ENHANCING PHYSICAL AND MECHANICAL PROPERTIES OF NORMAL CONCRETE DURING ACCIDENTAL FIRE BY EXERTING SUPER ABSORBENT POLYMER (SAP) IN CONCRETE

Maruf Hossain Hredoy*[1], Sk. Md. Kamal Uddin[2], Abhishek Sarkar[3] and Md. Jaber Hossain[4]

[1] *Graduate, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh, e-mail:*
marufhossain1701081@gmail.com
[2] *Assistant Professor, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh, e-mail:*
kamaluddin@ce.kuet.ac.bd
[3] *Postgraduate Student, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh, e-mail:*
sarkar1701019@gmail.com
[4] *Graduate, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh, e-mail:*
jabercekuet@gmail.com

***Corresponding Author**

ABSTRACT

Concrete may be exposed to high temperatures during fire accidents or when located adjacent to a furnace. The mechanical properties of concrete, including strength, elastic modulus, and volume deformation, experience a significant decrease when subjected to heat, resulting in reduced structural quality. Super Absorbent Polymer (SAP) is employed as an internal curing agent for concrete to enhance its strength. This study investigates the behaviour of concrete incorporating SAP's improved characteristics during fire accidents and estimates the duration a structure can endure before collapsing. To achieve this, the study conducted time-temperature profiles, tests for compressive and tensile strength, water penetration, weight loss due to heating, and inspections for surface cracking to evaluate SAP's performance. Two types of cylindrical specimens were created: Normal Concrete (NC) without the polymer and Polymer Concrete (PC) containing 0.1% of the polymer by weight of the cement. Cylindrical specimens measuring 100 mm × 200 mm were heated to four different temperatures (200°C, 400°C, 600°C, and 800°C) in an electric furnace for a consistent 2-hour duration, followed by a 1-hour cooling period at room temperature. A data recorder equipped with a K-type thermocouple monitored the furnace and specimen temperatures. The time-temperature profiles revealed that the PC specimen absorbed heat at a slower rate compared to the NC specimen and also dissipated heat more gradually. Both NC and PC specimens experienced reductions in compressive and tensile strength as the temperature increased. Nevertheless, the water penetration depth of the PC specimens remained lower than that of the NC specimens across all tested temperatures. While both NC and PC specimens lost weight with rising temperatures, the PC specimens exhibited slightly greater weight loss than the NC specimens. Cracking on the surface of the specimens of both types commenced between 600°C and 800°C, with the NC specimens displaying more intense cracking compared to the PC specimens. Concrete spalling at 600°C was observed exclusively in NC specimens. The findings suggest that more time is available to implement precautions against fire incidents involving PC, making it a more viable option than NC for improving the characteristics of concrete buildings exposed to high temperatures and ensuring safety during fire emergencies.

Keywords:*Fire Accidents, Super Absorbent Polymer (SAP), Concrete Structures, Internal Curing Agent, Time-Temperature Profiles.*

1. INTRODUCTION

The composition of concrete is a mixture of fine and coarse aggregates bound together by a fluid cement paste that dries out over time. It is currently the most commonly used building material in the world. Additionally, the kind and properties of the aggregates have a big impact on how concrete reacts to high temperatures (Arioz, 2007). Due to its composite nature, wherein its constituents have different properties, as well as its sensitivity to moisture and porosity, concrete has particularly complex thermal properties. When concrete is exposed to high temperatures, it changes significantly in both its physical structure and chemical composition. The main consequences of high temperatures on concrete include the cement paste drying out, becoming more porous, changing the moisture content, changing the rate of thermal expansion, shifting the pore pressure, losing strength, and experiencing incompatibility, thermal creep, and excessive pore pressure-induced thermal spalling (Krishna et al., 2019).

Significant financial and human losses result from building fires, and these losses are made worse by prevailing problems like poverty, poor housing conditions, and low levels of education. Due to their historical susceptibility to various disasters, residential, commercial, and industrial projects frequently receive a large portion of the total construction costs. One of the main concerns about how high temperatures affect concrete is comprehending the complex changes that take place in the material when it heats up. At the structural level, spalling occurs frequently in concrete, with the majority of cracks running parallel to the heated surface. Notably, heating significantly alters properties like colour, surface texture, density, volume, compressive strength, and elastic modulus, which reduces structural stability. The way that concrete behaves in hot weather is primarily related to the numerous fires that happen in buildings, high-rise buildings, tunnels, and drilling platforms (Hager, 2014). Concrete's chemical makeup and physical characteristics are significantly altered by high temperatures, with calcium silicate hydrate water dehydration becoming a significant factor above 1100°C. Many studies investigating the behaviour of concrete in high-temperature scenarios have been carried out over the years (Awal & Shehu, 2015).

Superabsorbent polymers (SAPs) belong to a class of polymer materials known for their exceptional water-absorption capacity, often exceeding their own weight. SAPs exhibit robust waterabsorption capabilities. Upon introduction of SAP into the mix, it absorbs water, reducing the free water content in the cement paste. This, in turn, impedes the early hydration of cement and results in a period of reduced strength in the concrete. Consequently, concrete experiences a substantial loss in early strength. However, as curing time progresses, SAP particles release water into the cement paste, augmenting the free water content and facilitating cement hydration reactions. This leads to a swift improvement in concrete strength, with the loss of strength at 28 days being less significant compared to that at three days (Shan & Guo, 2015).

The main objectives of this study are to investigate the impact of prolonged exposure to high temperatures on the physical and mechanical properties of concrete containing SAP. The primary goal of this research is to assess the performance of concrete when incorporating superabsorbent polymer (SAP) at varying temperatures. Previous studies have predominantly focused on the impact of SAP on concrete properties. Additionally, it is essential to explore the interplay between concrete and SAP, considering both the physical and mechanical characteristics of SAP under different temperature conditions.

Concrete is a commonly used structural material in construction, appreciated for its inherent strengths, durability, ease of fabrication, and non-combustible characteristics that set it apart from other construction materials. However, concrete is vulnerable to damage when exposed to fire, which not only results in property damage but can also lead to injuries or fatalities and even job losses, as many structures destroyed by fire are not rebuilt. Concrete structural elements employed in buildings must conform to specific fire safety requirements outlined in building codes. Examining the effects of subjecting concrete to various elevated temperatures is crucial for assessing the mechanical and physical properties and determining whether a building can remain in use after exposure to fire.

2. METHODOLOGY

2.1 Materials

Cement: As shown in Figure 1(a), the Ordinary Portland cement (OPC) based binders have been extensively employed due to their wide availability and cost-effectiveness. OPC is a fine powder that, when mixed with water, forms the cement-like binder responsible for bonding the particles in concrete. While OPC may have lower resistance to chemical attacks, it exhibits excellent resistance to cracking and shrinkage. The physical properties of ordinary Portland cement were assessed in the laboratory, and the results are presented in Table 1.

Table 1: Physical Properties of Ordinary Portland Cement (OPC)

Characteristics	Tested Value	Standard Value (ASTM C187)
Normal Consistency	24.9	-
Initial Setting Time (min)	130	>45
Final Setting Time (min)	245	<375

Fine Aggregates: Fine aggregates made from Sylhet sand were used to create cylindrical specimens, as shown in Figure 1(b). The properties of fine aggregates, such as unit weight, specific gravity, and moisture content, were determined following the testing standards of ASTM C128, ASTM C136, and ASTM C129, as shown in Table 2.

Coarse Aggregates: Coarse aggregates of 12.5 mm downgrade black stone were employed after sampling, as shown in Figure 1(c). The specific gravity, moisture content, and unit weight of these coarse aggregates were determined according to the standard code, as previously mentioned, as shown in Table 2.

Super Absorbent Polymer (SAP): Super Absorbent Polymer (SAP) is an organic macromolecule substance that has found application in modern civil engineering as a novel internal curing agent. SAP possesses carboxyl (–COOH), hydroxyl (–OH), and other highly hydrophilic groups and features a three-dimensional crosslink network structure (Ding et al.,2017).This research utilised 0.1% SAP of cement content under dry conditions, as shown in Figure 1(d). Each gram of dry SAP can absorb 32 grams of water, as shown in Table 2.

Table 2: Properties of Fine Aggregates, Coarse Aggregates, and Super Absorbent Polymer (SAP)

Parameters	Fine Aggregates	Coarse Aggregates	SAP
Nominal Max Size (mm)	4.75 mm	12.5 mm	0.38 mm
Unit Weight (kg/m³)	1555	1490	-
Specific Gravity	2.48	2.71	-
Water Absorption (%)	2.80	1.95	32 (g/g)
Moisture Content (%)	1.2%	2.73%	-
Fineness Modulus	2.40	3.96	-
Colour	Red	Black	White


(a) (b) (c) (d) (e)

Figure 1: (a) Cement, (b) Fine Aggregates, (c) Coarse Aggregates, (d) SAP, and (e) Thermocouple

Thermocouple: A Type K thermocouple comprises temperature sensors containing chrome and Alumel conductors. These thermocouples have a wide temperature range, with Thermocouple grade wire ranging from -270 to 1260°C and Extension wire from 0 to 200°C. A type K thermocouple is made when a wire of Nickel-Chromium is welded to a wire of Nickel-Alumel. A 4-inch stick K-type thermocouple was used in this research work, as illustrated in Figure 1(e).

2.2 Construction of Concrete Specimens

Concrete Mix Design: All concrete specimens utilised in this research adhered to a prescribed mix ratio, as illustrated in Table 3, following concrete mix design guidelines outlined in (ACI 211.1-91).

Table 3: Mix Proportions of Concrete

Sample	Cement	Fine Aggregate	Coarse Aggregate	Water	SAP
Without SAP	1	1.77	1.85	0.47	0%
With SAP	1	1.77	1.85	0.47	0.1%

Concrete Mixing Methods: The concrete ingredients, including cement, aggregates, and water, were mixed using both mechanical and manual methods. Specifically, normal concrete samples were manually mixed, while polymer concrete samples were mechanically mixed, as depicted in Figure 2(a).

Casting of Concrete Specimens:46 specimens were prepared for this research, consisting of 23 normal concrete (NC) specimens and the remaining 23 polymer concrete (PC) specimens. Before casting, standard-sized moulds measuring 100mm x 200mm were prepared by applying a greasing agent, as shown in Figure 2(b).The slump value was measured to achieve the required strength, as depicted in Figure 2(c). The slump value for normal concrete was 75mm, while for polymer concrete, it was 100mm.Finally, cylindrical specimens were cast, as shown in Figure 2(d). A K-type thermocouple was inserted up to a depth of 4 inches at the midpoint from the upper surface of the concrete after it was poured into the mould.

Demoulding of Concrete Specimens: After 24 hours, the cylindrical specimens were de-moulded to prepare for curing, as displayed in Figure 2(e).

Table 4: Types and Number of Specimens for Testing Concrete

Temperature (°C)	Number of Specimens	Specimen Designation	Types of Tests
Ambient Temperature, 25	3	NC 25 (1), NC 25 (2), NC 25 (3)	Compressive Strength
	3	PC 25 (1), PC 25 (2), PC 25 (3)	
	1	NC 25 (4)	Tensile Strength and Water Penetration
	1	PC 25 (4)	
200	3	NC 200 (1), NC 200 (2), NC 200 (3)	Compressive Strength
	3	PC 200 (1), PC 200 (2), PC 200 (3)	
	1	NC 200 (4)	Tensile Strength and Water Penetration
	1	PC 200 (4)	
400	3	NC 400 (1), NC 400 (2), NC 400 (3)	Compressive Strength
	3	PC 400 (1), PC 400 (2), PC 400 (3)	
	1	NC 400 (4)	Tensile Strength and Water Penetration
	1	PC 400 (4)	
600	3	NC 600 (1), NC 600 (2), NC 600 (3)	Compressive Strength
	3	PC 600 (1), PC 600 (2), PC 600 (3)	
	1	NC 600 (4)	Tensile Strength and Water Penetration
	1	PC 600 (4)	
800	3	NC 800 (1), NC 800 (2), NC 800 (3)	Compressive Strength
	3	PC 800 (1), PC 800 (2), PC 800 (3)	

	1	NC 800 (4)	Tensile Strength and Water Penetration
	1	PC 800 (4)	

Curing of Concrete Specimens: All specimens were fully submerged in water following demoulding to ensure proper concrete hardening and curing, as shown in Figure 2(f).

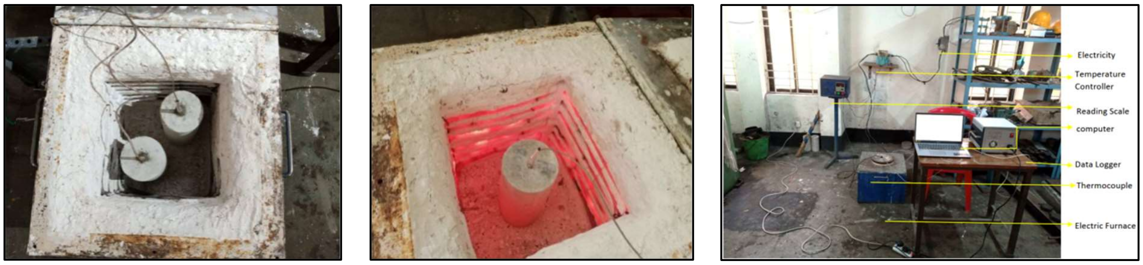
Designation of Concrete Specimens: The concrete tests conducted in this research were designated as indicated in Table 4. In the table, "NC" signifies normal concrete, "PC" signifies polymer concrete, and the temperature values represent the heating temperatures in an electric furnace for 2 hours. After cooling for 1 hour, the compressive strength was determined.


(a) (b) (c) (d) (e) (f)

Figure 2: Construction of Concrete Samples: (a) Mechanical Concrete Mixing, (b) Preparing Moulds, (c) Slump Test, (d) Casting of Concrete in ConcreteMoulds, (e) Demoulding, (f) Curing

2.3 Data Collection Process

Adigitaldata logger was utilised to monitor the heating process in the furnace and develop a time-temperature profile for both the specimen and the furnace temperature. The digital data logger facilitated this data collection process.Two specimens were concurrently placed inside an electric furnace for heating, as shown in Figure 3(a). During the heating of polymer concrete, vapour and smoke were emitted from the furnace due to the significant water content within the concrete's molecular structure.The specimens were heated to temperatures of 200°C, 400°C, 600°C, and 800°C for two hours, as displayed in Figure 3(b). Subsequently, a one-hour natural air cooling process was employed. The time-temperature profile for the specimen and furnace was developed using a data logger connected to a computer with multi-scan software. The entire setup, including the furnace, is depicted in Figure 3(c).



(a) (b) (c)

Figure 3: Data Collection: (a) Sample Placement in Furnace, (b) Heating Process, (c) Experimental Setup for Data Recording with a Computer

2.4 Compressive Strength Test

Following the exposure of the specimens to various temperatures, compressive strength tests were conducted. All specimens were vertically placed on load cells, as shown in Figure 4(a). The compressive strength was calculated by dividing the crushing load by the cross-sectional area of the sample.

2.5 Tensile Strength Test

The tensile strength test was exclusively performed, followed by a water penetration test. This involved subjecting both normal and polymer concrete specimens to water pressure. The specimens were then split along the longitudinal direction using a compressive machine, as depicted in Figure

4(b), to determine the tensile strength and the depth of water penetration. Only one cylindrical specimen was used for each set, following ASTM C 496.

2.6 Water Penetration Test

Following BS EN 12390-8 standards, a water penetration test was conducted. The samples were exposed to different elevated temperatures and placed vertically on the pressure cell, as shown in Figure 4(c). The standard water pressure used in the test was 72 Psi.


(a) (b) (c)

Figure 4: (a) Compressive Strength Test, (b) Tensile Strength Test, and (c) Water Penetration Test

3. RESULTS

In this study, approximately 23 concrete cylinders were tested to investigate the impact of high temperatures on the physical and mechanical properties of concrete produced with Super Absorbent Polymer (SAP).

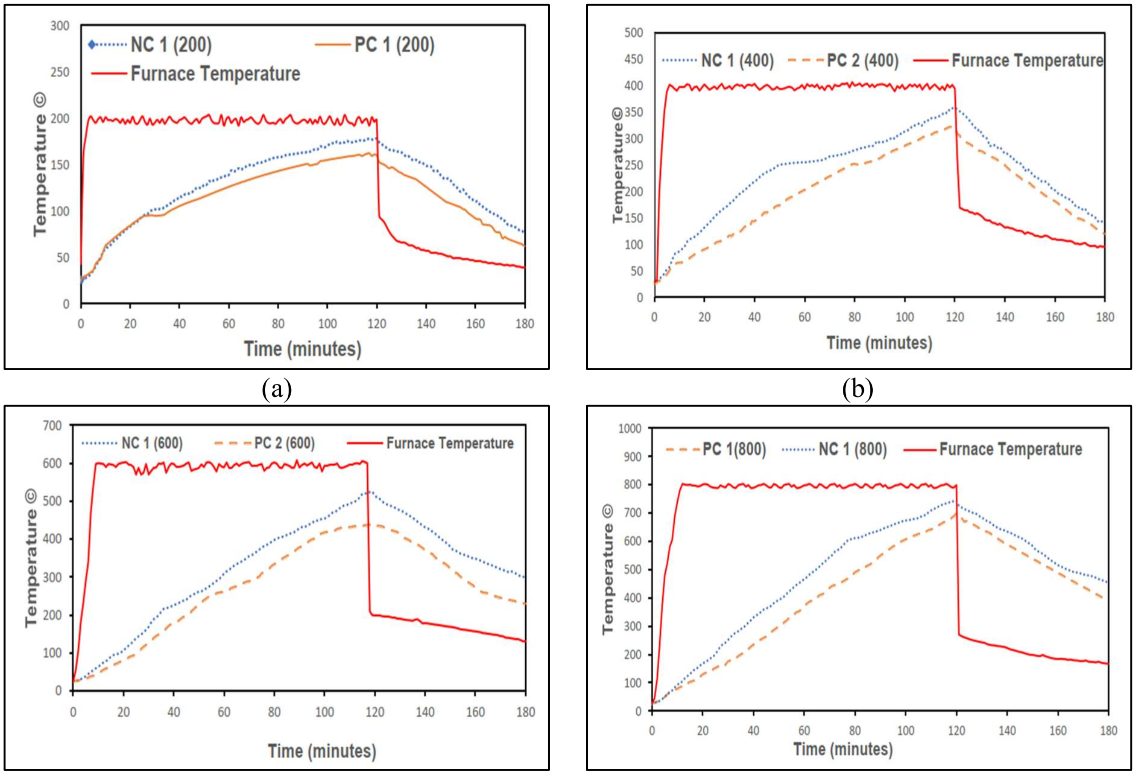
3.1 Time-Temperature Profiles of Concrete Specimens

Sustained high temperatures of 200°C, 400°C, 600°C, and 800°C were applied to four specimens labelled as A, B, C, and D. For each exposure for each temperature.,Two specimens were used to measure the temperature using thermocouples for both Normal Concrete (NC) and Polymer Concrete (PC) specimens. Time-Temperature Profiles for each trial were established, as shown in Figure 5.

Table 5 presents a comparison of the total Heating Time of Specimens heated at different temperatures. The temperature variance between NC and PC specimens was 13°C and 18°C at 200°C for heating durations of 60 and 120 minutes. At 400°C, the temperature difference increased to 34°C and 35°C during the same time intervals. Similarly, at 600°C, the temperature gap remained at 35°C and 70°C for 60 and 120 minutes, respectively. Finally, at 800°C, the temperature disparity expanded to 70°C and 43°C over the 60 and 120-minute heating periods.

Table 5: Comparison of Total Heating Time of Specimens

Furnace Temperature (°C)	**Total Time Heated**	**Temperature of Specimen at 60 mins (°C)**		**Temperature of Specimen at 120 mins (°C)**	
		NC	**PC**	**NC**	**PC**
200	2 hours	138	125	178	160
400		256	222	358	323
600		315	280	535	465
800		451	381	722	679



(a) (b)

(c) (d)

Figure 5: Comparison of Time-Temperature Profiles between NC and PC at Different Temperatures: (a) 200°C, (b) 400°C, (c) 600°C, and (d) 800°C.

3.2 Compressive Strength of Concrete Specimens

Table 6: Compressive Strength of NC and PC Specimens at Different Temperatures

	Normal Concrete (NC)				Polymer Concrete (PC)			
Temperature Range (°C)	**Specimen ID**	**Compressive Strength (MPa)**	**Avg. Compressive Strength (MPa)**	**Relative Compressive Strength (%)**	**Specimen ID**	**Compressive Strength (MPa)**	**Avg. Compressive Strength (MPa)**	**Relative Compressive Strength (%)**
Ambient Temperature, 25	NC 25 (1)	34	28	100%	PC 25 (1)	43	37	100%
	NC 25 (2)	23			PC 25 (2)	32		
	NC 25 (3)	27			PC 25 (3)	37		
200	NC 200 (1)	23	27	96%	PC 200 (1)	38	32	86%
	NC 200 (2)	31			PC 200 (2)	26		
	NC 200 (3)	28			PC 200 (3)	32		
400	NC 400 (1)	17	16	57%	PC 400 (1)	20	22	59%
	NC 400 (2)	15			PC 400 (2)	24		
	NC 400 (3)	16			PC 400 (3)	22		
600	NC 600 (1)	7	8	29%	PC 600 (1)	10	12	33%
	NC 600 (2)	9			PC 600 (2)	12		
	NC 600 (3)	8			PC 600 (3)	13		
800	NC 800 (1)	2	2.5	9%	PC 800 (1)	3	3.5	10%
	NC 800 (2)	3			PC 800 (2)	2.5		
	NC 800 (3)	2.5			PC 800 (3)	5		

The compressive strength of normal concrete (NC) and polymer concrete (PC) at various elevated temperatures, including 25°C, 200°C, 400°C, 600°C, and 800°C, is detailed in Table 6. The relative compressive strength of the NC specimen exhibited a decreasing trend at various temperatures, registering values of 100%, 96%, 57%, 29%, and 9% for 25°C, 200°C, 400°C, 600°C, and 800°C, respectively. A slight decrease was noted at 200°C, followed by a significant reduction from 400°C to 600°C. Similarly, at different temperatures (25°C, 200°C, 400°C, 600°C, 800°C), the relative compressive strength of the NC specimen declined, measuring 100%, 86%, 59%, 33%, and 10%, respectively. A substantial decrease was particularly noticeable from 200°C. Throughout all temperature ranges, the compressive strength of the PC specimen consistently surpassed that of the NC specimen. This distinction is evident in Figure 6. Moreover, the relative compressive strength of the PC specimen consistently exceeded that of the NC specimens. Both SAP and NC concrete displayed a shear failure pattern in their compressive strength, as depicted in Figures 8(a) and 8(b).

3.3 Tensile Strength of Concrete Specimens

Table 7: Tensile Strength of NC and PC Specimens at Different Temperatures

Temperature Range (°C)	**Normal Concrete (NC)**			**Polymer Concrete (PC)**		
	Specimen ID	**Tensile Strength (MPa)**	**Relative Tensile Strength (%)**	**Specimen ID**	**Tensile Strength (MPa)**	**Relative Tensile Strength (%)**
25	NC 25 (4)	2.28	100	PC 25 (4)	2.35	100
200	NC 200(4)	1.79	79	PC 200 (4)	2.02	86
400	NC 400 (4)	0.6	27	PC 400 (4)	1.20	51
600	NC 600 (4)	0.35	16	PC 600 (4)	0.79	34
800	NC 800 (4)	0.1	4	PC 800 (4)	0.2	8.5

The tensile strength of the NC specimen was measured at 2.28, 1.79, 0.6, 0.35, and 0.1 MPa at temperatures of 25°C, 200°C, 400°C, 600°C, and 800°C, respectively. The relative tensile strength of the NC specimen was recorded as 100%, 79%, 27%, 16%, and 4% at the same temperatures, as shown in Table 7. At 200°C, there was a slight decrease in relative strength, but a significant change occurred between 200°C and 400°C. The predominant failure patterns observed in the tensile strength test for the NC specimen were substratum failure, with some instances of pure interface failure. In comparison, the tensile strength of the PC specimen was found to be 2.35, 2.02, 1.20, 0.79, and 0.2 MPa at temperatures of 25°C, 200°C, 400°C, 600°C, and 800°C. The relative tensile strength of the PC specimen was determined as 100%, 86%, 51%, 34%, and 8.5% at the respective temperatures. Figure 7 illustrates that the tensile strength of the NC specimen decreased with an increase in temperature, with a significant decline between 200°C and 400°C, followed by a gradual decrease between 400°C and 600°C. The primary failure pattern for the PC specimen in the tensile strength test was interface failure with partial substrate, along with some instances of substrate failure. Notably, the tensile strength of the PC specimen exceeded that of the NC specimen, and the relative tensile strength of PC specimens was consistently greater than that of NC specimens, as shown in Figures 8(c) and 8(d).

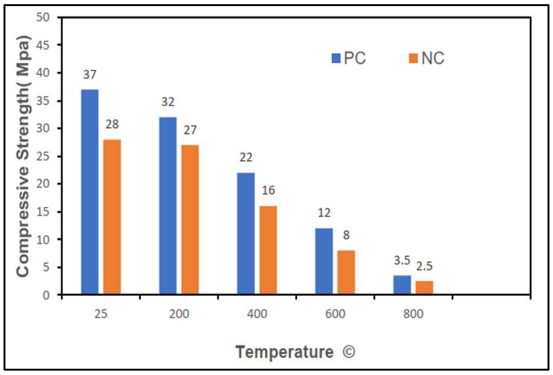


Figure 6: Comparison of Compressive Strength between NC and PC with VaryingTemperature

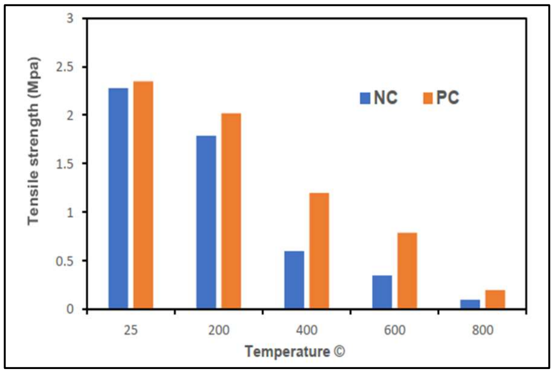


Figure 7: Comparison of Tensile Strength between NC and PC with VaryingTemperature

(a) (b) (c) (d)

Figure 8: Failure Patterns of (a) Compressive Strength Test of NC, (b) Compressive Strength Test of PC, (c) Tensile Strength Test of NC, (d) Tensile Strength Test of PC.

3.4 Water Penetration Depth of Concrete Specimens

The results fromthe water penetration depth test for the NC specimen revealed values of 32mm, 85mm, and 115mm at temperatures of 25°C, 200°C, and 400°C, respectively, as shown in Table 8. However, at 600°C and 800°C, the NC specimen could not withstand high water pressure (72 Psi). The water penetration depth of the NC specimen demonstrated a rapid increase with a rise in temperature. In contrast, the water penetration depth of the PC specimen exhibited a slower increase with an elevation in temperature. Notably, the water penetration depth of the NC specimen exceeded that of the PC specimen, as illustrated in Figure 9. In the PC specimen, the superabsorbent polymer (SAP) created a jelly-like structure that replaced air voids and porosity. This structural modification in the PC specimen effectively blocked water penetration compared to the NC specimen.

Table 8: Water Penetration Depth of NC and PCSpecimens at Different Temperatures

Temperature Range (°C)	Normal Concrete (NC)			Polymer Concrete (PC)		
	Specimen ID	Water Penetration Depth (mm)	Relative Penetration Depth (%)	Specimen ID	Water Penetration Depth (mm)	Relative Penetration Depth (%)
25	NC25 (4)	32	100	PC25 (4)	28	100
200	NC200 (4)	85	265	PC200 (4)	36	129
400	NC400 (4)	115	360	PC400 (4)	46	164
600	NC600 (4)	Failed Instantly	Failed Instantly	PC600 (4)	Failed Instantly	Failed Instantly
800	NC800 (4)	Failed Instantly	Failed Instantly	PC800 (4)	Failed Instantly	Failed Instantly

3.5 Weight Loss of Concrete Specimens

The weight changes in normal concrete after heating at 200°C, 400°C, 600°C, and 800°C are detailed in Table 9. The weight loss of the NC specimen exhibited a rapid increase at 200°C due to the vaporisation of moisture, as shown in Figure 11. Subsequently, the weight loss gradually escalated between 400°C and 800°C, due to the cement mortar's dehydration. Similarly, the weight loss of the PC specimen experienced a swift increase at 200°C, primarily caused by the vaporisation of moisture. The weight loss continued to rise gradually between 400°C and 800°C due to the dehydration of cement mortar. Notably, the weight loss of the PC specimen surpassed that of the NC specimen, as depicted in Figure 10. This discrepancy is attributed to the polymer's enhanced water absorption, displacing air voids in concrete and providing internal curing. The continuous vaporisation of water during heating led to a consistently greater weight loss in the PC specimen compared to the NC specimen.

Table 9: Loss in Weight of NC and PC Specimens at Different Temperatures

	Normal Concrete (NC)			**Polymer Concrete (PC)**		
Temperature range (°C)	**Specimen ID**	**Weight Loss (%)**	**Avg. Weight Loss**	**Specimen ID**	**Weight Loss (%)**	**Avg. Weight Loss**
Ambient Temperature, 25	PC 25 (1)	0.0	0.0	PC 25 (1)	0.0	0.0
	NC 25 (1)	0.0		PC 25 (2)	0.0	
	NC 25 (2)	0.0		PC 25 (3)	0.0	
200	NC 25 (3)	5.48	5.93	PC 200 (1)	5.0	6.6
	NC 200 (1)	6.35		PC 200 (2)	5.57	
	NC 200 (2)	5.97		PC 200 (3)	9.23	
400	NC 200 (3)	8.50	8.48	PC 400 (1)	9.83	9.9
	NC 400 (1)	8.86		PC 400 (2)	9.89	
	NC 400 (2)	8.10		PC 400 (3)	8.10	
600	NC 400 (3)	10.15	10.18	PC 600 (1)	11.32	11.24
	NC 600 (1)	10.16		PC 600 (2)	11.02	
	NC 600 (2)	10.24		PC 600 (3)	11.39	
800	NC 600 (3)	10.39	10.45	PC 800 (1)	12.55	12.87
	NC 800 (1)	10.38		PC 800 (2)	12.66	
	NC 800 (2)	10.60		PC 800 (3)	13.42	

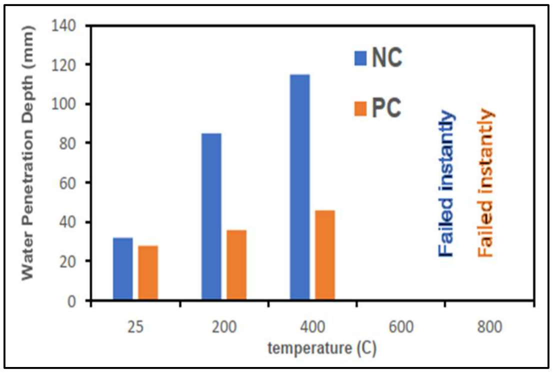


Figure 9: Comparison of Water Penetration Depth between NC and PC with Varying Temperature

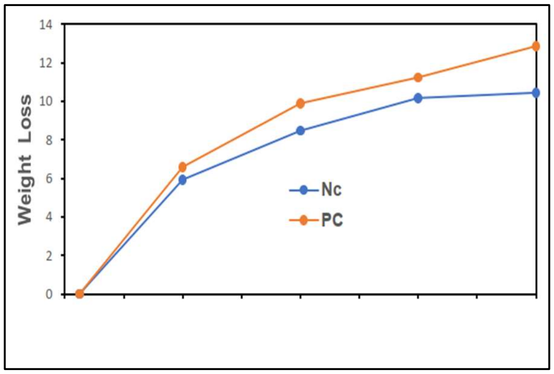
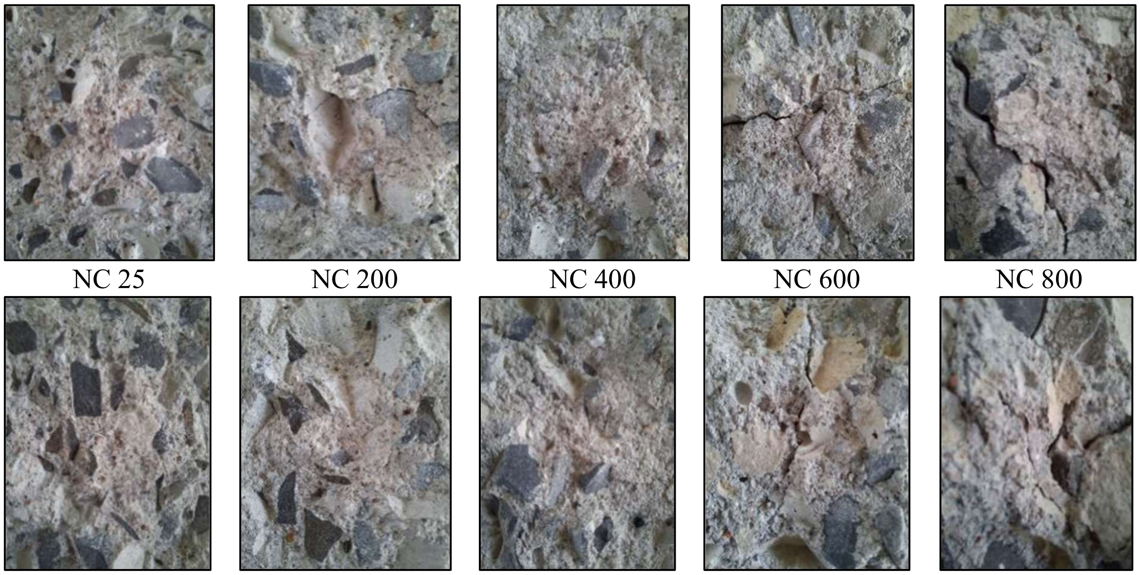


Figure 10: Comparison of Weight Loss between NC and PC Specimen with VaryingTemperatures

3.6 Integral Colour of Concrete Specimen

The integral colour changes of NC and PC specimens after heating at different elevated temperatures are summarised in Table 10.The integral colour of the specimens changes based on the heating temperatures, as shown in Figure 11.



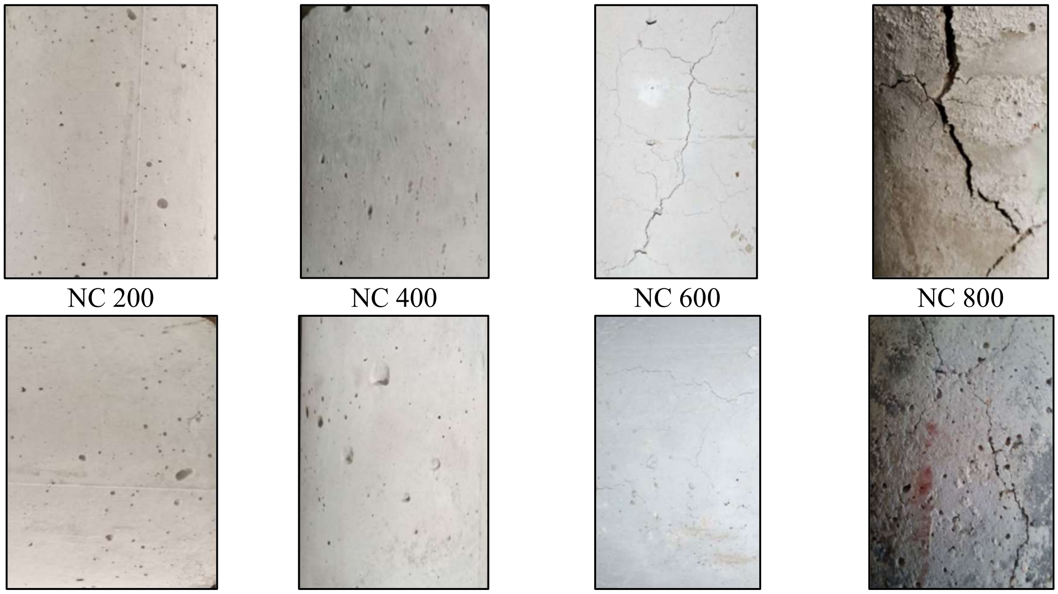
NC 25 NC 200 NC 400 NC 600 NC 800

PC 25 PC 200 PC 400 PC 600 PC 800

Figure 11: Integral Colour Change of NC and PC Specimens Heated at Different Temperatures

3.7 Surface Colour and Crack of Heated Concrete Specimen

The colour change and surface crack characteristics of heated NC and PC samples with temperature variations are outlined in Table 10. Up to 400°C heating, the surface crack of concrete was not visible to the naked eye; however, microcracks were generated but remained imperceptible without magnification. Visible cracks started to appear at 600°C, showing the surface colour change and cracks of the heated cylindrical specimens, as shown in Figure 12.



NC 200 NC 400 NC 600 NC 800

PC 200 PC 400 PC 600 PC 800

Figure 12: Surface Colour and Cracks of NC and PC Specimens Heated at Different Temperatures

Table 10: Integral Colour Change and Surface Colour of Heated NC and PC Specimens

Temperature Range (°C)	Integral Colour Change		Surface Colour	
	NC Specimen	PC Specimen	NC Specimen	PC Specimen

25	Grey	Medium Grey	Light Brown	Moderate Light Brown
200	Light Brown	Light Brown	Dark Brown	Off White
400	Dark Brown	Dark Brown	Ash White	Dark Ash
600	Dark Brown	Light Brown	Light Grey	Dark Grey
800	Red	Dark Brown	Dark Grey	Blackish

4. CONCLUSIONS

The study explores the impact of Super Absorbent Polymer (SAP) on concrete's physical and mechanical properties under elevated temperatures. Analysis of time-temperature profiles reveals that polymer concrete (PC) exhibits slower heat absorption during heating than normal concrete (NC).

Compressive strength results indicate that the PC specimen surpasses the NC specimen by 32%, 18.5%, 37.5%, 50%, and 40% at ambient temperatures, 200°C, 400°C, 600°C, and 800°C, respectively. Similarly, the tensile strength of the PC specimen outperforms the NC specimen by 3.1%, 12.90%, 100%, 125%, and 100% at the same respective temperature points.

Regarding water penetration depth, the NC specimen shows an increase compared to the PC specimen by 14.3%, 136%, and 150% at ambient temperatures, 200°C, and 400°C, respectively. However, both NC and PC specimens fail instantly at 600°C and 800°C.Weight loss of the PC specimen is higher than the NC specimen by 11.3%, 16.75%, 10.4%, and 23% at 200°C, 400°C, 600°C, and 800°C, respectively. Surface cracks become visible at 600°C for both PC and NC samples, with no visible cracks before this temperature. The size of cracks in NC concrete is more pronounced than in PC concrete at 800°C.

In summary, polymer concrete demonstrates superior performance compared to normal concrete. Recommendations for further research include examining strain temperature profiles during heating, conducting rapid chloride permeability tests (RCPT), exploring different SAP content percentages, and investigating various time durations of concrete heating (e.g., 1/2 hr and 6 hr) for comparison with the existing 2-hour heating duration.

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