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The Effect of High-Temperature on Concrete Properties and the Role of Waste Pozzalanic Material to Increase Concrete Resistance, A Review

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ABSTRACT

The performance of the structural materials (concrete and steel reinforcement) and the behavior of the structural members after they were exposed to high temperatures have been considered the main topics of the current literature review. All varieties of concrete mixtures lost their compressive strength after 300°C, even though there was no discernible strength loss between 150 and 300°C. It was also discovered that the heating time had no appreciable impact on the strength loss when the exposed to heat less than 300 °C. Above 300 °C. Concrete begins to lose strength after being exposed for longer than one hour; the greatest loss of strength occurs during the first and second hours of exposure. Both the cured cement pastes and the aggregates undergo chemical and physical changes at temperatures ranging from 600 °C to 900 °C. The 5% weighted rice husk ash (RHA) blended concrete still had an advantage in compressive strength, over the concrete when subjected to temperatures up to 700 C for two hours. Adding more recycled glass and ceramic particles to regular concrete increases its overall compressive and tensile strengths. Concrete becomes more durable and has fewer cracks when there is a higher replacement rate for ceramic and glass particles. The splitting tensile strength decreased with increasing temperature, changing from 60% to 70% of its initial strength after 600 °C. In this review, the better performance of concrete than the other concrete in terms of mechanical, physical, and durability properties at both room temperature and high temperature were concrete with 10% waste glass powder (WGP) substitution as a partial of cement and 10%–20% crushed glass (CG) substitution as a partial of aggregate.

1. Introduction

When exposed to a fire disaster, the two main goals of fire safety are to keep people safe and avoid failure. Fire lead to reinforced concrete's (RC) strength declines and in the event that there is no collapse after a fire, fire-related damage could occur. The next concerns are whether the building is still safe, how much weight it can support, and how the fire has affected it. A thorough understanding of how building materials behave following a fire is crucial to provide appropriate answers to these queries.

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Fire and high temperatures are among the most important factors and risks that threaten concrete and have direct impact on it, the risk of exposure to an accidental fire in the buildings increased. High temperatures lead to the change in the properties of the material from which concrete is formed and thus affect the strength and adhesion property of cement (Arioz, 2007). Many studies have investigated the effect of heat on concrete and have tried hard to find effective solution to reduce the effect of heat on it. Concrete buildings are constantly at risk of fire and other risks all over the world, which can cause material and human losses. Elevated temperatures negatively impact concrete due to the breakdown of hardened cement paste and aggregate, which reduces the material's stiffness and increases irreversible deformation. The cement quickly decomposes and turns into calcium oxide (CaO) at a temperature of 450–550°C and It consumes roughly 15-20% of the cement by volume. This change causes surface fissures in the concrete, which is thought to be a primary factor in the concrete specimen's significant loss of strength after 400°C. The weakening of cement concrete is the reason for the CH dehydration when subjected to high temperatures. During a building fire, the structural performance of the reinforced concrete construction, which makes up a significant portion of structures, is harmed, structural deformation increases, and load-carrying capacity diminishes (Dong, Cao, Bian, & Zhang, 2014).

With knowledge of deformations and characteristic changes, the fire resistance ability of a structural part can be estimated using traditional structural mechanics approaches. A quantitative approach to estimating structural beam fire resistance is made possible by the availability of material characteristics at severe temperatures (Kodur, Dwaikat, & Raut, 2009). Concrete's performance can be negatively impacted by thermo-physical and thermo-chemical changes at high temperatures, despite the material's generally positive reputation as being nonflammable and having low heat conductivity (Bažant & Kaplan, 2018) Concrete undergoes changes in its physical structure, chemical makeup, and moisture content when exposed to high temperatures. These alterations are mostly seen in the cement paste, while they are also noticed in the aggregates. When high temperatures are reached, the hardened cement paste becomes dehydrated and calcium hydroxide transforms into calcium oxide, causing the chemically bound water to gradually release and become free water. Additionally, aggregates lose their evaporating water, and hydrous aggregates dehydrate at high temperatures and crystallize, resulting in a temperature at which their volume expands significantly (Angst, Elsener, Larsen, & Vennesland, 2009).

At 150C, it was found that the specimens started to lose some of their original strengths and that the concrete's qualities started to erode. All varieties of concrete mixtures lost their compressive strength after 300˚C, even though there was no discernible strength loss between 150 and 300˚C. It was also discovered that the heating time had no appreciable impact on the strength loss (Kizilkanat, Yüzer, & Kabay, 2013; Bingöl, & Gül, 2004). It was found that the length of exposure had a significant impact on strength loss as well. Concrete begins to lose strength after being exposed for longer than one hour; the greatest loss of strength occurs during the first and second hours of exposure.

Both cement paste and aggregates undergo chemical and physical changes at temperatures ranging from 600 °C to 900 °C. Water evaporates from aggregates and alters porosity when dehydration of hardened cement paste occurs (Bažant & Kaplan, 2018).

In order to aid engineers in their structural evaluation of concrete following exposure to elevated temperatures, this study aims to provide a thorough and detailed explanation as well as a simplified estimation of the combined effect of fire-induced damages produced in concrete and steel bars in structural members. The most pertinent research on the subject at hand was compiled into this review. It can serve as a guidance for future research and serve as an example of the knowledge gap that has been filled in this area.

2. Influence of High Temperature on mechanical properties of Concrete

Compressive strength, indirect tensile strength, elasticity modulus, and the stress-strain curve of the constituent materials at high temperatures are the mechanical properties that dictate how reinforced concrete elements behave in a fire.

A fire-resistant design's essential consideration is the concrete's compressive strength at high temperatures. At room temperature, the water-cement ratio, the area where the aggregate and paste transition, the curing conditions, the sort and size of the aggregate, the types of admixtures, and the type of stress all affect the compressive strength of concrete. First thing it should know the degree of rising temperatures comparing and comparing it with the room temperatures also the area where the aggregate and paste transition gives indication to bond area between aggregate and cement paste, curing condition (keeping concrete wet in order to complete hydration operation) determine the water quantity inside concrete that would evaporate after exposed to high temperatures Because water vapor causes concrete to become very porous, it facilitates straightforward pore pressure transfer consequently increasing the voids and cracks in concrete .porous concrete have little compressive strength (Mehta & Monteiro, 2006).

The same variables that govern concrete compressive strength also govern concrete tensile strength (Shah, 1992). Concrete's tensile strength is far less than its compressive strength because of how easily cracks propagate under tensile loads. Tensile strength is significantly less for High Strength Concrete (HSC) and only 10% for normal strength of concrete (NSC) when compared to compressive strength. Because of this, when estimating strength at ambient and higher temperatures, the tensile strength of concrete is commonly disregarded. However, it is a crucial feature since tensile pressures are usually what induce concrete cracking, and the progression of microcracking regularly results in significant harm to tension elements (Fischer & Shuxin, 2003). When a concrete structural element is exposed to fire and experiences fire-induced spalling, the tensile strength of the concrete becomes particularly crucial (Khaliq & Kodur, 2012).

Another factor affecting fire resistance in concrete is its modulus of elasticity, which decreases with temperature. Elastic modulus decreases at high temperatures due to the decomposition of wet cement materials and the breaking down of bonds in the cement paste's microstructure and lead to resistance loss; the degree of this drop depends on moisture loss, rising temperatures, creep, and aggregate type (Fischer & Shuxin, 2003).

Stress-strain relationships, which are widely used as input data in mathematical models for evaluating the fire resistance of concrete components, are a common way to characterize the mechanical responses of concrete (Khaliq & Kodur, 2012).

Umran (2002) looked into how fire exposure affected a few concrete mechanical qualities. The specimens were exposed to flames with temperatures ranging from 25 to 700°C. Four distinct exposure times of 0.5, 1.0, 1.5, and 2.0 hours were selected for three temperature levels of 400, 500, and 700°C without any applied loads during heating. After being exposed to a fire flame for 30, 60, and 90 days, the specimens were heated and cooled using the same protocol before being examined. Measurements were made of the flexural strength of 100×100×400mm prisms and the compressive strength of 150mm cubes. Tests were also conducted on the Dynamic Modulus of Elasticity (Ed) and Ultrasonic Pulse Velocity (U.P.V). He discovered that at 400°C, the residual compressive strength varied from 70–85%, at 500°C, from 59–78%, and at 700°C, from 43–62%. It was discovered that the flexural strength was more vulnerable to exposure to fire flames than the compressive strength. At 400°C, 40–67%, 500°C, and 700°C, the residual flexural strength ranged from 20–45%.

The concrete suffers "thermal shock" and significant damage when it cools down quickly under water cooling or water spraying for longer than thirty minutes. Concrete's compressive strength can be higher than that of concrete left at room temperature if it is exposed to 200 ꟷC and allowed to cool naturally. In concrete, higher temperatures trigger the activation of more hydration of remaining cement; quick cooling techniques, such as water spraying, have a smaller effect (Peng, Bian, Guo, Zhao, Peng, & Jiang, 2008). In the unstressed residual property testing, the specimen is heated to the target temperature at a predetermined rate without preload and is kept there until the thermal steady state is reached, as Phan and Carino (2012) showed. After that, the specimen is allowed to cool to laboratory temperature at a predetermined rate.

According to Poon et al. (2001), there are three testing techniques available to determine the concrete's residual compressive strength at high temperatures: the unstressed test, the stressed test, and the unstressed residual strength test. Although the last approach works well for figuring out the properties that remain after exposure to high temperatures, the first two ways prefer to find the strength of concrete during high temperatures. It was found that the third approach provides less strength and is, thus, more suited for determining limiting values (Poon, Azhar, Anson, & Wong, 2001).

Concrete may experience a range of chemical and physical changes as a result of exposure to high temperatures. After the exposure period, some of these changes can be reversed by cooling, while others cannot be reversed and could cause the concrete structure to become less viable. Porous concrete can hold a certain quantity of water. This water starts to evaporate at temperatures above 100 °C, which typically causes pressure to build up inside the concrete. In actuality, the boiling temperature range tends to stretch from 100 to roughly 140 °C because of the pressure effects. When the temperature rises to approximately 400 °C, the dehydration of calcium hydroxide in the cement will start, producing more water vapor and also leading to a further notable decrease in the material's physical strength beyond the likelihood of vaporization deterioration, vapor cause internal pressure which leads to weaken the bonds between concrete particles. Consequently cause loss in compressive strength of concrete. Higher temperatures can cause changes in aggregates as well. these physical and chemical alterations in concrete will worsen the material's tendency to lose compressive strength. The calculated values for siliceous (430 °C), carbonate (660 °C), and sand lightweight concrete (650 °C) indicate that the critical temperature of strength loss is highly depending on the kind of aggregate, according to the researchers' findings (Fletcher, Welch, Torero, Carvel, & Usmani, 2007).

A variety of factors influenced the behavior of concrete that had been exposed to high temperatures. These include the following: the duration of exposure, the rate at which the temperature rises, the highest temperature at which the concrete mass will reach, the initial temperature of the concrete prior to exposure to high temperatures, the degree of water saturation in the concrete, the concrete's maturity, the type of aggregate and cement used, the ratio of aggregate to cement, and the loading status of the concrete at the time of exposure. A rise in external temperature generally causes a progressive decrease of mechanical strength in mature concrete. The concrete's mechanical, thermal, and deformation properties all affect how well a concrete structural part performs when it is exposed to fire (Koksal, Gencel, Brostow, & Lobland, 2012).

Like other materials, the thermos-physical, mechanical, and deformation properties of concrete vary greatly within the temperature range associated with building fires. These characteristics are dictated by the characteristics and composition of the concrete and vary with temperature. Both at room temperature and at higher temperatures, the strength of concrete greatly influences its properties.

3. Influence of High Temperature on mechanical properties of steel reinforcement

The impact of elevated temperatures on the strength and stiffness characteristics of four different-sized reinforcing steel bars was examined. Three main factors were intended to be measured by the test program: yield stress, ultimate strength, and elastic modulus. Below 300°C, they saw no discernible change in the normalized value. Between 520°C and 580°C for the yield stress and between 540°C and 700°C for the elastic modulus, a 50% reduction in both the ultimate strength and yield stress was found (Holmes, Anchor, Cook, Crook, 1982).

The behavior of grade 60 reinforcing bars with a diameter of 12.7 mm after being exposed to fire was examined. 500 °C to 800 °C was the burn temperature of the bars. After being run at maximum temperature for around sixty minutes, the furnace cooled gradually. The bars were inspected in tension after they had cooled. Both the yield stress and the ultimate strength were reduced to at least 73 and 83 percent, respectively, of the unburned one. The reinforcement's heating and cooling did not alter the shape of the stress-strain curves (Edwards & Gamble, 1986).

According to Abramowicz and Kowalski (2007), the steel yield strength and steel modulus of elasticity both considerably decrease with rising temperatures. However, reinforcing steel typically regains most of its material qualities after a fire when the building cools down. The real degradation results from these notifications, as exposure to fire can cause the reinforcement in some structural elements to break at the bar anchoring, rendering the element worthless.

The mechanical properties deterioration of high-fire strength steels was examined by Qiang et al. (2012). Two commonly used steel grades, 460 and 690 MPa, were subjected to tensile strength tests after cooling from the maximum temperatures, up to 1000 o C. The post-fire modulus of elasticity, yield strength, ultimate strength, and stress-strain curves were obtained by this experiment. After fire, mild steels and high-performance steels have different mechanical properties (Qiang, Bijlaard, & Kolstein, 2012).

4. Role of Waste Pozzalanic Material to Increase Concrete Resistance to High Temperatures

Materials used for both ordinary and high strength concrete must meet specific high-temperatures resistance requirements as outlined by the various standards, depending on the intended use of the construction (Ismail, Ismail, & Muhammad, 2011). It is noted that the combination of temperature and color changes during fire is the primary method for inferring the maintained compressive strength (Li, Qian, & Sun, 2004).

One of the most important new materials for building and restoration that is currently available worldwide is mineral admixture concrete. Mineral admixtures, such as fly ash, blast furnace slag, and silica fume, have been demonstrated to improve the strength and longevity of concrete. These pozzolans combine with cement to create more calcium silicate hydrates (C-S-H), which strengthens and extends the life of concrete (Bouzoubaa, Fournier, Malhotra, & Golden, 2002; Igarashi, Watanabe, & Kawamura, 2005).

A byproduct of the rice milling process is rice husk ash (RHA). Throughout its growth, the rice plant gathers silica from the earth and integrates it into its structure (Smith & Kamwanja, 1986).

To produce an ash that is non-crystalline and amorphous, rice husk is burned at temperatures between 500 and 800 degrees Celsius (Mehta, Monteiro, 2014). Bahrami et al. (2017) reported on the extraction of crystalline and amorphous silica powder from rice husk using water as a liquid medium (Bahrami, Simon, Soltani, Zavareh, Schmidt, Pech-Canul, & Gurlo, 2017).

They discovered that whereas monoliths made of amorphous rich husk ash had a higher surface area, those made of crystalline rice husk ash demonstrated a higher mechanical strength. Rice husk ash is a byproduct of the rice milling industry (RHA).

Powęzka, Szulej, and Ogrodnik (2020) examine the effect of high–temperatures on concrete containing glass cullet as aggregate. The obtained test results have demonstrated the possibility of producing unique concrete altered by goods made from heat-resistant culets. Sufficient performance parameters are often what define this type of glass waste. Compressive strength decreased by 23.57% and 13.75% when heat-resistant cullet was substituted for natural aggregate. 56 MPa was discovered to be the target strength based on control samples. Furthermore, the effect of recycle on the developed composite's strength parameters was observed. When added at a 5% level to the concrete mix, the strength of the concrete decreases by approximately 25% and 31% after 28 and 180 days of maturation, respectively, in comparison to the control concrete. A lesser loss in strength—roughly between 23% and 16%—was noted when the amount of recycle was increased to 10%. According to the test results, the increased amount of re-rectal in the composite results in an increase in the compressive strength of concrete.

Patil and Patil (2021) examine how mortar containing glass waste powder (WGP) behaves at higher temperatures, as well as how water cooling affects mortar strength. Glass waste powder was substituted for cement in this investigation. In comparison to the reference sample, the mortar mix that had 20% (WGP) instead of cement for both cooling conditions retained a higher relative residual strength, according to the testing results. The average strength loss from water cooling was 38.62% for temperatures over 400 °C. In a similar vein, the average strength loss for air-cooling samples was 51.8% as opposed to 48.90% for the reference sample. Consequently, the fact that mortars containing glass powder lose less strength could be associated with the fact that they contain less calcium hydroxide.

After being exposed to extreme temperatures, Kadik et al. (2020) assessed the performance of High-Performance Concrete (HPC) produced with GP. In the combinations under study, up to 30% of the cement can be replaced by GP. Following high-temperature treatment (200°C to 800°C), the mechanical performance and structural changes were evaluated. The specimens' compressive and tensile strengths were tested to assess their mechanical performance. Following exposure to high temperatures, concrete with WGP performed better below 600°C than reference concrete. However, the strength of the concrete with WGP decreased somewhat more than that of the reference concrete after heating to 800°C (Kadik, Cherrak, Bali, Boutchicha, & Hannawi, 2020) .

Mustafy et al. (2022) investigated the mechanical characteristics of concrete including glass-recycled aggregate (GRA) and ceramic recycled aggregate (CRA) at higher temperatures. In addition to volumetric sand substitutions of 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% in other mixtures, this work highlights normal concrete (NC). The following temperatures were used to assess the overall mechanical and chemical changes in NC and recycled concrete: 25°C, 100°C, 200°C, 400°C, 600°C, and 800°C. According to the study, adding more recycled glass and ceramic particles to regular concrete increases its overall compressive and tensile strengths. Concrete becomes more durable and has fewer cracks when there is a higher replacement rate for ceramic and glass particles (Mustafy, Hasan, Shuvo, & Mujib, 2022).

To examine the impact of varying waste glass replacement rates on the performance of concrete following high temperatures, Wu et al. (2023) developed a novel method of replacing coarse aggregate (CA) and fine aggregate (FA) with crushed glass (CG) and glass powder (GP), respectively. The substitution rates of GP and CG by volume ranged from 0% to 30% among ten sets of mix proportions that were constructed. The samples were heated at a rate of 5 °C per minute from 20 °C to 600 °C. According to the results, compressive strength rose by 3-6% between 20 and 150 degrees Celsius. After that, it progressively dropped, and a 30–40% strength loss was noted after 600 degrees Celsius. On the other hand, the splitting tensile strength decreased with increasing temperature, changing from 60% to 70% of its initial strength after 600 °C (Wu, Mao, Zhang, Li, & Ma, 2023). In this review, concrete with 10% waste glass powder (WGP) substitution to cement and 10%–20% crushed glass (CG) substitution to aggregate performed better than the other concrete in terms of mechanical, physical, and durability properties at both room temperature and high temperature.

5. Conclusions

1. Porous concrete hold a certain quantity of water. This water starts to evaporate when exposed to high temperatures especially above 100 °C, which typically causes pressure to build up inside the concrete.
2. When the temperature rises to approximately 400 °C, the dehydration of calcium hydroxide in the cement will start, producing more water vapor and also leading to a further notable decrease in the material's physical strength beyond the likelihood of vaporization deterioration.
3- Higher temperatures can cause changes in aggregates as well. Consequently, these physical and chemical alterations in concrete will worsen the material's tendency to lose compressive strength.
4. A fire-resistant design's essential consideration is the concrete's compressive strength at high temperatures. At room temperature, the water-cement ratio, the area where the aggregate and paste transition, the curing conditions, the sort and size of the aggregate, the types of admixtures, and the type of stress all affect the compressive strength of concrete.
5. The real degradation results from these notifications, as exposure to fire can cause the reinforcement in some structural elements to break at the bar anchoring, rendering the element worthless.
6. The 5% weighted rice husk ash (RHA) blended concrete still had an advantage in compressive strength, over the OPC concrete when subjected to temperatures up to 700 C for two hours.
7. Adding more recycled glass and ceramic particles to regular concrete increases its overall compressive and tensile strengths. Concrete becomes more durable and has fewer cracks when there is a higher replacement rate for ceramic and glass particles.
8- The splitting tensile strength decreased with increasing temperature, changing from 60% to 70% of its initial strength after 600 °C.

References

Abramowicz, M., & Kowalski, R. (2007). Residual mechanical material properties for the reassessment of reinforced concrete structures after fire. *Engineering Structures*, 16-18.

Angst, U., Elsener, B., Larsen, C. K., & Vennesland, Ø. (2009). Critical chloride content in reinforced concrete—A review. *Cement and concrete research*, *39*(12), 1122-1138.

Arioz, O. (2007). Effects of elevated temperatures on properties of concrete. *Fire safety journal*, *42*(8), 516-522.

Bahrami, A., Simon, U., Soltani, N., Zavareh, S., Schmidt, J., Pech-Canul, M. I., & Gurlo, A. (2017). Eco-fabrication of hierarchical porous silica monoliths by ice-templating of rice husk ash. *Green Chemistry*, *19*(1), 188-195.

Bažant, Z. P., & Kaplan, M. F. (2018). *Concrete at high temperatures: material properties and mathematical models*. Harlow: Longman.

Bingöl, A. F., & Gül, R. (2004). Compressive strength of lightweight aggregate concrete exposed to high temperatures. *Indian Journal of Engineering and Materials Sciences*, *11*(1), 68-72.

Bouzoubaa, N., Fournier, B., Malhotra, V. M., & Golden, D. M. (2002). Mechanical properties and durability of concrete made with high-volume fly ash blended cement produced in cement plant. *Materials Journal*, *99*(6), 560-567.

Dong, H., Cao, W., Bian, J., & Zhang, J. (2014). The fire resistance performance of recycled aggregate concrete columns with different concrete compressive strengths. *Materials*, *7*(12), 7843-7860.

Edwards, W. T., & Gamble, W. L. (1986). Strength of grade 60 reinforcing bars after exposure to fire temperatures. *Concrete International*, *8*(10), 17-19.

Fischer, G., & Shuxin, W. A. N. G. (2003). Design of engineered cementitious composites (ECC) for processing and workability requirements. In *Brittle matrix composites 7* (pp. 29-36). Woodhead Publishing.

Fletcher, I. A., Welch, S., Torero, J. L., Carvel, R. O., & Usmani, A. (2007). Behaviour of concrete structures in fire. *Thermal science*, *11*(2), 37-52.

Holmes, M., Anchor, R.D., Cook, G.M.E., Crook, R.N. (1982). The effects of elevated temperatures on the strength properties of reinforcing and prestressing steels. *Structural. Engineering*. *60B*(1), 7-13.

Igarashi, S. I., Watanabe, A., & Kawamura, M. (2005). Evaluation of capillary pore size characteristics in high-strength concrete at early ages. *Cement and Concrete Research*, *35*(3), 513-519.

Ismail, M., Ismail, M. E., & Muhammad, B. (2011). Influence of elevated temperatures on physical and compressive strength properties of concrete containing palm oil fuel ash. *Construction and Building Materials*, *25*(5), 2358-2364.

Kadik, A., Cherrak, M., Bali, A., Boutchicha, D., & Hannawi, K. (2020). Effect of glass powder on the behaviour of high performance concrete at elevated temperatures. *Advances in concrete construction*, *10*(5), 443-454.

Khaliq, W., & Kodur, V. (2012). High Temperature Mechanical Properties of High-Strength Fly Ash Concrete with and without Fibers. *ACI Materials Journal*, *109*(6), 665.

Kizilkanat, A. B., Yüzer, N., & Kabay, N. (2013). Thermo-physical properties of concrete exposed to high temperature. *Construction and Building Materials*, *45*, 157-161.

Kodur, V., Dwaikat, M., & Raut, N. (2009). Macroscopic FE model for tracing the fire response of reinforced concrete structures. *Engineering Structures*, *31*(10), 2368-2379.

Koksal, F., Gencel, O., Brostow, W., & Lobland, H. H. (2012). Effect of high temperature on mechanical and physical properties of lightweight cement based refractory including expanded vermiculite. *Materials Research Innovations*, *16*(1), 7-13.

Li, M., Qian, C., & Sun, W. (2004). Mechanical properties of high-strength concrete after fire. *Cement and concrete research*, *34*(6), 1001-1005.

Mehta, P. K., & Monteiro, P. J. M. (2014). *Concrete: Microstructure, Properties, and Materials*. 4th ed. New York: McGraw-Hill Education.

Mehta, P.K., & Monteiro, P.J.M. (2006). *Concrete: Microstructure, Properties, and Materials*. 3rd Edition. McGraw-Hill, New York.

Mustafy, T., Hasan, M. M., Shuvo, N. A., & Mujib, J. M. S. (2022). Characterization of mechanical properties of concrete recycled ceramic and glass powder exposed to elevated temperatures. *MIST International Journal of Science and Technology*, *10*(1), 1-14.

Patil, S. S., & Patil, Y. D. (2021). Effect of elevated temperature on the mechanical strength of glass mortar. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1070, No. 1, p. 012046). IOP Publishing.

Peng, G. F., Bian, S. H., Guo, Z. Q., Zhao, J., Peng, X. L., & Jiang, Y. C. (2008). Effect of thermal shock due to rapid cooling on residual mechanical properties of fiber concrete exposed to high temperatures. *Construction and Building Materials*, *22*(5), 948-955.

Phan, L. T., & Carino, N. J. (2012). Fire performance of high strength concrete: research needs. In *Advanced technology in structural engineering* (pp. 1-8).

Poon, C. S., Azhar, S., Anson, M., & Wong, Y. L. (2001). Comparison of the strength and durability performance of normal-and high-strength pozzolanic concretes at elevated temperatures. *Cement and concrete research*, *31*(9), 1291-1300.

Powęzka, A., Szulej, J., & Ogrodnik, P. (2020). Effect of high temperatures on the impact strength of concrete based on recycled aggregate made of heat-resistant cullet. *Materials*, *13*(2), 465.

Qiang, X., Bijlaard, F. S., & Kolstein, H. (2012). Post-fire mechanical properties of high strength structural steels S460 and S690. *Engineering Structures*, *35*, 1-10.

Shah, S. P. (1992). Do fibers increase the tensile strength of cement-based matrix?. *Materials Journal*, *88*(6), 595-602.

Smith, R. G., & Kamwanja, G. A. (1986). The use of rice husk for making a cementitious material. In *Proc. Joint Symposium on the Use of Vegetable Plants and their Fibers as Building Material, Baghdad*.

Umran, M. K. (2002). *Fire flame exposure effect on some mechanical properties of concrete* [Master Thesis, College Engineering, Civil Department, Babylon University].

Wu, D., Mao, Z., Zhang, J., Li, S., & Ma, Q. (2023). Performance evaluation of concrete with waste glass after elevated temperatures. *Construction and Building Materials*, *368*, 130486.