STRENGTHENING OF FIRE DAMAGED RC COLUMN AT VARIOUS TEMPERATURE USING FERROCEMENT JACKETING

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ABSTRACT

Generally, reinforced concrete structural member exhibit good performance when exposed to normal conditions. When reinforced concrete (RC) members are exposed to high temperatures during a fire accident, the strength, stiffness, stability, and potential for surface spalling are all severely affected. Fire reduces the load carrying capacity and serviceability of the structural members of a building. In the past, many research and investigation indicated that the considerable loss of compressive strength of reinforced concrete members due to the rise of temperature. However, when reinforced concrete structure exposed to high temperatures, concrete strength is significantly reduced. As long as the residual strength is repairable, service life of the structural materials can be extended using appropriate repair procedures like retrofitting. The lost strength is recoverable to an acceptable limit with the application of ferrocement jacketing. Strengthening with a jacket made up of locally available wire mesh and binding materials can be widely used for making a weak structure durable and safe. In this study, ferrocement jacketing is applied to the fire-damaged RC columns. Jacketing in single layer showed improvement in the recovered strength of concrete over the lost strength of fire-damaged columns. In this study, the strength of normal RC, fire damaged RC columns at various temperature and the strength of fire damaged RC columns at various temperature with ferrocement jacketing in single layer were determined. Load carrying capacity of fire-damaged RC columns with and without ferrocement confinement, were compared with a reference RC column to evaluate the results. The results revealed that columns with ferrocement confinement almost recovered their strength after being damaged by fire.

***Keywords**:* Fire damage RC column; Ferrocement jacketing; Furnace; Wire mesh; Load carrying Capacity; Compressive strength; UTM machine; Various Temperature.

1. INTRODUCTION

Elevated temperatures occurring in the course of fire incidents have a notable impact on the robustness, rigidity, steadiness, and surface integrity of reinforced concrete (RC) elements. The structural capacity and operational efficiency of a building's constituent parts can be markedly diminished. Thorough research and examinations have indicated that being subjected to high temperatures can result in a significant decline in the compressive strength of concrete.

Rehabilitation serves as a procedural approach applied to rectify weakened or impaired structures or any of their structural components, aiming to restore them to their initially designated performance levels. Through the rehabilitation process, the adverse effects of damage can be rectified, rendering the repaired components reusable. A widely adopted method involves fortifying a sheath comprising readily available wire mesh and binding materials, which stands out as a commonly utilized technique for amplifying both the durability and safety of a building characterized by structural weaknesses.

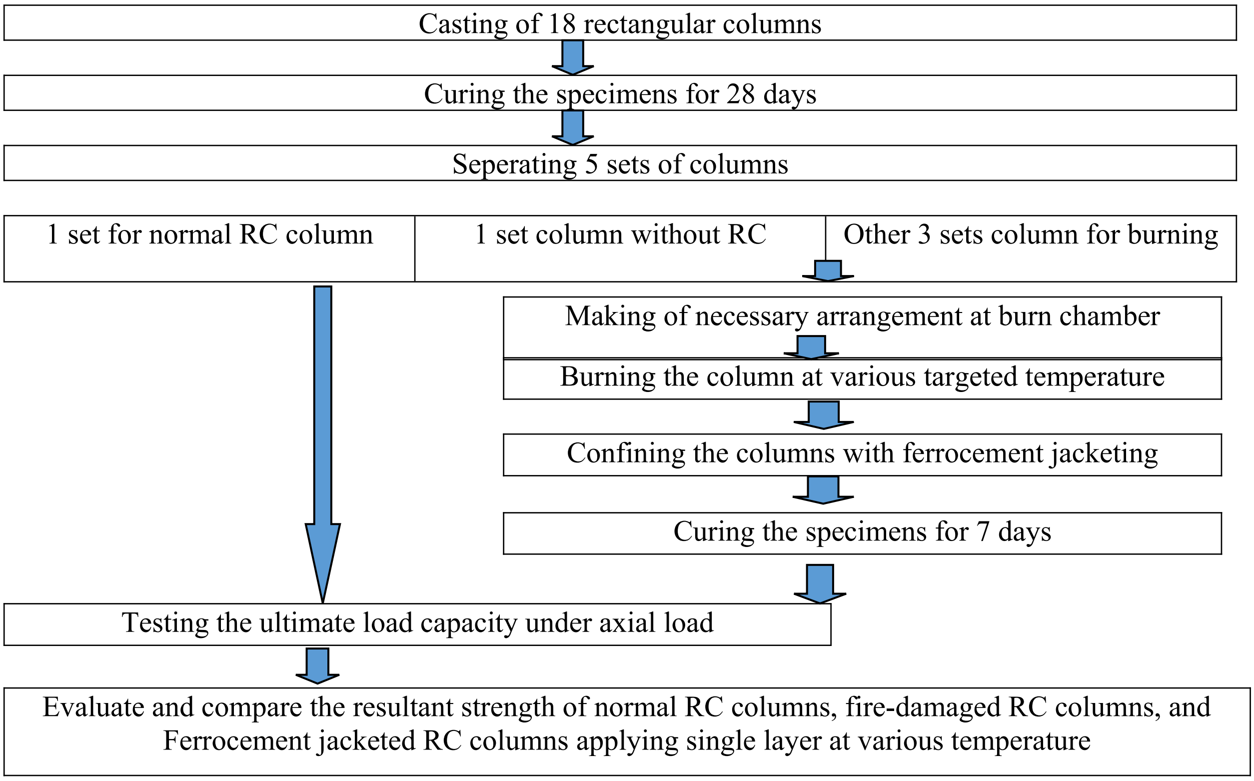
Various types of jackets commonly employed for retrofitting encompass constructions made from carbon fiber, glass fiber, fiber-reinforced polymer composite, steel, and reinforced concrete. Popular retrofitting techniques involve the use of jackets crafted from FRP (Fiber Reinforced Polymer), CFRP (Carbon Fiber Reinforced Polymer), ferrocement, additional shear walls, steel bracing, wall thickening, mass reduction, epoxy injection, and more. These methodologies play a pivotal role in enhancing the structural integrity and resilience of buildings, offering diverse options to address specific retrofitting needs.

In developing nations like Bangladesh, the inclination towards construction materials favors local, cost-effective alternatives over pricier options with prolonged lifespans. Among the local jacketing methods, ferrocement emerges as the most accessible and economical choice, hence its current consideration.

Ferrocement is a construction material characterized by a thin layer of ferro-concrete. Typically, it comprises Portland cement mortar reinforced with closely spaced layers of steel wire mesh with relatively small diameters. This combination results in a resilient and versatile building material known for its strength and adaptability in various construction applications. In this paper, discusses on retrofitting that is exposed on ferrocement jacketing.

2. METHODOLOGY

Experimental methodology is shown in the flow chart in the following:



2.1 Column casting and identifying

According to IS 10262: 2019, steps for mix design for grade M25 (Compressive strength 25MPa) at 28 days that was followed to cast fifteen rectangular columns are in the following:

Step 1: The necessary components for casting columns, including coarse aggregate, sand, cement, water, admixture, and reinforcement, were gathered.

Step 2: A wooden formwork was constructed as shown in Figure.

Step 3: According to IS 10262: 2019 for M25, Cement, sand, stone chips were mixed at the ratio of 1: 1.55: 2.7. Water cement ratio was 0.45 for M25 at 28 days after curing. Three cylindrical specimens of diameter 110.6 mm & height 110.6 mm were constructed keeping the same material and same ratio

Step 4: The columns are casted in the forma after the concrete has been mixed, and a vibrator is used to achieve optimum compaction as shown in Figure 3.6.

Step 5: To attain the desired strength, both the columns and cylindrical samples were subjected to a 28-day water curing process.

3. ILLUSTRATIONS

3.1 Figures and Graphs

3.1.1 Figures

After the burn chamber was tested and ready for burning the specimens, four of each set of column was put down into the chamber. Total of 3 sets of 12 rectangular columns were similary put down. Considering the heat loss, first set of column was burnt at 350°C and it took one hour and fifteen minutes. Consequently, 2nd and 3rd sets of columns were burnt at 450°C and 600°C respectively and these sets of columns took two hours and ten minutes & three hours and forty-five minutes respectively. After reaching the targeted temperature, the heaters were switched off and cooled down to room temparature which took 12 to 14 hours as per average. The burnt columns were dispatched off the chamber once it came down to room temperature as shown in Figure 3.1.1 and figure 3.1.2

Figure: 3.1.1 Burning of column at burn chamber

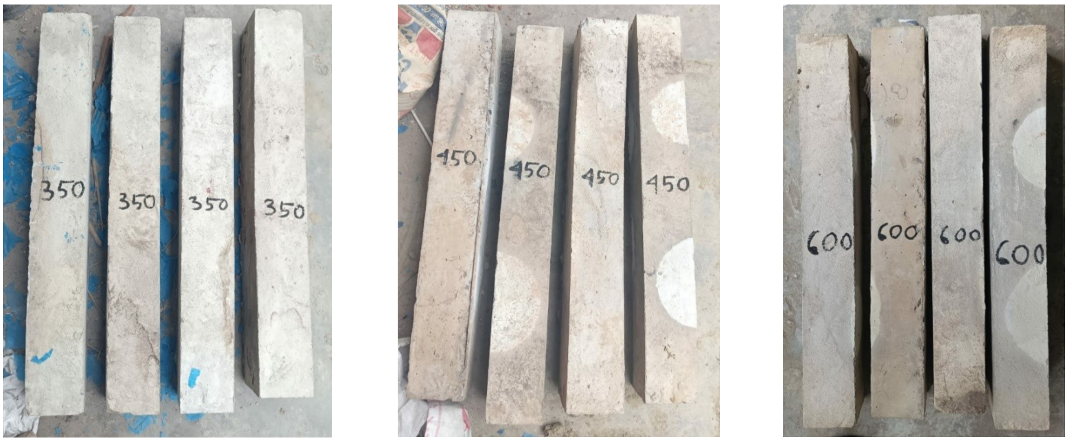


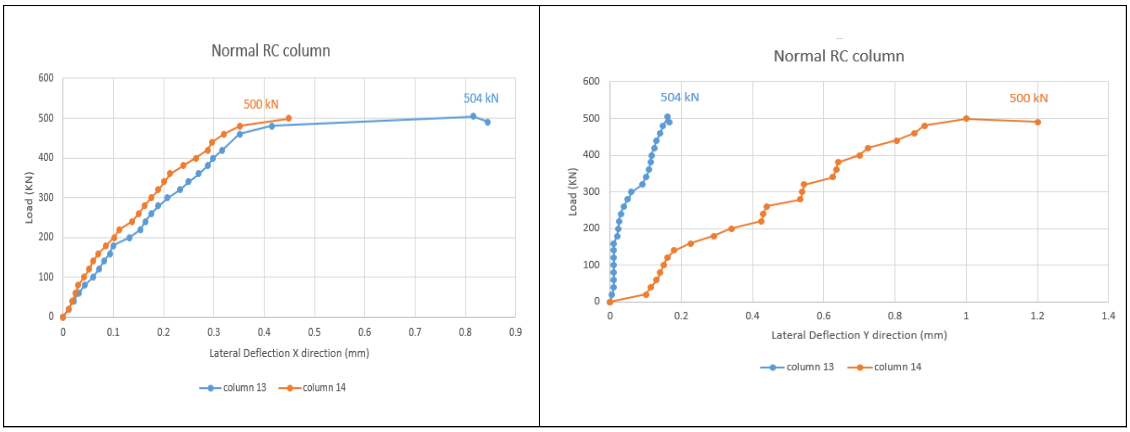
Figure 3.1 Columns after fire damage at 350, 450 & 600 degree centigrade respectively

3.1.2 Ferrocement Jacketing

Ferrocement is a construction material simply consisted of 5% wire mesh and 95% cement mortar. The wire mesh used in this study had a diameter of 0.65 mm and center to center spacing 8 mm. Locally available MS wire mesh was used. A ratio of 1:2 of cement and sand was applied following a water cement ratio 0.4 as shown in Figure. Hand plastering was done to properly bind the new material with the existing material as shown in Figure. The jacketing was done in single layers as shown in Figure 3.1.3.

Figure 3.1.3 Columns after ferrocement jacketing with single layer.

3.1.3 Graphs



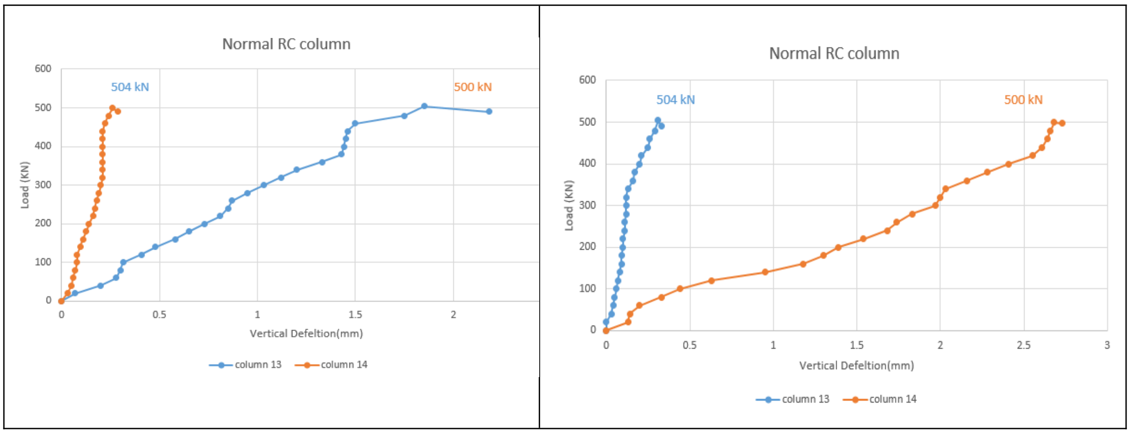


Figure 4.10 Applied Load with respect to Lateral X,Y, Vertical Deflection at mid & entire height

(**Normal RC Columns**)

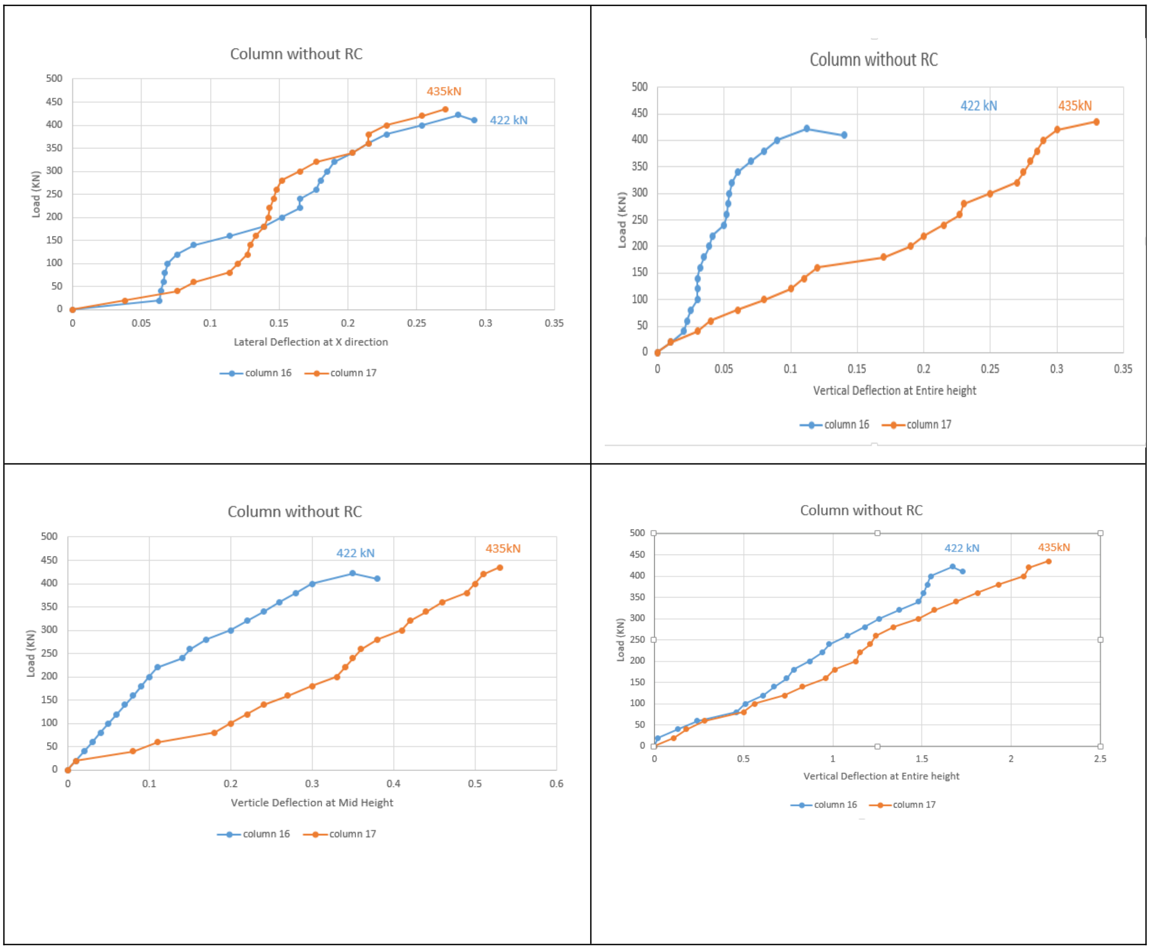


Figure 4.10 Applied Load with respect to Lateral X,Y, Vertical Deflection at mid & entire height

(***Columns without Reinforcement***)

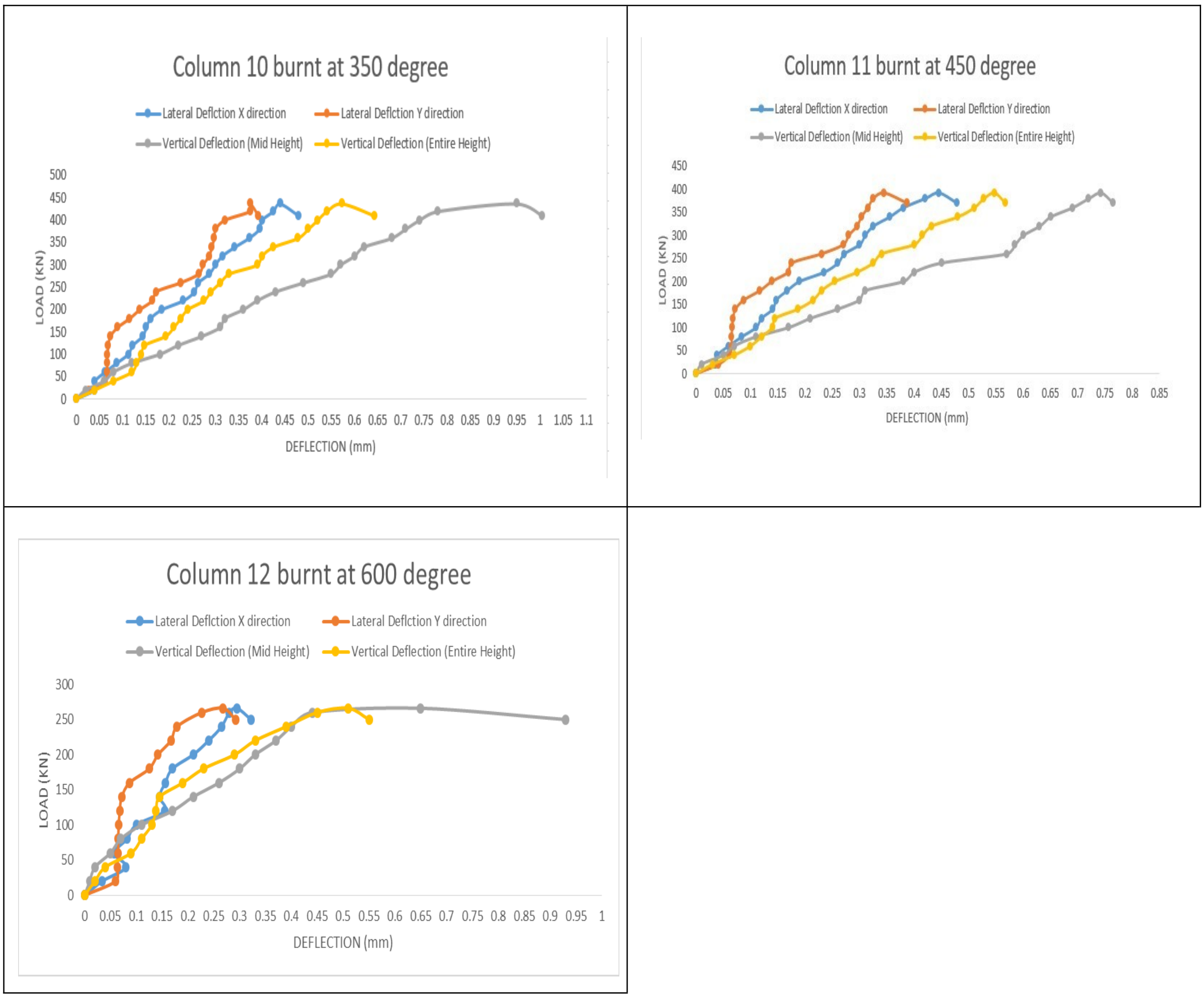


Figure 4.13: Applied Load with respect to four types of deflections (X,Y direction, Mid and Entire height) at **350, 450 & 600 degrees centigrade** respectively

3.2 Equation

To calibrate the manual sensor meter with respect to laboratory thermometer which can measured upto 360 degree centrigrade and thus attained the actual targeted temperature. Here, the calibration data equation:

$$y=1.0311x+11.104 \quad (1)$$

3.3 Tables

Table 3.3.1 Categorization of Columns:

Name	Category
Column 10,11,12	Fire-damaged RC columns at 350,450 & 600 degree centigrade respectively.
Column 13,14,15	Normal RC columns
Column 16,17,18	Normal columns without reinforcement
Column 1'(a,b,c)	Fire-damaged RC columns burnt at 350 degree with Single layer confinement
Column 2'(a,b,c)	Fire-damaged RC columns burnt at 450 degree with Single layer confinement
Column 3'(a,b,c)	Fire-damaged RC columns burnt at 600 degree with Single layer confinement

Table 3.3.2 Maximum load carrying capacity of normal RC columns

Sl. No.	Specimen Name	Maximum Load(kN)	Lateral Deflection (X-direction) (mm)	Lateral Deflection (Y-direction) (mm)	Vertical Deflection (mm)	Vertical Deflection (Entire height) (mm)
1	Column 13	504	0.816	0.161	1.850	0.310
2	Column 14	500	0.449	1.000	0.260	2.680
3	Column 15	503	0.128	0.733	0.696	2.110

Table 3.3.3 Maximum load carrying capacity of columns without reinforcement:

Sl. No.	Specimen Name	Maximum Load(kN)	Lateral Deflection (X-direction) (mm)	Lateral Deflection (Y-direction) (mm)	Vertical Deflection (mm)	Vertical Deflection (Entire height) (mm)
1	Column 16	422	0.280	0.112	0.350	1.670
2	Column 17	435	0.271	0.330	0.530	2.210
3	Column 18	425	0.200	0.530	0.470	2.130

Table 3.3.4 Maximum load carrying capacity of fire-damaged RC columns:

Sl. No.	Specimen Name	Maximum Load(kN)	Lateral Deflection (X direction) (mm)	Lateral Deflection (Y direction) (mm)	Vertical Deflection (mm)	Vertical Deflection (Entire height) (mm)
1	Column 10	437	0.45	0.64	1.87	0.46
2	Column 11	392	0.51	0.57	1.42	0.65

3	Column 12	266	0.60	0.36	0.97	0.86

- 1(a,b,c) are the fire damage jackted column that is burnt at 350 degree centigrade.

Table 3.3.5 Maximum load carrying capacity of columns ferrocement jacketing :

Sl. No.	Specimen Name	Maximum Load(kN)	Lateral Deflection (X-direction) (mm)	Lateral Deflection (Y-direction) (mm)	Vertical Deflection (mm)	Vertical Deflection (Entire height) (mm)
1	Column 1- a	487	0.73	0.45	0.46	1.76
2	Column 1- b	483	0.68	0.40	0.42	1.73
3	Column 1- c	490	0.90	0.50	0.48	1.85

The average regained strength is 488 KN after jacketing.

- 2(a,b,c) are the fire damage jackted column that is burnt at 450 degree centigrade.

Table 3.3.6 Maximum load carrying capacity of columns ferrocement jacketing :

Sl. No.	Specimen Name	Maximum Load(kN)	Lateral Deflection (X-direction) (mm)	Lateral Deflection (Y-direction) (mm)	Vertical Deflection (mm)	Vertical Deflection (Entire height) (mm)
1	Column 2- a	477	0290	0.500	0.190	1.800
2	Column 2- b	474	0.270	0.498	0.160	1.770
3	Column 2- c	489	0.300	0.515	0.200	1.815

The average regained strength is 476 KN after jacketing.

- 3(a,b,c) are the fire damage jackted column that is burnt at 600 degree centigrade.

Table 3.3.7 Maximum load carrying capacity of columns ferrocement jacketing :

Sl. No.	Specimen Name	Maximum Load(kN)	Lateral Deflection (X-direction) (mm)	Lateral Deflection (Y-direction) (mm)	Vertical Deflection (mm)	Vertical Deflection (Entire height) (mm)
1	Column 3- a	417	0.64	0.43	1.19	6.37
2	Column 3- b	421	0.77	0.55	1.42	6.81

3	Column 3- c	420	0.30	0.48	1.21	6.45

The average regained strength is 419 KN after jacketing.

4. CONCLUSIONS

The test results from experiment indicate a decrease in the load capacity of fire-damaged columns compared to normal reinforced concrete (RC) columns. Additionally, the assessment of the regained strength following ferrocement confinement over the fire-damaged RC columns is presented graphically. This graphical representation offers a visual depiction of the effectiveness of ferrocement in restoring and enhancing the load-bearing capacity of the affected columns after exposure to fire damage.The study presents the following conclusions such that,

- ✓ Average normal strength of RC column is 502KN, the residual strength of fire damaged column after burning at 350, 450 and 600 degrees are 437KN, 392KN, 266KN.
- ✓ Normal strength of RC column is reduced by 13%, 22% and 47%, after burning at 350,450 and 600 degrees respectively.
- ✓ Jacketing in single layer regained the lost strength by 79%, 76% and 65% for 350, 450 and 600 degrees respectively.

RECOMMENDATION

The application of additional layers is recommended for further studies to see the variation in the recovery of the lost strength.

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