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Strengthening of fire damaged reinforced beams by using ferro cement

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Erroneous design

ABSTRACT

Now-a-days repair and rehabilitation of the existing structures in developing countries has become solitary of the most thought-provoking tasks in Civil Engineering sector. Imperfections, fiasco and general distress in the structures can be the outcome of fundamental deficiency produced by inaccurate design, poor workmanship or overloading of the construction. It can also be instigated by corrosion, fire and natural calamities. A spoiled or distrait structure can be modernized to an acceptable level of performance at a reasonable cost by different approaches is called retrofitting. One of these techniques consists of strengthening fire damaged concrete beams by applying Ferro cement with wire mesh. Two types of Ferro cement with wire mesh are used with single layer and double layer in beam. One third point load test according to ASTM C78-02 is performed to measure the flexure performance of four specimens. The ultimate load carrying capacity for using the single layer Ferro cement strengthening, double layer Ferro cement strengthening showed an improvement of 46% and 72% respectively over the fire damaged specimens.

1. INTRODUCTION

Concrete is a stone like operational substantial with great load resounding capacity, improved structural performance, brilliant method and financial property. The excellent performance is accomplished by strengthening the core concrete with restriction. When the transversal strain of the concrete is better than that of the strengthening material, the shipping stress between the concrete and strengthening material proliferations with the axial load, which restrains the event of micro cracks in concrete. For this reason, the axially load carrying ability and distortion performance are significantly improved.

From several investigations it's been found that Ferro cement is a perfect substantial for reintegration as well as re-strengthening of structures for the reason that it progresses crack confrontation joint with great toughness, the power to be cast into any form, fast construction with no heavy machinery, small supplementary weight enforced and low cost of construction. In Bangladesh Ferro cement material is extensively utilized in repairing and strengthening of distressed structural elements of the buildings. This versatile material has enormous potentials as a protective covering of the structural elements against corrosion within the coastal areas of the country. It's documented that in Bangladesh conventional formwork normally contributes 20% to 25% of the value of ferroconcrete. Significant economic advantages may occur if the Ferro cement cover are often used as permanent formwork for ferroconcrete beams. Additionally, structural benefits could also be obtained if the Ferro cement layer are often made to act compositely with the concrete core of the support. Ferro cement may be a sort of thin-wall ferroconcrete commonly constructed of Portland cement mortar, reinforced with closely spaced layers of unremitting and comparatively minor diameter wire mesh. It's considered to be an extension of reinforced beam. Most of the research works regarding Ferro cement ferroconcrete beams are limited to the evaluation of the superior performance of those

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beams as compared to the standard ferroconcrete beams. But the composite behavior of Ferro cement concrete technology with comparatively better mechanical goods and durability than normal ferroconcrete. Inside convinced loading restrictions, it acts as a constant elastic material and these limits are broader than of normal concrete Material.

The studies by presents the experimental performance of concrete when improved by great modulus of elasticity carbon FRP (Tepfers and De Lorenzis, 2003) That firming up attains a big intensification of both the concrete strength besides the axial strain ductility that are reliant on mostly on the lateral pressure provided by the FRP and on its axial severity (Rafeeqi et al. 2005). However, the upper the modulus of elasticity of the strengthening is the lower its deformability to disaster. When strengthening concrete with materials of various modulus of elasticity and of an equivalent lateral severity, the strengthening usefulness in terms of load ability and strain at failure is higher for the fabric of lower modulus of elasticity. Thus, the competence of ultralow modulus of elasticity materials like polypropylene is prophesied to be amazing parameter for strengthening.

1.1. OBJECTIVE

In this research, the suitability and effectiveness of the Ferro-cement strengthening system to repair RC beams damaged by heating are investigated. The particular objectives of the present study are as follows:

1. To oversee the effects of strengthening and evaluate experimentally the ultimate load carrying capacities of fire damaged reinforced concrete beam when it is retrofitted by ferro cement with wire mesh;
2. To compare the performance (load carrying capacities, deflection) of specimens at different state under one third point loading test.

1.2. LITERATURE REVIEW

Rcc beams to study the efficiency of visibly attached molded ferro cement plates in solidification beams display shear misery. The qualified efficiency of the attaching media (C-S mortar, epoxy) employed in attaching the molded F.C Plates to the ends of beams are calculated. Ferro cement is occupied on account of striking for this solicitation on its high lastingness, little load cheap in cost, better lifetime of action and exact valuation of the additional strength expanded (Anggawidjaja et. al. 2006).

Shear mode of disaster in beams is undesired mostly being a fragile disaster. Consequently, strength has been prepared by these people to discover the capacities of ferro cement in transporting the inelastic mode to yielding mode. Ferro cement shawl and similarly spread-out strips with one or two layers of woven square mesh are accessible and associated with RC beam designed as shear undersupplied in both (Choi 2008; Dai et al. 2011). These investigators from their studies had determined that the strengthened beam displayed a marked enhancement in enactment at facility load, significantly upgraded ductility at decisive with either a yielding shear catastrophe or ostensibly a conversion from shear to flexure mode of disaster. Besides ferro cement wraps are humbler than ferrrocement strips. Another thing of reputation inferred is that the augmentation in load resounding capability isn't significant, still is contemporary. Service range had been prepared to upsurge the rigorousness of strengthened beams and also decreases the crack width and rebound as associated with un-strengthened beam [Amin et al. 2021; Colombo and Felicity 2007).

The compressive strength of concrete may reduce up to 50% when the concrete is exposed to 600°C. At 800°C, the residual compressive strength of the concrete is only 20% of the original value. Furthermore, normal-strength concrete experiences a sharper loss in tensile splitting strength than compressive strength at 600°C. Exposure to high temperatures may also change the pore structure of concrete through pore structure coarsening, which leads to increased permeability but reduced durability of the concrete. After exposure to 600°C, the cumulative pore volume in normal-strength concrete increases twice. At temperatures higher than 600°C, extreme C-S-H gel dehydration and pore structure coarsening contribute to the strength loss of the concrete. Fires in concrete structures rarely result in serious global structural damage, and most of the damaged structures can be successfully reinstated. Therefore, repair of fire-damaged concrete structures is a more viable and economical option than demolition and rebuilding (Zahid et al. 2018).

2. METHODOLOGY

Total procedure is performed by a flow diagram which are shown in below;

The specimens are cast into wooden frame as beam. This casting process is measured because of the slight extent of beam cross section. Hand compaction is applied to dense the concrete with the use of a 16 mm (diameter) tamping rod. Each time the slump value is measured and it is between 80– 105mm. Beam specimens are demolded after 24 hours of casting.

2.1. MATERIALS INVESTIGATION

The material properties are determined according to ASTM standard method and they are summarized below;

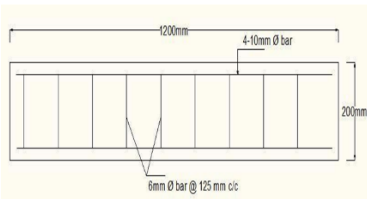
Table 1. Properties of Materials

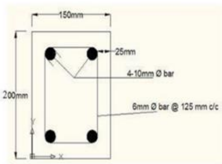
Materials	Properties	Unit	Value
Binder (OPC)	Specific Gravity		3.15
Fine Aggregate	Specific Gravity (SSD)		2.50
	Absorption	%	3.36
	Unit Weight	Kg/m³	1629
	FM		2.58
Coarse Aggregate	Specific gravity (SSD)		2.82
	Void	%	28.90
	Absorption	%	2.02
	Unit Weight	Kg/m³	1619
	FM		4.68
Reinforcement	Yield Strength	MPa	450
	Ultimate Strength	MPa	520
Concrete	Compressive strength	MPa	19.1

To prepare the normal strength concrete according to the ACI standard a suitable mix design ratio is used. The expected compressive strength is 3000 psi after 28 days. Cement: Sand: Coarse Aggregate (1: 1.5: 3), Water: Cement is 0.48, Nominal maximum size of Coarse aggregate 12.80 mm.

a). Mixing procedure b). Slump test

Figure 2. Preparation of Concrete



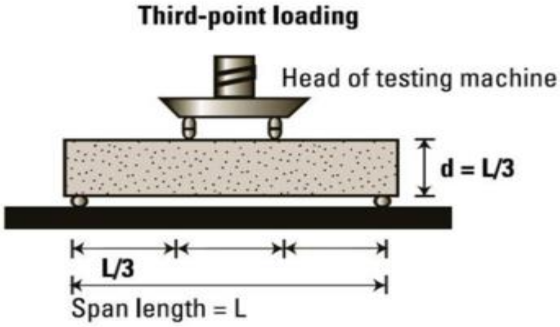


a). Longitudinal section b). Cross-section

Figure 3. Sectional view of specimen

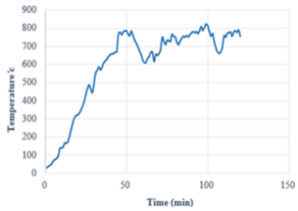
The flexural strength of plain concrete is almost wholly dependent upon the tensile strength. Experiments show, however, that the modulus of rupture is considerably greater than the strength in tension. Flexural strength is of importance in the design of concrete pavements. 3rd point loading system for the test of flexural strength of this specimen.

a). Casting b). lab setup



c). 3rd point loading system

Figure 4. Beam casting and setup for test



a). Damage by fire b). Temperature and time

Figure 5. Process of beam damage

For heating the beams, a chamber is made by using bricks, CI sheets and steel reinforcements. The temperature is measured by thermocouple and digital meter. The highest temperature during fire of building is 805 ⁰c and temperature varied at a range of 700-800 ⁰c for two hours and then cooled to room temperature. When the beams are cooled down, there are some cracks and spalling of concrete seen on beams.

As concrete is weak in tension, cracks and spalling formed in the tension zone of the beams under fire, the concrete in the tension zone become ineffective. The depth of the cracks is show in beam within 1 inch. Hence, soffit of the beams (tension zone clear cover) is chiseled, cleared of loose debris and cleaned with wire brush.

Figure 6. Chiseling of beam

After fire damaged, samples are strengthened with a Ferro cement and wire mesh (single layer and double layer). A single layer square shaped steel wire mesh having wire spacing of 10 mm and thickness of 0.6 mm is used.

Figure 7. External strengthening of beam

A rich mortar ratio of cement/sand 1:2 and w/c ratio 0.4 is selected. The sand is used which the sample passing by No.16 sieve is 80%. Hand plastering is used for the period of the strengthening process. Mortar is pressed through the pores of wire mesh. Plastering is properly done to confirm an even and smooth surface. The Ferro cement strengthened samples are additional cured for 7 days. It necessitates a huge amount of water and proper supervision for the period of curing process, due to rich mortar and low water-cement ratio.

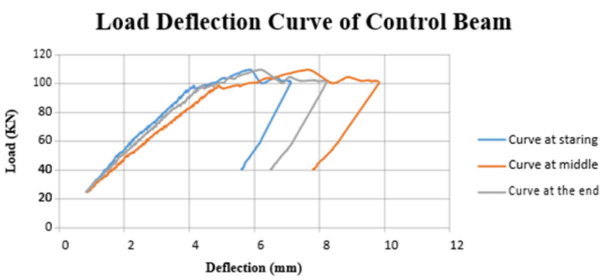
3. RESULTS AND DISCUSSION

The ultimate load resounding capabilities of both control and strengthened beams are determined by third point loading method. The lateral deformations at mid height and of the specimens are also recorded with an incremental load. The load vs deflection diagram for all types of specimens has been established through dial gauge readings. The effect of strengthening has been evaluated by comparing the results with control specimens.

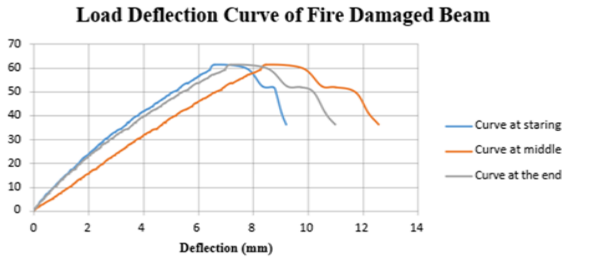
Table 2. Load capacity of several specimens

Name of Specimen	Ultimate Load (kN)	Improvement over fire damage Specimen (%)	Decline over control Specimen (%)
Control beam	114	-	-
Fire damaged specimen	61	-	46
Single layer Ferro cement strengthened	89	46	22
Double layer Ferro cement strengthened	105	72	08

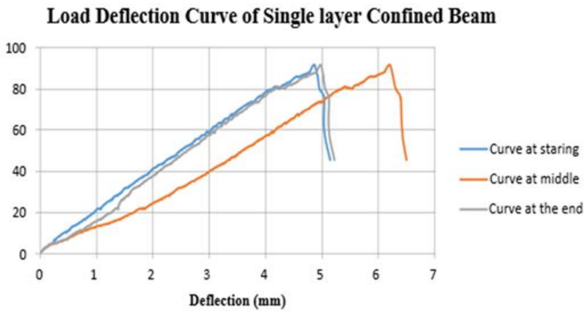
The flexural strength characterizes the maximum stress practiced inside the material at its moment of rupture. Most of the specimens fail due to flexure failure. Flexure cracks are developed at the mid-section, after that flexure shear cracks as well as web shear crack are developed before the beam is failed.



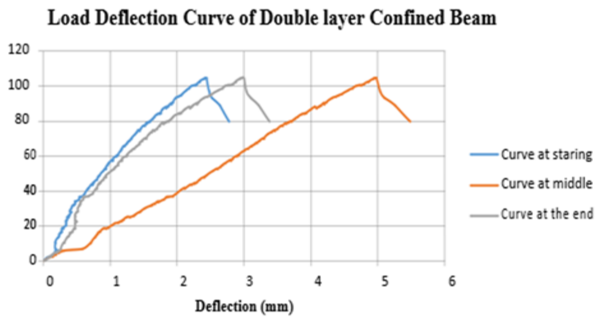
a). Control beam



b). Fire damaged beam



c). Single layer Ferro cement strengthened beam



d). Double layer Ferro cement strengthened beam

Figure 8. Load deflection curve of specimens

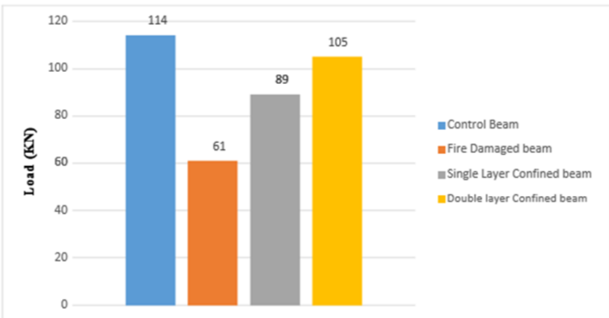


Figure 9. Load capacity of several specimens

Due to the strengthening effect, the deformations first initiated in the Ferro cement layers. After the failure of the layer, the core failure takes place. In case of single- and double-layer Ferro cement strengthened concrete beams, the crack is initiated simultaneously from the base and top of the beam. After initiation, with the increase of load the cracks are propagated. The propagation of cracks is slow due to the presence of thickly populated wire mesh. Both cases showed great improvement in ultimate load carrying capacity and slow crack formation over the fire damaged specimens.

a). Fire damaged beam

b). single layer Ferro cement strengthened beam

Figure 10. Cracking and failure pattern of specimens

4. CONCLUSION

The behavior of RC beams is subjected to heating and cooling and the repair of such damaged beams by wrapping with Ferro cement and wire mesh at different layer. The level of heating exposure considerably reduced the residual concrete compressive strength by about 46 %. The ultimate load carrying capacity for using single layer Ferro cement with wire mesh strengthening, double layer Ferro cement with wire mesh strengthening show an improvement of 46% and 72% respectively over the fire damaged specimens. The Flexural strength of RC beams increases directly proportion to the number of Ferro cement with wire mesh layers is used. The Ferro cement with wire mesh confinement with two layers show greater improvement than the confinement technique with one layer, both in load carrying capacity and slow crack formation.

5. RECOMMENDATIONS

Based on the findings of this research, it is considered that further research should be undertaken to the behavior of strengthened concrete beams under uniformly distributed loading. The following suggestions ought to be taken into consideration both point and uniformly distributed loading.

- The shrinkage and creep of concrete can be investigated when exposed to fire;
- Bond behavior and thermal properties of concrete when exposed to fire may be checked;
- The effect of mix proportions, types of coarse aggregates heating rate and burning time can be overlooked.

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Author contributions

Al Amin: Writing-Original draft preparation **Shorup Chowdhury Tamal:** Conceptualization, Methodology **A. K. M. Fayzul Bari:** Investigation, Visualization **Milan Mazumder:** Data curation **Md. Ariful Hasan**: Writing-Reviewing and Editing

Conflicts of interest

The authors declare no conflicts of interest.

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