Study of RCC Beams Damaged By Fire

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***Abstract*: Object of this study was to check the strength of fired standard size beams .In this regard 36 beams were constructed, 18 were constructed without plaster and 18 have ¾" thick plaster .The total specimens be cure in similar controlled circumstances in the laboratory for the age of 28 days, while 18 plastered were further cured for 7 days after their plaster. Beams were placed under the fire for different intervals of time. These beams were tested in the Universal Testing Machine (UTM) of the Department at MUET. The changes appeared in color consider as the first impact in the structure due to fire Became dark black and grey. Together with lopsided crack, spalling and infringement surface. Fall in compressive strength of concrete due to brutal temperature was detected. All the information about the behavior of both type of beams are studied. Significant effects of fire on strength and aesthetic view of concrete are observed.**

***Keywords*: Concrete, reinforcement, fire, plaster, spalling, cracks**

I. INTRODUCTION

Concrete is a united substance which mainly comprises of a binding middle of cement and water or normally cement stick and immobile fillers name aggregate. Ordinary Portland cement (OPC), aggregate like gravel, lime stone or material retain 4.75mm sieve, and fine aggregate such as sand or stuff fleeting 4.75mm sieve are assorted by means of water, form thick compacted substance called as concrete. The water eliminated from the concrete due to heat of hydration concrete becomes hardened position gaining strength.With the extensive researches accrued in a extremely gigantic way where the prescribed has generate extensive receipt due to subsequent purposes the RCC structure and steel structure were introduce. It have a comparatively elevated compressive strong point, enhanced fight to fire and steel and extended repair life with small safeguarding price. Sometimes, the structures like dam, pier and footings are the mainly rational structural objects. It can be emanate to get the figure obligatory, make it broadly use in precast structural component. It yield unyielding member with smallest obvious deflection.

Most of researches are done on the basis of maintained temperature of fire either in an oven or in a kiln, with controlled environment of the laboratory. But when an unpredicted fire occurs in a building, there is no maintained temperature of fire. Materials present in the building and the flow of air in the surroundings of building provide fuel for its persistence; at that time how much loss occurs is the problem to study in this research.

II. MATERIALS & METHODS

MATERIAL

Essential property of concrete ingredient like aggregates, cement and steel were experimentally studied. Concrete was designed by weight method of every component. Concrete were prepared in the Concrete Laboratory of Civil Engineering Department, Mehran University of Engineering and Technology, Jamshoro. In arrange to get the plan and objectives of this revise 18 beams by two different steel strengthening as utilize the aggregate of Petaro-based quarry and mount sand find commencing Bolhari be construct in the laboratory Whereas 18 beams of similar geometry and concrete were constructed but having cement plaster of 3/4 inches in the same laboratory.

METHODOLOGY

From 36 beams, 12 beams will be tested without fire 12 beams will have exposure up to 3 hrs of fire and remaining 12 beams will have exposure of 6 hrs of fire of ordinary furnace. The temperature was not fixed but it was measured with the help of asphalt thermometer was 600-800° C. All the beams will be then colored with white color and then tested in the laboratory.

CASTING OF R.C.C BEAMS

Steel moulds have span of 3 ft. and cross sectional area 6 in2 were worn in this probe revise. The moulds and their base were clamp jointly earlier than case in arrange to avoid the leak of concrete. Prior to drizzling the concrete intense on the moulds, their mate facade and the area surface are covered with oil to avert the increase of attachment stuck between the mould and the concrete. The considered quantity of concrete constituent were put into an electrically operate concrete mixer, for concerning 5 min. and the concrete be then in use out and packed in the moulds. The normal prearranged by BS 1881: part 108:1983 was follow to block the moulds. All coating of concrete is compressed via 25 blows actually by means of the help of 5/8 in. dia steel rod. The moulds were then set aside on electrically in service vibrating table for suitable compaction. After having finished top surface by means of float, beams were left for 24 hrs in open air. At the end of this time, the moulds were unscrewed and beams were placed into the water tank for curing.

ARRANGEMENT OF FIRE

Most of research on effect of fire on strength and other property of concrete are done under controlled and maintained temperatures but when a building is under fire exposure temperature is not maintained, it varies with time due to atmosphere and other things which can provide fuel for continuation of fire like furniture, wood work, electric wires etc. For this research work ordinary furnace is made, wooden blocks arrangement is used. Though the temperature was not maintained but was calculated 600 °C- 800 °C.

III. RESULTS

All together36 R.C.C beams were made, 18 beams named as MnDn were tested for all parameters of study with no plaster and 18 named as MnDnP having ¾" plaster were tested for the set parameter of the study. The photographs of all the tested beams are given in this chapter which shows the crack pattern and failure mode of tested beams. The load deflection performance has also been existing by plotting graph between load and deflection.

TESTING OF R.C.C BEAMS

All together 36 beams were cast and tested in the light of set parameters .After manufacturing beams were left in water tank for curing of 28 days. When curing was finished 18 beams we taken out and plastered, with ¾" cement plaster, beams were left one day dry and again left in water tank for 7 days curing. This is a simulation of real practice in construction After end of curing age of all beams were taken out and dried for 7-20 days .after fully dry these beams were proceeded to exposure under real fire circumstances of ordinary furnace, made with C.C blocks was made outside the laboratory of the department, under real fire circumstances beams completely loss their color and became black in color .Beams was washed with water and left to become dry .When beam turn into dehydrated these beams be colored with white color so that reasonable vision about recognition of face crack can be envision while the load be apply on them at the time of testing. After painting the surface of beams, aluminum strip 1" wide and 12" in length were fixed at the center at beam soffit with the help of glue epoxy so that deflection measurement became convenient. Dial gauge are used to record deflection in Universal Testing Machine (UTM).

Beams were tested in UTM machine having capacity of 180 tones. Prior to applying load to beams dial gauge reading was made zero. The 5KN addition is set; at every addition note down the deflection readings were record. Crack pattern and crash modes of the beams also recorded. The all tested beams Figures are presentation crack pattern and failure modes are given in this chapter in next section.

Table 1: Comparison of virgin and plastered beams without fire

M4D6		**M5D4**		**M4D6P**		**M5D4P**		**Remarks**
L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	
0	0	0	0	0	0	0	0	Beams containing high main steel have taken high load in comparison to smaller main steel beams in both forms. Plastered beams has taken high load than un plastered beams
5	0.45	5	0.5	5	0.5	5	0.49	
10	0.8	10	0.8	10	0.8	10	0.8	
15	1.2	15	1.2	15	2.2	15	1.3	
20	1.8	20	1.5	20	2.5	20	1.9	
25	2.4	25	1.8	25	2.9	25	2.4	
30	2.9	30	2.2	30	3	30	2.9	
35	3.5	35	2.5	35	3.1	35	3.6	
40	3.9	40	3	40	3.4	40	3.9	
45	4.1	45	3.4	45	3.8	45	4.1	
50	5.5	50	4	50	4	50	5.5	
55	9.1	55	4.8	55	4.5	55	9.1	
60	14.3	60	6.4	60	4.8	60	14.3	
65	20.8	65	6.9	65	6.9	65	19	
70	21.8	70	9.8	70	9.8	70	14.3	
		75	15.8	75.336	15	75	21.85	
						79.8	22	

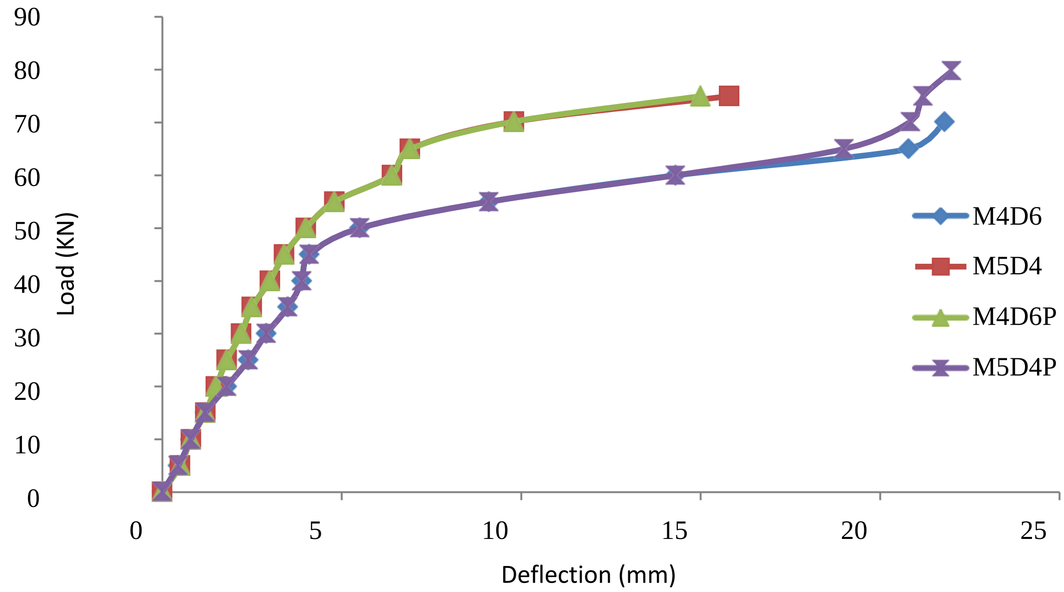

Fig:1 Graphical representation of comparison of beams

Table 2: Comparison of virgin and plastered beams without fire

MDD6		M5D4		M4D6P		M5D4P		Remarks
L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	
0	0	0	0	0	0	0	0	Beams containing high main steel have taken high load in comparison to smaller main steel beams in both forms. Plastered beams has Taken high load than un plastered beams.
5	0.35	5	0.3	5	0.5	5	0.4	
10	0.5	10	0.5	10	0.7	10	0.6	
15	0.9	15	0.9	15	0.9	15	0.9	
20	1.5	20	1	20	1.25	20	1	
25	3	25	1.3	25	1.4	25	1.7	
30	4.5	30	1.6	30	1.9	30	2.4	
35	5	35	2	35	2.4	35	2.7	
40	6.8	40	2.3	40	2.6	40	3	
45	8.3	45	2.6	45	3	45	4	
50	9	50	3	50	3.5	50	4.8	
55	10.2	55	3.5	55	4.1	55	5.6	
60	11	60	3.9	60	5.1	60	7.3	
65.4	13.5	65	9.6	65	6.2	65	8.2	
		70	10.2	70	9.8	70	9	
		75.3	11	75	16.8	75	9.6	
				80.3	18	80	11.4	
						85.3	11.5	

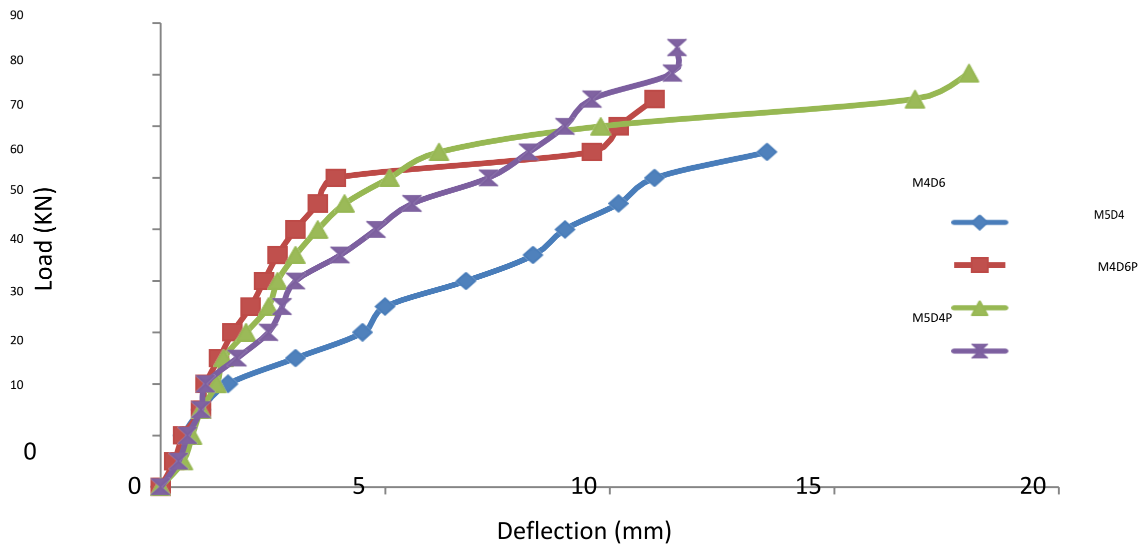

Fig. 2: Graphical representation of comparison of beams

Table 3: Comparison of virgin and plastered beams without fire

M4D6		M5D4		M4D6P		M5D4P		Remarks
L(KN)	**Δ(mm)**	**L(KN)**	**Δ(mm)**	**L(KN)**	**Δ(mm)**	**L(KN)**	**Δ(mm)**	
0	0	0	0	0	0	0	0	Beams containing high main steel have taken high load in comparison to smaller main steel beams in both forms. Plastered beams has taken high load than un Plastered beams.
5	0.3	5	0.5	5	0.15	5	0.4	
10	0.5	10	0.95	10	0.2	10	0.9	
15	0.9	15	1.3	15	0.25	15	1.1	
20	2	20	1.7	20	0.3	20	2	
25	2.3	25	2	25	0.4	25	3.4	
30	4.6	30	2.5	30	1.2	30	3.7	
35	5	35	2.9	35	1.9	35	4.2	
40	7.9	40	3.5	40	2.3	40	4.6	
45	8.6	45	4	45	4.2	45	4.8	
50	11.3	50	4.5	50	5.5	50	5.3	
55	15	55	5.2	55	13.7	55	6	
60	15.5	60	5.8	60	14	60	6.8	
65	17	65	7.2	65	14.2	65	8.1	
69.3	18.2	70	8.9	70	15	70	9	
		73.5	9.8	74.5	16.8	75	9.9	
						80	11.9	
						85	16.8	

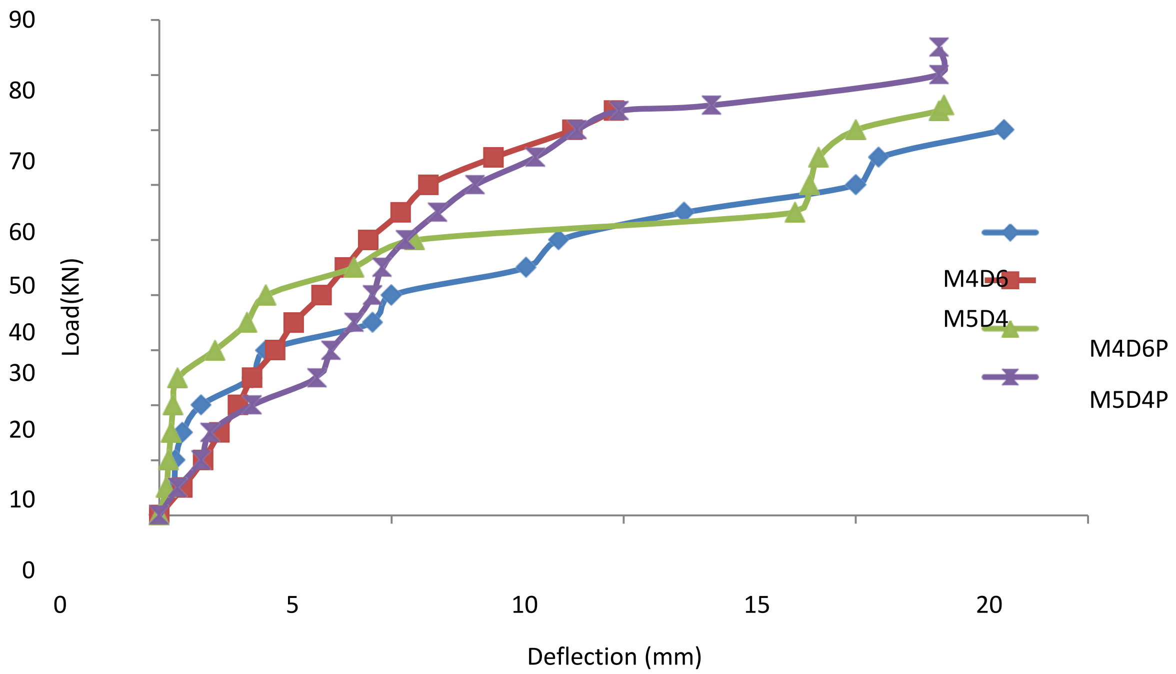

Fig. 3: Graphical representation of comparison of beams

Table 4: Comparison of virgin and plastered beams after 3 hours fire:

M4D6		M5D4		M4D6P		M5D4P		Remarks
L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	
0	0	0	0	0	0	0	0	Beams containing high main steel have taken high load in comparison to smaller main steel beams in both forms.Palstered beams has taken high load than un Plastered beams.
5	0.71	5	0.5	5	1.3	5	0.5	
10	1.15	10	0.8	10	2.9	10	0.8	
15	1.6	15	1.2	15	3.2	15	1.2	
20	1.9	20	1.5	20	4.1	20	1.4	
25	2.3	25	2.5	25	5	25	1.7	
30	3	30	3.2	30	6	30	1.9	
35	3.44	35	4	35	6.6	35	2.3	
40	4	40	5.5	40	7.1	40	2.6	
45	4.5	45	6.3	45	7.4	45	3.1	
50	5.5	50	7.6	50	11.8	50	5.7	
55	13.2	55	12.6	55	16.7	55	6.1	
60	16.6	57	15.8	60	17	60	9.8	
						65	19.2	

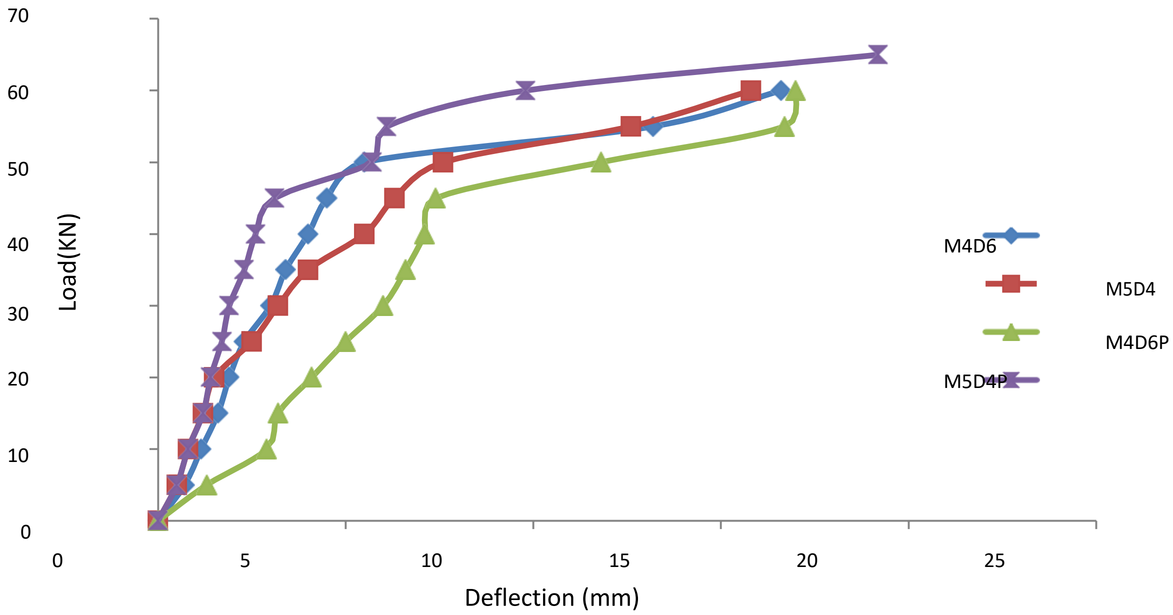

Fig. 4: Graphical representation of comparison of beams.

Table 5: Comparison of virgin and plastered beams after 3 hours fire

M4D6		M5D4		M4D6P		M5D4P		Remarks
L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	
0	0	0	0	0	0	0	0	Beams containing high main steel have taken high load in comparison to smaller main steel beams in both forms. Plastered beams has taken high load than un Plastered beams.
5	0.3	5	0.6	5	0.5	5	0.4	
10	0.8	10	1	10	1.2	10	0.6	
15	1.2	15	1.6	15	1.4	15	0.65	
20	1.8	20	1.9	20	1.7	20	0.7	
25	2.4	25	3.6	25	2.4	25	0.8	
30	3.1	30	4	30	3.2	30	1.2	
35	3.9	35	4.5	35	4.5	35	1.5	
40	4.8	40	6.6	40	5.5	40	1.9	
45	5.8	45	9.5	45	6.4	45	2.8	
50	7.7	50	12.9	50	7.4	50	3.6	
55.6	12	55	13	55	7.9	55	4.8	
				60	12.2	60	5.2	

64	18.4	65	6.9
		70	10.9

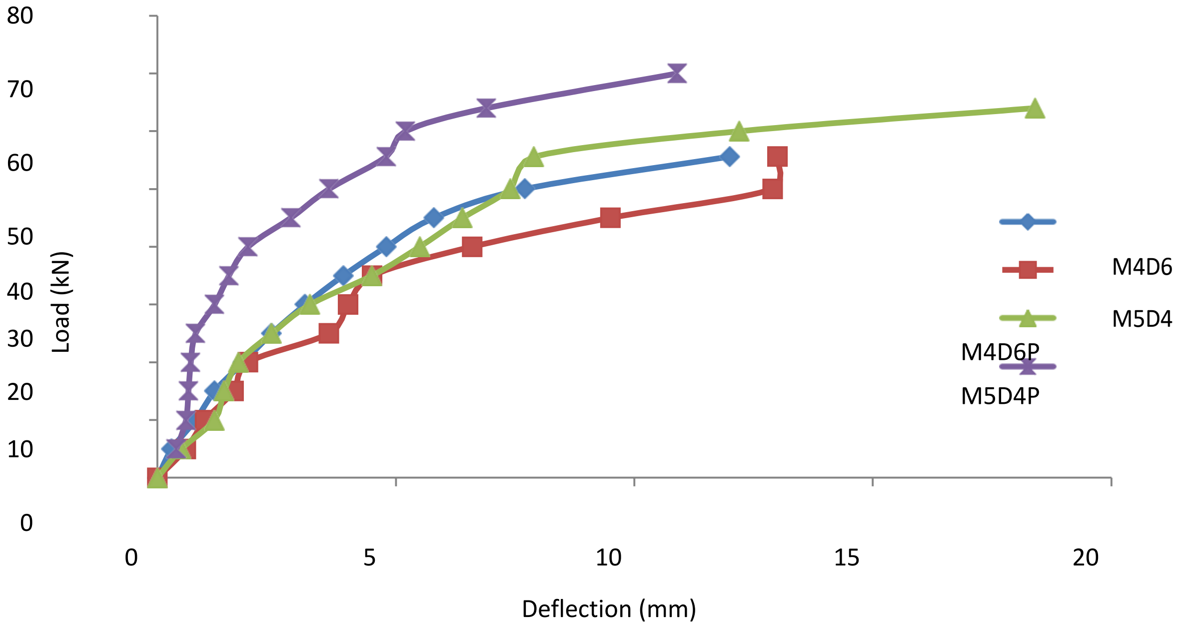

Fig.5: Graphical representation of comparison of beams.

Table 6: Comparison of virgin and plastered beams after 3 hours fire

M4D6		**M5D4**		**M4D6P**		**M5D4P**		**Remarks**
L(KN)	**Δ(mm)**	**L(KN)**	**Δ(mm)**	**L(KN)**	**Δ(mm)**	**L(KN)**	**Δ(mm)**	
0	0	0	0	0	0	0	0	Beams containing high main steel have taken high load in comparison to smaller main steel beams in both forms. Plastered beams has taken high load than un Plastered beams.
5	0.6	5	0.4	5	0.5	5	0.8	
10	1.4	10	0.8	10	0.9	10	1.3	
15	2.2	15	1.3	15	1.1	15	1.9	
20	2.3	20	1.8	20	1.6	20	2.4	
25	2.5	25	2.3	25	2.1	25	4.8	
30	3.4	30	5.8	30	2.4	30	6.2	
35	5.4	35	6.5	35	2.8	35	7.2	
40	6	40	7	40	3.3	40	8.3	
45	6.6	45	7.6	45	3.9	45	9	
50	7.95	50	8.9	50	4.1	50	9.7	
55	9.8	55	10.2	55	5.7	55	10.2	
59.2	10	60.2	13.1	60	6.3	60	11	
				62	13.5	65	11.2	
						69	13	

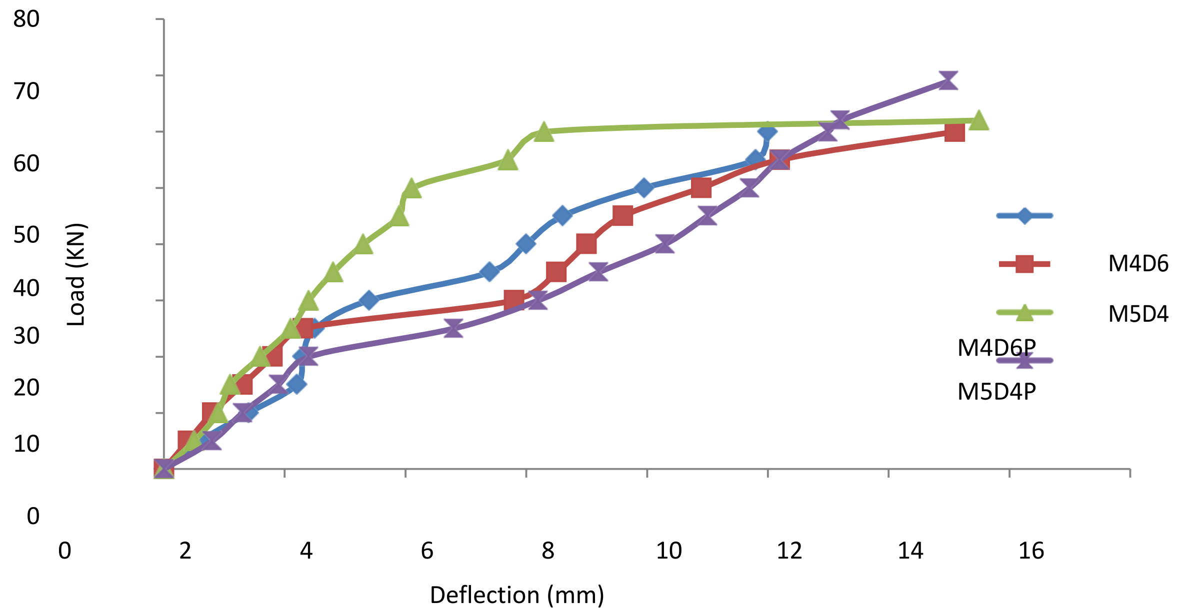

Fig. 6: Graphical representation of comparison of beams

Table 7: Comparison of virgin and plastered beams after 6 hours fire

M4D6		M5D4		M4D6P		M5D4P		Remarks
L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	
0	0	0	0	0	0	0	0	Beams containing high main steel have taken high load in comparison to smaller main steel beams in both forms.Palstered beams has taken high load than un plast- ered beams.
5	0.1	5	0.3	5	0.5	5	0.4	
10	1	10	0.7	10	0.95	10	0.9	
15	1.4	15	1.2	15	1.4	15	1.3	
20	3	20	1.7	20	2	20	1.6	
25	3.1	25	2.3	25	2.6	25	2.6	
30	4	30	3	30	3.5	30	2.7	
35	5.2	35	3.2	35	4.5	35	2.9	
40	6.4	40	5.6	40	7.9	40	3	
45	13.3	45	14.15	45	15.9	45	3.3	
50	13.8	50	16	50.3	16.95	50	3.7	
54.65	14.9					55	4.5	
						59.98	9.8	

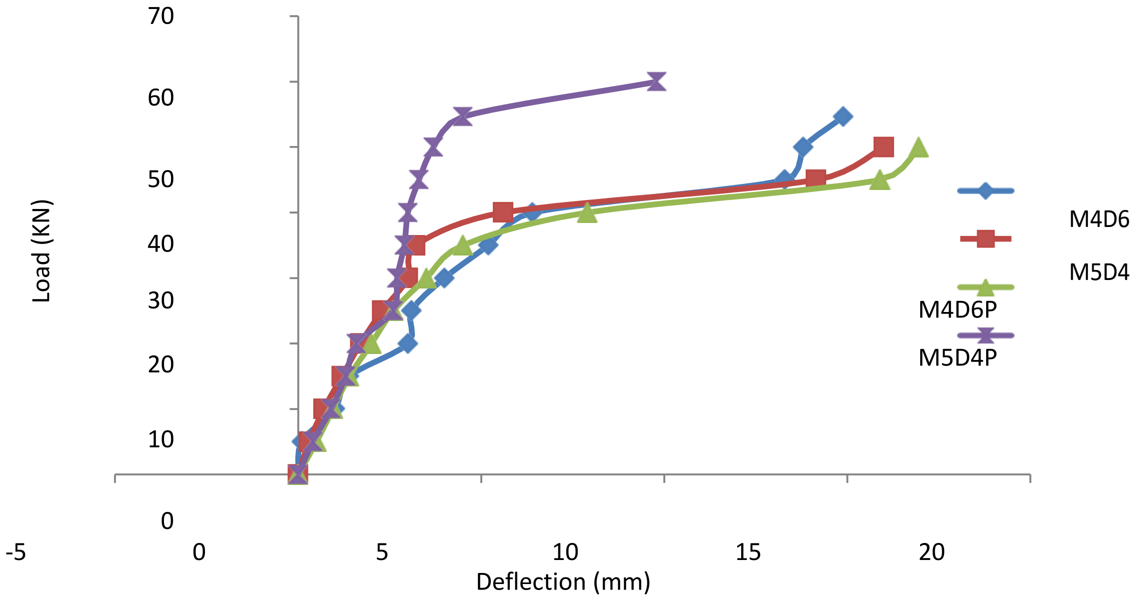

Fig. 7: Graphical representation of comparison of beams.

Table 8: Comparison of virgin and plastered beams after 6 hours fire

M4D6		M5D4		M4D6P		M5D4P		Remarks
L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	L(KN)	Δ(mm)	
0	0	0	0	0	0	0	0	Beams containing high main steel have taken high load in Comparison to smaller main steel beams in both forms. Plastered beams have taken high load than un plastered beams.
5	0.4	5	0.4	5	0.6	5	0.2	
10	1	10	1.1	10	1.1	10	0.5	
15	1.5	15	1.6	15	1.6	15	0.8	
20	2	20	2	20	2.1	20	1.2	
25	2.6	25	2.9	25	2.9	25	1.5	
30	3.4	30	4.2	30	3.7	30	1.9	
35	4.6	35	5.4	35	5.5	35	2.1	
40	6.8	40	6.2	40	6.3	40	2.4	
45	11.2	45	9.8	45	7.4	45	2.7	
50	15.3	50	13.8	50.135	15.6	50	3	
		52.66	14.7			55	3.4	
						60	6.1	

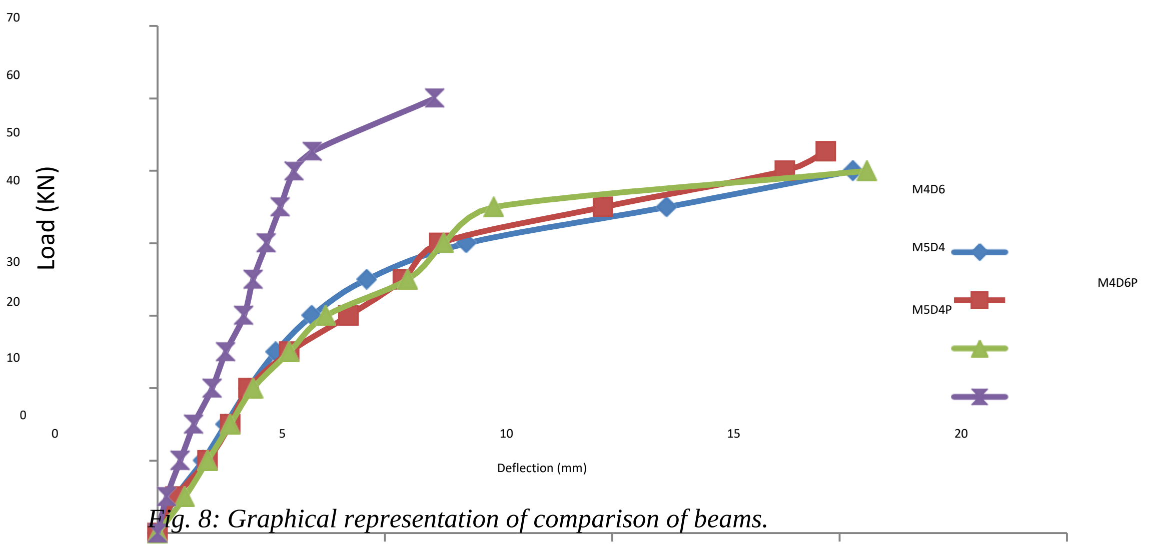

Fig. 8: Graphical representation of comparison of beams.

Table 9: Comparison of virgin and plastered beams after 6 hours fire

M4D6		**M5D4**		**M4D6P**		**M5D4P**		Remarks
L(KN)	**Δ(mm)**	**L(KN)**	**Δ(mm)**	**L(KN)**	**Δ(mm)**	**L(KN)**	**Δ(mm)**	
0	0	0	0	0	0	0	0	Beams containing high main steel have taken high load incomparison to smaller main steel beams in both forms. Palstered beams has taken high load than un plastered beams.
5	0.9	5	0.9	5	0.6	5	0.5	
10	1.22	10	1.1	10	1.1	10	0.8	
15	2	15	1.5	15	1.7	15	1	
20	3.6	20	2.9	20	2.4	20	1.2	
25	3.9	25	3.3	25	3.1	25	1.4	
30	4	30	5	30	4.2	30	1.6	
35	4.6	35	6.6	35	8.6	35	1.9	
40	9.8	40	7.8	40	9	40	2.1	
45	10.2	45	8.6	45	10.2	45	2.3	
48.3	11	49.6	9	50	11	50	4	
				55.9	13.2	55	6.5	
						60.8	8.3	

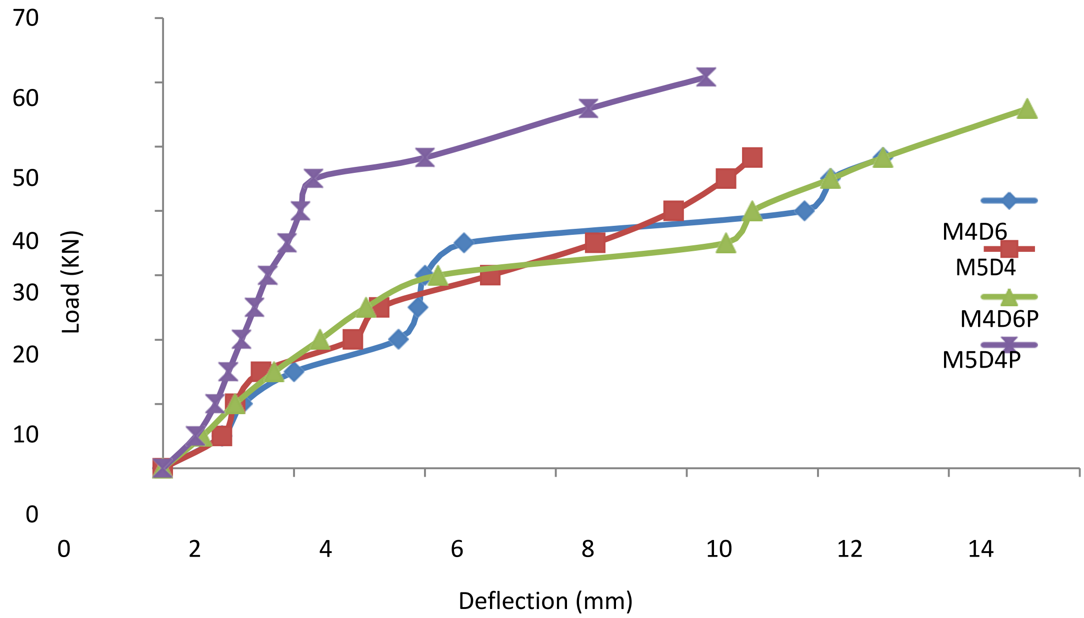

Fig.9 Graphical representation of comparison of beams

Table 10: Summary of tested beams with average loads with respect to time intervals

S. No	Fire (hours)	Average load (KN)			
		M4D6	**M5D4**	**M4D6**	**M5D4P**
1	0	68.29	74.6	76.71	83.36
2	3	58.26	57.4	62	68
3	6	50.98	50.75	52.11	60

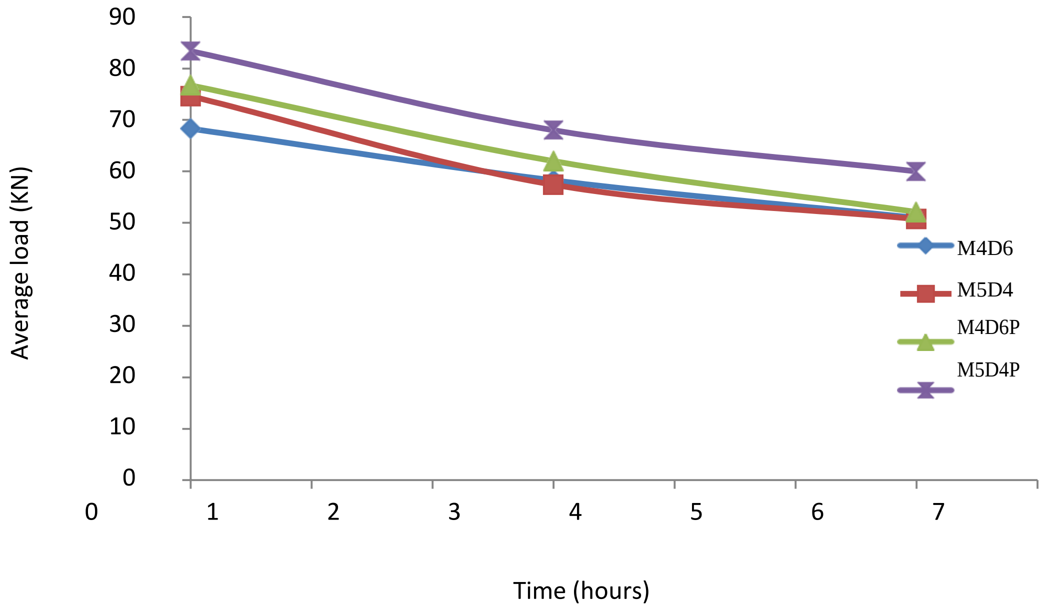

Fig.10: Comparison of average load with respect to time

CONCLUSIONS

1. Though the temperature was not maintained, and beams were exposed to real fire of ordinary furnace we have taken the average of three beams for each batch.
2. The deterioration in reinforced concrete structures measured by bearing capacity for the affected elements of structure. The changes in appeared color consider the first impact to the fires impact in the structure. By necked eyes, from the first step of physical inspection it's recognized that color of beams became dark black and grey, damages touches all the surfaces of beams. A extensive range of varying damage degrees has been noted through assessment .This range includes damage of different types and intensities such as color change, non-regular cover, spalling and breaking off.
3. Spalled surfaces and cracks were often the visible consequences of fire on concrete in both cases.
4. For plastered beams ¾" cement plaster was spalled when the temperature was increased in different time interval. The surface became chipped off on cooling the beams after fire.
5. Non – regular breaking off of concrete on the surface of beam was the most recognized sign, and random cracks were also noticed.

6. Deflection of beams was increasing continuously on increasing the load.
7. Reduction in compressive strength of concrete due to severe temperature and prolonged exposure to fire in both types of beams was detected.
8. Beams under fire of 3 hours exposure M4D6 decreases 14% strength and beams M5D4 decreases 23% of strength as compared to beams which are tested without fire.
9. Beams under fire of 6 hour exposure M4D6 decreases 33.2% strength and beams M5D4 decreases 31.9% as compared to beams without fire.
10. Plastered beams under fire of 3 hour exposure M4D6P decreases 19% and beams M5D4P decreases 18% strength as compared to beam without fire .
11. Plastered beams under fire of 6 hour exposure M4D6P decreases 32% and beams M5D4P decreases 27% strength as compared to beams without fire.
12. Out of 36 beams only 10 beams were failed in shear, and 26 were failed in flexure ,though we are taking average of 3 beams form each batch ,here we can say that mode of failure of tested beams is flexure.

RECOMMENDATIONS

In the light of above conclusion as described; following suggestions I recommended here,

- The cement plaster of ¾" makes sufficient resistance to strength of beams as compared to beams which have no plaster.
- In the high raise buildings and factories more thick plaster should be done to prevent form fire hazards.
- In other researches different thicknesses of plaster can also be used
  Fire extinguishing materials must be provided at various floors of the building. In this research beams are studied, whereas columns and slabs can also be studied
- The high raise buildings and factories specially the ones with flammable products should not be designed as a normal building ,special considerations in the design and in the safety measures should be applied according to the country code of practice in order to limit the fire spread and damage.
- Using insulation materials, and fire- proof plastering and painting primary recommended to be taken into consideration on RCC structures which might expose to high temperature or fire.

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