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Prediction Model for the performance of Fly-Ash Based High-Strength Concrete at Elevated Temperature

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ABSTRACT

High-Strength Concrete (HSC) is generally acknowledged for its robustness and long-lasting nature, making it essential in a wide range of applications. HSC experiences a reduction in its compressive strength after being exposed to fire. Diverse techniques are employed to determine the residual strength after fire exposure. Fire performance of HSC is not explored extensively; therefore, this study has developed the HSC using Fly Ash. Furthermore, Computational models that can accurately forecast the residual strength of concrete are required to minimize time, cost, and financial resources. This study evaluates the performance of Fly Ash-Based High-Strength Concrete (HSC) when exposed to high temperatures, highlighting its importance in situations that demand durable fire-resistant materials. For this purpose, the cylindrical Samples are tested for (HSC) at room temperature and then exposed to the temperature ranging from 300 ℃ to 900 ℃ with a constant duration of 4 hr. This study compares the difference between the residual strength of heated cylinder for 2 Groups, G1 Control Mix consists of pure cement, while G2 Binary Mix(Ash) 10% Fly Ash, The comparison of G1 and G2 after post fire performance shows that at 300 ℃ compressive strength (CS) for G2 is 9% lower than that of G1 while at 900℃ G1 have 45% more better strength than G1 and this is due to FA. Furthermore, 2 regression Equation are formed for both groups and their predicted and experimental results are compared which have 5 to 7% difference with R square value is 0.9666, 0.9794 and 0.9103, 0.8957 respectively.

KEYWORDS: High Strength Concrete (HSC), Fly Ash, Temperature, Multiple Regression Model.

ABBREVATIONS: (HSC) High Strength Concrete, (Control Mix/G1) mix having pure cement, (Binary Mix ASH/G2) Mix in which Cement is replaced by 10% Fly Ash.

1 INTRODUCTION

Concrete's strength, durability, and fire-resistant characteristics have established it as the most significant material in the field of building construction. Over the years, there has been an increased demand for high strength in structural elements.**[1]** Therefore, it is crucial to characterize their heat resistance and mechanical properties in order to forecast their behaviour after exposure to fire. To assess the fire resistance characteristics of high-strength concrete and examine the impact of including Fly Ash as an additional material. Furthermore, concrete is cost-effective, simple to manufacture, and practical. However, its physical and chemical characteristics undergo alterations when subjected to high temperatures, leading to significant deterioration. It also undergoes various reactions and transformations, resulting in the breakdown of the cement gel and a decrease in the durability and strength of concrete.**[2]** After exposure to fire, it is imperative to determine the remaining strength of a structure to determine whether it should be demolished or renovated. The residual strength of concrete is influenced by various elements, such as the mix proportion, maximum temperature, and loading circumstances. **[3, 4]** The strength of concrete declined as a result of increased temperature, particularly in terms of compressive strength, which is a primary issue in construction projects. **[5]** The compressive strength of concrete is a fundamental necessity for all concrete structures, as it determines their ability to withstand any type of applied load. The compressive strength of concrete serves as a reliable indicator for most other qualities that are of practical importance. Throughout the construction process, a standard test specimen was thoroughly examined to verify the quality of the concrete. The strength of concrete is determined by preparing, curing, and testing samples in accordance with the relevant standard requirements and rules. Post-fire performance assessment in High Strength Concrete (HSC) is essential for fire safety.**[6]** However, it is difficult to estimate residual capacity of (HSC) due to their composite composition. Also, destructive testing methodologies involved expensive procedures for the estimate of residual capacity after fire exposure.**[7]** Therefore, Innovative computational approaches utilizing advanced methodologies are needed.

The objective of this research is to create a predictive model that can handle different levels of fire intensity (300 ℃ to 900 ℃). The data collected from these variations can be used in a multiple regression model to establish an equation for predicting the residual strength of HSC after fire exposure. This approach offers a practical alternative to the resource-intensive fire testing methods currently used, while also addressing the limitations of cost and time.

2 EXPERIMENTAL PROGRAM

Materials

The materials utilized in this investigational program along with specification were summarized as.

2.1 Cement

The ASTM C150 standard was followed in using ordinary Portland cement to prepare concrete with a fineness of 4.32%.

2.2 Fine Aggregate

A fine aggregate sourced from a local sand supplier, Lawrancepure, was utilised. The sieve analysis was performed following the guidelines of ASTM C136, with a fineness modulus of 2.72

2.3 Coarse Aggregate

A regional coarse aggregate sourced from Margala, which had a maximum nominal size of 12.51 mm. As per ASTM C 136, a sieve analysis was required to be conducted.

2.4 Mix Proportion

High Strength Concrete (HSC) was used in this study. Using water cement ratios of 0.28 and the concrete was made in the ratio of 1:1.01:1.81. To achieve the slump of 100mm by using water reducing admixture of 1.75 by weight of cement. The addition of calculated amount of water and admixture were added to achieve the targeted slump.

3 RESEARCH METHODOLOGY

The methodology of this research is shown in flow Chart shown in Figure 1. The flow chart start from Testing at room temperature and so on.

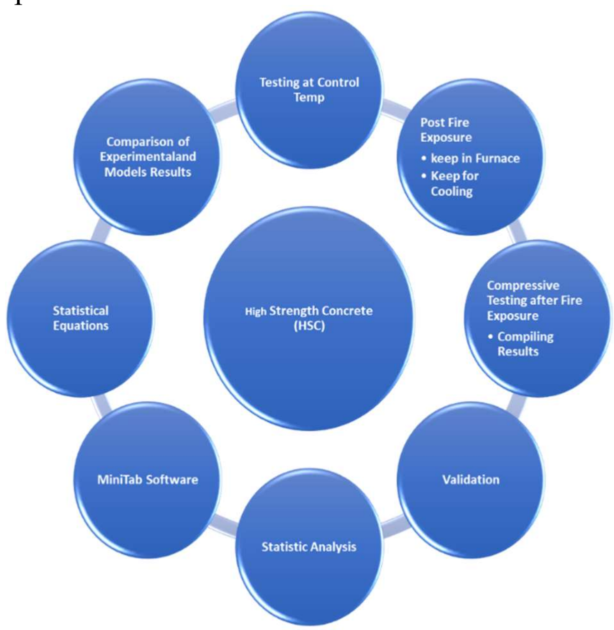

Figure 1: Flow Chart of Methodology

4 RESULTS AND DISCUSSIONS

4.1 Compressive Strength After Elevated Temperature

When concrete is subjected to elevated temperatures, both its physical and chemical properties are observed. Traditionally, concrete might experience a decrease in its strength due to an increase in temperature. Figure 1 clearly demonstrates the presence of two distinct groups of HSC, that have been exposed to different temperatures. G1 Control Mix consists of pure cement, while G2 Binary Mix (Ash) consists of cement that has been replaced by fly ash. The examination of Figure 1 indicates that an increase in temperature leads to a decrease in the strength of concrete. However, G2 exhibits superior performance compared to G1 under these conditions. The decrease in strength at a temperature of 300 ℃ compared to room temperature is 21% for G1 and 16% for G2. At a temperature of 500 ℃, the reduction reported was 41% and 35%, however at temperatures of 700 ℃ and 900 ℃, the reduction percentages were 77% and 70.1%, and 89% and 82%, respectively. Moreover, the decrease in compressive strength for G2 as compared to G1 at a temperature of 25,300 and 500 ℃ was measured to be 14%, 9% and 5% and at temperatures of 700 ℃, and 900 ℃, the increase in strength is found 11%, and 45% correspondingly.

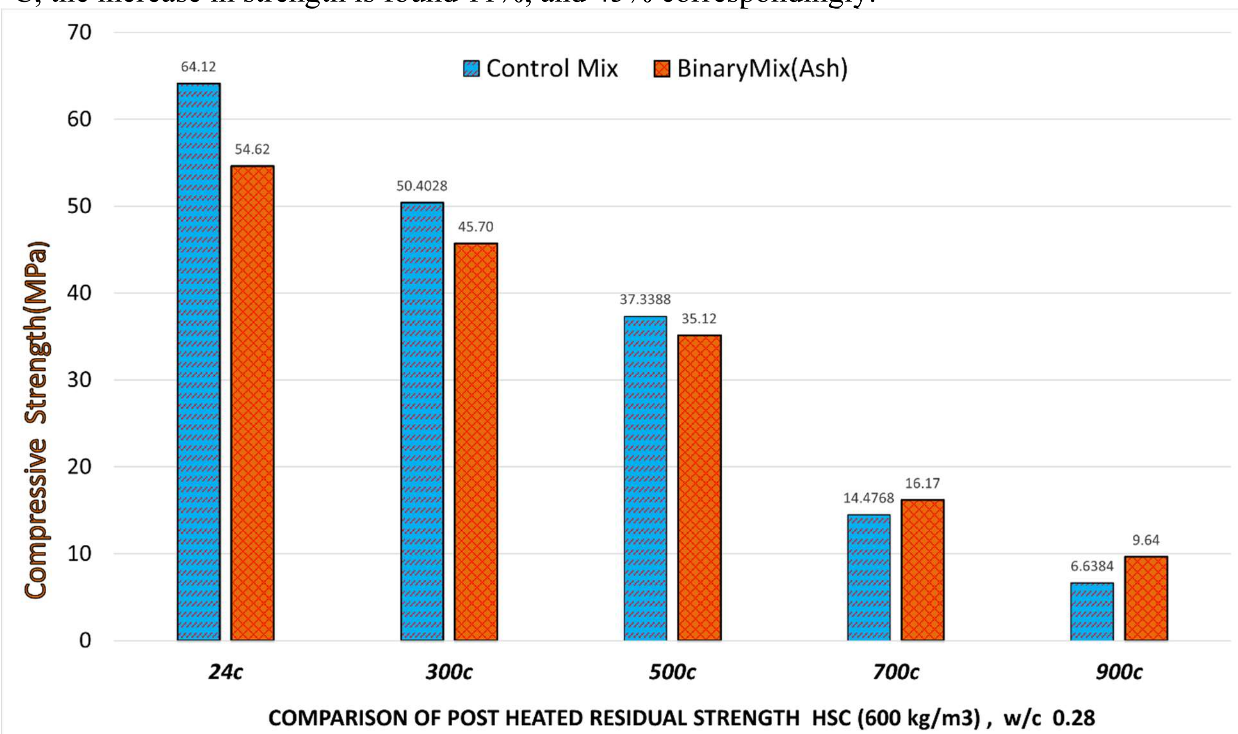

Figure 2: Residual Compressive Strength (HSC)

From the data, which is recorded from compressive testing, a statistical analysis is made for validation of data. For this purpose, Mini Tab software is used. After Multiple regression analysis 2 equation are formed. Table.1 shows these equations, EQ-1 is equation for prediction of residual compressive strength of Control Mix, and EQ-2 is equation for prediction of Binary Mix.

Table 1: Regression Equation for The Predicted Residual Compressive Strength of Concrete (25 ℃ - 900 ℃) HSC

Control Mix	Fc'=69.9082−1.83364∗$duration$−0.05083∗intensity	**Eq-1**
Binary Mix (Ash)	Fc'=60.2706−3.7611 ∗$duration$−0.04109 ∗intensity	**Eq-2**

Comparison between Experimental and Empirical results of G1 are shown in Figure 2. The experimental outcome was acquired within the boundaries of the laboratory. While the empirical results were calculated using mathematical equations after regression analysis which are shown in

Table 1. The difference between the G1, Experimental and Empirical values at 300°C is -6.2%. While at, 500 °C, 700 °C and 900 °C the difference was found to be 5.9%, 6.7%, 6.3% respectively.

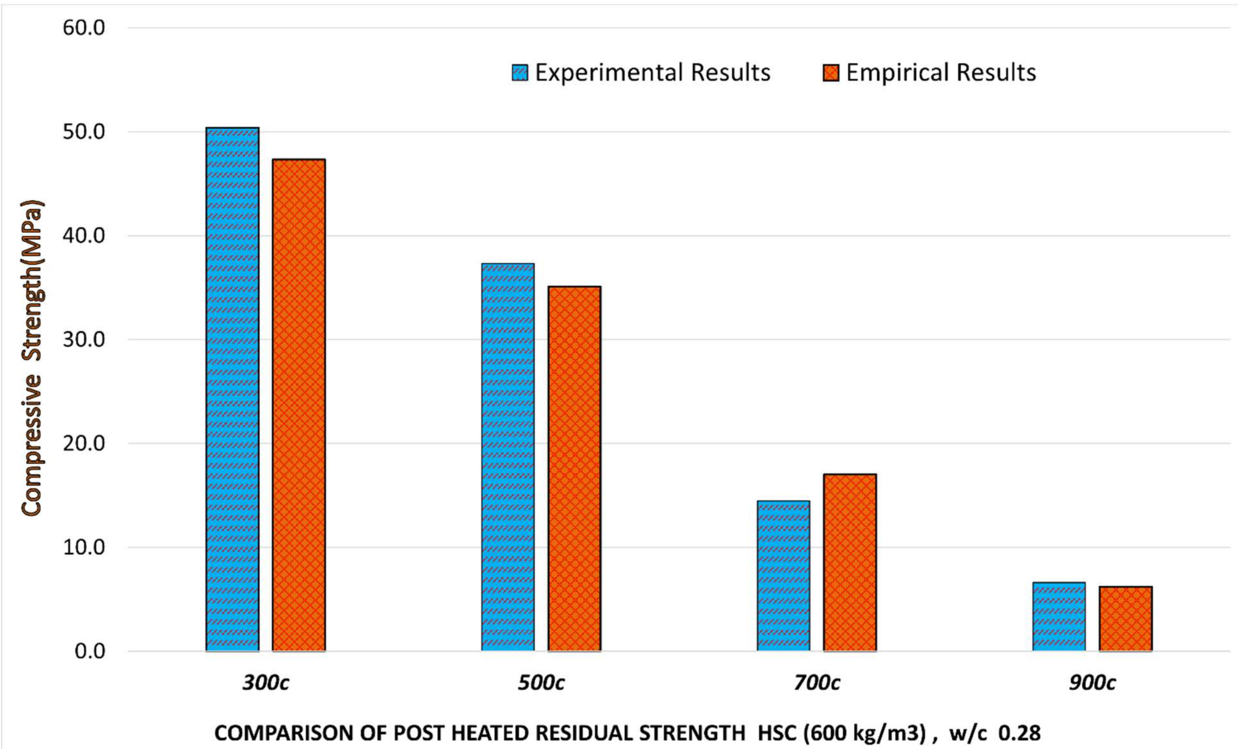

Figure 3:Comparison of Experimental and Empirical results (HSC) for G1

In Table 2, statistical analysis demonstrates that Predictor factors and compressive strength had a good correlation in the control mix (Multiple R = 0.9825). The predictors account for approximately 95.64% of the variability in compressive strength (R Square = 0.936254). The number of predictors is taken into consideration by the adjusted R Square (0.981263). The standard error is 2.19802. The association is marginally weaker but still significant for the binary mix with ash (Multiple R = 961276). R Square = 0.9802311 indicates that 92.04% of the variability in compressive strength is explained. The explanatory power of the adjusted R Square (0.902759) is still strong. The error standard is 2.179187. These findings support the accuracy of our models and provide insight into the variables affecting compressive strength.

Table 2:Regression Statistic Table for HSC 25℃-500℃

	Multiple R	R Square	Adjusted R Square	Standard Error
Control Mix	0.982562	0.936254	0.981263	2.19802
Binary Mix (Ash)	0.961276	0.9802311	0.902743	2.179187

Comparison between Experimental and Empirical results of G2 are shown in Figure 3. The experimental outcome was acquired within the boundaries of the laboratory. While the empirical results were calculated using mathematical equations after regression analysis which are shown in Table 1. The difference between the G1, Experimental and Empirical values at 300°C is 11%. While at, 500 °C, 700 °C and 900 °C the difference was found to be 6.1%, 8%, 14% respectively.

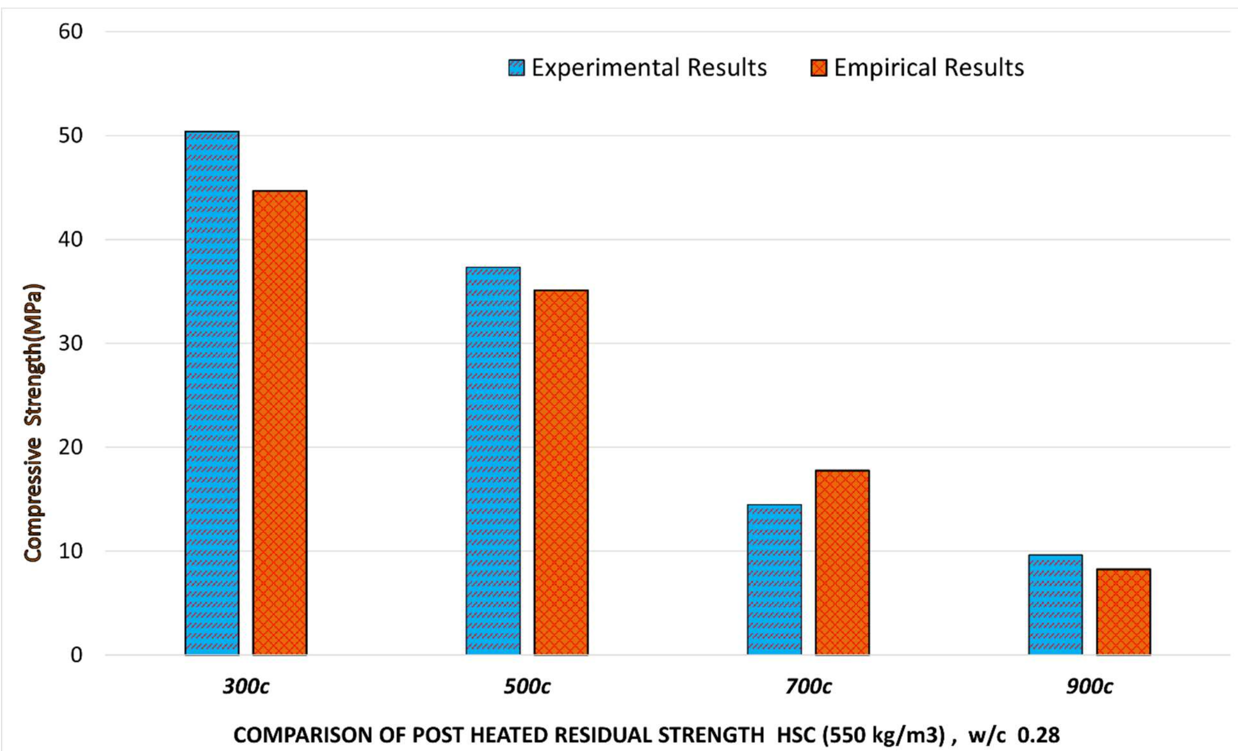

Figure 4:Comparison of Experimental and Empirical results (HSC) for G2

5 CONCLUSIONS

Following conclusions can be drawn from the conducted study:

1. This study concluded that at 300 ℃ compressive strength of G2 is 9% lower than G1. While at 900°C, G2 HSC have 45% more better strength than G1 because Fly ash acts as a pozzolan.
2. Furthermore, study shows that difference between the G1, Experimental and Empirical values at 300°C is 6.2%. While at 500 °C, 700 °C and 900 °C the difference was found to be 5.9%, 6.7%, 6.3% respectively.
3. Finally, it is concluded that difference between the G2, Experimental and Empirical values at 300°C is 11%. While at 500 °C, 700 °C and 900 °C the difference was found to be 6.1%, 8%, 14% respectively.
4. It is concluded that the computational model shows reasonable results so these equation are feasible.

6 FUTURE APPLICATIONS

The equations, EQ-1 and EQ-2, will be used for the evaluation of residual strength of HSC under these boundary conditions without any heavy resource extensive testing equipment while saving time and cost also.

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