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STUDY ON RESIDUAL COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY OF STANDARD CONCRETE IN STRESSED STATE EXPOSED TO ELEVATED TEMPERATURES

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ABSTRACT

The present study aims to investigate the residual compressive strength and residual modulus of elasticity of standard concrete, when it is simultaneously sustained with load and temperature. The grade of cement for the study is Portland Pozzalana cement and concrete is M25 cured for a period of 28 days. The temperatures under study are 100, 200, 300, 400, 500, 600, 700 and 800 ^{o}C sustained for half an hour duration. The stress levels are 0.2 $f_{ck,}$ 0.5 f_{ck} and unstressed condition. Experiments resulted residual compressive strength and residual modulus of elasticity. Results indicated that at 0.2 f_{ck} stress level, residual compressive strength and residual modulus of elasticity slightly improved in comparison with unstressed concrete specimen. But at 0.5 f_{ck} stress level, residual compressive strength decreased at high temperatures and residual modulus of elasticity improved when compared to unstressed specimen.

INTRODUCTION

Almost all multistory structures are constructed with concrete. Most of Reinforced concrete members in India are generally constructed with standard concrete. As per IS 456 - 2000 [1] standard concrete is designated as concrete with grade M25 to M55, that must be use in construction of structural members. So this structural standard concrete should perform better during fire accidents in buildings. Now and then lot of fire accidents occur especially in residential structures. At this incidence, structural elements are in stressed condition wherein structural concrete members experience temperature and stress or load simultaneously.

Concrete generally offers better resistance to elevated temperatures even though it exhibits lot of structural and micro structural changes. These changes may lead to catastrophic failure of structure. Particularly when concrete is in stressed condition its strength assessment need to be known. The three different test methods for testing concrete at elevated temperatures are stressed, unstressed and unstressed residual strength test Phan LT [2]. The present research is based on stressed test.

OBJECTIVE AND SCOPE

The objective of the present study is to determine compressive strength of concrete at elevated temperatures when it is in stressed condition. The range of temperature is 100 to 800 degrees centigrade at an interval of 100 ^{o}C sustained for half an hour duration. At all temperatures, concrete specimens are stressed to stress levels 0.2 and 0.5 f_{ck} which are compared with unstressed concrete specimens at an age of 28 days. The residual compressive strength, along with residual modulus of elasticity is studied for M25 grade of concrete. Results of present study helps to estimate the strength of concrete in stressed condition.

LITERATURE

Long T. Phan and Nicholas J. Carino [3], investigated mechanical properties of high strength concrete exposed to high temperature. Four concrete mixes ranging from 51- 98 MPa are made with silica fume with water cement ratios 0.22 to 0.57. Concrete is exposed to temperatures 100 to 900°C. The specimens are cylinders with 100 mm diameter and 200 mm length. They are exposed to elevated temperatures up to 600°C at a rate of 5^{o}C/min after curing for a period of 28 days. The compressive strength is investigated considering size effect on unstressed specimens and stressed specimens with preload of 40% of ultimate load. From this study it is concluded that unstressed specimens show higher strength loss than stressed specimens. From temperatures 600 to 800°C, the rate of decrease in modulus of elasticity decreased. The modulus of elasticity decreased by 5-15% and 20-25% when specimens are exposed to temperatures 100°C to 300°C and 800°C respectively with respective to its room temperature. It was further reported that the complex behavior of concrete is due to and also depends upon the water cement ratio.

Castillo Carlos, M.S. [4], investigated the effect of transient temperature on high strength concrete (55 MPa) and normal strength concrete (20 MPa) made with ordinary Portland cement of type I with ASTM type F super plasticizer. Concrete is exposed to temperatures 100 to 900°C. The specimens are cylinders with 50 mm diameter and 100 mm height cast and cured for a period of 28 days prior to heating. The specimens are exposed to elevated temperatures for 5 to 10 minutes at a rate of 7 to 8^{o}C/min. The compressive strength is investigated on unstressed specimens and stressed specimens with preload of 40% of ultimate load. The effect of size of specimen on compressive strength of concrete exposed to elevated temperatures is also studied. From the study it is concluded that unstressed specimens show higher strength loss to that of normal strength specimens. The compressive strength decreased by 15 to 20% up to 300°C. The loss in strength is more for high strength concrete to that of normal strength concrete. Further there is a decrease in rate of modulus of elasticity from temperatures 600 to 800°C. The modulus of elasticity decreased by 5-15% and 20-25% for temperatures 100°C to 300°C and 800°C respectively with respective to its room temperature.

Cheng, F.P., et al [5], carried an experimental research on stress–strain relationship of high strength concrete (75-84 MPa) after heating to temperatures of 100–800°C. To ensure workability half of the super plasticizer is added at plant and other half at site. Forty concrete specimens are having diameter 10 x 20 cm length and 20 cylinders are of size diameter 15 x 30 cm length, made with siliceous (Granite) and carbonate (Limestone) aggregate. The specimens are heated at a rate of 2 ^{o}C/min. The exposed duration is 1 hour. From the studies it has been concluded that, up to 400 ^{o}C the change in strain corresponding to peak strength is not significant. Further it is observed that the ultimate strain is affected by the type of aggregate for high strength concrete exposed to elevated temperatures. It is also concluded that carbonate aggregate concrete specimens shown 40% larger strains for corresponding peak stress when compared to siliceous aggregate concrete.

MATERIAL PROPERTIES AND MIX DESIGN

The properties of ingredients are obtained by preliminary investigations. In the present study is Portland Pozzalana Cement which compiles the requirements of IS: 1489-1987 [6]. Its specific gravity is 3.12. Fine aggregate is 1.8 conforming to zone I of IS: 383-1970 [7] with specific gravity 2.62. The specific gravity and fineness modulus of coarse aggregate are 2.73 and 6.8 respectively. For mixing concrete, portable water is opted as per specifications IS: 3025-1986 (Parts22 and 24) [8]. From the preliminary investigations, after several trail batches design mix obtained as per IS: 10262-1982 [9] for M25 grade of concrete as given in table 1.

Table 1 Concrete mix proportion

Ingredient	Mix proportion
Cement	1
Fine aggregate	1.6
Coarse aggregate	3
Water to cement ratio	0.48

EXPERIMENTAL SETUP AND TESTING

Ingredients of concrete are mixed as per proportions in table 1 in pan mixture. The sizes of cube specimens are 150 x 150 x 150 mm where as cylinder specimens are 150 x 300 mm are cast with M25 concrete as shown in fig.1. These specimens are demould and cured as shown in fig.2 in a curing tank for a period of 28 days. A total number of 90 cured cubes and 90 cured cylinders are ready for testing.

The test setup consists of a digital universal testing machine of 100 ton capacity along with an attached cylindrical furnace with maximum temperature 1000 ^{o}C as shown in fig.3. The temperature attainment in the furnace is as per ISO:834-1975 [10] specifications. Into the entire test set up specimens (cubes/cylinders) are inserted successively. To obtain compressive strength 54 cube specimens are exposed to temperatures 100, 200, 300, 400, 500, 600, 700 and 800 ^{o}C at stress levels 0.2 and 0.5 f_{ck} respectively. 27 cubes are tested for same temperatures but in unstressed condition while 09 specimens are controlled concrete specimens (27 ^{o}C) for unstressed and stressed strength tests. The total cubes and cylinders are 90 respectively. Similarly all cylinders are tested to obtain residual modulus of elasticity in stressed condition.

Cubes for compression and cylinders for modulus of elasticity are tested in the stressed set up as in Fig.3. The specimens are exposed to required temperature and stress level, that is load is sustained for a period of half an hour and then increased up to failure. The rate of loading is 140 kg/sq cm/min as per IS: 516-1959 [10].

Fig.1 Specimens in moulds

Fig.2 Specimens in curing tank

Fig. 3 Universal testing machine along with cylindrical furnace

RESULTS AND DISCUSSIONS

Results obtained from stressed tests are analyzed and discussed. The percentage residual compressive strength is the ratio of strength at any temperature to controlled concrete strength, multiplied by 100. The residual modulus of elasticity is the ratio of modulus of elasticity at any temperature to modulus of elasticity at room temperature (controlled concrete modulus of elasticity). The legend in the 0.2 f_{ck}, 0.5 f_{ck} indicates level at which concrete is stressed.

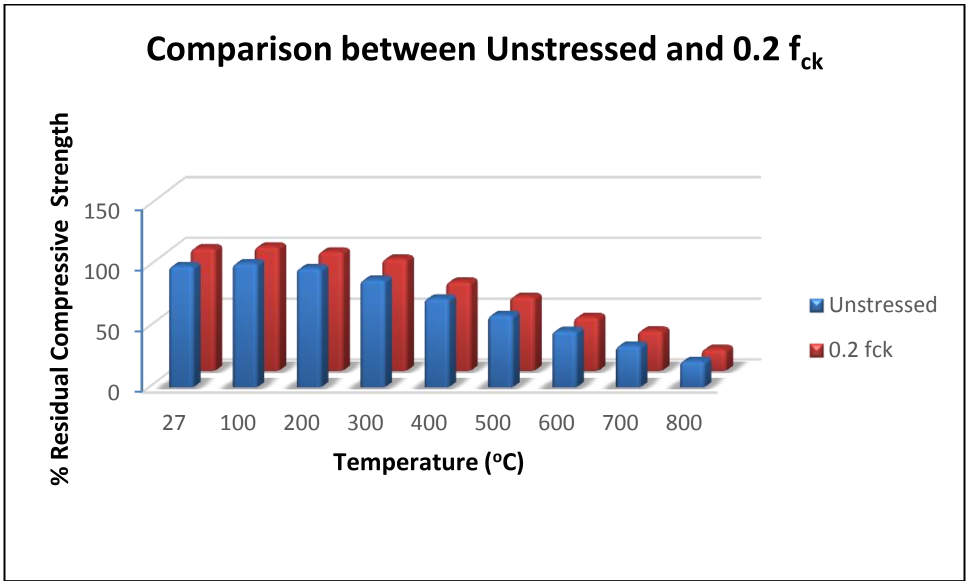

Fig.4 % Residual compressive strength with temperature for unstressed and 0.2 f_{ck} stressed specimen

Fig. 4 represents variation of % Residual compressive strength with temperature for unstressed and 0.2 f_{ck} stressed specimen. The % residual strengths are 100, 102.26, 98.14, 88.69, 73.3, 59.73, 46.61, 34.52 and 21.79 for temperatures 100, 200, 300, 400, 500, 600, 700 and 800 °C respectively for stressed specimen. For 0.2 f_{ck} the % residual strengths are 100.95, 102.4, 98.28, 92.31, 73.44, 61.04, 44.3, 33.17 and 18.12. As the temperature increased the strength of concrete gradually decreased for all temperatures except at 100 °C. Comparing 0.2 f_{ck} stressed specimen and unstressed specimen, the strength of stressed specimen is slightly higher due to densification of paste.

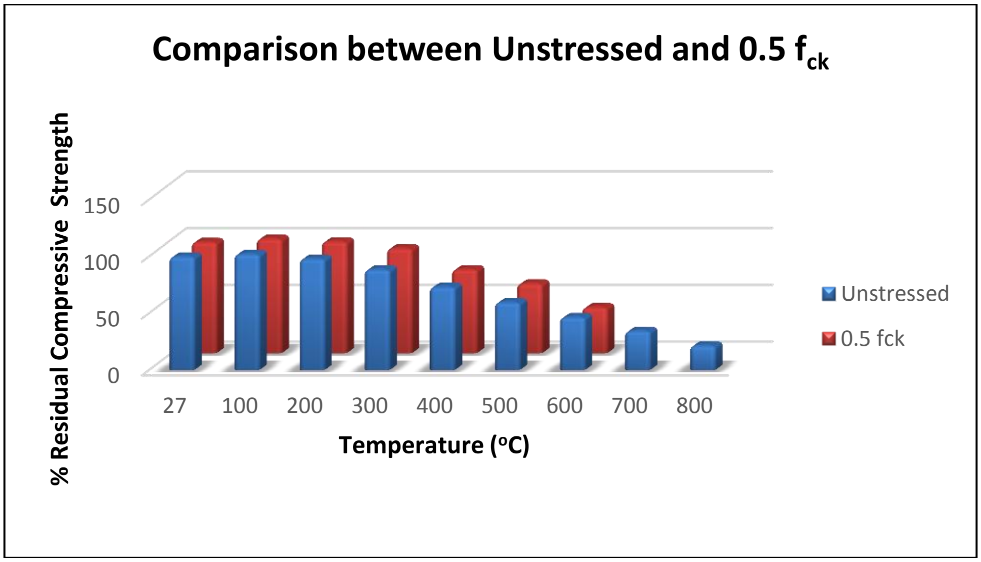

Fig.5 % Residual compressive strength with temperature for unstressed and 0.5 f_{ck} stressed specimen

Fig. 5 represents variation of % Residual compressive strength with temperature for unstressed and 0.5 f_{ck} stressed specimen. The % residual strengths are 100, 102.26, 98.14, 88.69, 73.3, 59.73, 46.61, 34.52 and 21.79 for temperatures 100, 200, 300, 400, 500, 600, 700 and 800 °C respectively for stressed specimen. For 0.5 f_{ck} the % residual strengths are 98.06, 100.95, 98.51, 92.49, 73.98, 61.45, 40.5, 0 and 0. As the specimen is stressed to 0.5 f_{ck} the strength on concrete decreased at higher temperatures but performed better at lower temperatures. Because at higher temperatures the binding matrix concrete could not with stand for both stress and temperature.

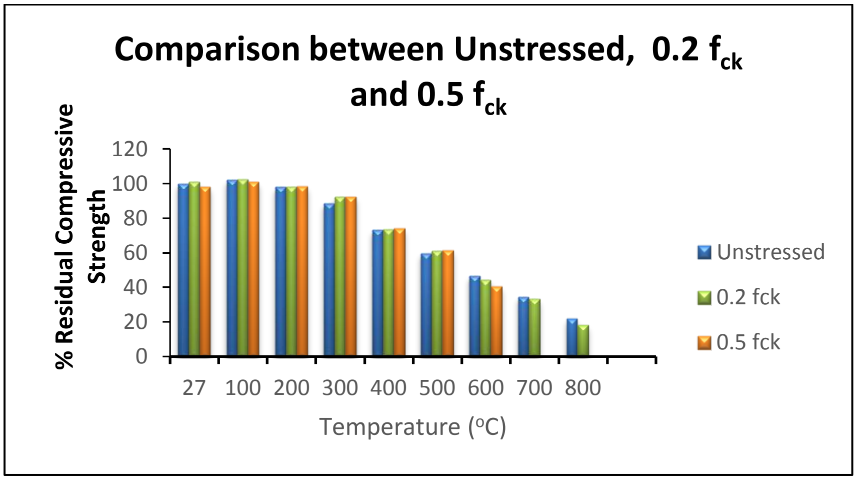

Fig.5 % Residual compressive strength with temperature for unstressed, 0.2 f_{ck} and 0.5 f_{ck} stressed specimen

Fig. 6 represents variation of % Residual compressive strength with temperature for unstressed, 0.2 f_{ck} and 0.5 f_{ck} stressed specimen. At all temperatures and stress levels including unstressed specimen concrete shown a trend of strength decreased as observed by Vani [12] for unstressed specimen. Further there is a slight improvement in strength at 0.2 f_{ck} strength at all temperatures due to reduction in pores. But for 0.5 f_{ck} the strength the specimens at 700 and 800 ^{o}C could not sustain resulting Zero strength.

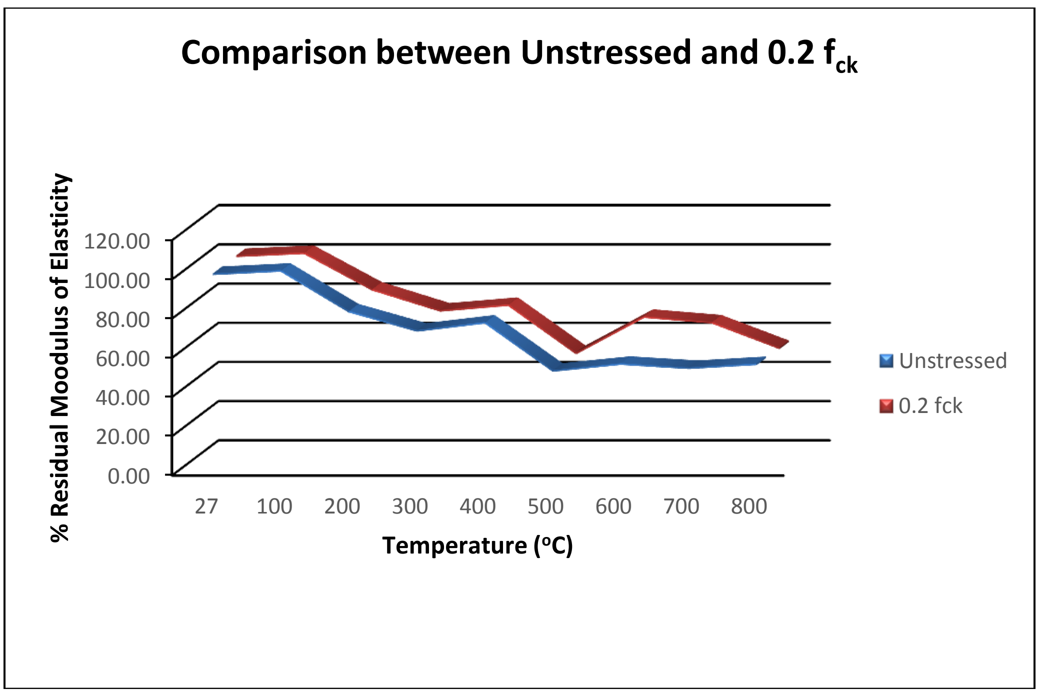

Fig.6 % Residual modulus of elasticity with temperature for unstressed and 0.5 f_{ck} stressed specimen

Fig. 6 represents variation of % Residual modulus of elasticity with temperature for unstressed and 0.2 f_{ck} stressed specimen. When compared to unstressed specimen 0.2 f_{ck} specimen has shown slightly higher modulus of elasticity. As the temperature increased modulus of elasticity decreased except at 100 ^{o}C. At 0.2 f_{ck} stressed due to densification of paste stiffness might have been improved resulting slightly higher stress and modulus of elasticity.

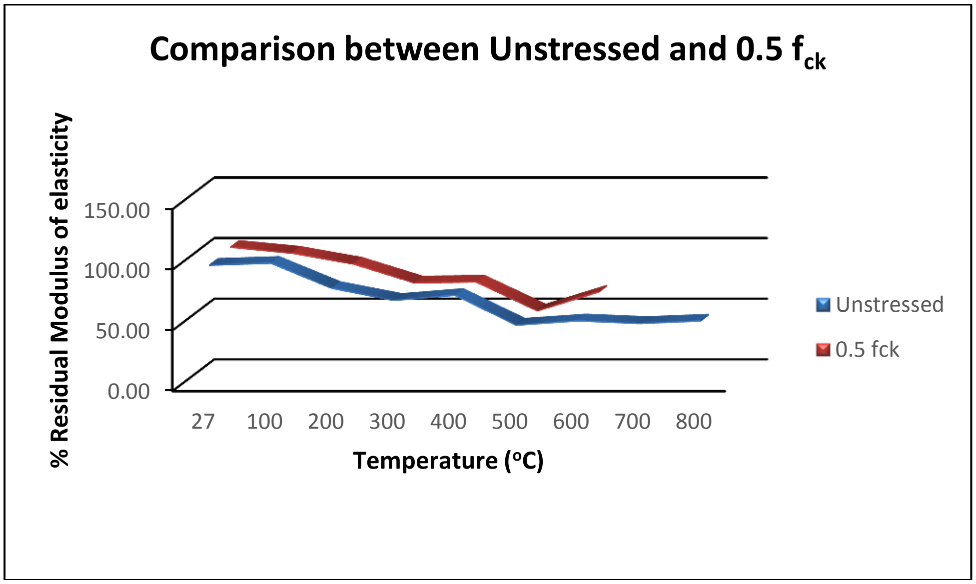

Fig.7 % Residual modulus of elasticity with temperature for unstressed and 0.5 f_{ck} stressed specimen

Fig. 7 represents variation of % Residual modulus of elasticity with temperature for unstressed and 0.5 f_{ck} stressed specimen. As temperature increased modulus of elasticity of concrete decreased. The modulus of elasticity shown a overall increase in trend for 0.5 f_{ck} stressed specimen when compared to stressed specimen. This may be due to reduction in stiffness at high temperatures and stress levels.

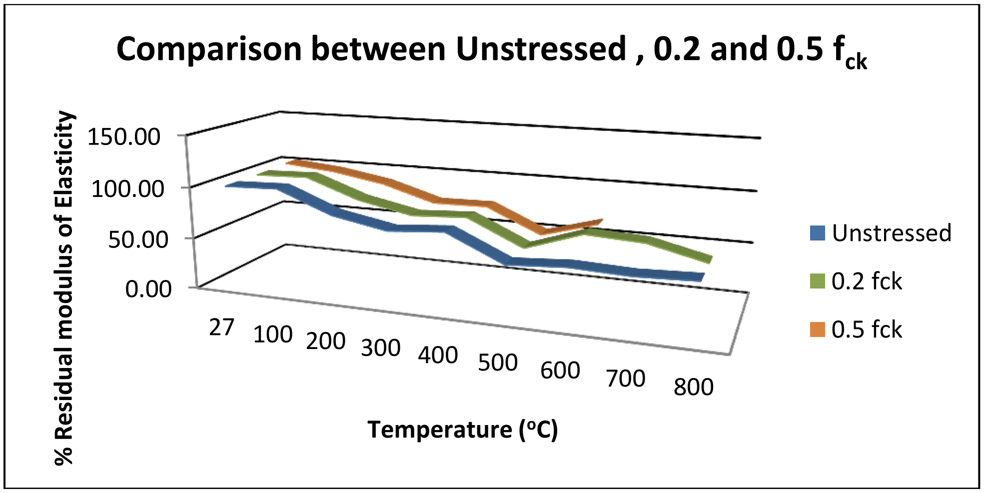

Fig.8 % Residual modulus of elasticity with temperature for unstressed, 0.2 f_{ck} and 0.5 f_{ck} stressed specimen

Fig. 8 represents variation of % Residual modulus of elasticity with temperature for unstressed, 0.2 f_{ck} and 0.5 f_{ck} stressed specimen. Fig. 8 clearly indicates that as the temperature increases modulus of elasticity decreases at all stress levels. Between unstressed, 0.2 f_{ck} and 0.5 f_{ck} stressed specimen, 0.2 f_{ck} stressed specimens resulted better modulus of elasticity.

CONCLUSIONS

The following conclusions are made from the present research

- The maximum % residual compressive strength is 100.94, exhibited by 0.2 f_{ck} stressed specimen at 100 °C.
- The minimum % residual compressive strength is 0 (Zero), exhibited by 0.5 f_{ck} stressed specimen at 700 and 800 °C.
- The maximum % residual modulus of elasticity is 101.76, exhibited by 0.2 f_{ck} stressed specimen at 100 °C.
- The minimum % residual compressive strength is 0, exhibited by 0.5 f_{ck} stressed specimen at 700 and 800 °C.
- At 0.2 f_{ck} stress level residual compressive strength and residual modulus of elasticity improved in comparison with unstressed concrete specimen.
- At 0.5 f_{ck} stress level residual compressive strength decreased at high temperatures and residual modulus of elasticity improved when compared to unstressed specimen.

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