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Research Article

Effect of Variation of Elevated Temperature on Compressive Strength of Metakaolin Concrete: Literature Study

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Abstract

It has been found that high early temperature has negative impacts on later compressive strength of concrete. Some researchers investigated the adverse effect on long term strength of concrete due to high initial temperature. The effect of temperature on different properties of concrete is considerable and remained the subject of research activities of a lot of researchers. Different investigators moved in different ways and investigated temperature effect by changing different parameters such as w/c ratio; mix ratio, early change in temperature etc. The objective of this literature work is to provide an overview of the effects of elevated temperature on the behavior of Metakaolin concrete materials and structures. In meeting this objective the effects of elevated temperatures on the properties of concrete constituent materials and concretes are summarized. The effects of elevated temperature on high-strength concrete materials are noted and their performance compared to normal strength concretes.

Keywords: *Compressive Strength, Metakaolin Concrete etc.*

1. Introduction

Concrete is a material often used in the construction of high rise buildings and in case of unexpected fire, the concrete properties are changes after fire. Hence, it is important to understand the change in the concrete properties due to extreme temperature exposures. As the concrete used for special purpose, the risk of exposing it to high temperature also increases. To be able to predict the response of structure after exposure to high temperature, it is essential that the strength properties of concrete subjected to high temperatures be clearly understood. High temperature can cause the development of cracks.

These cracks like any other cracks propagation may eventually cause loss of structural integrity and shorting of service life. The influence of elevated temperatures on mechanical properties of concrete is of very much important for fire resistance studies and also for understanding the behavior of containment vessels, chimneys, nuclear reactor pressure vessels during service and ultimate conditions structures like storage tanks for crude oil, hot water, coal gasification, blast furnace foundation and cokocola industries, furnace walls chimneys, runways for air craft etc., will be subjected to elevated temperatures. So that the differentiation of compressive strength, performance are some of the important parameters to be investigated when concrete structures are subjected to elevated temperatures.

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The production of Portland cement is a costly as well as energy intensive & it also produces large amount of carbon emission. The one ton production of Portland cement produces one ton of CO_2 in the atmosphere. Limestone is a raw material. It is primary used for production of cement material. It was used directly to form silica flume mortar as a binding material in construction. Supplementary cementitious materials are used to reduce cement contents and improve the workability of concrete, increase strength and enhance durability of hardened concrete. SCMs used in the manufactured concrete products industry as well as a review of blended cements. The various types of supplementary cementitious material such as fly ash, silica fume, slag cement, metakaolin, rice husk ash, coconut shell etc. available in nature. Out of these metakaolin is used to investigate the mechanical properties of concrete by various experiments.

Metakaolin is the refined kaolin clay that is fired under carefully controlled conditions to create an amorphous aluminosilicate which is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), metakaolin reacts with the calcium hydroxide (lime) by products produced during cement hydration. Mk is a dehydroxylated form of the clay mineral kaolinite. Rocks that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The size of particles of metakaolin is smaller than cement particles, but not as fine as silica fume. The quality and reactivity of metakaolin is dependent of the characteristics of the raw material used. It can be produced from a variety of primary and secondary sources containing kaolinite: High purity kaolin deposits, Kaolinite deposits or tropical soils of lower purity, Paper sludge waste (if containing kaolinite), Oil sand tailings (if containing kaolinite).

The effect of temperature on different properties of concrete is considerable and remained the subject of research activities of a lot of researchers. Different investigators moved in different ways and investigated temperature effect by changing different parameters such as w/c ratio; mix ratio, early change in temperature etc.

The objective of this literature work is to provide an overview of the effects of elevated temperature on the behavior of Metakaolin concrete materials and structures. In meeting this objective the effects of elevated temperatures on the properties of concrete constituent materials and concretes are summarized. The effects of elevated temperature on high-strength concrete materials are noted and their performance compared to normal strength concretes.

1.1 The Objectives of Present Study

The objectives of this topic are to investigate the effects of high temperatures on Metakaolin Concrete performance. High temperature resistance is defined as the ability of a structural element to withstand its load-bearing function under high temperature condition. The concrete behavior at high temperature is of concern in predicting the safety of building and construction in response to certain accidents or particular service conditions. The behavior of concrete with respect to high temperature where tested on groups of specimens to identical testing condition.
To study the properties of fresh concrete.

To Study the properties of concrete with replace of cement by supplementary cementitious material as Metakaolin.

To study the effect of sustained elevated temperature ranging 50oc to 200oc for 5 hour and then cooling in air and water on M35 grade concrete without steel with reference to compressive strength.

To compare the results obtained, with M35 grade concrete at room temperature.

2. Literature works

A lot of research work has been done and is going on the use of Metakaolin as cement replacement in enhancing different properties of concrete.

Research work done by different researchers is discussed here in brief.

Gyu-Yong Kim, Young-Sun Kim, Tae-Gyu Lee: Recently, the effects of high temperature on compressive strength and elastic modulus of high strength concrete were experimentally investigated. The present study is aimed to study the effect of elevated temperatures ranging from 200 to 700° C on the material mechanical properties of high-strength concrete of 40, 60 and 80 MPa grade. During the strength test, the specimens are subjected to a 25% of ultimate compressive strength at room temperature and sustained during heating, and when the target temperature is reached, the specimens are loaded to failure. The tests were conducted at various temperatures (200 to 700° C) for concretes made with W/B ratios of 46%, 32% and 25%, respectively. The results show that the relative values of compressive strength and elastic modulus decrease with increasing compressive strength grade of specimen.

To study the effect of transient high temperature on the strength and deformation characteristics of high strength concrete, the test specimens of high-strength concrete with nominal strength of 40, 60 and 80 MPa were subjected to temperatures up to 700 °C and loaded to failure under axial compression. For each type of concrete, the specimens were tested under stressed conditions. In stress tests, the specimens were preloaded to 25% of their ultimate compressive strength at room temperature. High-strength concrete was made from type Portland cement, natural sea sand, and crushed granitic gravel. Owing to the low W/C ratio adopted, the super plasticizer was used to increase the workability. A commercially available suffocated naphthalene formaldehyde-type super plasticizer was used in Mix and Mix II, and the polycarboxylic-acid type super plasticizer was used in Mix Ⅲ to obtain high-strength concrete. The properties of the used materials and the mix proportion are given in Tables 1 and 2, respectively.

R V Balendran, T Maqsood, A Nadeem: A great deal of research has been conducted on the fire resistance properties of concrete. With the advent of use of HSC in 1970's, the researchers are trying to establish the body of knowledge concerning different aspects, for example, differences with normal strength concrete, effects of various ingredients on the overall performance of High Strength Concrete etc. Such knowledge established so far is considerable but when it comes to the fire properties of HSC it becomes scarce, showing this area is still under researched. It has been observed that HSC has certain shortcomings in the form of increased brittleness and decreased fire resistance. High strength concrete (HSC) becomes more brittle with the increase in strength and silica fume content.

The strength of HPC degenerated more sharply than the conventional concrete with the increase of exposed temperature but it was found that HPC had higher residual strength. With low water/cementitious material ratios and addition of silica fume, HSC becomes denser and it is more difficult for the vapour to escape in the case of fire. Therefore, the risk of spalling is increased for HSC. This paper forms the part of research project undertaken to establish and evaluate fire properties of HSC and is specifically related to seek the effect of 'Cooling Method', if any, at two curing ages to further align and refine the research methodology. The paper illustrates an investigation undertaken to demonstrate the effect of quick and slow cooling on residual compressive strengths of various high strength concrete grades (60, 90, 110, 130 MPA) cured for 28 days and 180 days and heated to the temperatures of 200°C and 400°C. It was found that cooling method has a significant effect on the residual compressive strength. The strength loss

Pattern produced by quick cooling at 200°C and 400°C is almost similar for all the concrete grades tested. It was also found true for slow cooling. However the strength loss was found to be higher at 400°C than at 200°C under both cooling conditions. The specimens lost the strength in the range of 30-45% of the original when quick cooled in water and 2-20% when slow cooled in air. In addition, specimens cured for 180 days exhibited more loss in strength than those cured for a period of 28days, under both cooling conditions. It is concluded that the critical condition may occurs when a concrete cured for an age of 180 days or more is subjected to an elevated temperature of 400°C and quick cooled later, causing a loss of 40-45% of its original compressive strength.

Adel A. El-Kurdi, Ali Abdel-Hakam, Mohamed M. El-Gohary: Limestone is normally less expensive than Portland cement and can cost effectively replace a part of the powder content in most concretes. For this suppose, the scope of this work is to provide experimental data on the residual mechanical and physical properties of concrete containing limestone powder as a replacement or additive of cement content by mass subjected to heat. For this goal, five mixtures were casted, one as a control mixture and the others were with 10 and 15% limestone fines as a replacement and additive of cement content by mass. Reductions in both compressive and flexural strength results along with the extent of weight loss were examined. The mineralogy in unheated and preheated concrete at 20, 200, 400 and 600ºC was identified by means of thermogravimetry (TGA/DTG).

Finally the scanning electron microscope (SEM) was done to study the microstructure of the hardened concrete. According to the results, limestone fines had a considerable effect on the properties of the concrete. The results indicated that, the residual compressive and flexural strength of 10 and15 % limestone fines as additive to cement content by mass are generally higher than those of convention concrete. In other words, elevated fire temperature is more damaging to the traditional concrete compared with additive limestone concrete.

It has been established that limestone replacement causes reduce the compressive and flexural strength due to the dilution effect. The presence of limestone fines generally reduces the weight loss of heated concrete. TGA/DTG curves of unheated and preheated specimens can be used to estimate the degree of temperature which may the concrete exposed in accidental building fire as a practical part. Based on SEM images, no obvious cracks in limestone concrete whether as limestone replacement or additive up to 600ºC and the CaCO3 clearly observed without decomposition.

Balakrishnaiah.D, Balaji.K.V.G.D, Srinivasa Rao.P: The extensive use of concrete as a structural material for the high-rise buildings, nuclear reactors, pressure vessels, storage tanks for hot crude oil & hot water and coal gasification & liquefaction vessels increases the risk of concrete being exposed to elevated temperatures. Concrete is most suitable to resist high temperatures because of its low thermal conductivity and high specific gravity. The mechanical properties like strength, modulus of elasticity, colour etc., are affected by the high temperatures exposure. High Performance Concrete (HPC) made with the partial replacement of cement by additives such as fly ash, silica fume, Metakaolin, finely grounded pumice(FGP), group granulated blast furnace slag (GGBS), polypropylene fibre(PP fibre), palm oil fuel ash(POFA), Portland pozzolana cement (PPC), rice husk ash(RHA) provides higher fire resistance. These concretes play very important role in the present day durable concrete construction utilizing the mineral and chemical admixtures with low water cement ratio and high strength aggregates. The researchers focused on the use of HPC subjected to elevated temperatures to know their fire resistance. It was investigated that the loss in structural quality of concrete due to a rise of temperature is influenced by its degradation through changes induced in basic processes of cement hydration and hardening of the binding system in the cement paste of concrete. Similarly many researchers worked on various materials and combinations of materials that can resist the changes in the mechanical properties of concrete when subjected to high rise in temperatures.

The present review presents information of such investigations that provide insight into the effect of elevated temperatures on the mechanical properties of various High Performance Concretes made by adding different admixtures.

Concrete, the second highest consumed material after water in the world, plays a vital role in the construction field because of the versatility in its use. Developments during the last two decades have shown a marked increase in the number of structures involving the long time heating of concrete.

In recognition of its importance, many researchers have attempted to investigate the effect of elevated temperature on mechanical properties of concrete. These researchers, during their investigation, used materials with varying combination and different experimental conditions. These materials include cement, different percentages of admixtures like fly ash, silica fume, Metakaolin, finely grounded pumice (FGP), group granulated blast furnace slag(GGBS), polypropylene fibre (PP fibre), palm oil fuel ash(POFA), Portland pozzolana cement(PPC), rice husk ash(RHA), different fine and coarse aggregates, super plasticisers, retarders and the conditions included a temperature range of 28oC to 1200oC . The other conditions that were varied are the shapes and sizes of test specimens, curing methods, curing conditions and test methods. The analysis of these investigations and their results are reviewed and presented in this paper.

Research paper by Hong-Sam Kim, Sang-Ho Lee, Han-Young Moon on strength properties and durability aspects of high strength concrete uses Metakaolin; It is a cementitious material used as admixture to produce high strength concrete. Various tests were conducted on concrete specimen in order to evaluate & compare the properties & durability of concrete by using mk. such as compressive, tensile & flexural tests, durability tests like rapid chloride permeability test, immersion test in acid solution, repeated freezing & thawing test & accelerated carbon test. Strength tests revealed that the most appropriate strength was reduced significantly as the proportion of silica fume & mk binders increased. The tests implemented in this study confirmed that Metakaolin constitutes a promising material as a substitute for the cost prohibitive silica fume.

Samir N. Shoukry, Gergis W. William, Mourad Y. Riad, Brian Downie: Concrete is widely used in various structures that are exposed to continuous variations in temperature and moisture content. The mechanical and physical properties of concrete are more complex than most materials as they are impacted by the environmental conditions when it is poured and cured. Enormous research was conducted on the curing of concrete during extreme cold and dry conditions, cool and damp conditions, warm and humid conditions, as well as extreme hot and dry conditions.

As a result, in extreme weather conditions such as extreme cold or hot, construction may be delayed until the environment improves unless precautions are taken for concrete curing. For example, normal concrete can be poured in sub-freezing temperatures if the surfaces are heated and the concrete is covered. Normal concrete can also be poured in hot dry conditions if the surface is wetted periodically and covered. However, the main concern is how such a concrete would behave after curing under varying temperature and moisture conditions. Previous studies indicated that concrete exhibits change in its compressive strength and its modulus of elasticity as environmental conditions change.

Concrete mechanical properties are determined under laboratory conditions of ideal air temperatures between 20 and 22 °C and relative humidity between 40 and 60 percent. This paper describes the development of concrete mechanical properties when cured under different environmental conditions. Tests to measure Modulus of elasticity, compressive strength, and split tensile strength were conducted at varying temperatures and humidity conditions to examine what their effects on normal concrete. This was done with the aid of an environmental chamber constructed of widely available materials in the laboratory. The chamber works in conjunction with a freezer to provide chilled air and a heat gun to provide hot air. The chamber heating and cooling functions were controlled via a microcontroller. The moisture content in the concrete specimens was controlled by massing the specimens. The results indicate that concrete strength and modulus of elasticity are inversely related to temperature as well as moisture content in the concrete. Concrete modulus of elasticity was directly related to concrete compressive strength in both temperature and moisture testing. Mathematical formulas were developed for modulus of elasticity, compressive strength, tensile strength, and Poisson's ratio.

R. Sri Ravindrarajah, R. Lopez and H. Reslan: High-strength concrete is a material often used in the construction of high rise buildings. In the case of unexpected fire, the building concrete elements such as columns, slab and walls will be subjected to extreme temperatures. In order to assess the performance of high-rise reinforced concrete members it is important to understand the changes in the concrete properties due to extreme temperature exposure. Since the high-strength concrete produced may contain various binder materials in addition to cement, it is also becoming necessary to investigate the influence of the binder material type on the concrete properties under elevated temperature exposure. This paper summarizes and discusses the degradation of the strengths and stiffness of high-strength concrete in relation to the binder material type. The results showed that the binder material type has a significant influence on the performance of high-strength concrete particularly at temperatures below 800°C. The influence of the binder material type is significantly decreased at temperature of 1000°C. The strengths and stiffness of high-strength concrete are reduced with the increase in temperature without any threshold temperature level. The strengths are susceptible to the elevated temperatures compared to stiffness of concrete. High-strength concrete containing silica fume seems to be more sensitive to elevated temperature.

Ahmad A. H., Abdulkareem, And O.M: This research work includes an experimental investigation to study the effect of high temperatures on the mechanical properties of concrete containing admixtures. A comparative study was conducted on concrete mixes, reference mix without an additive and that with an admixture. Concrete was exposed to three levels of high temperatures (200,400,600)° C, for a duration of one hour, without any imposed load during the heating. Five types of admixtures were used, super plasticizer, plasticizer, retarder and water reducing admixture, an accelerator and an air entraining admixture. Mechanical properties of concrete were studied at different high temperatures, including: compressive strength, splitting tensile strength, modulus of elasticity and ultimate strain. Test results showed a reduction in the studied properties by different rates for different additives and for each temperature, the decrease was very limited at temperature up to (200°C) but was clear at (400,600)° C.

Venkatesh Kodur: Fire response of concrete structural members is dependent on the thermal, mechanical, and deformation properties of concrete. These properties vary significantly with temperature and also depend on the composition and characteristics of concrete batch mix as well as heating rate and other environmental conditions. In this chapter, the key characteristics of concrete are outlined. The various properties that influence fire resistance performance, together with the role of these properties on fire resistance, are discussed. The variation of thermal, mechanical, deformation, and spalling properties with temperature for different types of concrete are presented.

Usman Ghani, Faisal Shabbir, Kamran Muzaffar Khan: In this research work, the effect of low and high temperature on various properties of concrete was investigated. The properties investigated were modulus of rupture of concrete beams, compressive strength and tensile strength of concrete. Three different temperatures were used for this purpose. These were low, room and high temperatures. The low temperature was 5°C, room temperature was 28°C and high temperature was taken as 55°C. For compressive strength calculations, cubes of sizes (6″x6″x6″) were cast. Cylinders of sizes (6″x12″) were made for tensile strength measurement, and for modulus of rupture beams of sizes (4″x4″x18″) were cast. Locally available material was used in casting these samples. After casting these samples, curing was carried out at low and high temperature along with room temperature. These samples were then tested after three, seven and twenty eight days of curing and a comparative study was carried out.

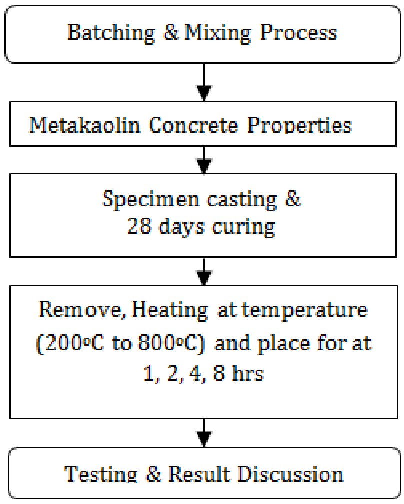
H. G. Mundle: The influence of elevated temperatures on mechanical properties of concrete is of very much important for fire resistance studies and also for understanding the behavior of containment vessels, chimneys, nuclear reactor pressure vessels during service and ultimate conditions structures like storage tanks for crude oil, hot water, coal gasification, liquefaction vessels used in petrochemical industries, foundation for blast furnace and coke industries, furnace walls industrial chimney, air craft runway etc., will be subjected to elevated temperatures. So that the variation of compressive strength, performance are some of the important parameters to be investigated when concrete structures are subjected to temperatures.

2.1 Concluding remark

It is observed from the literature survey that the use of Metakaolin is more advantageous as they enhance the overall mechanical properties of concrete than plain concrete. Thus, one can think of comparison in such plain concrete and Metakaolin concrete their different elevated temperature and check their engineering properties. It is also inferred that is better to study of concrete behavior with such.

3. Experimental works

3.1 Flow chart of works



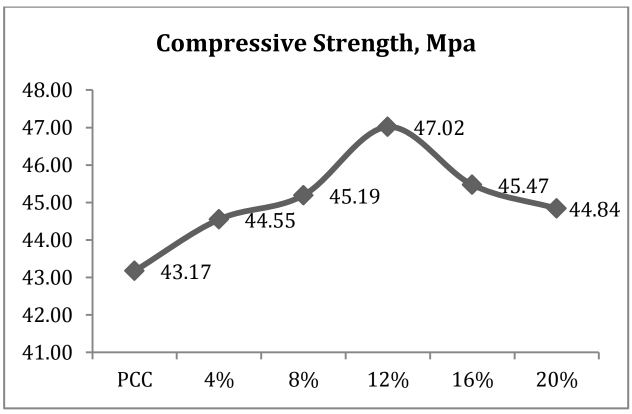
3.2 Test conducted on hardened concrete confirming to IS 516-1959

In present study cube compression test, flexural test on beams, split tensile test on normal concrete and properties of concrete with replace of cement by supplementary cementitious material as Metakaolin are carried out. The experimental results of compressive strength of concrete cube are described below.

3.3. Compressive strength test

A cube compression test is performed on standard cubes of plain and concrete with replace of cement by supplementary cementitious material as Metakaolin of size 150 x 150 x 150 mm after 3, 7 and 28 days of immersion in water for curing. THE compressive strength of concrete is shown graphically in Figures. The compressive strength of specimen is calculated by the following formula:

` fcu = Pc /A



Conclusions

The various litrature review provides the following conclusions based on the researcher work of various parameters

- The replacement of cement by natural and chemical admixtures like Metakaolin, silica fume, fly ash, finely ground pumice, Palm Oil Fuel Ash, Rice Husk would be caused the decrease in the compressive strength, modulus of elasticity, tensile strength, ultrasonic pulse velocity and colour change of the concretes at elevated temperatures.
- At the elevated temperature near abot 600^0c the use of different w/c ratios and different types of aggregates would be exhibited reduction of mechanical properties of concrete.
- Also different methods of curing irrespective of types of concretes made with different admixtures might be caused the reduction in the mechanical properties at elevated temperatures.
- Polypropylene fibres in concretes would be reduced the explosive spalling of concretes at elevated temperatures.

Scope of Future Investigation

1. The present work has good scope for future research. Some of the research areas are as follows:
2. Investigation of ductility parameters characteristics of SFRMC for potential application in seismic design and construction
3. Behaviour under creep and shrinkage.
4. To study the behaviour of mechanical and physical properties of SFRMC at low temperatures
5. Study the coatings for steel fibre to modify bond with the matrix and to provide corrosion protection.
6. Same parameters with recycled aggregates.
7. Fracture analysis.
8. Stress transfer mechanism.
9. Study of impact resistant, abrasion resistant and permeability of SFRMC and resistant to chemical attack.

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