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A Review - Effects of temperature on fracture toughness of concrete

A.Sethupalani[1], N.Sakthieswaran[2], G.Shiny Brintha[3], O.Ganesh Babu[4]
[1,2,3,4]Department of Civil Engineering
[1,2,3,4]Anna University Regional Campus, Tirunelveli, TN, India.

Abstract - In this paper an experimental investigation on the variation of residual fracture toughness of plainconcrete subjected to different elevated heating temperatures is described.A total of 16 beam specimens with uniform size of 65mm x85mm x365mm were prepared, half of which had precast initial notch of depth equal to 0.10 times the beam depth at midspan of the beams and the rest of which had precast initial notch of depth equal to 0.25 times the beam depth. The beam specimens were heated to constant temperatures of 300℃, 600℃ and 900℃ respectively. After cooling, half of the specimens were subjected to three-point bending test and the rest of them were subjected to four point bending test and fracture toughness values were determined for failure loads. The results show that the fracture toughness of concrete is influenced by elevated temperature.The fracture toughness values for various elevated temperatures were compared with the values obtained for room temperature which serve as a reference.
Keywords – Fracture, Toughness, notch, temperature, Concrete

I. INTRODUCTION

Concrete is widely used as a primary structural material. In structures like cooling towers in thermal power stations and pressure vessels in nuclear power plants, concrete is subjected to high temperatures.Fire in buildings, structures and tunnels etc., also contributes to high temperature in concrete members.The exposure of concrete to elevated temperatures affects its properties, mostly decreases the compressive, tensile and flexural strengths of concrete. Appropriate information about the mechanical properties of concrete such as strength, stiffness, toughness and brittleness is inevitably required to design these structures.Besides this, determining the flexural toughness is very useful in assessment of behavior of the structures under various loading and environmental conditions and assessing post fire safety of concrete structures.

II. LITERATURE REVIEW

Zdenek P. Baznt& Pere C. Prat (1988) performed fracture experiments to determine the dependence of fracture energy of concrete on temperature as well as specific water contents. The fracture tests were carried out at two types of humidity conditions – dry and wet. The dry tests included both the three point loaded specimens and eccentric compression specimens. The dry tests were conducted in oven at temperatures 20℃, 65℃,120℃ and 200℃. The wet tests included only three point bend specimens and were conducted on specimens placed inside a water filled tank heated to required temperatures. The temperatures adopted were 65℃ and 90℃. The results show that the fracture energy decreases monotonously and smoothly with the increase in temperaturei.eupto 50% at 200℃ compared with room temperature values and in saturated specimens the decreasing effect is more.

G. Prokopski (1995) measured the fracture toughness of ordinary and refractory concretes exposed up to 1300℃ at 28 days on the concrete beams under three-point bending. He found the fracture toughness for Mode I, KIC, continuously decreased with the increasing heating temperatures from 0.643 MN/$m^{1.5}$ at 20℃ to 0.044 MN/$m^{1.5}$ at 1100C for the ordinary concrete and from 0.718 MN/$m^{1.5}$ to 0.343 MN/$m^{1.5}$at 1300C for the refractory concrete.

Baker G (1996) measured fracture energy by conducting three point bending tests on ordinary concrete beams, after heating to temperatures of 120℃, 300℃ and 600℃ followed by slow and fast cooling to room temperature. He found that at high temperatures the fracture energy first increased with heating temperatures until a transition point was reached and then gradually reduced. For fast cooling an increase to about 1.5 times its value at room temperature, at 300℃ followed by decreasing fracture energy vs temperature relationship and for slow cooling, significant peak at 120℃ when fracture energy is 2.5 times of its value at room temperature were reported.

Felicetti et al.(1996) conducted experimental study to measure the fracture energy on two high performance concretes having water

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to binder ratio 0.43 & 0.30. Both direct tension test on notched cylinders and three point bending of beams were carried out after heating to temperature of 105°C, 250°C, 400°C and 500°C. They found that the residual fracture energy is independent of temperature level.

Hisham Abdel-Fattah &Sameer A. Hamoush (1997) hadmade investigation on fracture toughness of concrete with elevated temperatures by conducting three point bending test, under varying temperatures of 50°C, 100°C, 150°C, 200°C,250°C and 300°C. He also performed a study on cyclic heating effects and concludes that the residual fracture toughness decreases with the increase in temperature, and cyclic heating effects become more significant for temperatures greater than 100°C.

B.Zhang&N.Bicanic (2001) performed study on fracture energy of high performance concrete at high temperatures up to 450°C(hot) and cooled down stages. They also studied the behaviour of HPC with respect to modulus of rupture, compressive and tensile strength and residual youngs modulus at high temperatures. Three point bending test was conducted at temperatures of 105°C, 150°C, 200°C,250°C,300°C,350°C,400°C and 450°C. The findings of their study showed that fracture energy generally sustained a decrease-increase tendency with heating temperatures for hot concrete but increase-decease tendency for cold concreting, bi-linear decrease- increase relationship between fracture energy and ultimate weight loss for hot concrete and a tri-linear increase-decrease relationship between fracture energy and ultimate weight loss for cold concrete were found

C.V.Nielson&N.Bicanic (2003) studied the behavior of high performance and ordinary gravel concrete subjected to high temperatures. They conducted 3 point bending tests as per RILEM work of fracture test at temperatures 105°C, 270°C,360°C,450°C and 560°C. From the experimental results they found that mechanical degradation is severe in gravel concrete than basalt concrete, fracture energy increases significantly with 50% from its reference value at room temperature after exposure to temperature upto 400 C, thermal damage produces numerous micro cracks in cement paste where energy is dissipated and beyond 400 C fracture energy starts decreasing due to thermal damage.

A.A.A. De Souza& A.L. Moreno Jr.(2010) performed an experimental investigation on behavior of ordinary concrete when submitted to high temperatures of 300°C, 600°C and 900°C for two hours followed by slow cooling, to assess the variation of compressive strength, tensile strength and deformation modulus. They also investigated the effects due to rapid cooling of concrete. From the results of experiments they have drawn the conclusions of: It was observed that at temperatures close to 900ºC, mechanical properties of concrete, either to tension or compression,can reach values close to zero.The values of longitudinal deformation modulus with heating, which significantly interferes with the vertical displacement of a structural element, were observed to be close to zero for temperatures lower than 900ºC.It was also observed that rehydration after heating can contributefor recovering a significant portion of a concrete initial mechanicalstrength, either to compression, tension of deformation modulus.

Yi Jiangtao, Yu Kequan& Lu Zhoudao (2012) performed investigation on the influence of elevated temperature on fracture toughness of concrete. They conducted wedge splitting test on specimens at temperatures of 20°C, 120°C, 200°C,300°C, 400°C, 450°C, 500°C and 600°C, after cooling. On investigation they conclude that elevated temperature has significant influence on fracture toughness. The test results also showed that upto 200°C, only a limited influence was observed,at 200°C – 500°C the brittleness of concrete decreased and fracture toughness increased and above 500°C, the fracture toughness decreased.

Mohd. Shariq.et al. (2013)investigated the effect of elevated heated temperatures on the tensile strength of normal and high strength concrete with and without polyprophylenefibres. They measured the unstressedresidual split and flexural tensile strength of concrete by testing cylinder and prismspecimens as per the procedures in IS: 516 & IS:5816 codes. Thespecimens were subjected to single heating-cooling cycle with ahold period of 3 hours at 200°C, 400°C, 600°C and 800°C and were cooled in the furnacebefore testing the specimens for the residual split and flexuraltensile strength of concrete. From the test results they observed that: Flexural and split tensile strength decreases with the increase in temperature for all type of mixes.Reduction in flexural strength was found to be higher as compared to that of split tensile strength for all concrete mixes.HSC has shown the better split tensile strength at room and most of the considered elevated temperatures.Loss of flexural strength, At 200°C – Normal concrete 65%,and High strength concrete 13% and at 400°C – High strength concrete 89%, High strength fibre concrete 86% and At 800°C – all most all the strength was lost.Loss of split tensile strength, At 600°C -Normal concrete 95%, High strength concrete 67%.At 800° C – High strength concrete 83%, High strength fibre concrete 92%,

Jing Chan &Zhoudao Lu (2014) conducted wedge splitting test on fifty test specimenssubjected to heating temperatures range 20°C- 600°C. They found that the fracture toughness KR(Δa) increases with increase in crack length, KR curves decrease with increasing temperatures. It was also observed that not much thermal damage was found up to 120°C and much thermal damage was reported at 200 – 600°C. At 600°C, the KR curve is almost linear.

Binsheng Zhang, Martin Collen& Tony Kilpatrick(2014) conducted experimental study in which the fracture toughness K_{IC} of high performance concrete (HPC) was determined by conducting three-point bending tests at high temperatures up to 450ºC (hot) and in cooled-down states (cold). From the experimental study they have drawn the conclusions of K_{IC} for the hot concrete sustained a monotonic decrease tendency with the heating temperature, with a sudden drop at 105ºC and for the cold concrete, K_{IC} sustained a two-stage decrease trend, dropping slowly with the heating temperature up to 150ºC and rapidly thereafter. The results also showed that fracture energy related fracture toughnessK_{IC}, was twice as large as K_{IC} for all heating temperatures, for most heating temperatures, K_{IC}, for the hot concrete was always smaller than that for the cold concrete except for Tm ≥ 400ºC and a fairly linear relationship between K_{IC} and modulus of rupture existed.

III. NEED FOR STUDY

Concrete is an inflammable construction material and widely used as a primary structural material. Under normal conditions, most concrete structures are subjected to a range of temperature no more severe than that imposed by ambient environmental conditions, concrete itself is incombustible and it has excellent fire resisting properties when compared with other materials. Due to its low coefficient of thermal conductivity, it preserves effectively the steel reinforcement which is highly sensitive to high temperatures. However, there are important cases where these structures may be exposed to much higher temperatures such as jet aircraft engine blasts, building fires, chemical and metallurgical industrial applications in which the concrete is in close proximity to furnaces, and some nuclear power-related postulated accident conditions .Its exposure to elevated temperatures causes deterioration in properties (i.e) compressive strength, flexural strength, modulus of elasticity, bond etc. and leads to failure due to crack formation and spalling of concrete. Hence the design of these structures requires a complete knowledge of the basic properties of concrete like strength, stiffness, toughness and brittleness etc. Besides these properties fracture toughness is a very important and useful parameter in assessment of behaviour of concrete subjected to high temperatures. The extensive use of concrete as a structural material in high temperature environment had led to a demand for further study on the effect of highly elevated temperatures on concrete.

IV. CONCLUSION

In this study, the effects of heating temperature on fracture toughness of ordinary concrete was investigated by conducting three point bending tests and four point bending tests on single notched beam specimens in cooled down states, after being exposed to high temperatures of 300℃, 600℃ and 900℃From the results it is concluded that the elevated temperature hav**e** significant effects on fracture performance of concrete and the fracture toughness of concrete sustained an increase-decrease tendency with the increase in temperature (i.e) it increases at 300℃ and decreases thereafter.

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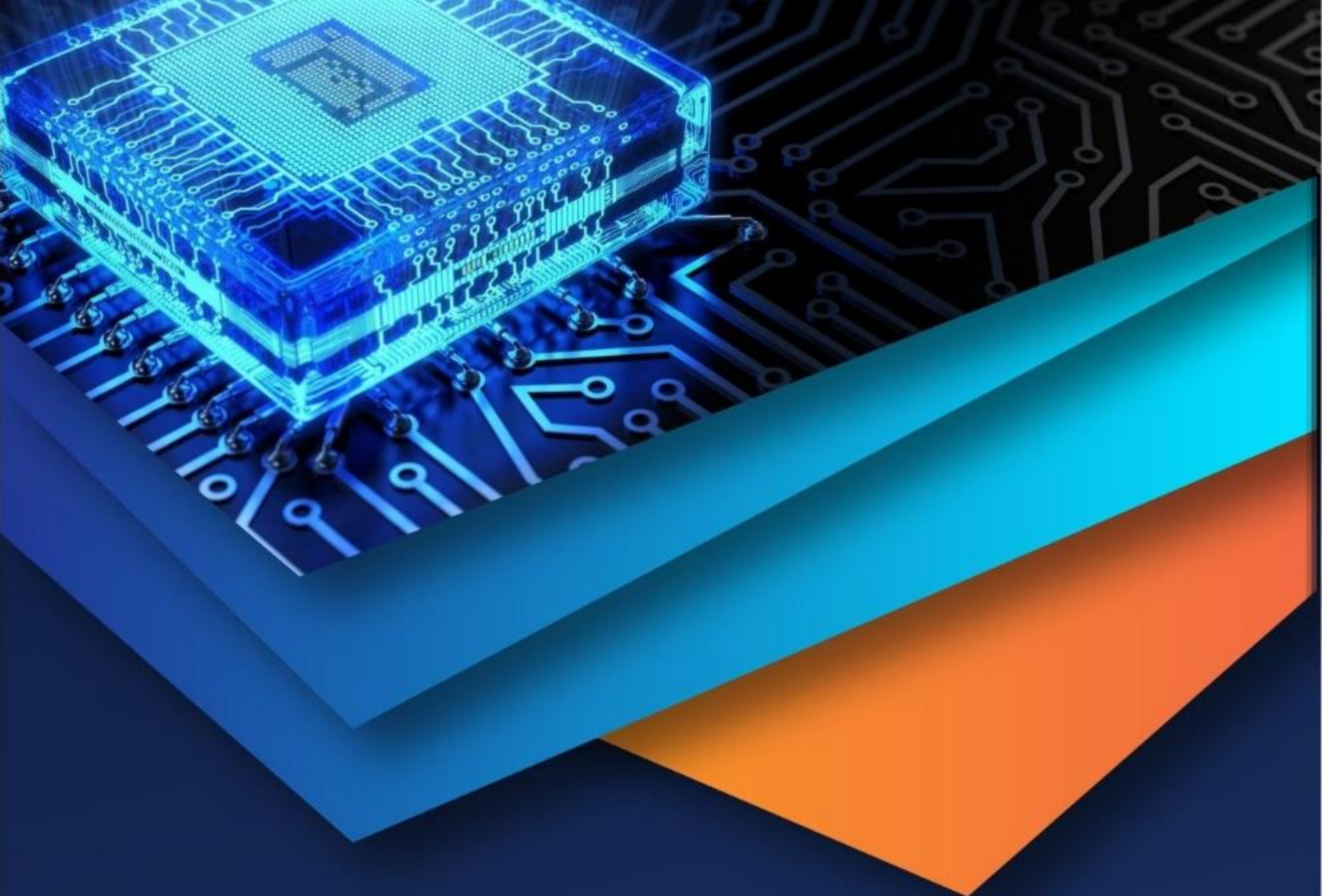

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