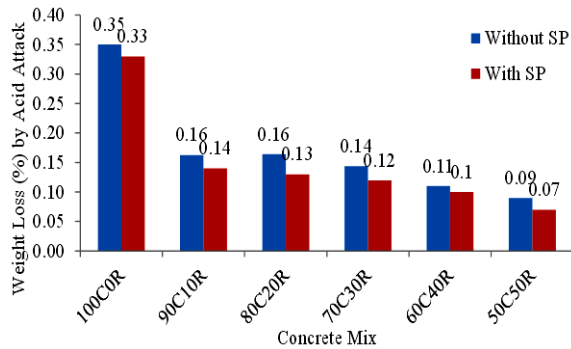


Figure 5. Weight loss result for concrete by acid attack

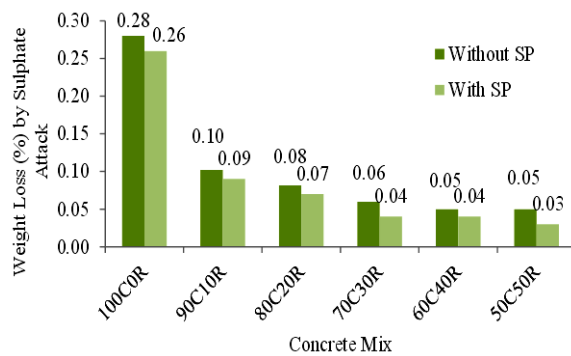


Figure 6. Weight loss result for concrete by acid attack

for the combination of RHA with SP was 0.03%. It was also noticed that an increase in RHA content the weight loss reduces. The possible reason for such improved behaviour of the blended concrete was due to the presence of dense CSH gel obtained from pozzolanic reaction by the reactive RHA. It resists to penetration of sulphate ion resulting an increase in durability of concrete.

CONCLUSIONS

From the test results and discussion, the following conclusions are drawn:

1. The workability of RHA concrete was improved due to addition of SP.
2. The maximum compressive strength for RHA blend concrete (90C10R) with SP was achieved than control concrete and samples without SP concrete.
3. The deterioration of concrete can be reduced by addition of RHA and SP resulting durability of enhanced concrete.
4. The effectively utilization of agricultural byproduct up to 30% in concrete with enhancements of the strength and durability of concrete. Hence the concrete makes sustainable and ecofriendly.

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CONFLICT OF INTEREST

There is no conflict of interest for this research.

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**Persian Abstract****چکیده**

در این کار تحقیقاتی، تأثیر خاکستر پوسته برنج (RHA) همراه با و بدون روان کننده (SP) بر خصوصیات بتن بررسی شد. کارایی و تراکم خوب پارامتر اصلی مقاومت و دوام بتن است و ممکن است با افزودن SP به بتن حاصل شود. در هند RHA به مقدار زیادی موجود است. این محصول جانبی کشاورزی است. در تحقیق حاضر سیمان پرتلند معمولی (OPC) با ۱۰ تا ۵۰ درصد RHA جایگزین شد. خصوصیات تازه به عنوان قابلیت کار و خواص سخت شده بتن به عنوان مقاومت فشاری مورد بررسی قرار گرفت. برای آزمایش دوام جذب آب، آزمایش اسید و حمله سولفات انجام شد. نتایج آزمایش نشان می‌دهد که با ۱۰ درصد RHA با SP حداکثر مقاومت بتن با توجه به ترکیب مخلوط بتن (CM) بدست آمده است. نتایج آزمون رضایت‌بخش برای دوام و مقاومت نشان داده شد. این نوع بتن مخلوط برای افزایش خواص بتن که باعث کاهش مصرف سیمان می‌شود، کارآمدتر است. استفاده از محصولات جانبی کشاورزی باعث پایداری بتن و کاهش مشکلات زیست محیطی می‌شود.