RELIABILITY OF CORES TEST RESULT AT ELEVATED TEMPERATURE IN CASE OF NORMAL STRENGTH CONCRETE

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Abstract- In the last decades the assessment of in situ quality of concrete and integrity of concrete elements have been tested through non-destructive approaches. Under the constant fire and earthquake risk it is very mandatory to determine the seismic performance of the existing structure and consequently, the strength of the concrete used in the construction should be known to decide for repairing and strengthening. In this instance concrete cores are taken from different places of structure and their compressive strength is determined by a test carried out on these core specimens. The core test is usually involved in the area of the concrete industry to evaluate strength and occasionally it develops a unique tool for safety assessment of concrete structures. In this study, the effect of temperature has been investigated and the reliability of the core test has been evaluated. For this purpose, the cylindrical core was extracted from Normal strength concrete (NSC) specimens that were exposed to the temperature ranging from 300 ℃ to 900 ℃ with a constant duration of 4 hr. This study compares the difference between the heated actual cylinder and the core taken from them after curing of 90 days. The difference of cylindrical control and binary mix samples and extracted core revealed that there is a 6.67% and 7.81% difference at 300 ℃, while this difference was found to increase up to 8.72%, 9.81% at 500 ℃ Furthermore this value is recorded as 10.47%, 11.81%, and 11.97%, 13.56% at 700 ℃ and 900 ℃ respectively, whereas a total number of four (4) equation to developed through regression model for predicted strength of concrete for both cylindrical and extracted core whose R square value is 0.9666, 0.9794 and 0.9103, 0.8957 respectively.

Keywords- Normal Strength Concrete (NSC), Core Test, Temperature, Multiple Regression Model.

1. Introduction

Nowadays in the field of civil engineering concrete is a widely used material. Some reasons concrete used in construction commonly are that it is economical, easy to produce, workable, and better material but its physical and chemical properties to be changed when it is exposed to elevated temperatures causing severe deterioration and experiencing several rection and transformation and resulting in a cement gel can breakdown and reduce the durability of concrete [1-2]. Due to elevated temperature, the strength of concrete was reduced, especially the compressive which is the main concern in any construction. Concrete compressive strength is a direct requirement for all concrete structures that are essential to resist the applied load of whatever nature. The compressive of concrete is a good index of most other properties of practical significance. During the construction, a standard test specimen was inspected to ensure the concrete quality. These samples which give the strength of concrete are prepared, cured, and tested according to the related standard specifications and codes. In another way, determination of the actual strength of concrete through the destructive method in any existing structure is not easy for these reasons one of the most common approaches to determining in situ strength of concrete is to drill and core test [3-5].

Even though the way consists of an expansive and time-consuming process, core gives the reliable and useful results since they are tested mechanically to destruct[3]. The in situ compressive strength of the existing structure is required for the evaluation of structural safety. The in situ compressive strength of concrete is commonly determined by taking a core from different structural members and testing them in the laboratory environment but the strength of core concrete is affected due to many factors such as the core diameter, overlength ratio, coring orientation, core moisture condition at the time of testing [6-8]. During the initial evaluation, the outside of concrete may not be detected in less damaged components. In situ, and laboratory tests provide more precise information on the state and internal structure of concrete. The concrete compressive strength is the most important factor to estimate. It is critical to identify the thickness of the external layer of the member in which the concrete has been damaged to the point where it should be considered destroyed [9-11].

In the present study, the reliability of the core test has been investigated in NSC concrete after the elevated temperature in the range of (300 ℃ - 900 ℃) and their data can be set in multiple regression models to develop the regression equation for the predicted strength of concrete. The novelty of this research on the reliability of cores at elevated temperatures in the case of normal strength is significant for several sectors because it provides an innovative approach to understanding material behavior and improving structural performance in high-temperature situations.

2. Experimental Program

2.1 Materials

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

2.2 Cement

The ordinary Portland cement type – I was used according to the ASTM C150 in the preparation of concrete having a fineness of 4.12%.

2.3 Fine Aggregate

A local sand from lawrancepure was used as a fine aggregate. The sieve analysis was conducted following ASTM C136 having a fineness modulus of 2.81.

2.4 Coarse Aggregate

A local coarse aggregate from Margala was used with a maximum nominal size of 12.5 mm. According to ASTM C 136, a sieve analysis was to be carried out.

2.5 Mix Proportion

Normal Strength Concrete (NSC) was used in this study. Using water-cement ratios of 0.5 and the concrete was made in the ratio of 1:2.5:2.5. To achieve the slump of 3 inches by using water reducing admixture of 0.75 by weight of cement. The addition of a calculated amount of water and admixture was added to achieve the targeted slump.

3. Research Methodology

3.1 Casting and Curing Method

The concrete ingredients (cement, sand, and aggregate) were appropriately mixed in dry conditions. Confirming the proper mixing of concrete cubes and cylinders was cast upon on standard procedure of compacting and placing in three layers. The samples were demolded after drying and then the samples were kept under control condition for 90 days. All these samples were removed from the control environment and allowed to dry at room temperature.

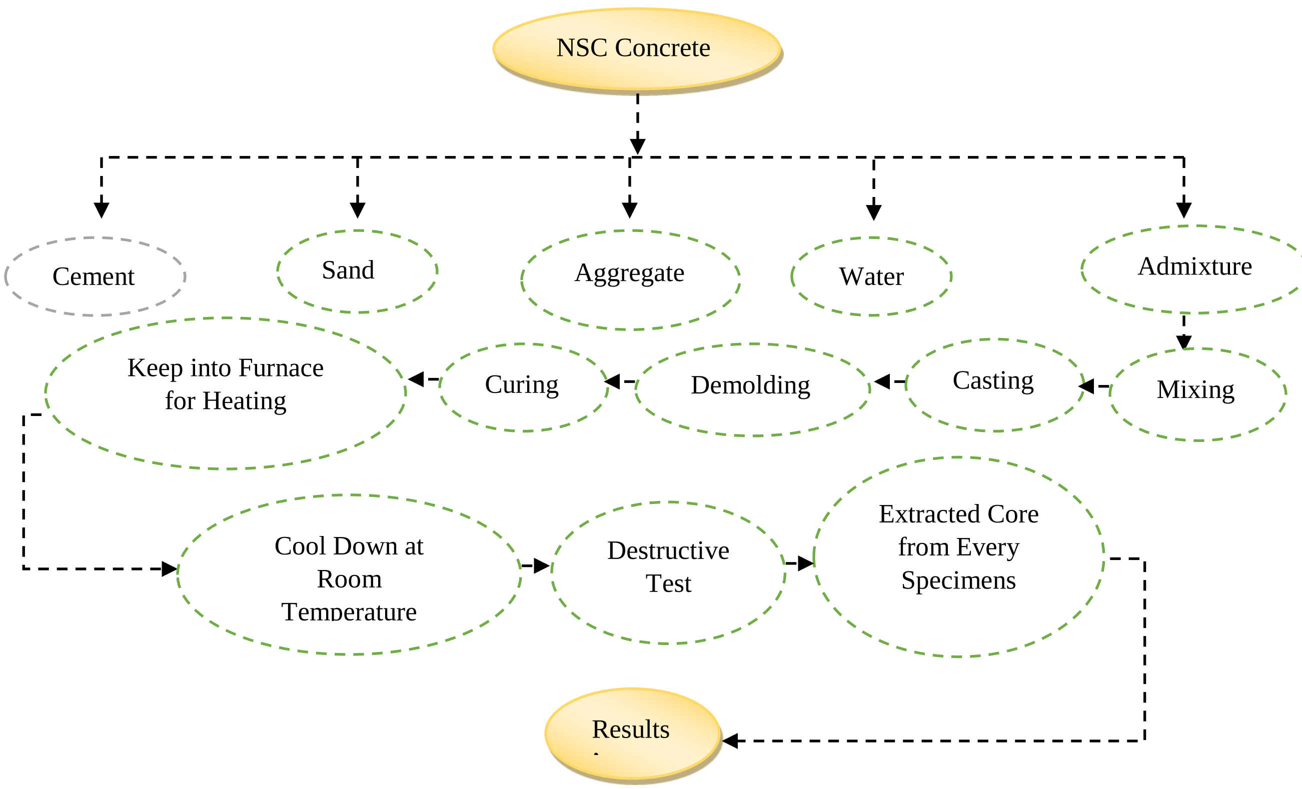

Figure 1: Methodology Flow Chart

3.2 Heating of Concrete

Locally furnace was developed to heat the specimens and its temperature was measured through thermocouples. The rising temperature of the furnace depended upon the arrangement supported by a valve and convey the appropriate thermocouples and thermostat fixed at each wanted compulsory point for a 4-hour constant duration. Throughout the mock testing, it was confirmed that the temperature rises in the furnace reached a maximum value of 1000 °C.

4. Results and Discussions

4.1 Compressive Strength After Elevated Temperature

When the concrete is exposed to higher temperatures its both physical and chemical properties are reported. Conventionally concrete can lose its strength to rising temperatures. It is evident from Figure 1 that there are NSC two groups that are experienced to the temperature the (G1) which contains pure cement and the (G2) cement replaced by fly ash.

The analysis of Figure 2 shows that when the temperature rises, the strength of concrete reduces but the G2 will perform better as compared to the G1. Due to the chemical reaction bond of cement, which is occurred from the hydration process, this bond would improve by partial replacement of pozzolanic materials[12-13].

The reduction in strength at 300 ℃ concerning room temperature in G1 and G2 are recorded is 28% and 22% respectively. Whereases at 500 ℃ the recorded reduction was 47% and 39% while at 700 ℃, 900 ℃ the reduction was 70% and 63%, and 82% and 74% respectively. Water is present in the mix of concrete which leads to enhance strength, but this water evaporates when the temperature is going to be increased from room environmental conditions this water evaporates from the concrete which leads to slowing down the chemical reactions[14-15]. Furthermore, the reduction between G1 and G2 at 300 ℃ was recorded is 6% while at 500 ℃, 700 ℃ and 900 ℃ the reduction was 8%, 7% and 8% respectively. It is clear from Table 1 that these are regression equations that were developed through Minitab software for the predicted compressive strength of concrete. Equation 1 shows the regression of G1 and 2 shows the regression of G2 (NSC) concrete.

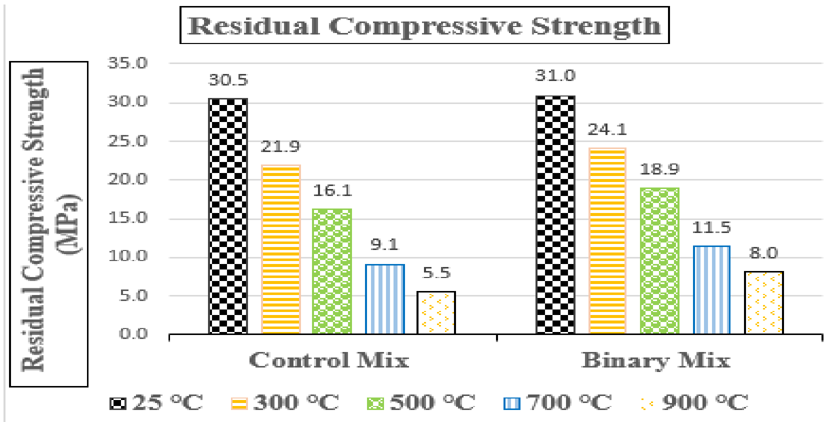

Figure 2: Residual Compressive Strength (NSC)

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

Type of Concrete	Regression Equation	R Square Value	Equation No.
NSC (Control Mix)	Y = (29.8999) – (0.0275*Fire Intensity)	0.9666	Eq. – 1
NSC (Binary Mix)	Y = (32.1282) – (0.0285*Fire Intensity)	0.9794	Eq. – 2

Figure 3 depicts the comparison between the G1 (Experimental and Empirical) results. The experimental result was obtained in the laboratory. While the empirical results were calculated from the mathematical equation shown in Table 1. The difference between the G1 (Experimental and Empirical) results at 25 °C is -4.23%. While at 300 °C, 500 °C, 700 °C and 900 °C the difference was recorded as -1.17%, 0.28%, 14.60%, and 2-5.19% respectively. As per findings of tensile strength which is the function of temperature were developed by multiple regression equations our research supports the regression equation in the case of compressive strength[16].

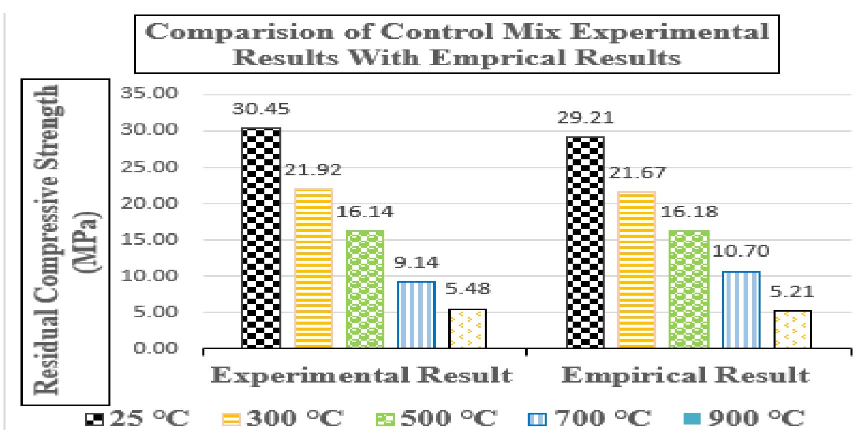

Figure 3: Comparison of Experimental and Empirical Results (NSC)

Figure 4 demonstrates the comparison between G2 (Experimental and Empirical) results. The experimental values were obtained in the laboratory while the empirical values were calculated from the mathematical equation which is clear in Table 1. The difference between G2 (Experimental and Empirical) recorded at 25 °C is 1.48%. While at 300 °C, 500 °C, 700 °C, and 900 °C difference was observed is -2.40%, -5.63%, 5.91%, and -24.39% respectively.

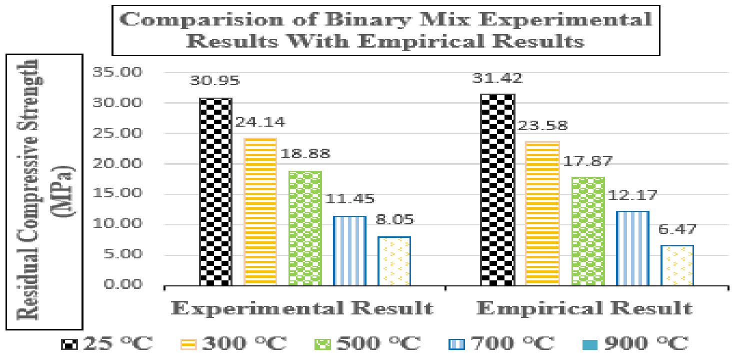

Figure 4: Comparison of Experimental and Empirical Results (NSC)

4.2 Residual Compressive Strength Using Core Method.

The core test is essential in evaluating the compressive strength, density, and permeability of concrete structures. The test determines the quality of the concrete mix, the strength of the concrete, and whether it meets the design requirements. The American Society for Testing and Materials (ASTM) provides standards for core testing procedures to ensure the accuracy and consistency of results. The core test is an integral part of the quality assurance process, and the data gathered can inform maintenance and repair decisions for concrete structures.

In conclusion, a core test is an essential tool in assessing the strength and durability of concrete structures. It provides critical information about the quality and performance of concrete, which can help identify potential issues and inform decisions regarding maintenance and repair. By following established testing procedures and guidelines, engineers and construction professionals can ensure the safety and endurance of concrete structures.

Figure 5 reveals that the residual compressive strength of concrete having a 75 x 150 mm core was extracted from a specimen. The figure shows that the strength of a concrete core can decrease with increasing temperature. The strength reduction was recorded in each temperature range concerning room temperature. The strength reduction observed at 300 °C in G1 and G2 were 31.32% and 25.43% respectively. While at 500 °C and 700 °C the reduction was 50.64%, 42.61%, and 72.48, 65.82% respectively. Similarly at 900 °C the reduction in strength recorded is 83.71% and 76.76 % respectively. Furthermore, the difference between G1 and G2 at 300 °C was observed is 5.88% while at 500 °C, 700 °C and 900 °C observed results were 8.03%, 6.66%, and 6.95% respectively. As per the aspect of core testing previous work support our work[17].

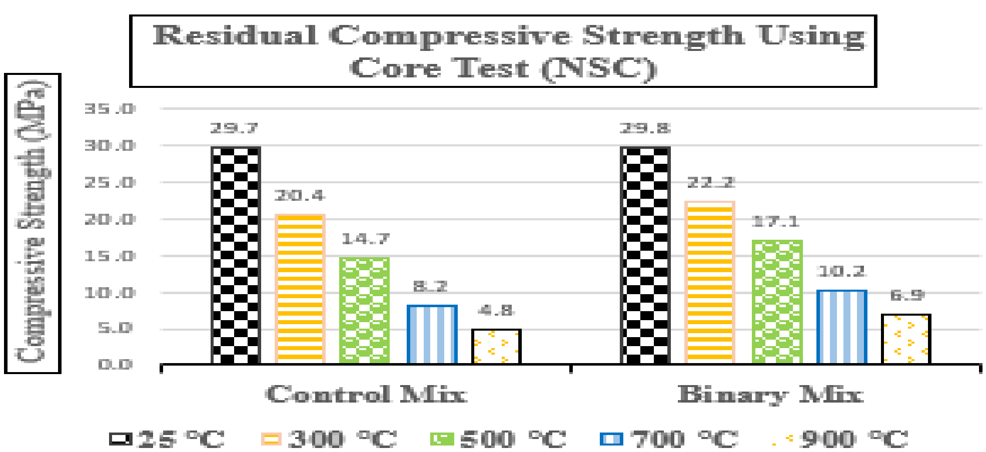

Figure 5: Residual Compressive Strength Using Core Test (NSC)

Table 2 communicates the regression equation of core test data which were developed through Minitab software which gives the predicted strength of concrete. Equation 3 shows the regression of G1 and 4 is the regression of G2.

Table. 2 Regression Equation for The Predicted Residual Compressive Strength of Concrete (25 °C - 900 °C) NSC

Type of Concrete	Regression Equation	R Square Value	Equation No.
NSC (Control Mix)	Y = (24.6909) – (0.0228*Fire Intensity)	0.9103	Eq. – 3
NSC (Binary Mix)	Y = (26.2719) – (0.0234*Fire Intensity)	0.8957	Eq. – 4

It is evident from Figure 6 the comparison between G1 (Experimental and Empirical) results. The experimental values were obtained in the laboratory while the empirical values were calculated from the mathematical equation which is clear in Table 2. The difference between G1 (Experimental and Empirical) recorded at 25 °C is 17.21%. While at 300 °C, 500 °C, 700 °C, and 900 °C the difference was observed is 10.59%, 7.08%, 15.69%, and 9.10% respectively. Similarly, Figure 7 communicates the differences between the G2 (Experimental and Empirical) Results. The difference observed at 25 °C was 11.10% while at 300 °C, 500 °C, 700 °C and 900 °C, the observed value was 10.88%, 12.65%, 5.63%, and 19.26% respectively.

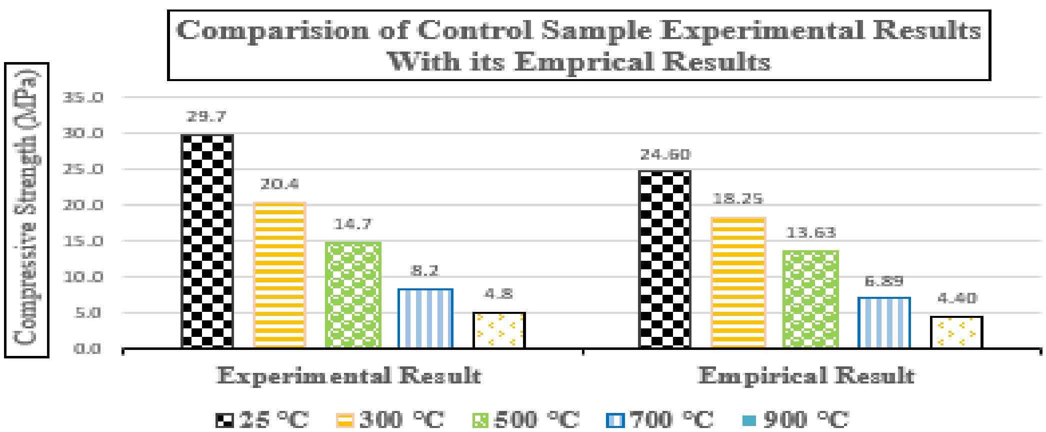

Figure 6: Comparison of Experimental and Empirical Results (NSC)

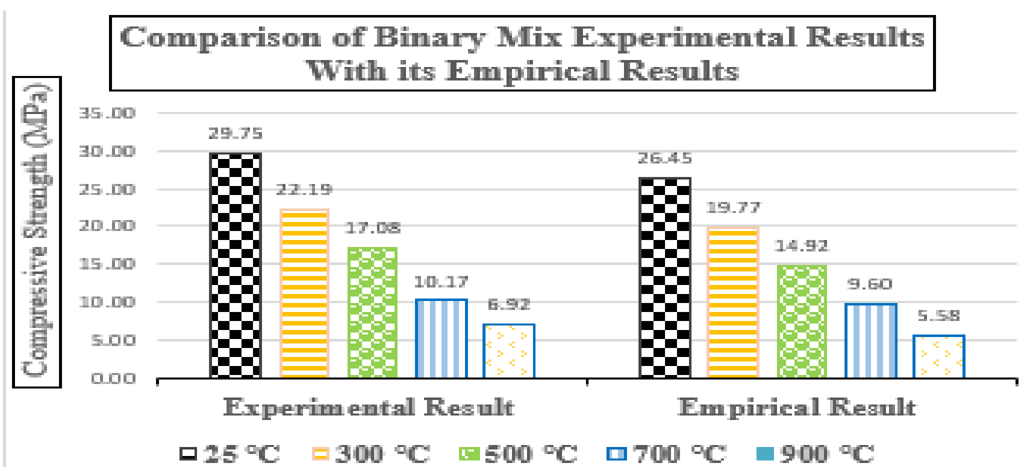

Figure 7: Comparison of Experimental and Empirical Results (NSC)

5. Practical Implementation

When a structure has been subjected to fire or high temperatures, you must evaluate the residual strength of the affected concrete. Researchers can provide insights into the performance of fire-damaged structures and aid in the decision-making process for repair, rehabilitation, or strengthening measures by investigating the reliability of cores test results at elevated temperatures.

6. Conclusions

The following conclusions can be drawn from the conducted study:

1 It is concluded from findings that G1 and G2 will perform relatively the same behavior at room temperature but at the higher temperature G2 perform better than G1. At room temperature, the difference between the actual and cores test in G1 and G2 is recorded as 2.58% and 4.12% respectively. Thus, the core results are very much reliable and show 100% real behavior at room temperature in connection to real testing.

2 The difference between the actual and core test at (300 °C – 500 °C) is relatively more as compared to room temperature which is recorded as 6.67%, 7.81%, and 8.72%, 9.81% in G1 and G2 respectively. Thus, the core results are partially reliable at medium elevated temperatures in connection to real behavior (Laboratory Destructive testing).

3 At higher temperatures (700 °C – 900 °C) this difference recorded between the actual and core test in G1 and G2 is 10.47%, 11.81%, and 11.97%, 13.56% respectively. Thus, the core results are not very reliable to defect the true scenario at higher elevated temperatures in connection to real testing**.**

7. Recommendations

It is extensively checking the behavior of concrete in binary mix condition at elevated temperature for 4 hours. It is recommended for future that check the behavior of concrete in case ternary mixes under elevated temperature for extreme exposure. Furthermore, the SEM test is also recommended before and after elevated temperature for internal behavior of the concrete.

8. Limitations

- The samples are heated with a 4-hour constant duration up to 900 °C.
- The normal strength concrete is made of many waters cement ratio, but this is made on a 0.5 water cement ratio.
- The core is taking from the specimens as per ASTM standard with a size of 75 mm x 150 mm.

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