Erudite Journal of Engineering Technology and Management Sciences

Vol. 2, No. 2, June, 2022, pp. 01-03

Journal homepage: http://www.ejetms.com

Effect of Elevated Temperatures on Properties of Ultrafine Slag Concrete – A Review

D Sreekanth, T Harshitha, V Sai Lokesh*, B Siva Ganesh, D Upendra

[1] Department of Civil Engineering, Sri Venkateswara College of Engineering & Technology (Autonomous), R.V.S Nagar, Chittoor, Andhra Pradesh, India

Corresponding Author Email: lokeshvarisetty2000@gmail.com

Received: 09 May 2022

Accepted: 12 June 2022

Keywords:
Ultrafine slag, Elevated temperatures, Cement replacement, Compressive strength, Weight loss,

ABSTRACT

Concrete is a versatile engineering material used in the construction industry. It is usually subjected to elevated temperature in an accidental fire, or industrial installations fire prolonged duration known as Sustained Elevated Temperature. The change in properties of concrete due to elevated temperature depends on many factors like maximum temperature, duration, concrete grade, etc. The present literature gives the changes in concrete considering maximum temperature, and the results are based on time-temperature curves. It does not reveal much information on the duration effects of temperature

1. INTRODUCTION

Several factors influence the variation of the strength in concrete with temperature. In their classic publications, Lea and Strandling (1922) explored the factors that can influence the strength of concrete at elevated temperatures. Some of the critical factors that affect are 1. Water-cement ratio 2. Type of aggregate 3. Age of specimens 4. Rate of heating and duration of heating 5. Loading during temperature exposure 6. Cooling of samples 7. Cement blend 8. Moisture content. In addition to the above, experiments have shown that the method of testing, duration of heating, size and shape of the test specimen, and the loaded condition, size, and shape of aggregate significantly affect the change of strength with temperature.

When concrete is exposed to high temperatures, complex transformations take physically and chemically, resulting in a significant loss in strength. As concrete is employed in structures primarily to resist compressive stresses, the study on the effect of elevated temperatures on the compressive strength of concrete has engaged the attention of many research workers in various countries. The effect of elevated temperature on the properties of concrete embraces the temperature activated - accelerated processes or phenomena such as changes in the degree of hydration, moisture content, and the other microstructural features, as well as moisture and temperature-difference, produced stresses and their consequences, etc., all of which more or less affect the strength of concrete. The effect of high temperature on the mechanical properties of concrete has been investigated since the 1940's Mezel (1943), Biimer (1949), Malhotra (1956), Saemann (1957), and Gustaferro (1967). These studies may be divided into two categories: materials testing and element testing. Material testing involves mainly tests on plain concrete specimens. Materials testing results provide information on the effects of temperature on mechanical properties, such as compressive strength, modulus of elasticity, and ultimate strain. Elements testing involves tests on reinforced structural elements such as beams, columns, and slabs. Results of element testing can be used to assess the fire endurance of particular concrete structural elements and to provide data for developments for rules for the fire design of concrete structures.

When employed as a partially replaced ingredient for cement in concrete, metakaolin combines with $Ca(OH)_2$, one of the products of the hydration process, resulting in additive C-S-H gel and an enhancement in different strength qualities of concrete. It also lowers the permeability of hardened concrete. As a result, partially substituting Metakaolin for Portland cement decreases carbon dioxide emissions into the environment during cement manufacturing and enhances structures' service life [1-5].

Concrete's mechanical and water absorption characteristics are primarily determined by the hardened cement paste structure and the continuously growing paste-aggregate interface. Because of the increased silicon dioxide powder concentration, nano silica, a novel pozzolanic material created artificially in the form of a water emulsion of Ultra Fine Amorphous Colloidal Silica (UFACS), has better characteristics than silica fume. The use of Nano Silica can increase the impermeability and strength of concrete. The current study attempted to evaluate the combined application of Metakaolin and Nano Silica on the performance of concrete [6-12].

2. COMMON TEST METHODS

Literature shows that the test methods used in experimental programs of concrete subjected to elevated temperature can be broadly classified into two groups based on i) Temperature variation and ii) Stress variation.

2.1 Temperature Variation Tests

A number of different test methods were used in experimental programs to determine the mechanical properties of concrete at elevated temperatures. The test methods can be generally grouped into two categories: steady temperature tests and transient temperature tests Schneider (1985), Schneider (1988) and Comite Euro International du Belton (CEB) (1991). The test method selected for a particular study depended on the desired test data, e.g., stress-strain relationships at different temperatures, stress Vs time relationships at different temperatures, etc. Various test methods were also selected to simulate the internal stress conditions related to specific structural elements, such as beams and columns. The test results' interpretation and applicability depend on the method employed.

2.1.1 Steady State Test

The specimen is heated slowly to a target temperature; the external temperature is held constant to allow the internal specimen temperature to reach a uniform value. The properties are measured after a uniform internal temperature is reached.

2.1.2 Transient Test

The specimen is exposed to an ambient temperature that increases at a relatively fast rate, and temperature gradients exist in the sample during the test. During the heating, the specimen could be subjected to a constant load or deformation (resistant provided). Steady-state tests are better suited for measuring the effects of temperature on material properties, and transient tests are better suited for investigating behavior conditions that may be countered during an actual fire. Thus, transient tests are usually conducted for tests on structural elements. Finally, different methods of loading are possible to measure mechanical properties. These include Stress-rate control - the stress is increased at a constant rate, Strain- rate control - the strain is increased at a constant rate, Constant strain (creep) - stress is maintained constant and deformation is measured as a function of time, Constant strains (relaxation) - strain is kept constant and stress is calculated as a function of time. The first two of these are commonly used to develop the stress-strain relationship of the concrete. The latter two types of loading are used to measure time-dependent response, which may be of limited importance considering the relatively short fire duration.

2.2 Stress Variation Tests

Three common test methods referred to as stressed, unstressed and unstressed residual strength testing has been used in most experimental program on the fire performance of concrete. A general description of these test methods is given below.

2.2.1 Stressed Test

A preload in the range of 20% to 40% of the ultimate compressive strength at room temperature (usually 20°C) is applied to the concrete specimen prior to heating and the load is sustained during heating period. Heat is applied at a constant rate until a target temperature is reached and the temperature is maintained until a thermal steady state is achieved (reportedly 5 to 10 minutes). Load or strain is then increased at a prescribed rate until the specimen fails. The results of this test are most suitable for representing fire performance of concrete in a column or in the compression zone of beam.

2.2.2 Unstressed Test

The specimen is heated without preload at a constant rate to the target steady state is reached within the specimen. Load or strain is then applied at a prescribed rate until failure occurs. This test method is identical to the steady state temperature, stress, or strain-controlled test. The results of this test are most suitable for representing the fire performance of concrete in the tension zone of beam or concrete in an element with a small preload.

2.2.3 Unstressed residual strength tests

The specimen is heated without preload at a prescribed rate to a target temperature, which is maintained until a thermal steady state is reached within the specimen. The specimen is then allowed to cool also following a prescribed rate to room temperature. Load or strain is applied at room temperature until the specimen fails. The unstressed residual strength test differs from all the test methods described above and its results are most suitable for assessing the post-fire (or residual) properties of concrete.

2.2.4 International standard test methods

A major problem in comparing data on fire performance from different laboratories is the lack of common test methods. RILEM committee 129-MHT on test methods for mechanical properties of concrete at high temperatures is in the process of developing a set of recommendations that may provide the basis for future international standards. In the experimental assessment of the performance of concrete exposed to elevated temperature, several key features of test methods need to be considered in order to interpret and compare results Phan(1996) and these include:

- Temperature distribution in the specimen during the measurements of material properties.
- Relationship between temperature and load histories.
- Type of loading.

2.2.5 Time-Temperature Curves

Different countries and codes have developed time-temperature curves to determine the fire endurance of concrete structural elements based on temperature history. These curves are followed in most experimental programs to compare the results of testing programs at different places in the same country or other countries.

In some studies, they differ from the curves based on their need for sustaining the temperature effects. This sustained temperature effect is varied from a few hours to several years, depending on the necessity of the studies.

Three fire test methods, the international organization of standards (ISO), American Society for Testing and Material (ASTM Ell9), and Japanese Industrial Standard (JIS A1304) were summarized. All three methods prescribe similar criteria for determining fire endurance of concrete structural elements. In terms of temperature history, the standard temperature curves of the three test methods are also identical, as shown in fig 1. the ISO 834 standard fu-e curves differ from those of ASTM E119 and JISA1304inthat it allows the temperature to rise continuously with exposure time, without a specified upper limit. ASTM E119 specifies a temperature rise up to 480 minutes, after which the temperature is kept constantat1260°C; JIS A 1304 has an exposure time limit of 240 minutes, corresponding to a fire endurance rating of "4 hours heat".

Concerning the properties of concrete at high temperatures, information from the CEN Eurocodes, ACI 216 R-89, CEB Bulletin D' information the RILEM 44-PHT. Properties at high temperature and the CRSI report were reviewed. The CEN Eurocodes (2 and 4) provided the most comprehensive treatment of concrete properties at high 10 temperatures. A strength reduction factor kc A is specified for normal weight and unit weight aggregate concretes. The CEB bulletin D' information, fire design of concrete structures, and the report of RILEM committee 44-PHT, properties of materials at high-temperature concrete provide experimental data for different concrete properties at high temperatures as well as recommended design curves, based on these experimental data. ACI 216 R-89, Guide for determining the fire endurance of concrete elements and the CRSI report, reinforced concrete fire resistance, also described the effect of high temperatures on concrete properties based on experimental data, but without a prescriptive mathematical formulation as that proposed in the CEN Eurocodes. 9It should be noted that the experimental data that provided the basis for recommendations and observations made in the above documents were from tests of normal strength concrete. Most of the tests were conducted in the 1960s and 1970s. The maximum room temperature compressive strengths used were about 50 MPa. Thus the applicability of these design recommendations to ESC(Early Strength Concrete) must be verified before using them for the design of ESC.

REFERENCES

[1] Al-Shaikhli, M. S., Badaruzzaman, W. H. W., Baharom, S., & Al-Zand, A. W. (2017). The two-way flexural performance of the PSSDB floor system with infill material. *Journal of Constructional Steel Research*, *138*, 79-92.

[2] Campbell, F. C. (2010). *Structural composite materials*. ASM international.

[3] Kirca, Ö. (2018). Ancient binding materials, mortars and concrete technology: History and durability aspects. Structural Analysis of Historical Constructions; Modena, C., Lourenço, PB, Roca, P., Eds, 87-95.

[4] Sobolev, K., & Yeğinobali, A. (2005). The development of high-strength mortars with improved thermal and acid resistance. Cement and Concrete Research, 35(3), 578-583.

[5] Menou, A., Mounajed, G., Boussa, H., Pineaud, A., & Carre, H. (2006). Residual fracture energy of cement paste, mortar and concrete subject to high temperature. *Theoretical and Applied Fracture Mechanics*, 45(1), 64-71.

[6] Salih, M. A., Farzadnia, N., Demirboga, R., & Ali, A. A. A. (2022). Effect of elevated temperatures on mechanical and microstructural properties of alkali-activated mortar made up of POFA and GGBS. *Construction and Building Materials*, 328, 127041.

[7] Aydın, S., & Baradan, B. (2007). Effect of pumice and fly ash incorporation on high temperature resistance of cement based mortars. *Cement and concrete research*, 37(6), 988-995.

[8] Aydın, S. (2008). Development of a high-temperature-resistant mortar by using slag and pumice. *Fire safety journal*, 43(8), 610-617.

[9] Reddy, P. N., Jindal, B. B., Kavyateja, B. V., & Reddy, A. N. (2020). Strength enhancement of concrete incorporating alccofine and SNF based admixture. *Advances in concrete construction*, 9(4), 345-354.

[10] Reddy, A. N., Mounika, P., & Moulika, R. (2018). Study on effect of alccofine and nano silica on properties of concrete-A review. *International Journal of Civil Engineering and Technology (IJCIET)*, 9(13), 559-565.

[11] Reddy, N., Naveen, K., & Rani, N. S. (2015). Use the Treated domestic waste water as a mixing water in cement mortar. *International Journal of Engg. Science Invention*, 23-31.

[12] Karthik, S., & Taylor, J. (2021). Comparative Analysis on Strength Parameters and Stress-Strain Behaviour of Sifcon with Ferrocement. *Erudite Journal of Engineering, Technology and Management Sciences*, 1(1), 01–05.

[13] Sai Karthik, & Jeremy Taylor. (2022). A Study on Effect of Compressive Strength of Ternary Blended Concrete using Metakoline and Nano Silica. *Erudite Journal of Engineering, Technology and Management Sciences*, 1(2), 17–19.