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RESEARCH NOTE

Combine Use of Fly Ash and Rice Husk Ash in Concrete to Improve its Properties

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ABSTRACT

This research paper describes the study of combined effect of Fly Ash (FA) and Rice Husk Ash (RHA) on properties of concrete as partial replacement of Ordinary Portland Cement (OPC). These by-products are having high pozzolanic reactivity. In this research, the composition of mix was used with 10% RHA along with 10, 20 and 30% FA as partial replacement of cement. In this research paper, the compressive strength, workability, durability performance, and microstructure of concrete were studied. The microstructures of the concrete sample were analyzed by Scanning Electron Microscope (SEM) and elemental contents by Energy Dispersive X-ray (EDX). The test results shows that the highest compressive strength was achieved by 10%RHA and 20%FA used and beyond that, the strength was shown similar to control concrete mix (CM). The Ultrasonic Pulse Velocity (UPV) test result values were above the 4.5km/s; hence it may be considered as excellent concrete as per IS code for all mix. Response Surface Methodology (RSM) was adopted for optimizing experimental data. Regression equation was yielded by the application of RSM relating response variables to input parameters. This method aids in predicting the experimental results accurately with an acceptable range of error. This type of concrete mix is very effective in enhancing the mechanical and durability properties of concrete by saving cement and cost. It also makes concrete sustainable as it reduces environmental problems.

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NOMENCLATURE

		Greek Symbols	
x	Coded variable		
ei	Error	β	Regration Coefficient
yi	Predicted strength	ξ	Natural Variable
		χ	Material

1. INTRODUCTION

The industrial and agricultural by-product such as fly ash (FA) [1, 2], silica fume (SF) [3], ground granulated blast furnace slag (GGBS) [4], metakaolin (MK) [5], granite slurry [6] and rice husk ash (RHA) [7, 8] produces in huge quantity in India and affect the environmental balance due to its disposal problem. To overcome this problem special attention must be given to the utilization of such by-product in concrete large quantity for the infrastructure development in the country. The cement is one of the main ingredients widely used in concrete. The production process of Portland cement creates large amount of CO_2 gas, it affects the environment [9]. The high reactive pozzolanic material can be utilized in concrete for improving the strength and durability of the concrete. The FA can improve the workability, shrinkage, long-term strength, and durability of concrete as reported by various researchers [10-12]. From the literature it observed that utilization of RHA in concrete improved the properties such as strength and durability, though it reduces the workability of concrete [13-15] hence to improve the workability of concrete FA can be added as secondary cementitious material along with the RHA and OPC to form a blended concrete mix. FA and RHA by partial replacement of OPC. The concrete is used in complement each other as FA compensate for

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workability loss due to RHA and RHA compensate for compressive strength loss due to FA. The literature review shows that the very few research has been done on combination of FA and RHA replacement of OPC in concrete and most of them on Self Compacting Concrete (SCC) [16]. However, in common practice normal concrete is more used. The main objective of this work is to make the FA and RHA blended concrete to investigate the effect on the properties of concrete with locally available material and reduce landfill area for dumping these materials.

1. 1. Potential of Rice Husk Ash and Fly Ash in India

The paddy rice husk is an agricultural waste and it is available in huge quantity in the Chhattisgarh state of India. The paddy rice husk is utilized for producing the RHA. The RHA is produced by burning of paddy rice husk at a controlled temperature [17]. RHA has a higher percentage of amorphous silica (SiO_2) content which is more useful for forming CSH gel in the cement concrete [18]. In 2014, the annual global production of paddy rice was 741.3 million tons and around 29.6 million tons RHA. The Indian paddy rice production is second highest in the world that was 154.55 million tons and 6.1 million tons of RHA produced [19]. In Chhattisgarh state, FA and RHA are easily available. In 2013, the paddy rice production in Chhattisgarh state was 6716.36 metric tons and around 241.78 metric tons RHA produced. The production and utilization of RHA as shown in Figure 1 [19].

The recent development of RHA used in ceramic industries; it could substitute of quartz used [20] and the FA. The FA generation and its utilization for year 2016 in India as per the central electricity authority New Delhi, around 176.74 million tons generated from 151 thermal power station and out of this only 107.77 million tons utilized and in Chhattisgarh state of India around 24.22 million tons generated from 19 thermal power station and out of this only 7.9 million tons FA utilized. The major modes of FA utilization as shown in Figure 2 [21].

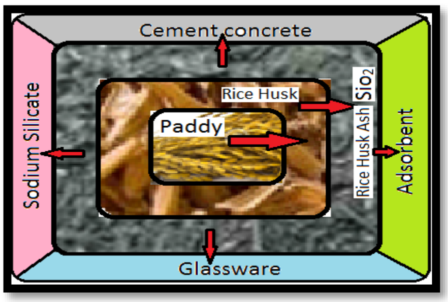


Figure 1. Production and utilization of RHA [9]

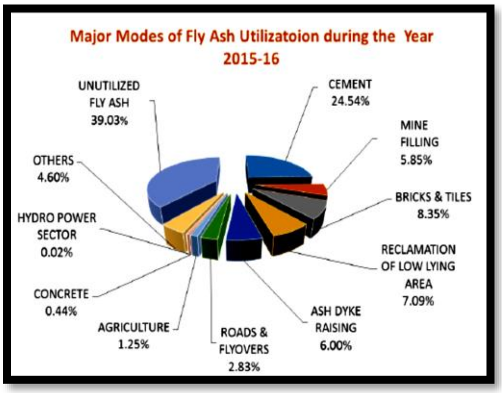


Figure 2. Modes of Utilization of FA [21]

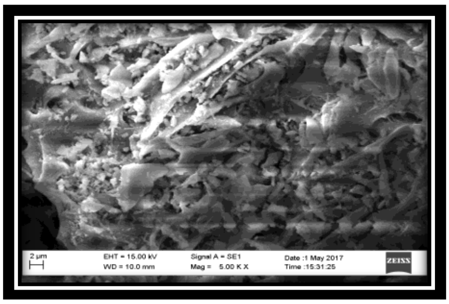
2. EXPERIMENTAL WORK AND METHODS

2. 1. Material

The locally available materials used in this research work consisted of OPC, river sand, coarse aggregate, water, FA and RHA. The OPC 43 grade with 3.05 specific gravity was used in all composition of concrete mix conforming to IS: 4031 (1988). The locally available river sand with specific gravity 2.4 Zone II was used as a fine aggregate. Coursed aggregate of maximum size 20 mm was used with specific gravity 2.6 conforming to IS: 383(1970). The FA was collected from Bhilai, Chhattisgarh, India and the pulverized RHA was collected from the local vendor, the rice husk ash was collected from boiled rice mill and it re-burned in the furnace at controlled temperature, after the burning the ash was allowed to cooled and ground it in powder form. Figure 3 (a) to (c) shows the SEM images of RHA, FA, and OPC sample. The pore structure of RHA clearly shown in Figure 3(a) also reported by Le Anh-Tuan Bui et al. [22]. The pore structure of RHA helps to reserved water in it at the time of concrete mixing and release after age and it helps for hydration process as an internal curing agent [23]. Figure 3(b) shows the spherical shape of FA particle it helps for improve the workability of the fresh concrete mix and minimize the demand of cement [24]. Figure 3(c) shows the irregular particle shape of OPC. The elemental values for for the given samples from EDX result were shown in Table 1. Figure 4 illustrates the particle size distribution of FA and RHA, the sand size particle in range of 4.5µm to 75µm retained as 17 and 0%. The silt size particle in range of 75µm to 2µm retained as 81 and 94%. And the clay size particle in range of less than 2µm retained as 2 and 6%. From this it can be considered the RHA particle is finer than FA.

2. 2. Compressive Strength

The concrete mix proportion was done as per the IS 10262- 2009.



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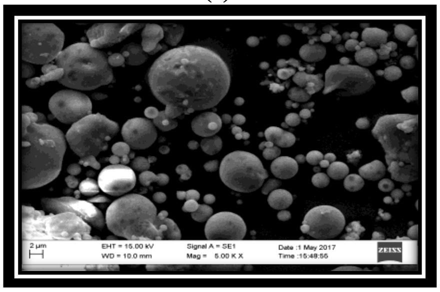

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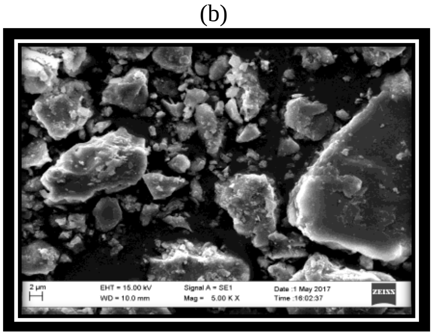


(c)

Figure 3. (a) The pore structure of RHA particle, (b) The spherical shape of FA particle, (c) The irregular shape of cement particle

TABLE 1. Elemental Contents of FA, RHA and OPC.

Chemicals	Elemental Contents (%)		
	FA	**RHA**	**OPC**
Silica (Si)	63.78	92.45	15.70
Calcium (Ca)	1.12	1.94	68.51
Aluminum (Al)	24.44	0.80	4.65
Iron (Fe)	5.01	1.12	3.76
Magnesium (Mg)	0.48	0.37	1.66
Potassium (K)	2.46	3.25	2.35
Sodium (Na)	0.11	0.07	0.37

The compositions of various concrete mixes are given in Table 2. The word (CM) referred control mix. The mix (R10FA10) was a combination of 10%RHA and 10%FA.

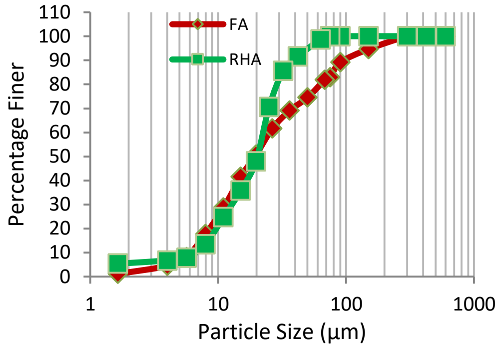


Figure 4. Particle size distribution of FA and RHA sample

TABLE 2. Concrete mix design in kg/m^3

Mix Designation	OPC	RHA	FA	Fine Aggregate	Coursed Aggregate	Water	W/C Ratio
CM	450	0	0	582	1120	180	0.4
R10 FA10	396	49.0	49.6	582	1120	180	0.4
R10 FA20	346	49.0	99	582	1120	180	0.4
R10 FA30	297	49.0	148.5	582	1120	180	0.4

In R10FA10 mix OPC was partially replaced with 10%RHA and 10%FA. The percentage of RHA was fixed at 10% as per previous literature [25] and FA changed by 10, 20 and 30%. The fine and coarse aggregate contents were fixed for compactability could easily be gained by changing only cement content [26]. The 100mm size cube moulds were used for casting around 9 cubes was cast for each mix. Then the specimens were left in the mould covered with gunny bag for 24 hours after that de molded and immersed in the water tank for 7, 14 and 28 days curing. The compressive strength of concrete was tested after the specified curing periods on the (CTM) compressiontesting machine of 2000kN capacity conforming to IS: 516(1959) [27].

2. 3. Ultrasonic Pulse Velocity Test The ultrasonic pulse velocity test was used to assess the quality of concrete such as uniformity, incidence or absence of internal flaws, cracks and segregation using the IS:13311 (part I): 1992 guidelines, which have been used for analyzing the quality of concrete in structures in terms of the ultrasonic pulse velocity. The pulse velocity value above the 4.5km/s considers as the excellent quality of concrete. The ultrasonic pulse velocity test was performed on the concrete specimen of all composition mix cured for 7, 14 and 28 days.

2. 4. SEM/EDX: (Scanning Electron Microscope) and (Energy Dispersive X-rays) The scanning electron method (SEM) analysis with high resolution was used to study the microstructure of sample. The energy dispersive X-ray (EDX) was used to obtain the elemental contents present in the given sample. For observation of SEM, the sample was coated with gold in sputter coater to obtained clear SEM images [28]. The testing was done on ZEISS Scanning Electron Microscope machine.

2. 5. Fresh Concrete Property The property of fresh concrete as workability was measured by slump cone test. The procedure for test was performed as per the IS: 1199-1956. The slump test results were cross checked by considering the slump range for all mix as 55mm to 75mm.

4. RESULT AND DISCUSSION:

4. 1. Workability Figure 6 shows the tested result of slump for all concrete mix. It was noticed that the slump were slightly decreased it may be due to the pore structure, more finer and rough surface of RHA but the slump was within the design range due to the effect of spherical particle of FA.

4. 2. Compressive Strength The compressive strength results of concrete as shown in Table 3 indicate that the ternary blend of RHA, FA and OPC has contributed to improving the strength of concrete. The strength of concrete blended mix R10FA10 and R10FA20 were improved by 5.5 and 11.2% in comparison to the control concrete mix at 28 days. It may be due to the good denseness of mix, high reactivity of RHA and pozzolanic reaction. It also shows that increasing the FA content the strength was decreased by 4.2%. This may be higher at 56 to 119days of curing. The integration of FA is responsible for the more gradual pozzolanic reaction with $Ca(OH)_2$ in the hydrated cement than only cement.

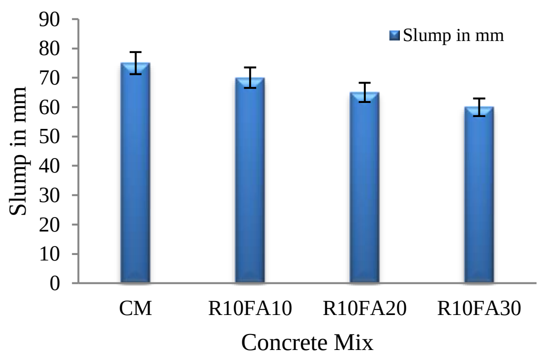


Figure 6. Slump of Concrete Mix

TABLE 3. Compressive strength of concrete

Mix Designation	Compressive strength (MPa)		
	7 days	14 days	28 days
CM	24.6	32.4	40.1
R10FA10	26.5	36.2	42.3
R10FA20	29.3	41.5	44.6
R10FA30	25.5	33.1	38.4

Concretely, as incrementing FA is utilized to supersede the cement in the concrete, the decrementing amount of cement results in a lower $Ca(OH)_2$ content it turn, reduces the compressive strength of the concrete and, consequently, the pozzolanic reaction rate for FA. However, judge against to the control mix the FA influence the harden of concrete due to inadequate hydration and a higher incremental the water requisite, which contributed to a decrement in the compressive strength [29].

4. 3. UPV Test The UPV test result of all ternary blended concrete mix was greater than the control concrete at all ages as shown in Figure 8. This is possible due to better particle packing and pozzolanic reaction. The UPV values are higher as around 2% than the control concrete for the concrete mix R10FA30 but less than control mix it may be because of an increase in FA content, the contribution of FA to the strength of concrete is lower than that of cement and hence less UPV values have been observed [30, 31].

4. 4. SEM/EDX Figure 9(a) and 9(b) show the SEM images of the control concrete mix and the sample made with RHA and FA. It is observed that the maximum content of unhydrated cement and voids present in the control concrete mix, where as less in the sample made with RHA and FA. It means more denseness in concrete. It's results in higher strength as 11.2% than control concrete mix.

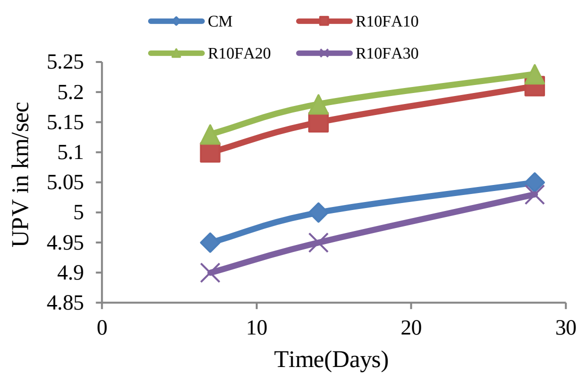
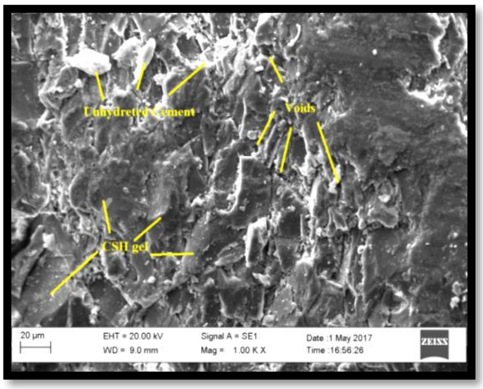


Figure 8. Ultrasonic pulse velocity for 28 days cured concrete



(a)

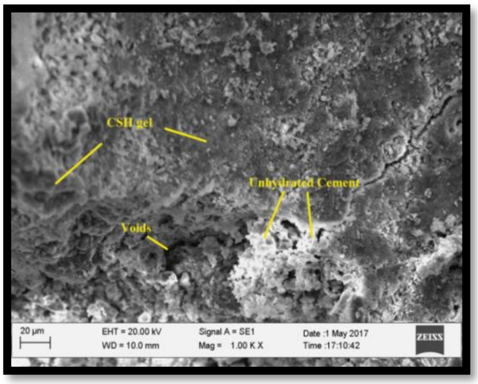


Figure 9. (a) Microstructure of Control Concrete , **(**b) Microstructure of concrete made by RHA and FA

In addition, maximum secondary CSH gel observed than control concrete [32], it is the most important component in concrete it provide cementitious or binding properties to the final product hence it contribute to strength of concrete.

4. 4. Cost Analysis The cost analysis of concrete made by FA and RHA and control concrete were workout as per the current market rate (May 2017). The partial replacement of cement by 20% of FA and RHA the cost of concrete was calculated reduced by 8.1% and for 30 and 40% of FA and RHA the cost reduced by 13.8 and 20.1%. It was noted that the cost of such type of concrete mix reduced cost of concrete with higher strength and durability than control concrete. Details are shown in Table 4.

TABLE 4. Cost analysis for 1m^3 of concrete

Concrete Mix	Total amount in Rs.	Cost reduction in %
CM	3860	---
R10FA10	3545	8.1
R10FA20	3329	13.8
R10FA30	3086	20.1

Hence, the use of industrial and agricultural byproduct in concrete as partial replacement of cement may result in cost saving with additional benefits of reducing the environmental problem [33, 34].

5. RESPONSE SURFACE METHOD (RSM)

The RSM is a set of statistical and mathematical techniques helpful for rising, improving, and optimizing the processes, design, development, and formulation of new products, as well as in the improvement of existing product designs. The RSM is more useful in the industrial world, where a lot of input variables potentially affect the performance actions or quality of the goods or process. These performance actions or quality are known as response [35]. The RSM was adopted for optimizing the experimental process. For the practical use of RSM [36], it is required to form an fairly accurate model for the true response surface [37]. The multi-linear first order response surface model, prepared with respect to regression analysis is given by Equation (1):

$$yi = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta nXn + \varepsilon \quad (1)$$

where, (yi) is observed compressive strength, Equation (2) is a linear function of the unknown parameters: β1, β2, . . . ,βn, which are called regression coefficients, and X1, X2, X3, . . . ,Xn which are coded variables that are usually defined to be dimensionless. The natural variables (Cement, RHA and FA) are converted into coded variable using the using the following relationship:

$$xi1 = \frac{\xi i1-[\max(\xi i1)+\min(\xi i1)]/2}{\xi i1-[\max(\xi i1)-\min(\xi i1)]/2} \quad (2)$$

where, (ξ) is the natural variables with maximum and minimum values. RSM analysis is performed using single replicate 2^n factorial design to fit first order linear regression model, (n) is the total number of input variables used in the analysis and matching to these variables. The number of sample requisite is 2^n. The least squares method is used to estimate the regression coefficients. The multilinear regression expression in the form of matrix is given by Equation (3):

$$Y= X\beta + \varepsilon \quad (3)$$

And the least squares estimators (b) are given by Equation (4):

$$b= (X'X)^{-1}X'Y \quad (4)$$

where, (X) is the coded variable matrix and the (Y) is the response in present research it represent the compressive strength of concrete. Analysis of residuals is conducted to examine if the regression equations provide an adequate approximation to the true system and verify that none of the least square regression assumptions is violated. The residuals from the first order response surface method, defined by ($e_i=y_i-\hat{y}_i$), ($i = 1, 2, 3,. . . , n$) where, (y_i) is the value obtained using the procedure based on constitutive model and ($\hat{y}_i$) is the predicted value from regression model play an important role in judging model adequacy. If the residual plot falls along a straight line, then the normality assumption is satisfied. The MATLAB software is used for the mathematical modeling, analysis, and optimization of the process variables. The response surface regression was established based on an experimental result. The best fit multiple regression Equation (5) for 7 days strength and Equation (6) for 28 days strength was proposed based on the test data as:

$$(yi) = \left[\frac{(-15064)-(8.8*x1)+(382*x2)-(8.6*x3)-(7or28days)}{1.36}\right] \quad (5)$$

where, (yi) is the predicted strength and ($x1$) is cement content, ($x2$) is the RHA content and ($x3$) is the FA content used in the concrete mix. The less error finds between predicted and experimental values, it indicating that the normality assumptions is satisfied. Figure 10 shows the residual plot falls in a straight line for 7 and 28 days strength result with R-square 0.95 value hence it may considered as the given regression model is adequate for the given research for optimized the experimental work. The Table 5 shows the results accurately with an acceptable range of error.

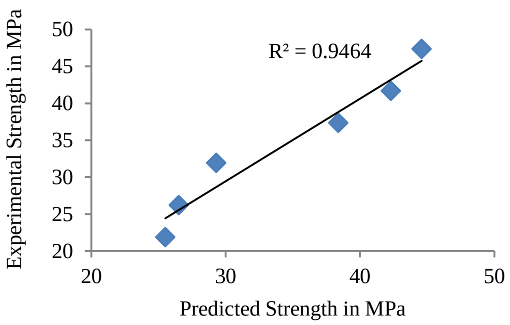


Figure 10. Residual plot for 7 and 28 days strength

TABLE 5. Experimental and Predicted values

Sr.No.	Curing Period in days	Experimental value of Strength (Y) in MPa	Predicted value of Strength ($\hat{y}_i$) in MPa	Residual $e_i=y_i-\hat{y}_i$
1		26.50	26.23	0.27
2	7	29.30	31.92	-2.62
3		25.50	21.89	3.61
4		42.30	41.67	0.63
5	28	44.60	47.36	-2.76
6		38.40	37.33	1.07

However, it may be noted that the regression equations are specific to the variables and its properties hence cannot be generalized, but are very useful in predicting the result from given response.

6. CONCLUSIONS

The following conclusion can be drawn from the experimental result,

1. The SEM and EDX result shows the porous structure of RHA particle with higher content of silica. The pores absorbed the water at the time of mixing reducing the workability, this effect can be compensated by adding the spherical particles of FA to improve the workability.
2. The compressive strength of ternary blend concrete was higher than control concrete. The highest strength was observed for R10F20 concrete mix. It may be due to the packing of finer particles, pozzolanic reaction and internal water curing by RHA.
3. The UPV test result showed the improved the durability of concrete by addition of FA and RHA.
4. The residual plot falls in a straight line for 7 and 28 days strength result hence it may considered as the given regression model is adequate for the optimized the experimental work.
5. This type of ternary blend concrete can effectively utilize up to 30% the industrial and agricultural byproduct with reduced cost of 20.1% and an environmental problem.

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Combine Use of Fly Ash and Rice Husk Ash in Concrete to Improve its Properties

RESEARCH NOTE

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چکیده

این مقاله پژوهشی، بررسی اثر ترکیبی خاکستر (Fly Ash) و برنج خزه (RHA) بر خواص بتن به عنوان جایگزینی جزئی از سیمان پرتلند معمولی (OPC) است. این محصولات جانبی دارای واکنش پوزولانی بالا هستند. در این تحقیق ترکیب مخلوط با 10٪ RHA همراه با 10، 20 و 30٪ FA به عنوان جایگزینی جزئی سیمان مورد استفاده قرار گرفت. در این مطالعه، مقاومت فشاری، کارایی، عملکرد دوام و میکروساختار بتن مورد بررسی قرار گرفت. میکروسکوپ اسکن الکترونیک (SEM) و محتویات عنصر توسط اشعه ایکس پراشنده (EDX)، میکروساختارهای نمونه بتن مورد بررسی قرار گرفت. نتایج آزمایش نشان داد که بیشترین مقاومت فشاری با 10٪ RHA و 20٪ FA مورد استفاده قرار گرفت و از آن بالاتر بود، مقاومت نسبت به ترکیب بتن کنترل (CM) نشان داده شد. مقادیر نتایج آزمایش (UPV) بالاتر از4.5 km /s بود؛ از این رو آن را می توان به عنوان بتن بسیار عالی در نظر گرفته شده در هر کد IS برای همه مخلوط. برای بهینه سازی داده های تجربی، روش پاسخ سطحی (RSM) مورد استفاده قرار گرفت. معادله رگرسیون با استفاده از متغیرهای مربوط به پاسخ RSM به پارامترهای ورودی بدست آمد. این روش در پیش بینی نتایج تجربی دقیق با دامنه قابل قبولی خطا کمک می کند. این نوع مخلوط بتنی با صرفه جویی در هزینه سیمان و سیمان در ارتقای خواص مکانیکی و دوام بتن بسیار موثر است. همچنین باعث می شود که پایدار بماند زیرا مشکلات محیط زیست را کاهش می دهد.

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