Behavior Of Steel And RCC Beam Under Controlled Elevated Temperature And Retrofitting Of RCC Beam

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Abstract*: The study is made to analyze the reinforced cement concrete subjected to specified elevated temperature at 100°C, 300°C, 600°C and 900°C. Fly ash is used to replace the cement by 20% and checked for flexure. Beam Specimens are cast with and without Fly Ash. Flexural testing is used to determine the flexure or bending properties of a material. From the study it was concluded that, as the temperature goes on increasing the strength of beam specimens goes on decreasing. Pure bending in beam specimens are seen from the temperature 100°C and shear flexure cracks were seen from the temperature 600°C. The Fly Ash can be effectively used as replacement of cement by 20% under elevated temperature because the percentage strength loss of beam with fly Ash is very less as compared to beam without Fly Ash. This paper also present an experimental evolution of effect of elevated temperature on R.C.C beam and its retrofitting with the help of glass fiber reinforced polymer sheet. The study is also made to analyze the steel subjected to specified elevated temperature at 100°C to 900°C.*

Keywords: RCC Beam, Flexural test, Elevated Temperature, GFRP Retrofitting.

1. INTRODUCTION:

With the increased incidents of major fires and fire accidents in buildings; assessment, repair and rehabilitation of fire damaged structures has become a topical interest. This specialized field involves expertise in many areas like concrete technology, material science and testing, structural engineering, repair materials and techniques etc. Research and development efforts are being carried out in these related disciplines. Any structure can undergo fire accident, but because of this the structure cannot be denied. To make a structure functional after the damage due to fire has become a challenge for the civil engineering community. The problem is where to start and how to proceed. It is vitally important that we create buildings and structures that protect both people and property as effectively as possible.

Fly ash is a fine residue that results from the combustion of powdered coal in modern boiler plants. The major problem of world is the utilization of waste. Local power utilities in West Virginia and other states produce coal ash from the burning of sub-bituminous coal, which consists of about 80 to 85 percent pulverized (fly) ash and 15 to 20 percent bottom ash. The ash produced is normally stored in bins, disposed of in landfills, or hauled away by a contractor. The American Society for Testing and Materials (ASTM) has developed the ASTM C 618 Standard for use of fly ash in concrete. Generally, there are two types of fly ash, Class F and Class C. Class C fly ash is produced by burning sub-bituminous coal or lignite. It has pozzolanic cementitious properties due to the presence of free lime, which makes it appropriate for use in concrete mixes.

We are all aware of the damage that fire can cause in terms of loss of life, homes and livelihoods. The loss of business resulting from fires in commercial and office buildings runs into millions of pounds each year. The extent of such damage depends on a number of factors such as building design and use, structural performance, fire extinguishing devices and evacuation procedures. Some structures are subjected to accidental fire. Because of accidental fire structures are undergone very high temperature, due to which concrete abruptly changes in physical, mechanical and chemical properties. The experimentation should be done to find out the impact of fire on reinforced cement concrete by heating the samples of beam at various elevated temperature and test for flexure.

It is need to check the safety of structure against fire. Thus the study is required to analyse the reinforced concrete subjected to high temperature & then its relative strength. The flexure strength & weight loss of the reinforced concrete at high temperature are found out. The attempt has been made to check the fire resistance of reinforced concrete in an economical way. Exposure to elevated temperatures causes physical changes, including large volume changes owing to thermal shrinkage and creep related to water loss. The changes in volume will result in large internal stresses thus leading to micro cracking. Elevated temperatures also bring in some chemical and micro-structural changes such as migration of water, increase in dehydration and thermal incompatibility of the interface between cement paste and aggregates. All of these changes will have a bearing on the decrease of the strength concrete. Fire resistance of concrete is primarily affected by factors like the temperature, duration and condition of the fire.

2. Methods:

Preparation for experiment:

The experimental work includes the casting, curing and testing of specimens with and without Fly Ash. A concrete mix M30 grade is designed. The locally available materials were used. The investigation is to evaluate the flexural strength of specimens when subjected to elevated temperatures of 100^{o}C, 300^{o}C, 600^{o}C, and 900^{o}C. The specimens of size 1000mm x 100mm x 150mm beams with and without Fly Ash were cast for this investigation. The specimen with Fly Ash was replaced for cement by 20% Fly Ash. The specimens after curing were placed in electric furnace and exposed to given specified temperatures. The specimens after curing were placed in electric furnace at specified temperatures of 100^{o}C, 300^{o}C, 600^{o}C, and 900^{o}C at constant time interval of 2hours. After removal from furnace, they were allowed to cool in dry conditions and were tested for flexure strength.

Also the size of beam 150mm x 150mm x 1000mm of M20 concrete grade is cast. The flexural strength of specimens when subjected to elevated temperatures of 100^{o}C, 300^{o}C, 600^{o}C, and 900^{o}C is checked. For each temperature interval four beams heated in the furnace and after that these beams are cooled under natural environmental condition. Out of four beams which is heated at one particular temperature two beams subjected to direct loading and the other two subjected to loading after their retrofitting

Heating Exposure Technique:

Electric furnace of maximum temperature of 1200°C was used. Specimens were placed unloaded in the cooled furnace chamber and the temperature was increased to reach desired degrees with increase of 9°C/min. After 2 hours of heating at constant temperature, the furnace is switched off and allowed to cool and then specimens are taken out and cooled & then they are tested.

Fig. 1: Beam exposed for Heating

Fig. 2: Control Panel

Test Setup:

The test set up consists of universal testing machine of 60 Ton capacity, Dial gauges for recording the deflection of beam specimens. The end conditions of beam were kept simply supported. Center to centre span of the beam is kept as 900 mm. Clear spans is equally divided into three equal parts. The dial gauges are fixed at centre point and under the loading points to measure the corresponding deflections. The needle of dial gauges is kept vertical for accuracy of readings. The rate of loading is kept 10 Kg. The deflections are measured for each 250 kg interval of loading.

3. Results:

Following are the results of beam cast with and without Fly Ash.

Table 1: Flexural strength of specimens Without Fly Ash

Sr. No.	Temp (°C)	Load (kN)	Average Load (kN)
1	Room Temp	60.00	59.17
		58.50	
		59.00	
2	100	58.50	58.67
		57.50	
		60.00	
3	300	49.50	49.83
		50.50	
		49.50	
4	600	41.00	41.47
		42.00	
		41.40	
5	900	26.50	25.50
		25.00	
		25.00	

Table 2: Flexural strength of specimens With Fly Ash

Sr. No.	Temp (°C)	Load (kN)	Average Load (kN)
1	Room Temp	57.50	56.00
		55.50	
		55.00	
2	100	56.00	55.50
		55.00	
		55.50	
3	300	45.00	47.67
		50.00	
		48.00	
4	600	39.00	39.67
		41.00	
		39.00	
5	900	22.50	24.50
		28.00	
		23.00	

Table 3: Percentage Decrease in Strength of Fly Ash specimen

Sr No	Temp (°C)	Average Load (kN)	Percentage Decrease in strength (%)
1	Room Temp	56.00	--
2	100	55.50	0.89
3	300	47.67	14.87
4	600	39.67	29.16
5	900	24.50	56.25

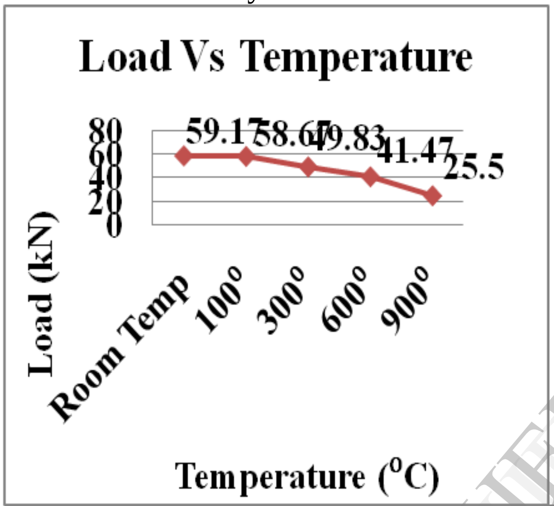
Table 4: Percentage Decrease in strength of Fly Ash specimen with respect to Without Fly Ash specimen

Sr No	Temp (°C)	Average (kN)		Percentage Decrease in Strength (%)
		With out Fly Ash	With Fly Ash	
1	Room Temp	59.17	56	5.35
2	100	58.67	55.5	5.4
3	300	49.83	47.67	4.33
4	600	41.47	39.67	4.34
5	900	25.5	24.5	3.92

Table 5: Permissible load of beams after exposure of elevated temperature

Sr. No.	Temperature (°C)	Permissible Load for Without Fly Ash beam (kN)	Permissible Load for With Fly Ash beam (kN)
1	Room Temp	50.22	47.80
2	100	50.15	47.77
3	300	36.52	35.52
4	600	31.90	30.63
5	900	14.87	13.47

The final deflection due to all loads including the effect of temperature and shrinkage should not exceed Span/250 = 4mm. Hence, the permissible load for the beams with and without Fly Ash at the 4mm deflection is calculated and given in Table No.5.



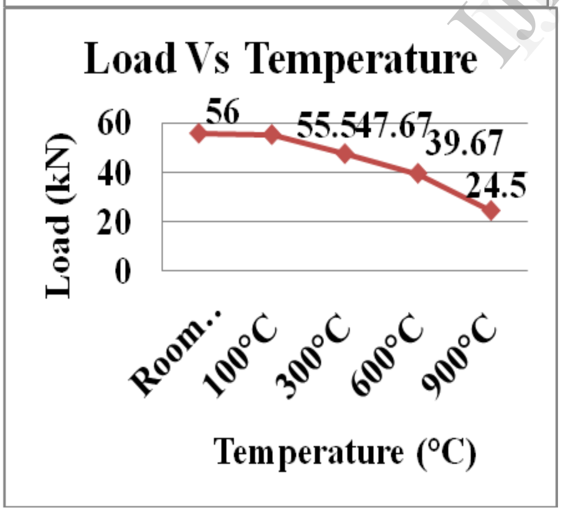


Fig. 3: Load Vs Temperature Graph for specimens with Fly Ash

Fig. 4: Load Vs Temperature Graph for specimens without Fly Ash

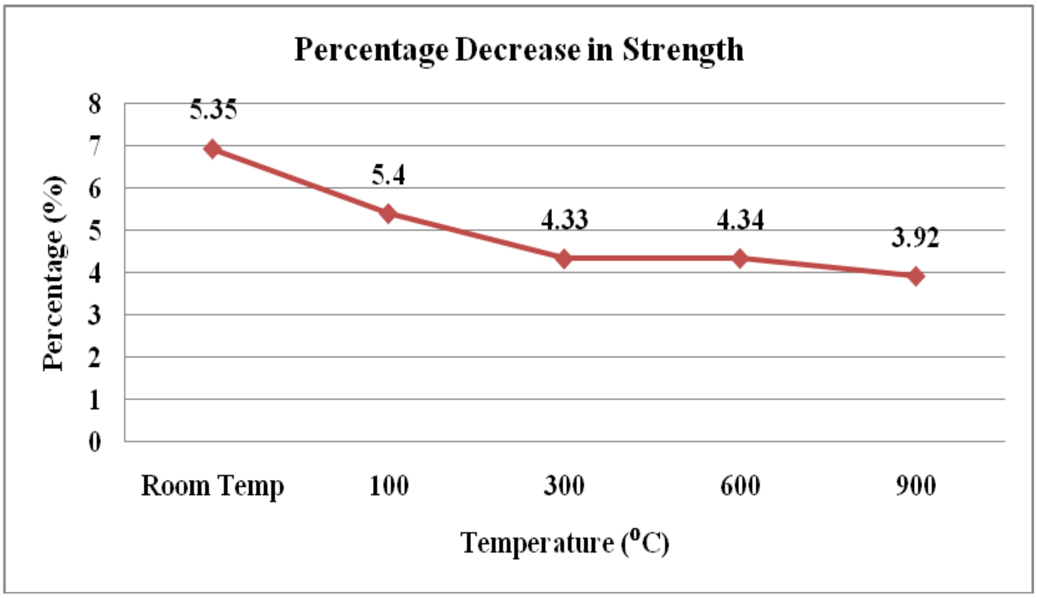


Fig. 5: Percentage Decrease in Strength of Fly Ash specimen with respect to without Fly Ash specimen

2. Following are the results for normal M20 grade concrete:

Table 6: Deflection of Control Beam (CB) at different temperatures.

Sr. No.	Load (KN)	Deflection of Beam at different Temperatures (mm)			
		Room Temp.	300^0 C	600^0 C	900^0 C
1.	5	0.22	0.02	0.25	0.11
2.	10	0.55	0.39	0.55	0.65
3.	15	0.85	0.71	0.8	1.35
4.	20	1.3	1	1.11	2.09
5.	25	1.58	1.29	1.4	3.08
6.	30	1.9	1.51	1.75	3.54
7.	35	2.18	1.79	2.15	
8.	40	2.44	2.19	2.44	
9.	45	2.73	2.5	2.72	
10.	50	3.03	2.8	3.09	
11.	55	3.42	3.09		
12.	60	3.83	3.4		
13.	65	4.59	3.79		
14.	70	5			

Table 7: Deflection of control beam retrofitted (CBR) at different temperatures

Sr. No	Load (KN)	Deflection of Beam at different temperatures (mm)			
		Room Temp.	300^0 C	600^0 C	900^0 C
1.	5	0.1	0.33	0.08	0.66
2.	10	0.3	0.54	0.39	1.19
3.	15	0.44	0.77	0.77	1.77
4.	20	0.54	0.99	1.09	2.28
5.	25	0.65	1.22	1.4	2.85
6.	30	0.82	1.55	1.77	3.6
7.	35	1.05	1.8	2.08	4.44
8.	40	1.33	2.1	2.34	5.49
9.	45	1.65	2.38	2.65	6.44
10.	50	1.94	2.77	3.05	
11.	55	2.22	2.99	3.35	
12.	60	2.5	3.39	4.1	
13.	65	2.74	3.89	4.77	
14.	70	3.09	4.38		
15.	75	3.4	4.49		
16.	80	4.33			

Table 8: Ultimate strength Vs Temperature

Temperature (°C)	Ultimate Strength(KN)	
	Without Retrofitting	After Retrofitting

Room temp. (27)	70	82.5
300	65	75
600	52.5	67.5
900	30	45

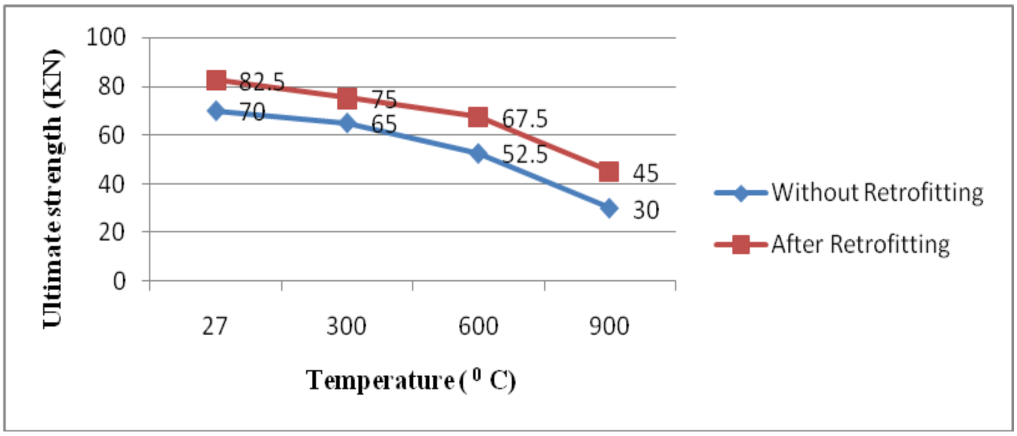


Fig. 6: Ultimate strength Vs Temperature

Table 9: Comparative analysis for different configuration of beam

Temperature	**Ultimate Strength(KN)**		**Load Caring Capacity Comparison**	
	(CB)	**(CBR)**	**(CBR) With (CB) at respective temperature**	**(CBR) With (CB) at room temperature**
Room temp. (27^0C)	70	82.5	Increased by18 $^0/_0$	Increased by 18 $^0/_0$
300^0 C	65	75	Increased by 16 $^0/_0$	Increased by 7.14 $^0/_0$
600^0 C	52.5	67.5	Increased by 29 $^0/_0$	Decreased by 3.57 $^0/_0$
900^0 C	30	45	Increased by 50 $^0/_0$	Decreased by 35.71 $^0/_0$

3. Following are the results for mild steel:

Table 10: Mild steel bar Ultimate load and Break point Load for different Temperature.

Temp. ⁰C	Ultimate load (KN)	Break point Load (KN)
27	109.680	90.644
100	107.321	91.429

200	105.457	90.742
300	103.200	82.600
400	99.866	78.088
500	99.081	77.981
600	98.001	74.458
700	90.252	77.499
800	86.720	61.018
900	84.072	55.524

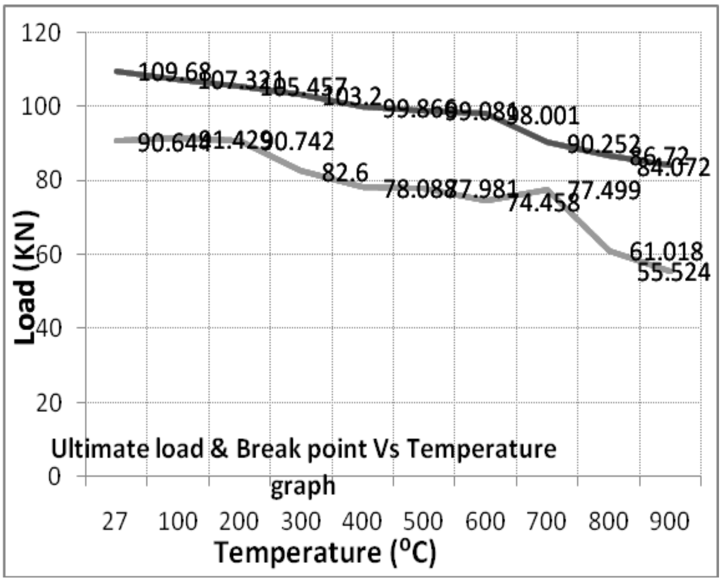


Fig 7: Comparisons of Ultimate load & Break point to Elevated Temperature for 16 mm diameter mild steel bar.

It can be observed that the ultimate load and break point load decreases. At room temperature ultimate load carrying by bar is 109.68KN, but after 900^{0}C temperature the ultimate load is 84.072KN.ultimate load is decrease by 25.608KN.

Table 11: Mild steel bar Elongation and Temperature:

Temp. ^{0}C	Elongation (%)
27	41.25
100	40.00
200	36.25
300	36.25
400	35.00
500	33.75
600	31.25
700	30.00
800	18.75
900	15.00

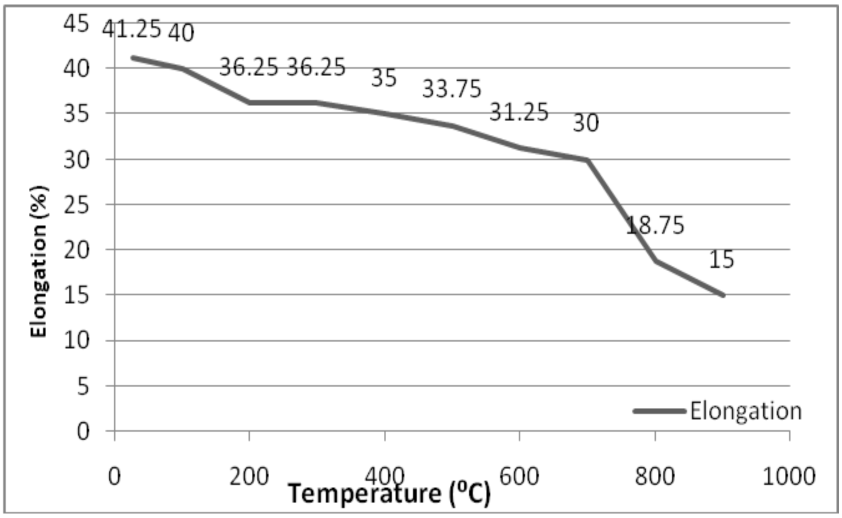


Fig. 8: Elongation Vs Temperature for 16 mm diameter bar.

It can be observed that the elongation of bar decreases with respect to temperature. At room temperature elongation of bar is 41.25%, but after 900^{0}C temperature the elongation of bar is 15%. Elongation of bar is decrease by 26.25%.

3.4.2 Failure pattern of Bars:

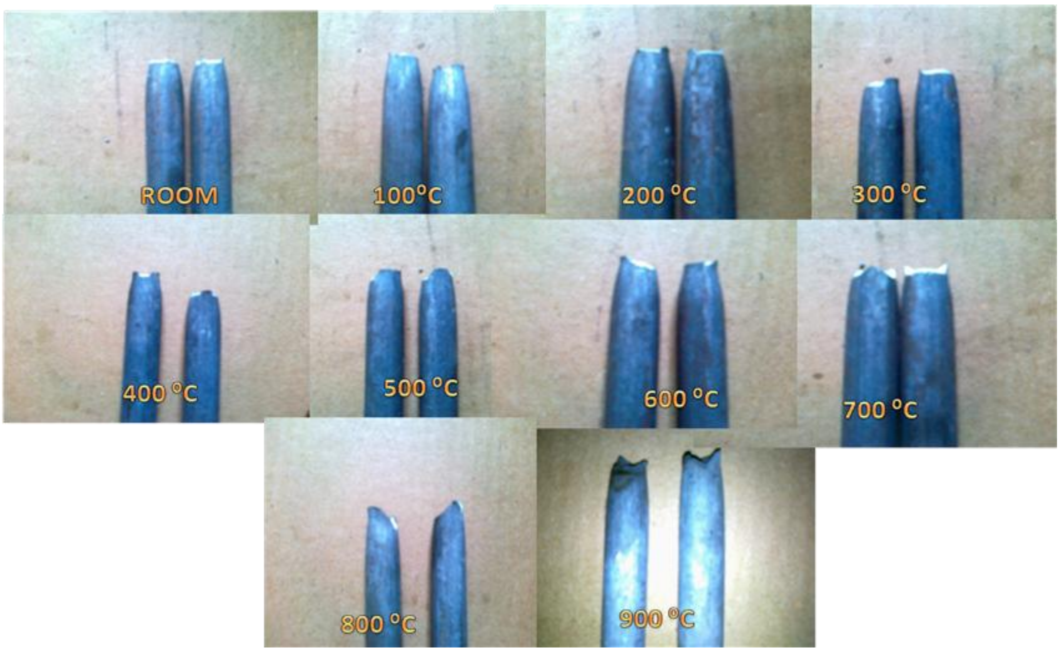


Fig. 9: Failure patterns of bars at different temperature.

4. Discussion and Conclusions:

The conclusions drawn from the results obtained in this study are as follows:

- The Flexural strength of beam was decreased as the elevated temperature was increased.
- After testing, beams showed flexural cracks in the pure bending region for elevated temperature at 100°C and 300°C and shear flexure cracks in the shear region for elevated temperature at 600°C and 900°C.
- The flexural strength of beams with Fly Ash at temperature 100^{o}C, 300^{o}C, 600^{o}C & 900^{o}C were less than the room temperature beams by about 0.89%, 14.88%. 29.16% and 56.25% respectively.
- The flexural strength of beams with Fly Ash at temperature 100^{o}C, 300^{o}C, 600^{o}C & 900^{o}C were less than beams without Fly Ash by about 5.35%, 5.4%, 4.33%, 4.34% and 3.92% respectively.
- The percentage decrease in strength of beam with Fly Ash and without Fly Ash is negligible, so we can effectively save the cement by 20% replacement of Fly Ash in concrete.

- The load carrying capacity of control beam is increased by 18 % after GFRP retrofitting.
- The load carrying capacity of control beam at 300^0 C is increased by 16 % after GFRP retrofitting.
- The load carrying capacity of control beam at 600^0 C is increased by 29 % after GFRP retrofitting.
- The load carrying capacity of control beam at 900^0 C is increased by 50 % after GFRP retrofitting.
- The failure diameter of bar increased with respect to increase in temperature 27˚C, 100°C to 900°C by 9.45mm, 9.50mm, 9.90mm, 10.15mm, 10.35mm, 10.35mm, 10.9mm, 10.95mm, 11.65mm and 11.90mm respectively.
- Percentage elongation of bar at temperature 27˚C, 100^0C to 900^0C are 41.25%, 40.00%, 36.25%, 36.25%, 35.00%, 33.75%, 31.25%, 30.00%, 18.75%, 15.00% respectively.

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