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Experimental Investigation of Strength Enhancement Between PVA Fibre & PVA Powder Modified Ferrocement Mortar Used Retrofitting on Challenging Structural Members

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***Abstract*—Strengthening of existing challenging structural members like reinforced concrete (RC) columns is a critical requirement for extending safe life span in structural rehabilitation. Ferrocement jacketing is a widely adopted retrofitting technique due to its efficiency and ease of application. Retrofitting technique can be further modified by adding different admix like fibre materials, silica fumes, fly ash, polymer etc with cement mortar. Enhanced ferrocement jacketing with polyvinyl alcohol (PVA) fibre reinforced mortar has been extensively studied for its crack resistance and ductility upgradation [9][10]. While limited research exists on the use of PVA powder modified mortar as a practical alternative. This study presents an experimental investigation comparing the performance of RC columns retrofitted, using 0.5% PVA fibre mortar and 0.5% PVA powder modified mortar. A total of six RC column specimens were casted, cracked, retrofitted and tested under axial compression. The results indicate that both systems exhibit comparable ultimate load capacity, while differences were observed in crack initiation and workability. The study highlights the research gap justification of the feasibility of PVA powder as a practical alternative to PVA fibre reinforcement in ferrocement jacketing applications.**

Keywords— Ferrocement jacketing, PVA fibre, PVA powder, retrofitting, RC columns, structural strengthening

I. Introduction

Structures are designed for a specific safe life span and depending on the nature of structure its design life varies. Deterioration can be mainly due to environmental effects which includes corrosion of steel, gradual loss of strength with ageing, repeated high intensity loading, variation in temperature, contact with chemicals and saline water etc. [12]. As complete replacement of deteriorated structure is not practical, strength enhancement by retrofitting is widely adopted as a practical alternative. Among various strengthening techniques, ferrocement jacketing has emerged as a cost-effective and efficient method for enhancing load-carrying capacity and ductility of RC columns [3][8][11].

Previous studies have extensively investigated fibre-reinforced mortars [2], particularly those incorporating polyvinyl alcohol (PVA) fibres [5], due to their superior crack-bridging capabilities and improved tensile behaviour [6]. However, practical challenges such as fibre dispersion, balling effect, and reduced workability often limit their field application.

In contrast, PVA powder modified mortar offers potential advantages in terms of uniform dispersion, improved workability, and ease of application [7]. Despite these advantages, limited experimental data is available comparing its structural performance with PVA Fibre-reinforced systems.

This study aims to address an identified research gap by experimentally comparing the performance of PVA fibre and PVA powder modified ferrocement jacketing in RC columns subjected to axial loading. At present literature review is found rare on the performance of PVA Powder retrofitting as a research subject

Subsequently, to justify the research gap, a comparative experimental investigation was undertaken between the optimum 0.5% PVA fibre mix and an equivalent 0.5% PVA powder modified mortar. The study evaluates and contrasts their effectiveness in enhancing the axial load carrying capacity of retrofitted RC columns.

II. Methodology

Previous studies have proved strength behaviour of ferrocement retrofitting can be further enhanced by adding fibre materials in mortar [1][4]. PVA fibre is marked as a

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widely used admix material for retrofitting. The role of powder form of PVA in retrofitting admix exist as a research gap and the present study focus on justifying this research gap. For conducting experiment sample columns were cast, cured, intentionally cracked, wrapped with steel wire mesh, applied suitable bonding agent. Two batches of mortar mix with PVA fibre & PVA powder were prepared and applied on the wire mesh wrapped columns as retrofitting jacket layer, cured and tested. The results obtained from PVA fibre retrofitted samples and PVA powder retrofitted samples are compared for performance evaluation. The flowchart of methodology is shown in Fig. 1

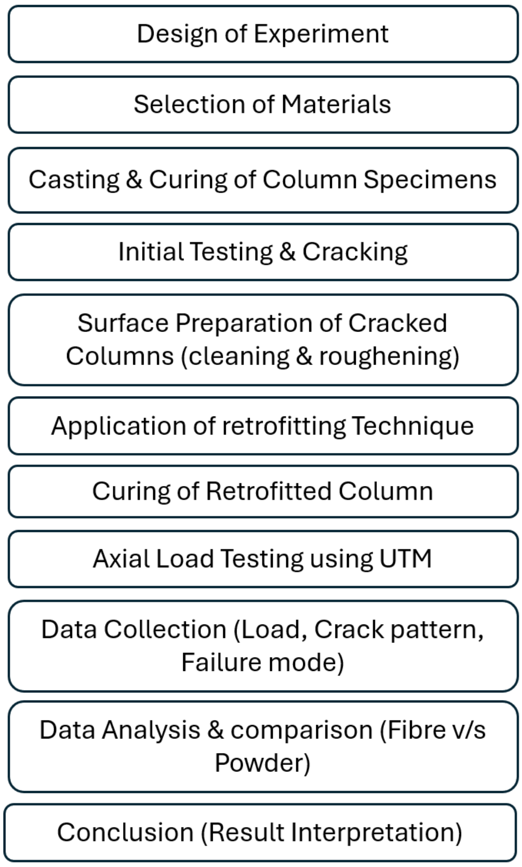

Fig. 1. Methodology Flow Chart

III. Experimental Program

A. Specimen Details

Six RC column specimens of identical geometry with scaled down measurements were prepared and tested. Assuming the original column size diameter as 400 mm and height 1500 mm, a scaling down ratio is derived and fix the specimen column size as diameter 160 mm and height 600 mm. The reinforcement size is also scaled down by this ratio as 6 mm diameter main bars and 4 mm diameter lateral ties. A clear cover of 20 mm (scaled down from 40 mm) is provided.

Fig. 2 shows details of specimen column. Suitable molds are prepared and the column specimens were casted and cured under standard conditions. The cured specimens were tested for ultimate load using UTM and then intentionally cracked to convert as retrofitting sample.

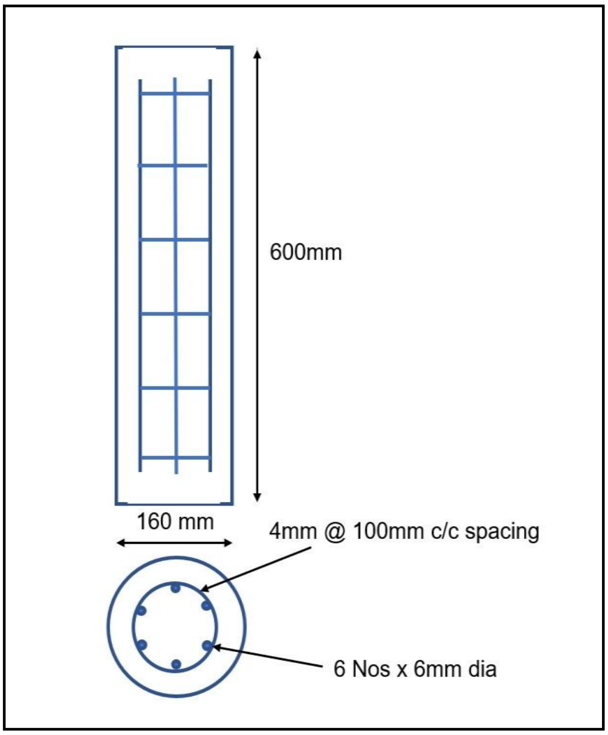

Fig. 2. Details of Specimen Column

B. Casting of Columns

A total number of 6 (six) short reinforced concrete column specimens were cast for the experimental investigation. The specimens were prepared using circular PVC molds with dimensions of 160 mm diameter and 600 mm height, corresponding to the dimensions adopted in the design stage. Prior to casting, the reinforcement cages consisting of longitudinal bars and lateral ties were fabricated according to the specified design detailing (Fig. 3a).

The cages were carefully placed inside the PVC molds maintaining the required 20 mm clear cover using suitable spacers. The molds were cleaned and properly aligned to ensure uniformity in shape and dimensions of all specimens. Concrete was prepared according to the finalized M25 mix design proportions. The materials were mixed thoroughly to obtain a homogeneous mixture with adequate workability. The concrete was then poured in the molds in layers, and each layer properly compacted to eliminate air voids and ensure good bonding between the concrete and reinforcement. Adequate care was taken during the casting process to maintain uniform compaction and prevent segregation of aggregates. After casting, the top surfaces of the specimens were finished and levelled properly to obtain a smooth and uniform surface. The specimens were left undisturbed for 24 hours to allow the initial setting of concrete. After this period, the column specimens were carefully demolded without any damage. Then all the columns were placed in a water curing tank containing clean water and were cured for a period of 28 days. Proper curing was maintained to ensure sufficient hydration of cement, which is essential for the development of the required compressive strength and durability of the concrete. After completion of the curing period, the specimens (Fig.3b) were taken out and prepared for further experimental procedures, retrofitting and load testing.

Fig. 3. (a) Reinforcement Cage and (b) Casted Columns

C. *Retrofitting Scheme*

A modified cement mortar with OPC 53 Grade cement, fine aggregate and 0.5% PVA Fibre is prepared and used to retrofit 3 numbers of cracked columns of Group A. The columns were prepared for ferrocement jacketing by wrapping two layers of steel wire mesh and 20 mm thick mortar is applied uniformly over the surface. A second batch of modified mortar is prepared by adding 0.5% PVA Powder in the same mortar mix design as above for retrofitting 3 numbers of cracked columns of Group B, the prepared mortar mix is applied over the steel wire mesh wrapped columns as retrofitting jacket. The final size of retrofitted column becomes 200 mm diameter including jacketing (Fig. 4).

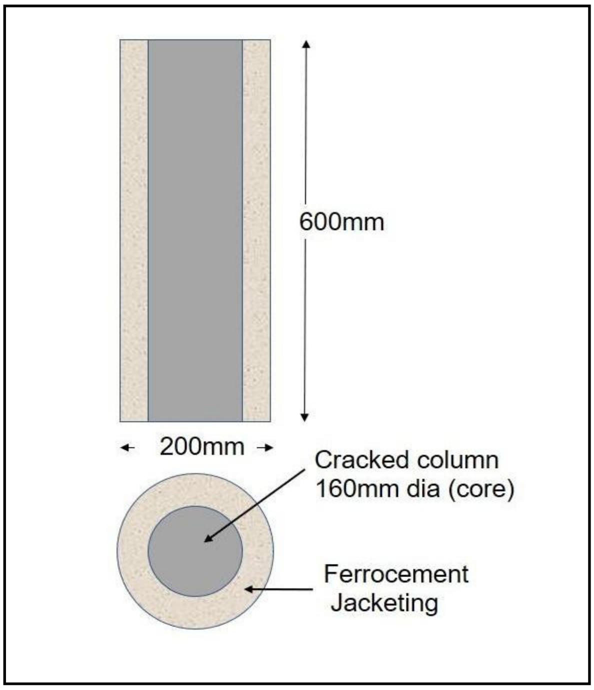

Fig. 4. Retrofitted Column Details

The retrofitted columns were cured and tested to make a comparative study of strength behaviour between PVA Fibre and PVA Powder enhanced mortar mix.

D. *Material Properties*

The materials used for casting columns and retrofitting were tested under standard procedure to meet quality standard requirements.

Cement

Ordinary Portland Cement (OPC) is used for the experiment. It is tested for physical properties (Table 1) in accordance with Indian Standard Specifications IS 12269:2013.

TABLE I. PROPERTIES OF CEMENT (OPC 53 GRADE)

Particulars	Observed Value
Specific gravity	3.1
Standard consistency	31%
7^{th} day compressive strength	30 MPa
28^{th} day compressive strength	55 MPa
Initial Setting time	140 min

Fine aggregate

Fine Aggregate passing through 4.75 mm sieve. The grading zone of fine aggregate is Zone II as per Indian Standard Specifications IS 383:2016. The properties are tested and tabulated (Table 2.)

TABLE 2. PROPERTIES OF FINE AGGREGATE (RIVER SAND)

Particulars	Observed Value
Specific gravity	2.45
Bulk density	1870 Kg/m^3
Particle size distribution	Zone II
Fineness modulus	2.41
Water absorption	1%

Coarse Aggregate

The coarse aggregates used is retained on 12.5 mm size sieve as per Indian Standard Specification IS 383:2016. The properties are tested and tabulated (Table 3.)

TABLE 3. PROPERTIES OF COARSE AGGREGATE

Particulars	Observed Value
Specific gravity	2.83
Bulk density	1600 Kg/m^3
Water absorption	0.5%

Water

Potable water was used for mixing concrete and mortar.

Composite Materials

- Steel wire mesh: 12 mm square opening and 1 mm diameter wires [14]
- Bonding Agent: SBR Latex
- PVA Fiber (Fig. 5.)
- PVA Powder (Fig. 6.)

Fig. 5. PVA Fibres

Fig. 6. PVA Powder

E. *Retrofitting*

The cured specimens were tested for ultimate load using UTM and then intentionally cracked to convert as retrofitting sample. All the 6 numbers of cracked columns are prepared for retrofitting by cleaning surface by removing loose concrete, apply bonding agent and wrapped two layers of steel wire mesh

Two batches of cement mortar were prepared, one by adding 0.5% PVA Fibre and other by adding 0.5% PVA Powder. A batch of 3 numbers of prepared columns were retrofitted using first mortar mix of 0.5% PVA Fibre (Fig. 7) and the other batch of 3 numbers retrofitted using second mortar mix of 0.5% PVA Powder (Fig. 8). The mortar was carefully applied over the wrapped wire mesh so that it might fully encapsulated the mesh and formed a uniform jacket around the column surface. After application of mortar, finished the outer surface of jacketing layer smoothly and uniformly.

All retrofitted specimens were cured for 28 days to achieve maximum strength.

Fig. 7. Group A- Columns retrofitted with 0.5% PVA Fibre mortar mix

Fig. 8. Group B- Columns Retrofitted with 0.5% PVA Powder Mortar Mix

F. *Testing Procedure*

Finally, the cured column specimens were tested using a Universal Testing Machine (Fig. 9a) with a capacity of 1000 kN to determine the compressive strength and load carrying capacity of the retrofitted samples. All the six retrofitted column specimens were carefully placed in the testing machine and subjected to axial compressive loading (Fig 9b). The load was applied gradually and uniformly until failure occurred.

During the testing process, the behaviour of the columns, including cracking patterns and ultimate load carrying capacity, were observed and recorded. The test result obtained is tabulate and evaluated for the effectiveness of the retrofitting technique in improving the strength and performance of the columns in a comparable format.

a **b**

Fig. 9 (a) Universal Testing Machine (b) Test Setup of Sample Column

IV. RESULTS

A. *Load Carrying Capacity*

The results obtained from the experiment shows both PVA fiber and PVA powder retrofitted specimens exhibited similar ultimate load capacities Table 4.

TABLE 4. ULTIMATE LOAD CARRYING CAPACITY OF RETROFITTED COLUMNS

Retrofitting Type	Specimen ID	Ultimate Load (kN)	Average Ultimate load (kN)
Group - A PVA Fibre (0.5%)	4	602	618
	5	636	
	6	616	
Group - B PVA Powder (0.5%)	A	585	580
	B	592	
	C	563	

- Average ultimate load (PVA Fiber Retrofitted): 618 kN
- Average ultimate load (PVA Powder Retrofitted): 580 kN

A graph is plotted using the result obtained for comparative study. The graphical representation of average ultimate capacity comparison of 0.5% PVA fibre modified ferrocement jacketing retrofitted sample column and 0.5% PVA powder modified ferrocement jacketing retrofitted sample column is shown in Fig. 10

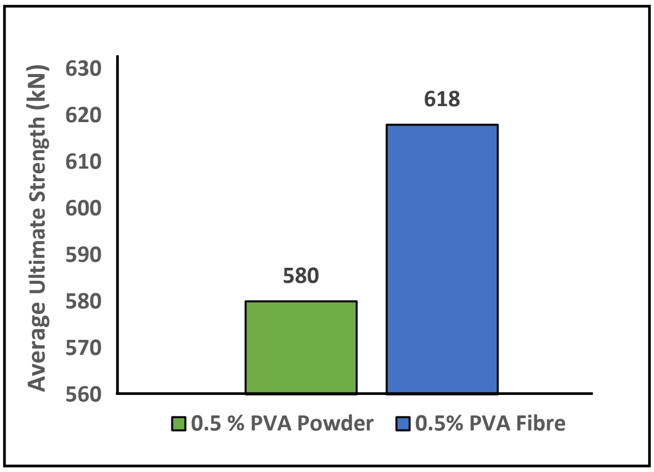

Fig. 10. Average Strength Comparison of Retrofitted Columns

B. Crack Behaviour

The crack behaviour of PVA Fibre sample and PVA Powder sample have specific distinctions. However, crack propagation patterns were similar in both cases. PVA Powder specimens showed earlier crack initiation at 196 kN applied load and PVA Fiber specimens showed delayed crack initiation at 237 kN applied load during testing (Table 5).

TABLE 5. LOAD AT FIRST CRACK OF RETROFITTED COLUMNS

Retrofitting Type	Specimen ID	Load at First crack (kN)	Load at first crack (kN)
Group - A PVA Fibre (0.5%)	4	242	237
	5	248	
	6	221	
Group - B PVA Powder (0.5%)	A	186	196
	B	192	
	C	210	

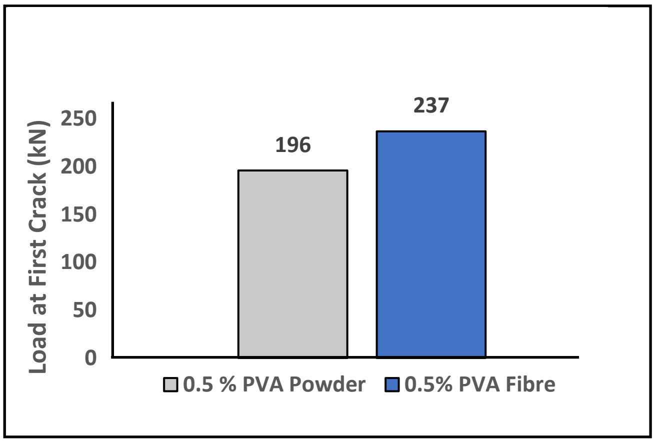

Fig. 11. Average Crack Initiation Load Comparison of Retrofitted Columns

The graphical representation of average crack initiation load comparison between 0.5 % PVA fibre and 0.5% PVA powder is shown in Fig. 11.

C. Workability

It was observed that a significant difference in workability during retrofitting process with the modified mortar mix. PVA Fiber mortar mix found difficult to apply while jacketing process due to fibre dispersion and balling effect. A smooth finishing cannot be achieved with PVA Fibre retrofitting.

PVA Powder mortar was found easy to apply due to uniform dispersion, improved workability and ease of application. PVA Fibre jacketing shows a rough finished surface while PVA Powder jacketing results smooth surface finishing.

V. DISCUSSIONS

A preliminary experimental investigation was conducted by the same group of Guide & Authors as a project work for curriculum requirement on the performance of varying PVA fibre content (0.5%, 1% & 1.5%) in modified mortar used retrofitting. The result obtained shows 0.5% PVA fibre dosage exhibited superior performance in terms of axial load capacity of the retrofitted specimen. Therefore, this optimum percentage, 0.5% was selected for the present comparative evaluation between PVA fibre & PVA powder modified mortar as a retrofitting material. The comparison between PVA fibre & PVA powder as an admix to retrofitting mortar was conducted as the extension of above study and justification of the identified research gap in this area of study.

By the present study, the performance of PVA fibre & PVA powder modified mortar indicates that the confinement provided by ferrocement jacketing governs the strength enhancement rather than the type of PVA modification. [11]

A delayed crack initiation in PVA fibre reinforced retrofitted specimen over PVA powder retrofitted sample was observed shows crack bridging mechanism [13] of discrete fibre content of PVA fibre material improves tensile resistance.

On the other hand, PVA powder, being uniformly dispersed, enhances the matrix properties but lacks discrete crack-bridging action, leading to earlier crack initiation.

From a practical perspective, PVA powder modified mortar offers significant advantages in terms of workability and ease of application, making it more suitable for field conditions compared to PVA Fibre modified mortar retrofitting.

VI. CONCLUSIONS

The present study experimentally investigated the performance of RC columns retrofitted using PVA fibre- and PVA powder-modified ferrocement jacketing systems. The effectiveness of both retrofitting techniques were evaluated by comparing their ultimate load-carrying capacity, crack behaviour, and workability. Based on the experimental findings and discussions, the following conclusions are drawn::

- Both PVA fiber and PVA powder modified ferrocement jacketing systems provide comparable ultimate load capacity.
- PVA fiber reinforcement delays crack initiation due to effective crack-bridging behavior.
- PVA powder modified mortar exhibits better workability and ease of application.
- PVA powder can be considered a practical alternative to fiber reinforcement in ferrocement jacketing without significant compromise in strength.

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