Effect of Temperature on High Strength Reinforced Concrete

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Abstract-

Buildings with a lot of height are frequently constructed with high-strength concrete. Extreme temperatures will be applied to the concrete components of the structure, including the walls, slab, and columns, in the event of an unplanned fire. Understanding how exposure to excessive temperatures alters the characteristics of concrete is crucial for evaluating the performance of reinforced concrete members in high-rise structures. Investigating the impact of the kind of binder material on the characteristics of the concrete during enhanced temperature exposure is increasingly essential since the high-strength concrete produced may contain other binder materials in addition to cement. The deterioration of high-strength concrete's strengths and stiffness in respect to the type of binder material is outlined and discussed in this research. The outcomes demonstrated that the kind of binder material greatly affects how well high-strength concrete performs, especially when temperatures are below 800oC. At 1000 degrees Celsius, the choice of binder material has much less of an impact.

Keywords— *Buildings, High-Rise Structures, Investigating, Impact, Binder Materials, Temperatures*.

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INTRODUCTION

The significance of building materials' performance at high temperatures has been brought to light by the fire-caused collapse of the World Trade Centre in New York, USA, which resulted in numerous deaths.

The designers must be aware of these materials' thermal and engineering characteristics, such as conductivity and expansion, as well as their strength and stiffness, while choosing substitute materials. Undoubtedly, elevated heat conductivity and steel expansion, together with reductions in strength and stiffness, had a role in the buildings collapsing in front of millions of spectators in a very little timeframe following the terrorist assault. Many people are now asking the obvious issue of what would have happened to these towers' performance if concrete had been employed. Is it realistic to anticipate improved results without a collapse despite fewer casualties? Without a doubt, the developers, designers, and owners of high-rise structures want to know the answers to these queries. Understanding how exposure to severe temperatures affects the characteristics of concrete used in high-rise building construction is essential to finding the answers to these issues. The use of high-strength concrete enhanced the building heights that could be achieved without decreasing column thickness. Since thermal conductivity regulates the spread of heat within a concrete element, it is a crucial feature of concrete. The steel reinforcement cover serves as a barrier and aids in regulating the flow of heat through the reinforcement. The study presented by Marshall (1972) and Malhotra (1956) allows for the following conclusions to be made. When concrete heats up, moisture escapes, reducing the material's heat conductivity. Conductivity in a concrete mixture is greatly influenced by the type of aggregate used. It is reasonable to anticipate that low-cement paste concrete, such as high-strength concrete, will have a lower heat conductivity than lean concrete mixes. The choice of binder material affects thermal conductivity inasmuch as high-temperature water release from the paste containing cement additional material, such slag from blast furnaces, happens. The effects of exposure to high temperatures on the characteristics of concrete have been recorded by Malhotra (1956), Zoldners (1960), Davis (1967), Abrams (1971), Faiyadh (1989), Khoury (1992), and Noumowe et al. (1994). There are several known reasons why high temperatures cause concrete to deteriorate. These include the following: the production of microcracks because of the thermal incompatibility between the aggregate phase and the cement paste matrix, the expansion of lime upon rehydration, the breakdown of the gel structure, and the phase transition of particular types of aggregate.

EXPERIMENTAL DETAILS

(i) Materials and mixture proportions- High binder material concentration and a low water to cement ratio are typical characteristics of high strength concrete compositions. In order to produce usable concrete at a low water cement ratio, high-water reduction admixtures, or superplasticizers, were used. This allowed the concrete to have a compressive strength of well over 100MPa after 28 days. Four mixtures with different binder components were examined in this experiment. 565 kg/m3 of general purpose cement (Type GP) and general blended cement (Type GB) with a 62% blast furnace slag content made up Mixes 1 and 2. In Mix 3, low-calcium fly ash (115 kg/m3) was used in place of 20% of the Type GP cement. 40 kg/m3 of condensed silica fume and 565 kg/m3 of general purpose cement were present in Mix 4. The water to binder ratio was maintained at 0.30 by weight for each of the four blends. The coarse and fine aggregates were crushed basalt (specific gravity: 2.65), with a maximum aggregate size of 10 mm, and river sand (specific gravity: 2.62). The fine aggregate content was 35% by weight, and the ratio of aggregate to binder components was 3.0 by weight. To create workable concrete mixes, a fixed dosage of superplasticizer (2% by weight of binder) was added to each batch.

(ii) Heating equipment- The concrete specimens were heated to a maximum temperature of 100 degrees Celsius using a vented oven. An electrically heated furnace with a maximum temperature of 1200°C was employed at temperatures 200°C and above. The inside chamber of the furnace, which measured around 400 by 400 by 800 mm, had refractory walls that were covered in exposed heating components.

In order to achieve homogeneous heating throughout each specimen, the test specimens were stacked with enough space between two adjacent specimens. Due to the furnace's restricted capacity, the test specimens were heated in batches. The hot concrete specimens were handled with extreme caution.

(iii) Experimental procedure- After a day, all of the concrete test specimens were demolded and kept in water at 20 degrees Celsius. The specimens were taken out of the water after 28 days and allowed to dry for the following two days in a laboratory setting with an average temperature of 20 oC and a relative humidity of 65%. Pre-drying is a critical process to reduce the likelihood of a concrete specimen exploding in the furnace when exposed to high temperatures. 200oC per hour of heating was the constant pace of operation. The specimens were kept at this temperature until the desired maximum furnace temperature was attained. All concrete specimens, regardless of the highest temperature, spent a total of 7 hours in the furnace. The study's highest temperatures were 200°C, 400°C, 600°C, 800°C, and 1000°C. As a result, when the maximum temperature rose from 200 to 1000 degrees Celsius, the soaking time was shortened from six to two hours.

EFFECTS OF COLD WEATHER ON CONCRETE

When concrete is exposed to freezing temperatures without taking extra measures, the following effects might occur:

(i) Delayed Setting- The development of concrete strength is delayed compared to the development of strength at normal temperatures when the temperature drops to around 5°C or lower.

This lengthens the hardening time, which is required before forms can be removed, and makes it impossible to apply the knowledge gained from concrete at room temperature.

(ii) Early Concrete Freezing - Concrete that is subjected to below-freezing temperatures runs the danger of irreversibly losing its strength and other properties, such as increased permeability and decreased durability.

(iii) Repeated Freezing and Thawing of Concrete- The ultimate properties of concrete may also be harmed if it is subjected to repeated freezing and thawing following final set and throughout the hardening phase.

(iv) Stresses Caused by Temperature Differences- It is generally known that significant temperature differences inside concrete members can encourage cracking and negatively impact their longevity. When form insulations are removed in cold weather, these differences are likely to happen.

PROCEDURES AND FUNDAMENTAL IDEAS

(i) Planning- Make sure you have a firm understanding of the cold weather concreting techniques before you pour. It is strongly advised to have a pre-placement meeting with the producer, laboratory, specifier, contractor, and any other relevant parties.

(ii) Curing and Protection- When concrete needs to reach a certain strength in a few days or weeks, it's necessary to protect it from temperatures exceeding 10°C (50°F).

(iii) Temperature Records- Regardless of the air temperature, the protective efficacy is determined by the temperature of the concrete. It is crucial to keep track of the concrete's temperature in situ.

(iv) Heated Enclosures- Must be strong enough to be windproof and weatherproof. Combustion heaters must be vented to the outside to prevent carbonation.

(v) Exposure to Freezing and Thawing- Concrete should be properly air entrained if it will be saturated and exposed to freezing and thawing cycles during construction.

(vi) Slump- All else being equal, lower slump and/or lower water/cement ratio mixes are particularly desirable in cold weather for flatwork. This reduces bleeding and decreases setting time.

(vii) Truck Travel Time- The distance from the plant to the point of placement can have a severe effect on the temperature of concrete.

(viii) Hot Water- While hot water improves setting time of cold weather concrete, after the first few batches of concrete hot water heaters may not be able to maintain hot water temperature. Later in the pour, concrete may be cooler than at the beginning of the pour.

EFFECTS OF HIGH TEMPERATURE

Most concrete constructions are typically exposed to a temperature range that is no harsher than that imposed by the surrounding environment. Nonetheless, there are significant situations in which these structures might be subjected to much higher temperatures (such as blasts from jet aircraft engines, building fires, industrial applications involving chemicals and metallurgy where the concrete is near furnaces, and certain hypothetical accident scenarios involving nuclear power). The thermal characteristics of concrete are more complicated than those of most other materials because it is a composite material with several elements and because its characteristics are also dependent on porosity and moisture. Concrete's mechanical and physical qualities are impacted by high temperatures.

EFFECTS ON STRENGTH OF CONCRETE

High early temperatures have been shown to have detrimental effects on concrete's subsequent strength. Several scholars looked at the detrimental effects of high starting temperatures on the long-term strength of concrete. High initial rate of hydration brought on by elevated temperature causes a non-uniform dispersion of the hydration products and delays future hydration. The cause is that there is not enough time available at high initial rates of hydration for the products of hydration to diffuse away from the cement particle and for a uniform precipitation to occur in the interstitial space. Due to the concentration of the products caused by all of this near the hydrating particles, the effects strength and hydration rate are subsequently delayed. The following experimental effort by researcher H. A. M. Bishr of Sana'a University, Yemen, might help us understand the influence of temperature on the compressive strength of concrete with rising temperature. Reference: ICCBT 2008 - A - (019) - pages 217–220

ACCELERATION OF CONCRETE HYDRATION IN COLD WEATHER

As a result of shorter protection periods, quicker form reuse, earlier shore removal, and less labour required to finish flatwork, the decrease of setting time and the acceleration of strength growth frequently result in significant savings.

- When finishing flatwork, timing is particularly crucial.
- Early form elimination is more dependent on early strength increase.
- Using Type III Portland cement and 20% more Type I or II cement to produce Type III reaction are two ways to promote acceleration.

The least expensive accelerator on the market is calcium chloride, but when exposed to air and moisture, it corrodes implanted metals. For this reason, the use of chlorides in concrete is restricted. Making sure non-chloride accelerating admixtures are not corrosive is crucial. Even accelerating admixtures with non-chloride labels may include ingredients that make the finished goods corrosive to metals that are incorporated in them. Although non-corrosive, non-chloride accelerators are more expensive initially, they end up being the most economical items when life-cycle costs and chloride-limiting restrictions are taken into account. Although they can be added to the mix after the cement has wetted, accelerators have been successfully added to concrete both before and after the cement has been added to the mix. Rarely, there may be unfavourable reactions with the tricalcium aluminate (C3A) in the cement if accelerators are introduced to the mixture before the batching of under-sulfated cements. These reactions might cause retardation. As a result, we advise testing the accelerator with the desired cement at the intended usage temperature before placing it if it is to be introduced upfront, before the cement. The setting periods of various blends and materials will vary. It is not reasonable to expect two distinct Portland cements to set at the same speeds. Prior to installation, trial mixes containing pozzolans should be added if they are going to be utilised in the concrete.

EXPERIMENTAL WORK

To show the effects of elevated temperature on compressive strength of concrete, basalt aggregate concrete was mixed according to ASTM C192.

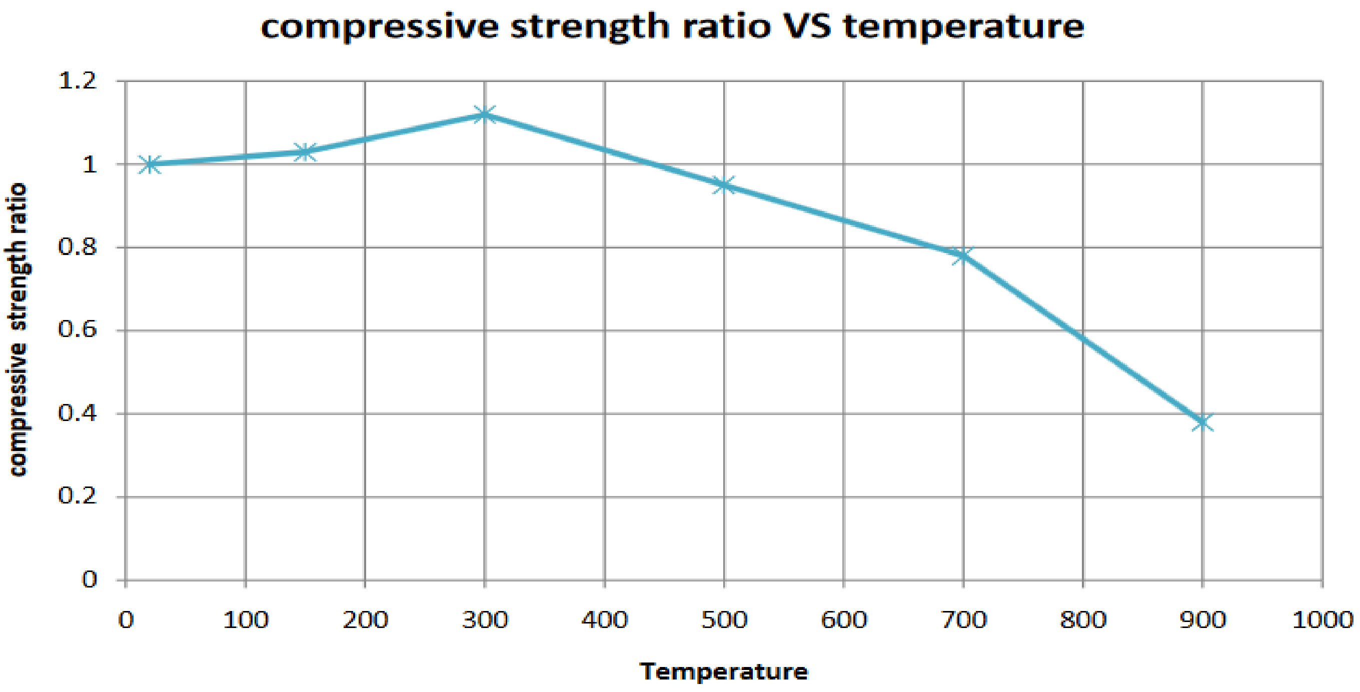

Figure 1- compressive strength ratio VS temperature

To perform structural evaluations on flat slabs, arch dams, tunnels, tanks, and other statically indeterminate elements, Poisson's ratio is required. Poisson's ratio for concrete under typical ambient circumstances ranges from 0.11 to 0.32, although it often falls between 0.15 and 0.20. The information that is currently available does not show a pattern for how Poisson's ratio changes with concrete strength, age, or other characteristics. Nonetheless, certain test findings show that the ratio decreases for concretes with greater strengths and rises with concrete age up to around two years. There are not many reliable and consistent data on how high temperatures affect Poisson's ratio. According to some statistics, the Poisson's ratio falls as temperature rises, but reports from other sources state that it rose above 400°C and varied from 0.11 to 0.25 between 20°C and 400°C. According to additional data on greater strength concrete, the ratio of toxins to peak value dropped when temperature increased as long as stress remained below 50% of peak value. The Poisson's ratio findings for a hard sandstone aggregate concrete are displayed in Fig. 01 for specimens that were either sealed or unsealed during heating. The results are shown for different heating times (i.e., 1, 7, 28, and 91 d) at 175°C. Poisson's ratio varied from 0.14 to 0.22, showing an increasing tendency as the concrete's moisture content increased.

The specifications of the specimens, concrete proportions and testing conditions are as follows:

- Cube specimens with dimensions 100*100*100 mm3.
- Cement : Ordinary Portland Cement 350 kg/ m3
- Coarse aggregate: Basalt aggregate (crushed stones)
- Fine aggregate : Local sand
- Water : 175 Liters (W/C = 0.50)
- Temperatures: 20, 150, 300, 500, 700, 9000 C.
- Curing age : 28 days

Specimens were left in the oven for 4 hours to achieve a uniform temperature distribution across them. After that, specimens were allowed to cool in the oven for 20 hours, a total of 24 hours of heating and cooling past the curing age. A loading rate of 3 kN/s was used to get the residual compressive strength of concrete.

CONCLUSION

One commodity that is frequently utilised is concrete. It's applied in a range of settings. Concrete is a very simple idea, but it may be difficult to understand at times, and even seemingly insignificant details like temperature can have a significant impact on how well concrete performs. For comparatively better, more useable, and long-lasting concrete, it is important to adhere to the rules for concreting in severe weather. Furthermore, the safety factor in unique constructions like nuclear reactors should be adjusted in accordance with the concrete's loss of strength in extremely hot weather. The following conclusions may be drawn from the experimental investigation's findings:

- Weight loss occurs in high-strength concrete regardless of the type of binder material utilised, and there is a nonlinear connection between weight loss and maximum temperature.
- Even at 200°C, there were considerable losses in the tensile and compressive strengths (over 15%), although there was only a slight decline in the elastic modulus, around 5%.
- The worst-performing concrete under elevated exposure temperatures below 800oC was silica fume-infused concrete.
- Regardless of the type of binder material employed, high-strength concrete has demonstrated a 90% reduction in strength when exposed to 1000oC.

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