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Research

COMPARISON IN STRENGTHENING OF RCC CONCRETE COLUMN USING FERROCEMENT AND POLYPROPYLENE FIBER ROPE

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ABSTRACT

Extreme loading and severe environmental exposures can cause deterioration of ferroconcrete (RC) columns, this research investigates the performance of external confinement on reinforced concrete short columns subjected to axial loading. Defects, failure and general distress in the structures can be the result of structural deficiency caused by erroneous design, poor workmanship or overloading of the structure. The effectiveness of confinement is achieved by comparing the behavior of retrofitted samples with that of controlled samples. Confining materials are used Ferrocement with wire mesh and polypropylene fiber rope in synthetic rubber adhesive like STAR bond which are easily available. Rectangular short columns having dimension of 150 mm × 150 mm × 900 mm has been cast and tested. The ultimate load carrying capacity for partial confinement (300 mm bottom and top of the column), single layer confinement, double layer confinement with Ferrocement and polypropylene fiber rope confinement are showed to improvement of 31.97%, 56.23%, 59.35% and 30.61% respectively over the control samples. The research results showed that, the confined samples can enhance the ultimate column capacity under concentric loading and improve failure characteristics.

Keywords: Retrofitting, Ferrocement, Confinement, Synthetic adhesive, Polypropylene fiber etc.

1. INTRODUCTION

The retrofit of existing members through external confinement may be a precondition during a seismic redesign strategy aiming at a highly energy-dissipative Ferrocement structure of high ductility. Such a structure could overcome potential overloads by accomplishing full utilization of used materials, sections and member's performance, thus achieving maximum safety for the users. When a concrete column is under axial compression, the interior lateral deformation occurs, leading to cracks. At now the external constraints is employed to supply radial reaction force to concrete, and to confine lateral deformation of concrete tightly. Thus the event of internal micro-cracks is often limited, in order that the development of ductility and compressive strength are often achieved. Consistent with this phenomenon, in engineering projects, the concrete using external lateral restraint to enhance its compressive strength and deformation ability is named confined concrete.

Strengthening the Ferrocement columns may become necessary for variety of reasons, like substandard detailing of the steel reinforcement and deterioration of the concrete under severe environmental conditions [1]. Recent evaluation of the engineering infrastructure has demonstrated that the majority of it'll need major repairs within the near future. Other needs for strengthening arise because either the planning codes have changed that make these structures substandard or larger loads are permitted on the components of the infrastructure where extensive retrofitting is required [2]. Polypropylene is an ultra-high deformability material, widely utilized in the shape of fibers to supply fiber-reinforced concrete with upgraded behavior against plastic shrinkage cracking or spalling of high strength concrete at elevated temperatures [3].

Ferrocement may be a highly versatile sort of ferrocement made from wire mesh, sand, water and cement, which possesses unique qualities of strength and serviceability. It is often constructed with a minimum of skilled labor and utilizes readily available materials. Retrofitting with ferrocement confinement is that the oldest and price effective technique wont to strengthen the concrete structures [4]. Polypropylene fiber ropes made from twisted strands polypropylene fibers provides high lastingness and may be used as an efficient material for strengthening the column and supply higher load carrying capacity. The closely spaced & uniformly distributed reinforcement and use of rich cement mortar provides ductility also as strength, thus improving the load capacity of the retrofitted members. ferrocement also possess some unique properties like waterproofing, fire resistant, low self-weight and sturdy, which makes it a perfect material for wider application. Thus, this research aims to research the general performance of ferrocement and polypropylene fiber rope confinement on normal strength concrete (NSC) reinforced rectangular columns to make sure maximum safety [5, 6].

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The load carrying ability and ductility of circular concrete columns confined by ferrocement including steel bars (FS) where they're proposed to extend the compressive strength alongside the ductility. The comparative analyses of those models show that the compressive strength of FS columns is improved by 30% than that of BS columns. Thanks to ferrocement caging alongside steel bars samples showed higher ductility, compressive strength and energy absorbing capacity than BS or FRP strengthened circular columns [7].

The utilization of low modulus vinylon and polypropylene fiber ropes as external confining reinforcements on standard concrete cylinders has ultrahigh tensile deformation at failure. The research examined low concrete strength columns in three levels of rope confinement, subjected to monotonic or cyclic loading. The elaboration included that the strain and strain values both at 3% axial strain and at ultimate strain. Suitable fiber rope confinement improved plain concrete strength by an element above 6.6 and provided an axial strain ductility above 40. No column wrapped by polypropylene fiber ropes reached fiber fracture [8].

In this research, the suitability and effectiveness of the ferrocement and polypropylene fiber rope confinement strengthening system to repair RC columns damaged by erroneous design, poor workmanship, overloading are investigated. The particular objectives of the present study are as follows:

1. To investigate the performance of normal strength concrete columns confined by partially, single, double layer ferrocement with wire mesh;
2. To find out the effectiveness of polypropylene fiber rope confinement with on normal strength concrete columns;
3. To compare the effects of confinement to evaluate the ultimate development on load capacities due to different retrofitting techniques.

2. MATERIALS INVESTIGATION

The material properties for binder (Portland cement), fine aggregate (Sylhet sand), and coarse aggregate (stone chips), that is required to calculate the mixture proportions and to maintain homogeneity in mixture proportions are determined according to ASTM (C187, C191, C136, C128, C39) standard procedure for binder, aggregate and reinforcement and also summarized in (Figure 1 and Table 1) are shown below;

a). Coarse Aggregate (stone)

b). Fine Aggregate (sand)

c). Reinforcement (steel)

d). polypropylene fiber rope

e). synthetic rubber adhesive

f). wire mesh

Figure 1. Materials used for research

Table 1. Properties of Materials

Materials	Properties	Unit	Value
Binder (OPC)	Specific gravity		3.15
	Normal consistency	%	27
	Initial setting time	minutes	35
	Final setting time	minutes	338
Fine aggregate	Specific gravity (SSD)		2.54
	Absorption	%	3.35
	Unit Weight	kg/m^3	1628
	Fineness modulus		2.56
Coarse aggregate	Specific gravity (SSD)		2.82
	Void	%	28.90
	Absorption	%	2.02
	Unit Weight	Kg/m^3	1619
	Fineness modulus		4.52
Reinforcement	Yield Strength	MPa	450
	Ultimate Strength	MPa	520

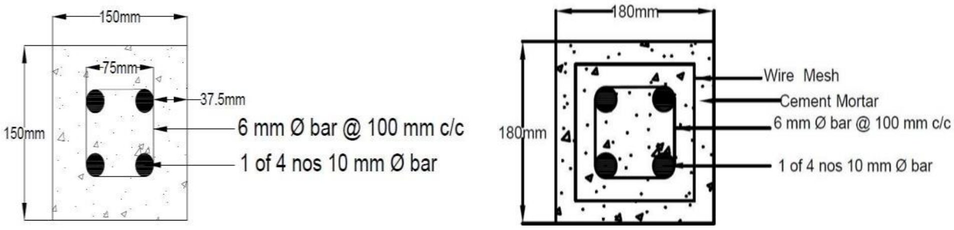
3. METHODOLOGY

To prepare the normal strength concrete according to the ACI-318 standard a suitable mix design ratio is used. The expected compressive strength is 3500 psi after 28 days. Cement: Sand: Coarse Aggregate (1: 1.5: 3), Water: Cement is 0.48, Nominal maximum size of Coarse aggregate 18 mm.

a). Mixing procedure b). Slump test

Figure 2. Preparation of concrete and test of workability

Total samples had been cast with a dimension of 150 mm × 150 mm × 900 mm and a reinforcement ratio of 1.3%. Locally available BSRM 500W bar was used as reinforcing steel (4 nos. 10mm Φ bar @ 4 corners & 6mm Φ bar @ 100mm c/c as tie bars).



a). Control samples b). Ferrocement with single layer

Figure 3. Sectional view of specimens

The samples are cast into wooden frame as beam. This casting procedure was considered because of the small size of column cross section. Hand compaction was used to compact the concrete with the use of a 16 mm (diameter) tamping rod. Each time the slump value was measured (ASTM C143) and it was between 35 mm – 55 mm. Column samples are demolded after 24 hours of casting.

A rich mortar ratio of cement: sand 1:2 & w/c ratio 0.4 was selected. 80% sample No.16 sieve passing sand is used. The overlapping between the wire mesh layers was 50 mm; the confinement thickness was 15 mm on all sides, making the confined specimen dimension 180 mm × 180 mm × 900 mm for single layer and the confinement thickness was 25 mm on all sides, making the confined specimen dimension 200 mm × 200 mm × 900 mm for double layer of ferrocement with wire mesh. Partially confined where Wire mesh layer is used at top 300 mm and bottom 300 mm height of the specimen, leaving the mid zone unconfined with wire mesh layer. The ferrocement confined samples are further cured for 7 days.

a). Confining with ferrocement b). Confining with ropes c).Confining with Partial ferrocement

Figure 4. Strengthening of different specimens

A locally available synthetic rubber adhesive is used to attach the ropes with the samples. Ropes were attached to the sample with manually applied pull force by hand. Ropes are tightly attached to the surface of the specimens. Samples were tested after 7 days and no special curing technique is used. But the sample were kept in a dry place to keep it away from getting wet in the rain.

4. RESULTS AND DISCUSSION

The ultimate load carrying capacities of both unconfined and confined columns are determined under centric compressive force. The lateral deformations at mid height of the samples are also recorded with an incremental load of 20 kN.

Table 2. The Ultimate load capacity of samples

Sl No.	Types of Specimen	Ultimate Load (kN)	Average load (kN)	% Improvement
01	Control sample	290	294	-
		298		
02	Partial confinement, C(FP)	395	388	31.97
		381		
03	Single layer ferrocement, C(FS)	447	450.5	53.23
		454		
04	Double layer ferrocement, C(FD)	467	468.5	59.35
		470		
05	Polypropylene fiber rope, C(PER)	385	384	30.61
		383		

The load vs mid height deflection diagram for all types of samples has been established through averaging the four dial gauge readings. The effect of confinement has been evaluated by comparing the results with unconfined samples. The ultimate load carrying capacity for partial confinement (300 mm bottom and top of the column), single layer confinement, double layer confinement with ferrocement and polypropylene fiber rope confinement are showed to improvement of 31.97%, 56.23%, 59.35% and 30.61% respectively over the control samples. The deflection behavior has been much improved in the confined samples.

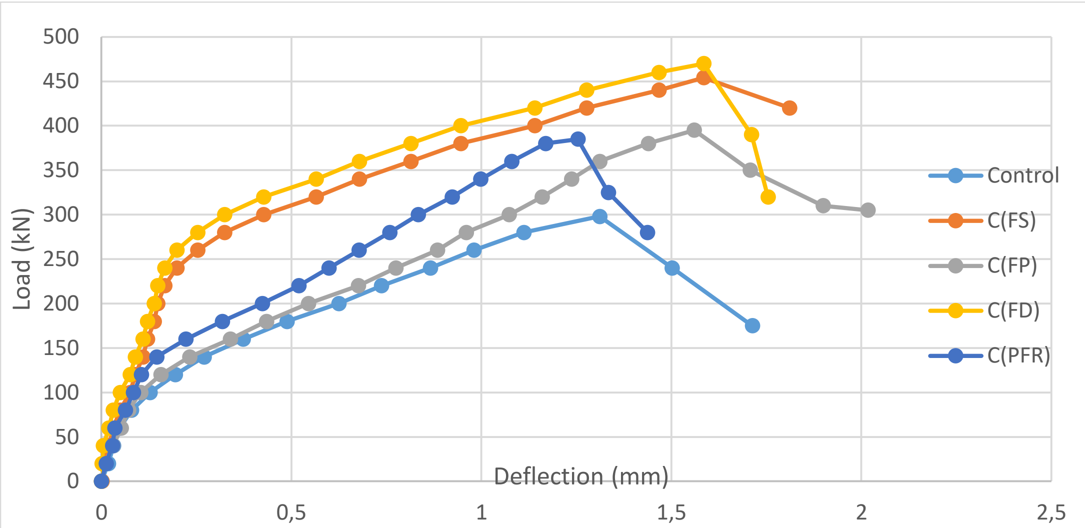


Figure 5. Load vs deflections curve at mid span of different specimens

Initially the deflection in the fully ferrocement confined specimen was less than the unconfined specimen and after the initiation of cracks in ferrocement layers the deflection data gradually increased in the mid-height zone. Compared to the fully confined samples, the partially ferrocement confined samples produced more cracks at mid height due to the absence of wire mesh layer at mid-zone and produced more deflection. The polypropylene fibre rope confined samples showed better results in overall load vs deflection failure mode and showing slightly less deflection than the unconfined samples. All the cases showed slow crack initiation and propagation with respect to the same amount of load over the unconfined samples.

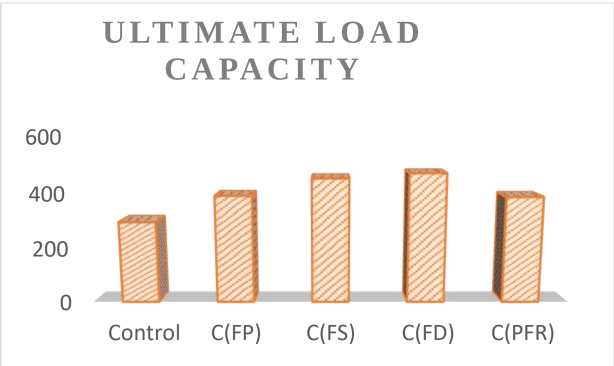


Figure 6. Ultimate load capacity

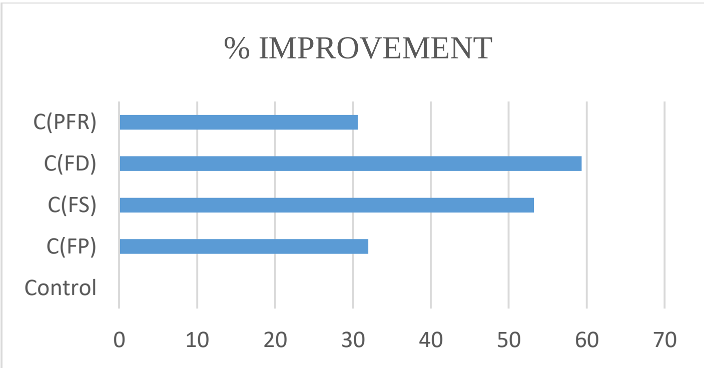


Figure 7. Percentage of improvement

Due to the confinement effect, the deformations first initiated in the ferrocement layers and the core failure took place. In case of fully ferrocement confined (single and double layer) concrete columns, the crack was initiated simultaneously from the base and top of the column. The propagation of cracks was slow due to the presence of thickly populated wire mesh. The crack growth in the fully ferrocement confined samples has been seen mostly at top and bottom along with the edges, but less at mid-height.

a). partially ferrocement confined b). Fully ferrocement confined c). Polypropylene rope layer

Figure 8. Failure mode of specimens

The partially ferrocement confined samples had more crack concentration at mid-height than the fully confined samples due to the absence of wire mesh layer at mid-height. But the edges of the partially confined samples have produced less cracks as the edges had been strengthened with an extra layer of wire mesh.

For the polypropylene rope confinement, the cracks are not visible from outside observation. Cracks initiated in concrete inside the rope layer. At the ultimate load the end crushing type failure became visible and the load readings began to decrease corresponding to the ultimate failure. Rope layer was removed after testing to see the crack pattern in the specimen. The ropes didn't tear off from the surface of the samples as they possess good tensile property and are connected to the specimen with the application of a synthetic rubber adhesive & tension forces.

5. CONCLUSION

The Ultimate load capacities and corresponding behavior of the unconfined and confined (partially, fully & polypropylene fiber rope) columns are determined under the concentric loading condition. External confinement significantly increases the ultimate load capacity of columns & is an effective technique of strengthening to ensure maximum safety. The fully ferrocement confinement showed greater improvement than the partial confinement technique, both in load carrying capacity and slow crack formation, whereas the polypropylene rope confined samples showed slightly less load capacity with a good amount of improvement in mid-height deflection criteria. The ultimate load carrying capacity for partial confinement (300 mm bottom and top of the column), single layer confinement, double layer confinement with Ferrocement and polypropylene fiber rope confinement are showed to improvement of 31.97%, 56.23%, 59.35% and 30.61% respectively over the control samples. The research results showed that, the confined samples can enhance the ultimate column capacity under concentric loading and improve failure characteristics.

6. RECOMMENDATION

The observations and subsequent outcomes of this research project are limited in their scope within the range of a few test variables investigated. It is believed that a wider area in this field is expected and the following recommendations is outlined for future research;

- The performance of confined columns under eccentric and lateral loading and the axial deformation behavior should be investigated.
- Influence of different wire mesh, w/c ratio and support conditions should be investigated.

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