EXPERIMENTAL STUDY ON RESIDUAL CHARACTERISTICS OF CONCRETE SUBJECTED TO ELEVATED TEMPERATURE

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Abstract - *The effect of high temperatures exposed on the concrete structural members is an important parameter to be considered in the design. The residual characteristics of temperature damaged concrete structural elements, the strength and stiffness degradation are considered to be very important in the modern design. The effect of this high temperature alter the physical, mechanical and microstructural characteristics of concrete thus the residual strength and stiffness becomes reduced. Experimental concrete cube test specimens were made and will be subjected to varying high temperatures 250ºC, 500ºC and 750ºC for a period of two hours and then these were cooled down to room temperatures before they were subjected to testing for its physical, mechanical characteristics. The specimens were cooled suddenly by quenched in water thus the high temperature is being reduced to room temperature. The effect of this sudden cooling of specimens will be compared and subjected to high temperatures and cooled normally. The differences in the mechanical characteristics and stiffness properties are being experimented and the observation are to be recorded. From these it would be interpreted the effect of sudden cooling vs the other types were compared and analyzed and will be reported as the results of this study outcomes.*

***Key Words*: Mechanical characteristics, microstructural characteristics, stiffness properties**

1. INTRODUCTION

1.1 General

Construction activity constitutes nearly 45% of our country's GDP and one of the key factors contributing for the national economy. Construction involves building up of roads, bridges, tunnels, buildings, dams, and other related infrastructure. In all these construction activity cement and steel is the most predominant material that is being used to the extent of 25% cost. Concrete is very widely used and one of the significant construction materials since more than a century .Concrete is a rigid material with high compressive strength and low tensile strength with low resistance to cracking. Most of the researches have been focused on strength, stability and stiffness related topics. In addition to that fibres can make concrete more homogeneous and can improve the tensile response, compressive strength, flexural strength, particular the ductility. A reasonable accuracy and theory have been developed for the making of concrete to its fresh concrete properties in addition to its hardened concrete properties for various loading conditions, including dead load, live load, wind load, earthquake load etc. However, in the recent few decades a group of researchers were working on the fire performance of concrete subjected to high temperatures in the order of about 1000ºC, which takes place when a concrete structure is getting in to a fire. The effect of high temperature on concrete completely changes its physical, chemical and mechanical properties. When concrete is subjected to high temperatures the basic properties of the material getting altered and thus the entire design validity becomes invalid. Hence it was interesting for many researchers to study on the different aspects of the concrete subjected to high temperatures.

2. LITERATURE REVIEW

Adel A. El-Kurdi et.al., (2014) 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 thermo-gravimetric (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 $CaCO_3$ clearly observed without decomposition.

Balakrishnaiah et.al., (2013) In their study they studied the effect of elevated temperature on mechanical properties and microstructure of silica flour concrete was investigated and studied using ordinary Portland cement (OPC) and silica flour (SF) in percentages varying from 0,5 to 20% with water/binder ratio of 0.5. After 28 days of curing, the specimens were exposed to 100ºC to 800ºc.

Franz-Josef et.al., (1996) They developed a macroscopic material model for heated concrete. The experimental determination of all the thermal dehydration function from in-situ measurements the elastic modulus versus furnace temperature rise was shown from experimental data available from concrete.

Gyu-Yong Kim, Young-Sun Kim, Tae-Gyu Lee, Mechanical properties of high strength concrete subjected to high temperature by stressed test [September 2009]: The present study is aimed to study the effect of elevated temperatures ranging from 200 to 700 ºC 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 ºC) 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.

H. G. Mundle, variation in strength of concrete subjected to high temperature [Feb 2014]: 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.

Ke-cheng He et.al., (2016) In order to investigate spalling and the compressive performance of the concrete types after exposure to high temperatures, four concrete mixes were prepared, including normal concrete (NC), lightweight aggregate concrete (LWAC), modification material I modified lightweight aggregate concrete (PLWAC), and modification material II modified lightweight aggregate concrete (GLWAC). After mixing, concrete types were cast into 100mm × 100mm× 300mmprism mould. After de-moulding concrete specimens were cured in a standard curing room at a temperature of 20 ± 2ºC and relative humidity above 95% for 28 days. Before the exposure to high temperatures, the extra water on the surface of the specimens was wiped off with a damp cloth. Before heating, the specimens in saturated-surface-dry condition were weighed at room temperature. Then, the specimens were placed in an electric furnace under unstressed condition and were heated to 200ºC, 400ºC, 600ºC, 800ºC, 1000ºC, and 1200ºC, respectively, with an increasing rate of 10 C/min. The elevation of temperature was controlled by a programming instrument with precision of 10ºC. When the target temperatures were achieved, the temperatures were maintained as constant for 3 h to allow the specimens to reach a thermal steady state. Then, the heated specimens were cooled down slowly to room temperature in the furnace. It can be observed that no Spalling occured for the concrete specimens when the temperature was below 400ºC. When the temperature increased to approximately 450ºC, Spalling occurred for the concrete specimens to different extents. After 1200ºC, the PLWAC and the GLWAC specimens still had 26% and 38% of the compressive strength retained, respectively, exhibiting superior resistance to high temperature.

R V Balendran, et.al., (2013) 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.

R. Sri Ravindrarajah et.al.,(2015) 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 800ºC. The influence of the binder material type is significantly decreased at temperature of 1000ºC. 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.

3. PROPERTIES AND MATERIAL USED

3.1 Cement

IS-8112, 43 Grade OPC was used in this work with specific gravity of 3.15 and standard consistency 26%.

3.2 Fine aggregate

Sand used in his work confirming to Zone-II, with fineness modulus of 2.81 and specific gravity as 2.63.

3.3 Coarse aggregate

Coarse aggregate consisting of crushed granite (angular), conforming to IS 383-1970 was used. The specific gravity of coarse aggregate was 2.84.

3.4 Mineral Admixture

Table 3.1-Properties of silica fume

Parameters	Specification	Analysis
SiO_2	Min 85.0%	89.2
Loss of ignition	Max 3.0%	0.7
Carbon	Max 6.0%	1.7
Specific surface	Max 15%	21.4
Bulk density	500-700 Kg/m³	620

3.5 Fly Ash

Class C fly ash produced from lignite coals was used. The fly ash is rich in Silicon and low in Calcium Oxide content.

3.6Chemical Admixture

Conplast SP 430 , Ceraplast 300 ,Naphthalene sulphonate based superplasticizer have been used to improve workability and strength of concrete.

3.6.1Ceraplast 300

Supply Form	: Liquid
Specific Gravity	: 1.2
Color	: Brown
Chloride content	: Nil
Recommended Dosage by weight of cement.	:0.4% to 1%

3.6.2 Conplast SP 430

Specific Gravity	: 1.22 to 1.22
Chloride content	: Nil
Air Entrainment	:1% (approximately)
Compatibility	: can be used with all types of cement

4. MIX DESIGN

Table 4.1 Mix Proportion

MATERIALS	**NSC**	HSC	**HPC**
Cement(kg/m³)	477	500	522.5
Fine aggregate(kg/m³)	701	640	638
Coarse aggregate(kg/m³)	1078	1170	1166
Water(1/m³)	203	160	160
Fly ash(kg/m³)	-	50	-
Silica fume(kg/m³)	-	-	27.5
Super plasticizers(1/m³)	-	3.2	3.2

5. CONCLUSION

The study have examine heat generation in the concrete which undergoes change in physical and chemical properties when subjected to high temperatures. The respective specimens in the furnace heated to 250C, 500C, 750C till reaches the steady state and maintained for a period 2hours in the respective temperatures. The weight loss must be observed significantly more in NSC concrete at 250C compared to others. This may be due to the loss of moisture at these lower level temperature. The concrete mix design is designed and the grade of concrete, mix proportion was found out. Materials like chemical admixtures and mineral admixtures were used to increase the compressive strength of concrete by reducing the amount of water in water cement ratio. The effect of high temperatures on concrete completely modifies its physical, chemical and mechanical characteristics. The three types of concrete like high performance concrete, high strength concrete and normal concrete were designed and standardized in this study. The temperature and its intensity, the distribution pattern, sustaining duration, exposed duration, mode of cooling etc., were of important sub factors associated with the temperatures. The mechanical properties of concrete viz the strength, tensile, compressive and shear strength apart from the Young's modulus and other residual engineering parameters were undergo reductions and these were attempted for quantification through this research work. Concrete is inherently fire resistant, virtually fire proof. The fire resistance and thermal properties of concrete depends on mineral constitutes of aggregates used.

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