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Shear Performance of RC Beam Subjected to Elevated Temperature

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***Abstract* - The paper involves the study on shear performance of RC beams at elevated temperatures. Totally twenty four RC beam specimens with cross-sectional dimension of 150X150mm for a length of 1100mm were tested. Out of which 12 beams were reinforced with 2 no. of 8mm diameter bars and remaining 12 specimens with 2 no. of 10mm diameter bars. Unstressed residual strength test was carried out on these specimens. The beam Specimens were tested under two point loading condition using UTM after heating them in an electric furnace at 300^{0}C, 400^{0}C and 500^{0}C for 2 hours sustained duration. Results shows a 25% increment in the shear capacity of the beam at room temperature when the percentage of tension reinforcement was increased by 0.25%. Also the shear carrying capacity of beams has decreased with the increase in temperature when subjected to elevated temperature.**

Keywords - Ultimate load carrying capacity, compressive strength, Deflection, Elevated temperature.

1. INTRODUCTION

When the beam is loaded with transverse loads, the bending moment varies from section to section. Shearing stresses are caused by variation of bending moment along the span. Shear behavior of reinforced beam depends on various factors like grade of concrete, percentage and grade of longitudinal tensile reinforcement, ratio of shear span to effective depth, compressive force, axial tensile force, shear reinforcement. So in order to know the behavior of beam in shear we have to study these parameters.

The increase in ambient temperature changes the temperature distribution inside a beam's cross sections. After exposure to high temperatures, the mechanical properties of reinforcing steel and concrete vary according to the temperatures. This leads to difficulty in knowing stress distribution in structures. The residual bending moment and shear force of RC beams after subjecting them to sustained elevated temperature beams are important factors in determining the safety of the structure. A traditional shear test on a reinforced concrete beam is depicted in Figure 1.1.The region of the beam between the two point loads is subjected to pure flexure, whereas the shear spans of the beam are subjected to constant shear and linearly varying moment. Because the behaviour of this member is changing from section to section along the shear span, it is difficult to use the results of such a test to develop a general theory for shear behaviour.

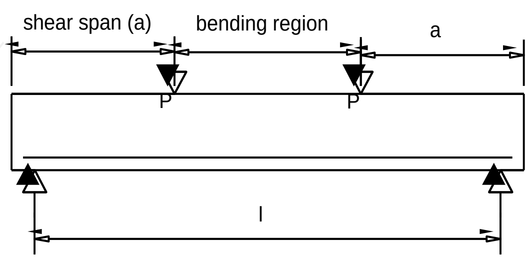

Figure 1.1 Reinforced concrete beam

The objective of the study was to determine the shear behavior of RC beam at elevated temperature with the variation of temperature and percentage of reinforcement.

2. SCOPE

With 3 beams for each parameter like, percentage of reinforcement, temperature for the duration of exposure of about 2 hours, 24 beams were cast. The water to cement ratio and quantity of aggregate were maintained same through the experiment for M20 grade mix. The cast specimen beams were exposed to temperature of 300, 400, 500 degree Celsius for a duration of 2 hours and then tested. The reinforcement grade is restricted to the Fe415 & Percentage of reinforcement is restricted to 0.44% & 0.7%.

3. MATERIAL AND METHODOLOGY

PPC confirming to IS: 1489-(1991), was used in the study. Coarse aggregate of specific gravity 2.5, having water absorption 0.4%: Locally available river sand falling under Zone II, having Specific gravity 2.6 with water absorption 1.2% was used. Mix proportion was carried out as per IS 10262-2010. A concrete mix of 20 MPa at the age of 28 days is proportioned. This concrete is used throughout the investigation. Beams of size 150x 150 x 1100 mm were cast along with cubes of 150mm. The cubes and beams were cured for 28 days. At the end of curing they were air dried for surface moisture by visual inspection. All these specimens were exposed to heating, for durations of 2 hours at temperature level of 300°C, 400°C & 500°C. On completion of heating, the cubes and beams were brought to room temperature and then tested for compressive strength and ultimate load carrying capacity.

3.1 Mix proportion

Cement : 383 kg/m^3
Water : 192 kg/m^3
Fine aggregate : 673 kg/m^3
Coarse aggregate : 1057 kg/m^3
Water cement ratio: 0.5
Cement: FA: CA : 1: 1.76: 2.76

Fig 3.1Setup for Heating of test specimen

4. TEST RESULTS & DISCUSSION

4.1 Compressive strength

Temperature In ◦c	Compressive strength in Mpa	% Reduction in strength	Residual strength in %
RT	40.06	0	100
300	35.15	12.26	87.74
400	33.06	17.47	82.53
500	30.3	24.36	75.64

When the cube specimens were exposed to 300^{0}C for the duration of 2 hours there is reduction in compressive strength. It is observed that percentage residual compressive strength decreases by 12.25% with respect to cube specimen under normal temperature.

When the cube specimens were exposed to 400^{0}C for the duration of 2 hours there is reduction in compressive strength. It is observed that percentage residual compressive strength decreases by 17.47% with respect to cube specimen under normal temperature. The similar type of work was conducted by Ahmad A.H (2010) et al the strength reduction was about 12-40% with variation of admixtures.

When the cube specimens were exposed to 500^{0}C for the duration of 2 hours there is reduction in compressive strength. It is observed that percentage residual compressive strength decreases by 24.36% with respect to cube specimen under normal temperature. The reduction is almost twice that of 300^{0}C.

The obvious loss begins at temperature after (300◦c) which represents the critical temperature at which the strength loss would be rapid and continues with temperature rise [A. M. Neville 1978]. It is well-known that the concrete consists of discrete aggregate dispersed in a continuous cement paste matrix, and that the transition zone between cement paste matrix and the aggregate is considered to be a critical zone and evidently affects concrete performance exposed to high temperatures[E. Tolentino et al 2002]. It is noticed that changes occurring in this zone is responsible for the loss of compressive strength through the pore structure coarse for the cement paste structure and aggregate, as a result of non –thermo identification between the cement paste and the aggregate which consequently causes a bond failure between the cement paste and aggregate surface; in addition to the effect of the vaporized water pressure during the heating process [E. Tolentino et al 2002], the chemical changes occurring in this zone – represented by the loss of free moisture, the increase in calcium content (C-S-H) and from elongation of calcium hydroxide crystals spreading tightly in cement paste at temperatures rise and so on[I. Janotka et al 2002]. Besides other chemical and physical changes such as shrinkage occurring in cement paste or mortar and aggregate expansion which leads to the appearance of micro- cracks in the concrete [G. T. G. Mohamedbhai 1986].

4.2 Ultimate load carrying capacity of beam

The ultimate load carrying capacity of a 24 beams are tabulated in table 4.2 a & 4.2 b.

4.2.1 Variation with temperature

As compressive strength is one of the factors which affect the ultimate load carrying capacity of the beam, the increase in temperature leads to the decrease in compressive strength as discussed above. The decrease in compressive strength due to increase in temperature will intern decrease the ultimate load carrying capacity of the beam. The graph shows the variation of ultimate strength of beam with temperature.

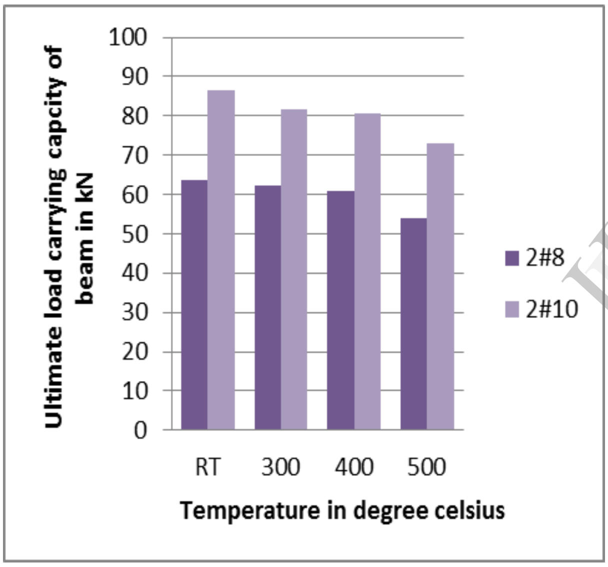

Figure 4.1 Ultimate load carrying capacity Variation with temperature

When the beam specimens were exposed to 300^0C for the duration of 2 hours there is reduction in strength of the beam but not to greater extent. It is observed that percentage reduction is about 1 to 6% with respect to beam specimen under normal temperature.

When the beam specimens were exposed to 400^0C for the duration of 2 hours there is reduction in strength of the beam. It is observed that percentage reduction is about 4-7% with respect to beam specimen under normal temperature.

When the beam specimens were exposed to 500^0C for the duration of 2 hours there is reduction in strength of the beam. It is observed that percentage reduction is about 15-16% with respect to beam specimen under normal temperature.

4.2.2 Variation with percentage of reinforcement

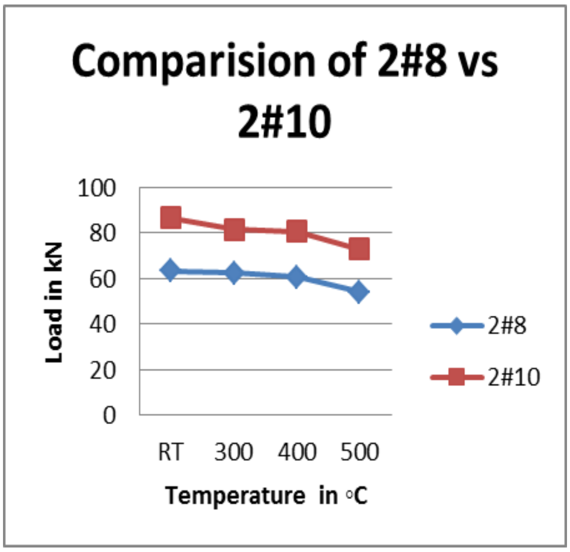

Figure 4.2 Ultimate load carrying capacity Variation with percentage reinforcement

The increase in percentage of reinforcement leads to increase in flexural strength of the beam which intern increase the load carrying capacity of the beam. The increase in 0.25% reinforcement caused to increase the load carrying capacity by 25%.The final deflection of the beam reduces with the increase in percentage of reinforcement.

4.3 DEFLECTION

4.3.1 Variation with percentage of reinforcement

The ultimate deflection in the beam decreases with the increase in the percentage of longitudinal reinforcement. At room temperature for the beams with 0.44% longitudinal reinforcement the maximum deflection was found to be 18.9mm and that of beams with 0.69% was found to be 10.3mm.

4.3.2 Variation with the temperature

The ultimate deflection decreases with the increase in temperature because of decrease in ultimate load carrying capacity.

At 300^0C the maximum deflection of beams was found to be 18mm for beams with 0.44% longitudinal reinforcement whereas the beam with the 0.69% longitudinal reinforcement the maximum deflection was found to be 7.29mm.

At 400^0C the maximum deflection of beams was found to be 17mm for beams with 0.44% longitudinal reinforcement whereas the beam with the 0.69% longitudinal reinforcement the maximum deflection was found to be 7.1mm.

At 500^{0}C the maximum deflection of beams was found to be 16.3mm for beams with 0.44% longitudinal reinforcement whereas the beam with the 0.69% longitudinal reinforcement the maximum deflection was found to be 4.92mm.

4.4 Shear stress

Shear force in kN	shear stress in N/mm^2	tou c as per IS456	Beam ID
31.95	1.6 9	0.45	A1
31.225	1.6 5	0.45	A2
30.41	1.6 1	0.45	A3
27	1.4 3	0.45	A4
43.35	2.2 9	0.54	B1
40.775	2.1 6	0.54	B2
40.325	2.1 3	0.54	B3
36.425	1.9 3	0.54	B4

Table 4.3 Shear parameter

The shear parameters are tabulated in the table 4.3.The shear stress in the beam exceeded the shear carrying capacity of the RC beam as per IS456-2000 provision provided in table 19.Hence the beams are failed due to shear which is characterized by the diagonal cracks as shown in the figure 4.3.

At 400^{0}C the shear carrying capacity of the beam has decreased by 4.8% for beams with 0.44% longitudinal reinforcement whereas the beam with the 0.69% longitudinal reinforcement the shear carrying capacity of the beam has decreased by 7% with respect to the RT.

At 500^{0}C the shear carrying capacity of the beam has decreased by 15.5% for beams with 0.44% longitudinal reinforcement whereas the beam with the 0.69% longitudinal reinforcement the shear carrying capacity of the beam has decreased by 16% with respect to the RT.

4.4.1Variation with the percentage of reinforcement

As percentage of tensile reinforcement is one of the important factor affecting the shear strength of the beam with the increase in percentage of reinforcement by 0.25% the shear carrying capacity of the beam has increased by 35%.

4.4.2 Variation with the temperature

With the increase in temperature the shear carrying capacity decreases as it is directly depend on the compressive strength of the concrete.

At 300^{0}C the shear carrying capacity of the beam has decreased by 2% for beams with 0.44% longitudinal reinforcement whereas the beam with the 0.69% longitudinal reinforcement the shear carrying capacity of the beam has decreased by 6% with respect to RT.

Figure 4.3 Crack pattern of the Beam

5 CONCLUSION

- The residual compressive strength of the concrete cube reduces by 12%,17% & 25% when subjected to 300^0C,400^0C&500^0C when compared with cubes under room temperature.
- The residual ultimate strength of the concrete beam reduces by 1-6%, 4-7% &14-15% when subjected to 300^0C, 400^0C &500^0C when compared with beams under room temperature.
- The increase in percentage of reinforcement leads to better shear performance. The increase in percentage of longitudinal reinforcement by 0.25% will lead to increase the load carrying capacity of the beam by 25%.
- With the increase in percentage of reinforcement the ultimate deflection was found to be decreased.
- It is observed that the portion between the point of application of load and the support is the most critical portion of the beam in shear performance of beam.

Average ultimate load carrying capacity of beam with 2#8mm bars			
Temperature in◦c	ultimate load in kN	Average ultimate load in kN	series of beam
RT	66.55	63.85	A1
	65		
	60		
300	65	62.45	A2
	65		
	57.35		
400	60	60.83	A3
	57.5		
	65		
500	54	54	A4
	50.5		
	57.5		

Table 4.2 a Ultimate load carrying capacity of A series beam

Average ultimate load carrying capacity of beam with 2#10mm bars			
Temperature in◦c	ultimate load in kN	Average ultimate load in kN	series of beam
RT	90.2	86.7	B1
	85.9		
	84		
300	85.3	81.55	B2
	83.75		
	75.6		
400	81.85	80.65	B3
	80.5		
	79.6		
500	73.3	72.85	B4
	70.25		
	75		

Table 4.2 b Ultimate load carrying capacity of B series beam

6. REFERENCES

1. A. M. Neville, "*Properties of Concrete*", Pitman Publishing Ltd, London (1975)
2. Ahmad,A.H. , Abdulkareem,O.M.," *Effect Of High Temperature On Mechanical Properties Of Concrete Containing Admixtures",* Al-Rafidain Engineering Vol.18 No.4 August 2010.
3. E. Tolentino, F. Lameiras, A. Gomes, C. Silva and W. Vasconcelos, *"Effects of High Temperature on the Residual Performance of Portland Cement Concretes", Materials Research, 5 (2002), p. 1 – 11.*
4. I.Janotka, and T. Nürnbergerova,*"Effect of temperature on Structural Quality of High-Strength Concrete with Silica Fume"*, Institute of Construction and Architecture, Slovak Academy of Sciences, Bratislava, Slovak Republic,(2003), p. 1 – 8
5. T. G. Mohamedbhai, "Effect of Exposure Time and Rates of Heating and Cooling on Residual Strength of Heated Concrete", *Magazine of Concrete Research,38(1986)P.no.151-158*
6. IS: 456 (2000), plain and reinforced concrete-code of practice, *Bureau of Indian Standards, New Delhi.*