EFFECT OF BURNING ON COMPRESSIVE STRENGTH OF STONE AGGREGATE CONCRETE

Md. Asadul Islam[1], Md. Khasro Miah[2], Sk Azharul Haque[3], Robiul Islam*[4]

[1]Graduate Student, Department of Civil Engineering, DUET, Gazipur, Bangladesh
e-mail: asadul111064@gmail.com
[2] Professor, Department of Civil Engineering, DUET, Gazipur, Bangladesh
e-mail: mkhasro@duet.ac.bd
[3] Graduate Student, Department of Civil Engineering, DUET, Gazipur, Bangladesh
e-mail: azharul.duet@gmail.com
[4] Graduate Student, Department of Civil Engineering, DUET, Gazipur, Bangladesh
e-mail: robiulimlammd986@gmail.com

***Corresponding Author**

ABSTRACT

Concrete exposed to unexpected fire often loses a significant portion of its mechanical strength, making it crucial to understand this behavior for accurate structural assessment. This study investigates how high temperatures affect the compressive strength of concrete. The relationships between compressive strength of concrete and exposure time were examined for two mix proportions with varying water cement (w/c) ratios, under heating levels of up to 800 °C. A total of 96 standard cylindrical specimens with a diameter of 150 mm and a height of 300 mm were cast using four water cement ratios of 0.45, 0.50, 0.55 and 0.60 and two mix ratios of 1:2:4 and 1:1.5:3, respectively. Among 96 specimens, 72 specimens were heated for varying durations of 2, 2.5, and 3 hours accordingly, while the remaining 24 specimens were kept as control samples. Compressive strength tests were then conducted to evaluate the effect of high temperature exposure on concrete. The experimental results clearly show that compressive strength is significantly affected by w/c ratio, mix proportion, and burning duration, highlighting the significant changes in mechanical behavior caused by high-temperature exposure. For the mix ratio of 1:1.5:3 with a w/c ratio of 0.50, maximum compressive strength losses of 25.83%, 31.52%, and 36.50% were observed for burning durations of 2, 2.5, and 3 hours respectively. On the other hand, the minimum strength loss observed at a w/c ratio of 0.45 at temperatures up to 800 °C. For the mix ratio of 1:2:4 with a w/c ratio of 0.55, the corresponding maximum strength reductions were 16.10%, 28.94%, and 40.13% for the same burning durations, compared to control specimens. The lowest strength loss for a 3-hour exposure was observed at a w/c ratio of 0.60. Overall, the study highlights that both the mix design and water cement ratio have a significant role in determining the residual compressive strength of concrete subjected to extreme temperatures. These findings are valuable for evaluating and predicting the structural performance of concrete subjected to extreme thermal conditions.

Keywords: *Thermal exposure; Compressive strength loss; Water–cement ratio; Mix proportion*

1. INTRODUCTION

Concrete is the most widely used structural material because of its high compressive strength, durability and adaptability to different construction needs. In buildings and industrial applications, concrete structures may be subjected to fires of varying intensities (Sudarshan & Vyas, 2019) or placed near high temperature sources such as furnaces, boilers and industrial reactors (Janotka & Nürnbergerová, 2005; Luccioni et al., 2003; Sakr & El-Hakim, 2005). Previous studies have shown that elevated temperatures degrade the mechanical and physical properties of concrete, including compressive and tensile strength, modulus of elasticity, and volumetric stability (Arioz, 2007; Xiao & König, 2004).

At high temperatures, the chemical composition and the internal structure of concrete are altered. As temperature increase, free and bound water evaporate, hydrated phase begins to decompose and differential thermal expansion between the aggregate and the cement paste induces cracking and sometimes spalling (Mohammed et al., 2022; Sundin et al., 2023). Khoury et al. (2002) reported that when concrete subjected to headway temperatures, both the chemical composition and the physical structure of concrete undergo indicatory changes. Besides, dehydration of calcium silicate hydrate (C-S-H), which becomes significant beyond about 110 °C, disrupts the binding matrix of concrete (Khoury et al., 2002). Above 300 °C, internal stresses from aggregate expansion and moisture movement increase formation of microcracks in concrete (Wang et al., 2025). These changes reduce stiffness and strength, threatening the residual load-bearing capacity of reinforced concrete structures after fire exposure. When the temperature exceeds 500 °C, most of these changes are considered irreversible, severely affecting the residual load-bearing capacity of reinforced concrete structures (Luccioni et al., 2003). In developing countries like Bangladesh, fire incidents are common and often prolonged due to limited firefighting capacity and inadequate safety system. Wikipedia contributors (2024) reported that major building fires including the BSEC Building fire in 2007, the Old Dhaka mixed-use building fire in 2007, the Bashundhara City Complex fire in 2009, and the Tazreen Fashion Factory fire in 2012 resulted in severe loss of life and structural failures, highlighting the gaps in fire safety management and emergency response systems. Post-fire assessment of such structures requires reliable data on the strength degradation of locally produced concrete made with crushed stone aggregate.

Previous studies have shown that the extent of concrete strength loss is depends on several factors such as aggregate type, water-cement ratio, and the duration of exposure to elevated temperatures (Arioz, 2007; Knaack et al., 2010). Although many investigations have explored the effects of elevated temperatures on concrete, detailed research considering burning duration alongside variations in mix proportion and water-cement ratio remains limited. Therefore, this study aims to evaluate how exposure to high temperatures influences the compressive strength of concrete made with stone aggregates under different mix designs and heating duration.

2. MATERIALS AND METHODOLOGY

2.1 Collection of Materials

Figure 1 Photographs of materials (cement, sand, and stone chips).

All materials used in this study (Figure 1) were collected from local sources available in Bangladesh. Crushed stone chips (19 mm down) were collected from a local supplier in Gazipur, coarse sand was used as fine aggregate, Ordinary Portland cement (Type I) was obtained from Seven Rings Cement, and potable tap water was used for both mixing and curing purposes. All materials were tested to ensure compliance with the relevant ASTM standards.

2.2 Tests on Materials

2.2.1 Coarse Aggregate

The properties of coarse aggregate were determined following ASTM C127 and ASTM C29. Table 1 presents the measured values and a comparison with previous findings.

Table 1 Properties of Coarse Aggregate

Property	Unit	Test Standard	Present Study
Fineness Modulus	-	ASTM C136 (2019)	6.98
Specific Gravity (SSD)	-	ASTM C127 (2007)	2.60
Water Absorption (%)	*%*	ASTM C127 (2007)	1.61
Unit Weight	*kg*	ASTM C29 (2017)	1558

The gradation of 19 mm downgraded stone chips was evaluated by sieve analysis (ASTM C136), and the grain size distribution curve was plotted accordingly shown in Figure 2.

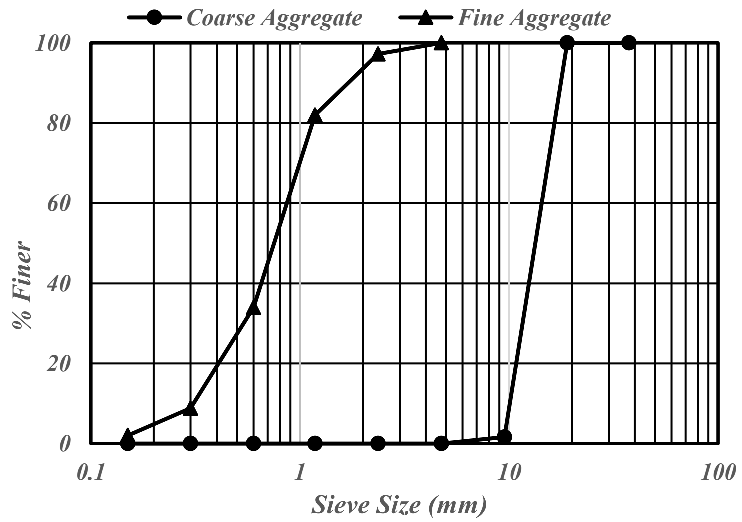

Figure 2 Grain size distribution curve of coarse and fine aggregates

2.2.2 Fine Aggregate

The Sylhet sand used as fine aggregate was tested per ASTM C128 and ASTM C29. The results are summarized in Table 2 and the gradation curve of fine aggregate is shown in Figure 2.

Table 2 Properties of Fine Aggregate

Property	Unit	Test Standard	Present Study
Fineness Modulus	-	ASTM C136 (2019)	2.76
Specific Gravity (SSD)	-	ASTM C128 (2007)	2.63

Water Absorption (%)	%	ASTM C128 (2007)	2.56
Unit Weight	kg	ASTM C29 (2017)	1630

2.2.3 Cement

The Ordinary Portland Cement (OPC) was tested as per ASTM C187 and ASTM C191 for consistency and setting time while compressive strength was assessed using ASTM C109. The results are presented in Table 3.

Table 3 Properties of Cement

Property		Test Standard	Present Study	ASTM C150
Normal Consistency (%)		ASTM C187 (2016)	28.5	28-32
Initial Setting Time (min)		ASTM C191 (2021)	48	≥ 45
Final Setting Time (min)		ASTM C191 (20210	350	≤ 375
Compressive Strength (MPa)	3 days	ASTM C109 (2016)	17.5	12
	7 days	ASTM C109 (2016)	24.40	19

2.2.4 Water

Throughout the mixing and curing processes, clean, potable tap water was used to maintain consistency. The water used for mixing was of high quality to ensure optimal hydration and proper performance of the concrete.

2.3 Mixing of Materials

Concrete was mixed in a tilting-type mechanical mixer operating at 15–20 rpm for 5–6 minutes to ensure thorough uniform blending. Materials were carefully batched by weight to maintain consistency across all samples. Two mix proportions were prepared: 1:1.5: 3 (rich mix) and 1:2:4 (lean mix). To study the effect of water content on high-temperature performance, four water-cement ratios (0.45, 0.50, 0.55, and 0.60) were used, and their influence on the compressive strength of concrete under elevated temperatures was evaluated. Table 4 shows the required quantities of materials for producing 1 m^3 of concrete.

Table 4 Required Materials for Making 1 m^3 Concrete

Mix Ratio	w/c	Cement (kg)	Sand (kg)	Stone Chips (kg)	Water (kg)
1:1.5:3	0.45	393	667	1275	177
	0.50	393	667	1275	196
	0.55	393	667	1275	216
	0.60	393	667	1275	236
1:2:4	0.45	308.5	698	1336	139
	0.50	308.5	698	1336	154
	0.55	308.5	698	1336	170
	0.60	308.5	698	1336	185

2.4 Preparation of Specimens

A total of 96 standard cylindrical specimens (Ø150 mm ×300 mm) were cast for the study. The concrete was placed in three layers, and each layer was compacted with 25 blows using a standard tamping rod. The molds were lightly oiled before casting to facilitate easy demolding. The specimens were demolded after 24 hours, then cured in water for 28 days to ensure proper hydration before testing. The casting and curing processes of the specimens are illustrated in Figures 3 and 4, respectively.

Figure 3 Casting and compaction of cylindrical concrete specimens.

Figure 4 Water curing tank at DUET Civil Engineering Laboratory.

2.5 Burning Procedure

Following the 28-day curing period, 72 concrete specimens were subjected to elevated temperatures using a controlled burner setup. Each specimen was heated to 800 °C for three different durations 2 hours, 2.5 hours, and 3 hours to systematically examine the effect of exposure time on the mechanical properties of concrete. The remaining 24 specimens were maintained as unburnt control samples for baseline comparison. After heating, all specimens were allowed to cool naturally to simulate realistic post-fire conditions. This procedure enabled a comprehensive evaluation of both the thermal degradation and post-fire performance of concrete under controlled yet representative conditions.

2.6 Tests on Specimens

Before compression testing, the ends of all specimens were leveled using a 1:3 cement sand paste (w/c = 0.48) to ensure smooth load transfer. Compressive strength was measured (Figure 5) with a 3000 kN capacity Universal Testing Machine in accordance with ASTM C39 (2021). The loading rate was maintained at 0.40 MPa/s, and the average strength of three specimens was taken as the representative compressive strength for each group.

Figure 5 Compressive strength test setup.

3. RESULTS AND DISCUSSION

This section presents the experimental results on how compressive strength and corresponding strength loss vary when concrete is exposed to high temperatures for different durations. Two mix proportions (1:1.5:3 and 1:2:4) and four water-cement ratios (0.45, 0.50, 0.55, and 0.60) were used to evaluate the influence of mix composition and porosity on thermal resistance. Across all mixes, compressive strength consistently decreased with longer exposure, showing the damaging effect of heat on the cementitious matrix.

3.1 Thermal Influence on Compressive Strength of 1:1.5:3 Concrete

Figure 6 shows how compressive strength and corresponding strength loss (%) changed with respect to burning time for concrete mixes with a ratio of 1:1.5:3 and water-cement ratios of 0.45 and 0.50, respectively. The primary vertical axis represents the compressive strength of concrete (MPa), while the secondary vertical axis indicates the percentage of strength loss for different burning hours. A consistent downward trend is observed with increasing exposure duration, reflecting the thermal degradation of the cementitious matrix. For the mix with w/c = 0.45, initially the maximum compressive strength was recorded at 26 MPa, which decreased to 17 MPa after 3 hours of burning, corresponding to a 34.5% strength loss, with approximately 25% of this reduction occurring within the first hour. For the mix with w/c = 0.50 exhibited an initial strength of 21.5 MPa, dropping to 13.75 MPa at 3 hours, indicating a 36% strengh reduction compared to control specimen. The most significant decline occurred within the first hour of exposure, beyond which the rate of deterioration gradually stabilized.

The mix with lower w/c ratio (0.45) consistently maintained higher residual strength and experienced less strength loss compared to the higher w/c ratio, demonstrating improved thermal stability due to its denser microstructure and reduced the pore connectivity (Liu & Chen, 2022). Overall, the figure highlights that prolonged thermal exposure markedly impairs the mechanical integrity of concrete, with the extent of degradation being inversely related to mix density (Babalola et al., 2021).

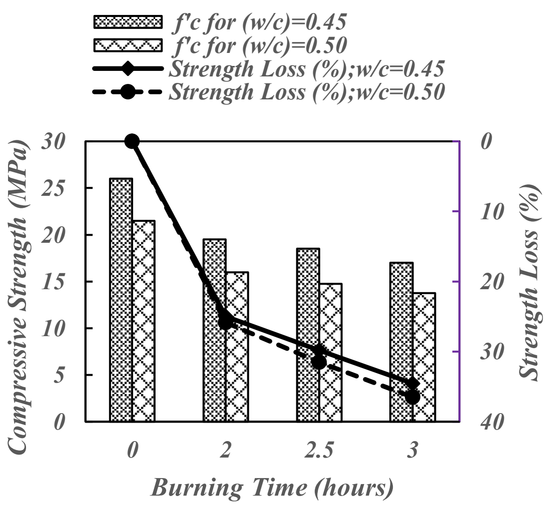

Figure 6 Variation of Compressive Strength and Corresponding Strength Loss versus Burning Time of 1:1.5:3 concrete (w/c =0.45, 0.50)

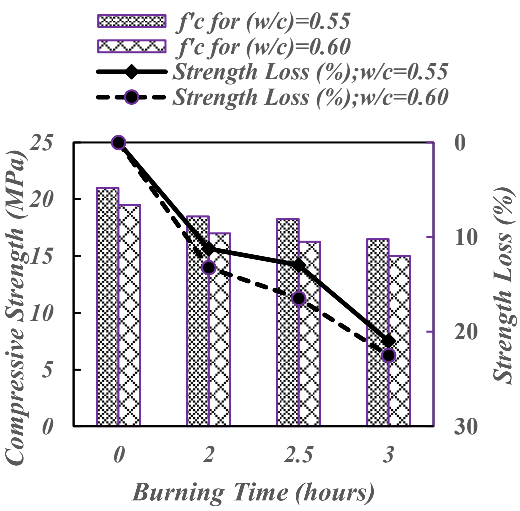

Figure 7 Variation of Compressive Strength and Corresponding Strength Loss versus Burning Time of 1:1.5:3 concrete (w/c =0.55, 0.60)

Figure 7 presents the relationship between compressive strength and strength loss (%) of concrete with respect to burning time for a 1:1.5:3 mix ratio incorporating water cement ratios (w/c) of 0.55 and 0.60. The primary axis shows the compressive strength (MPa), whereas the secondary axis corresponds to the percentage loss in strength at different exposure durations. As the burning duration increases, both mixes exhibit a gradual and consistent reduction in compressive strength, indicating the adverse influence of thermal exposure on the cementitious matrix. For w/c = 0.55, the strength decreased from 21 MPa (unheated) to 16.5 MPa after 3 hours, representing a 21% reduction. In comparison, the w/c = 0.60 mix showed a decrease from 19.5 MPa to 15.0 MPa, resulting in approximately 22.5% strength loss. The sharpest decline occurred in the first hour of heating, after which the degradation rate became relatively steady. The mix with the lower w/c ratio (0.55) showed higher residual strength and better thermal resistance due to its denser microstructure and lower permeability, which helped limit heat-induced cracking and internal vapor pressure buildup (Liu & Chen, 2022). According to Figure 7, it may be concluded that exposure to high temperatures noticeably reduces the compressive strength of concrete, with the damage becoming more severe as the water-cement ratios increases. This pattern is consistent with previous research (Naus, 2005) and reinforces that a denser mix provides better thermal stability.

3.2 Thermal Influence on Compressive Strength of 1:2:4 Concrete

The evolution of compressive strength and corresponding strength loss (%) of concrete subjected to elevated temperatures over varying burning durations for a 1:2:4 mix ratio with water-cement ratios (w/c) of 0.45 and 0.50 are shown in Figure 8. The primary axis represents compressive strength (MPa), while the secondary axis indicates the percentage reduction in strength across exposure periods.

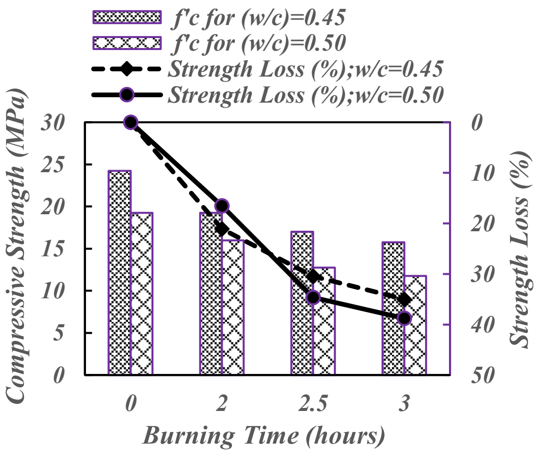

Figure 8 Variation of Compressive Strength and Corresponding Strength Loss versus Burning Time of 1:2:4 concrete (w/c =0.45, 0.50)

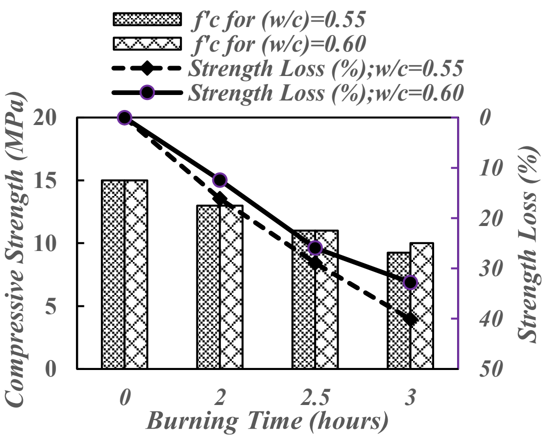

Figure 9 Variation of Compressive Strength and Corresponding Strength Loss versus Burning Time of 1:2:4 concrete (w/c =0.55, 0.60)

A clear reduction in compressive strength is observed as exposure time, illustrating the damaging impact of thermal loading on concrete performance. For the mix with w/c ratio of 0.45, compressive strength decreased from 24.25 MPa in unheated state to 15.75 MPa after 3 hours, a total loss of about 35%, with approximately 21% occurring within the first hour. The w/c = 0.50 mix followed a similar pattern, with strength decreasing from 19.25 MPa to 11.75 MPa, representing a 38.8% reduction. The rapid degradation of compressive strength during the initial hour of burning is likely driven by moisture evaporation, rising pore pressure, and early microcrack formation, followed by a slower reduction rate as the concrete matrix stabilizes (Shen & Xu, 2019). The mix with the lower w/c ratio (0.45) consistently preserved higher residual strength, indicating better thermal resistance. This improved performance can be attributed to its denser microstructure, improved paste-aggregate bond, and lower permeability, which together helps reduce crack development and mitigate the effects of internal vapor pressure under high temperature exposure (Pasztetnik & Wróblewsk, 2021).

The changes in compressive strength and the corresponding percentage of strength loss for concrete exposed to elevated temperatures for different durations, considering a 1:2:4 mix ratio with water-cement ratios (w/c) of 0.55 and 0.60 are shown in Figure 9. The results indicate a clear reduction in compressive strength with increasing exposure time, emphasizing the vulnerability of concrete under high temperatures. For the w/c = 0.55 mix, the strength decreased from 15.50 MPa (unheated) to 9.25 MPa after 3 hours, corresponding to a 40.13% reduction. A similar trend was observed for the w/c = 0.60 mix, where strength reduced from 15 MPa to 10 MPa, representing a 32.8% loss. The rapid loss observed during the first hour can be attributed to moisture evaporation, pore pressure development, and microcrack formation, followed by a slower degradation rate as the matrix structure gradually stabilized (Shen & Xu, 2019). The w/c = 0.55 mix consistently exhibited higher residual strength compared to w/c of 0.60, indicating improved resistance to thermal degradation. This improved performance is primarily linked to its denser microstructure, stronger paste-aggregate adhesion, and lower permeability, which collectively restrain crack propagation and mitigation internal stresses induced by vapor pressure under elevated temperatures (Ferdiansyah et al., 2025; Pasztetnik & Wróblewsk, 2021)

The key findings indicate that the compressive strength of concrete consistently decreases with increasing thermal exposure, with the most rapid loss occurring within the first hour. Mixes with lower water-cement ratios retained higher residual strength, demonstrating enhanced thermal stability, while higher w/c mixes showed greater deterioration. This enhanced performance of denser mixes is attributed to reduced porosity, stronger paste-aggregate bonding, and lower permeability, which collectively mitigate crack propagation and internal vapor pressure (Ferdiansyah et al., 2025). Overall, the results confirm that mix density and w/c ratio are key factors in controlling the thermal resilience of concrete.

4. CONCLUSIONS

Based on the above results and discussion, the following conclusions can be drawn:

i. Compressive strength of concrete decreases progressively with increasing burning duration, with the most significant loss occurring within the first hour of heating;
ii. Concrete mixes with lower water-cement ratios (0.45 and 0.50) consistently demonstrated higher residual strength and lower strength loss, confirming that reduced porosity enhances thermal stability;
iii. The extent of thermal degradation was found to be inversely related to mix density; denser mixes (1:1.5:3) retained greater strength than leaner mixes (1:2:4) under similar exposure conditions;
iv. Overall, thermal exposure significantly compromises the mechanical performance of concrete, highlighting the importance of optimized mix proportion and water-cement ratios to improve fire resistance and structural durability.

ACKNOWLEDGEMENTS

All praise to Allah. The authors gratefully acknowledge the Department of Civil Engineering, Dhaka University of Engineering & Technology, Gazipur, for providing laboratory facilities and financial support to conduct this research.

DECLARATION OF USE OF AI

Artificial intelligence tools were used only to help with editing the language and improving the clarity of writing. All experimental work, data analysis, technical content, and interpretation of results were fully carried out by the authors. Any AI-assisted edits were carefully checked and approved to ensure accuracy and originality. No AI tools were involved in generating the data, results, or scientific conclusions presented in this paper.

REFERENCES

Arioz, O. (2007). Effects of elevated temperatures on properties of concrete. *Fire Safety Journal*, *42*(8), 516–522. https://doi.org/10.1016/j.firesaf.2007.01.003

ASTM C109, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens), Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA, USA, 2016a. https://store.astm.org/c0109_c0109m-16a.html (accessed 2 June 2025).

ASTM C127, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA, USA, 2007. https://store.astm.org/c0127-07.html (accessed 2 June 2025).

ASTM C128, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA, USA, 2015. https://store.astm.org/c0128-15.html (accessed 2 June 2025).

ASTM C136, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA, USA, 2019. https://store.astm.org/c0136_c0136m-19.html (accessed 2 June 2025).

ASTM C150, Standard Specification for Portland Cement, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA, USA, 2022. https://store.astm.org/c0150_c0150m-21.html

ASTM C187 (2016). Standard Test Method for Normal Consistency of Hydraulic Cement. ASTM International, West Conshohocken, PA, USA

ASTM C191, Standard Test Method for Time of Setting of Hydraulic Cement by Vicat Needle, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA, USA, 2021. https://store.astm.org/c0191-21.html (accessed 2 June 2025).

ASTM C29, Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA, USA, 2017a. https://store.astm.org/c0029_c0029m-17a.html (accessed 2 June 2025).

ASTM C39 (2021). Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. ASTM International, West Conshohocken, PA, USA

Babalola, O. E., Awoyera, P. O., Le, D. H., & Bendezú Romero, L. M. (2021). A review of residual strength properties of normal and high strength concrete exposed to elevated temperatures: Impact of materials modification on behaviour of concrete composite. *Construction and Building Materials*, *296*, 123448. https://doi.org/10.1016/J.CONBUILDMAT.2021.123448

Ferdiansyah, T., Ismy, R., Shahzad, S., Rafiq, W., & Nadeem, K. (2025). The Influence of the Water–Cement Ratio on Concrete Resistivity: A Temperature and Saturation Dependent Analysis Using an Experimental and Predictive Approach. *CivilEng*, *6*(3), 38. https://doi.org/10.3390/civileng6030038

Janotka, I., & Nürnbergerová, T. (2005). Effect of temperature on structural quality of the cement paste and high-strength concrete with silica fume. *Nuclear Engineering and Design*, *235*(17–19), 2019–2032. https://doi.org/10.1016/j.nucengdes.2005.05.011

Khoury, G. A., Majorana, C. E., Pesavento, F., & Schrefler, B. A. (2002). Modelling of heated concrete. *Magazine of Concrete Research*, *54*(2), 77–101. https://doi.org/10.1680/macr.54.2.77.40895

Sudarshan, K. D., & Vyas, A. K. (2019). Impact of fire on mechanical properties of concrete containing marble waste. *Journal of King Saud University - Engineering Sciences*, *31*(1), 42–51. https://doi.org/10.1016/j.jksues.2017.03.007

Knaack, A. M., Kurama, Y. C., & Kirkner, D. (2010). Compressive strength relationships for concrete under elevated temperatures. ACI Materials Journal, 107(2), 164–175. https://doi.org/10.14359/51652920

Liu, C., & Chen, J. (2022). High Temperature Degradation Mechanism of Concrete with Plastering Layer. *Materials*, *15*(2). https://doi.org/10.3390/ma15020398

Luccioni, B. M., Figueroa, M. I., & Danesi, R. F. (2003). Thermo-mechanic model for concrete exposed to elevated temperatures. *Engineering Structures*, *25*(6), 729–742. https://doi.org/10.1016/S0141-0296(02)00209-2

Mohammed, H., Ahmed, H., Kurda, R., Alyousef, R., & Deifalla, A. F. (2022). Heat-Induced Spalling of Concrete: A Review of the Influencing Factors and Their Importance to the Phenomenon. In *Materials* (Vol. 15, Issue 5). MDPI. https://doi.org/10.3390/ma15051693

Naus, D. J. (2005). *The effect of elevated temperature on concrete materials and structures: A literature review* (ORNL/TM-2005/553). Oak Ridge National Laboratory. Prepared for the U.S. Nuclear Regulatory Commission

Pasztetnik, M., & Wróblewski, R. (2021). A Literature Review of Concrete Ability to Sustain Strength after Fire Exposure Based on the Heat Accumulation Factor. *Materials (Basel, Switzerland)*, *14*(16), 4719. https://doi.org/10.3390/ma14164719

Sakr, K., & El-Hakim, E. (2005). Effect of high temperature or fire on heavy weight concrete properties. *Cement and Concrete Research*, *35*(3), 590–596. https://doi.org/10.1016/j.cemconres.2004.05.023

Shen, J., & Xu, Q. (2019). Effect of elevated temperatures on compressive strength of concrete. *Construction and Building Materials*, *229*, 116846. https://doi.org/10.1016/J.CONBUILDMAT.2019.116846

Sundin, M., Hedlund, H., & Cwirzen, A. (2023). Eco-Concrete in High Temperatures. In *Materials* (Vol. 16, Issue 12). MDPI. https://doi.org/10.3390/ma16124212

Wang, Q., Luo, Z., He, W., & Hou, Z. (2025). Mechanism Study on the Influence of High-Temperature Exposure on the Thermal Transfer Characteristics of Explosion-Proof Concrete. *Processes*, *13*(9), 2712. https://doi.org/10.3390/pr13092712

Wikipedia contributors (2024). *2012 Dhaka garment factory fire*. In *Wikipedia*. https://en.wikipedia.org/wiki/2012_Dhaka_garment_factory_fire

Xiao, J., & König, G. (2004). Study on concrete at high temperature in China - An overview. *Fire Safety Journal*, *39*(1), 89–103. https://doi.org/10.1016/S0379-7112(03)00093-6