Experimental investigation on behaviour of RC circular and square columns confined with natural fabrics

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Abstract. In this paper natural fibers are confined with short circular and square columns for strengthening purpose with conventional wrapping technology. The substitution of natural fibres for synthetic fibres is a new approach to achieve sustainable construction. The most commonly used fibers are Glass, Carbon, Aramid, etc., but the fibers are costly and considered to be slightly uneconomical. Hence natural fibers namely Jute, Kenaf and Flax are utilized in this research. An experimental study reports the efficacy of the use of Jute, Kenaf, and Flax fabrics as external confinement for concrete columns furthermore, the outcomes propose that a huge improvement in the quality properties. Circular columns of 100mm diameter and 600mm height have been constructed and are tested under axial compression. The test outcomes show that the axial load carrying limit of FRP wrapped is increased than the control columns by a significant percentage. In these three natural fibers, Flax FRP wrapped columns offer more strength than Jute and Kenaf fiber wrapped columns. Natural fibers not only increase the strength it is cost-effective and environmental friendly as they are 100% bio-degradable.

Keyword: Textile reinforcement (TRC), Fabrics, Confinement column wrapping, Axial Compressive strength, Kenaf, Flax, Jute.

1. Introduction

Recent research on materials in the construction industry has resulted in the introduction of a new alternative competitive non-metallic material called Fibre Reinforced Polymer (FRP) to deal with durability problems of steel Reinforced Concrete (RC) structures. Textile reinforced concrete (TRC) is an new innovative technology used in high-performance composite material which has revealed many promising attributes in various applications for strengthening and repairing purposes, but test
methods and reliable numerical models need to be established to reduce uncertainty and the need for extensive experimental studies [1].

In the most recent decade, regular plant fiber (jute, sisal, coir, banana, hemp, kenaf, flax, and so on) are getting consideration from numerous scientists and academicians to use it as a substitute support of engineered fiber fortified polymer composites. These filaments are turning into an incredible substitution of regular strands, (for example, glass, carbon, and aramid) because of their light weight, minimal effort, carbon lack of bias, genuinely great mechanical properties, high explicit quality, and biodegradability attributes. Some compound medicines are needed to upgrade the fiber lattice interfacial quality and to limit the dampness ingestion by these strands which would eventually improve physico-mechanical properties of these fiber fortified composites[2].

An important issue that occurs internationally is the stabilization and rehabilitation of specific members. For reinforcement and regeneration, biomass, aramid and glass fibre reinforced polymer (FRP) composites are primarily used. However, because of its high price, lack of affordability and environmental consequences, its use is limited to a small scale. The use of locally available natural fibres and low-cost synthetic fibres is the solution to this problem. However, the strength models performed better than the strain models. The strength, fracture energy, ductility index, and post-peak response were substantially improved by the JPFRP wrapping. For a small-scale application, where little strength and high ductility is required, JPFRP confinement may therefore be used. In addition, it can be used to avoid concrete cover peeling and the intrusion of moisture into the concrete[3].

Fiber-strengthened polymer (FRP) composites are broadly utilized in cutting edge solid innovation given their predominance over conventional steel fortifications. These materials have high quality limit and erosion obstruction and can be utilized as the principle fortifications in blend with glues and docks to fortify strengthened cement (RC) pillar individuals. RC radiates are intended to give obstruction against flexure, shear, twist, exhaustion, effect, and impact stacking. The quality and flexibility of RC shafts can be improved through FRP reinforcing procedures with a mix of filaments. The general quality of FRP composites in RC radiates is constrained by fiber type, setup, and materials and reinforcing strategy[4].

An experimental campaign aimed at testing eight reinforced concrete (RC) columns, four of them being confined through E-glass fiber reinforced cementitious matrix (GFRCM) and four representing the bare specimens. The variables analyzed in this work are: the geometry of column cross-section (circular or square); two stirrups spacing values; the presence or not of the FRCM jacket, which was realized through two layers of fibers. The experimental behavior was characterized in terms of cracking pattern, axial stress-strain response (i.e., strength gain and ductility), and hoop strains development. Particularly, both strains in the GFRCM-jacket and in the inner steel stirrups were monitored during the test. Results in terms of fiber exploitation ratio are also compared with recent results obtained for carbon FRCM (CFRCM) jackets applied to RC columns, characterized by the same geometry[5].

Textile Reinforced Concrete (TRC) is an alternative strengthening material that has become of interest as of late is used in new structures, as well as in the strengthening of beams, slabs, columns and even walls. Textile reinforced materials which are most applicable for use in structures is alkali-resistant glass (AR-glass), carbon, and aramid fibers. Besides the above mentioned materials, basalt, kevlar, steel, some of the natural fibers and other polymers fibers can also be used. Another advantage of TRC in comparison with RC is that the reinforcement, the fiber mesh, which is lighter one and easier to replace and work with it. The textile mesh can be easily handled, bend it by hand or use it to wrap structural elements such as beams, slabs or columns. In comparison with working with the steel reinforcement bars, TRC is easier to work with and provides a rapid application on elements which are not strengthened.
The flexural and shear capacities of beams, columns and slabs can be improved by externally bonded textile fabrics. It can also be used internally as reinforcing bars by replacing the conventional steel reinforcement in RC structures, because of the outstanding properties possessed by them namely light weight, non-conductivity, immunity from corrosion, high strength to weight ratio, ease of handling, and availability in any length or shape. The strengthening layer consists of technical textile fabrics made of continuous high performance fibre bundles processed to create flat structures. In worldwide, the common method is followed for structural strengthening, retrofitting and repairing works are carried out by using FRP materials in the form of fabrics or mesh which is used in flexure or shear improving purposes [6-9].

An experimental study was carried out by Silva [7] about behavior of square and circular columns strengthened with carbon fibres or aramid fibres. In this study prismatic columns with square cross sections were divided into three categories according to corner radius of the column. Column specimens have been tested for axial loading and results showed that an equal strength gain for almost all the cylindrical columns. Columns with square cross sections and sharp corners have shown no improvement of strength nor ductility. Due to the less confinement of fabrics on the flat sides of the column. From the result which shows that corner radius of square cross sectioned wrapped columns will influence directly for the strength gain due to external CFRP reinforcement.

In most of the case study the mainly deals with the artificial fabrics in our study we have used the natural fiber instant of artificial fabrics. The objective of the study is to increase the compressive strength of the wrapped square and circular column.

2. Fiber reinforced polymer (FRP)

Fiber Reinforced Polymer (FRP) or Fiber Reinforced Plastic is a composite material which consists of a fibre reinforced polymer matrix. Glass, carbon and aramid fibres are widely used and other fibres are often used, such as paper, wood and asbestos.[10]. The polymers used are silicone and phenol formaldehyde resins that are thermosetted with epoxy, vinyl ester or polyester. Such composite structures may be engineered or are naturally available as well. But there are certain synthetic fibres that are more expensive. Therefore, some of the natural fibres used in the project are cost-effective and economical. Jute, Kenaf and Flax are the ones[11]. The properties of these fibers are discussed below in this study and shown in the Fig.1.

![Jute fabric](image1.png) ![Flax fabric](image2.png) ![Kenaf fabric](image3.png)

**Figure 1. Natural Fabrics**

3. Material Properties

3.1. Cement

Ordinary Portland Cement of 53 grade is used in this investigation of specific gravity 3.15.
3.2. Aggregate

Locally available clean, well graded, natural river sand having fineness modulus of 2.89 conforming IS: 383 – 1970 was used as the fine aggregate of zone II. Coarse aggregates will occupy 70 to 80 percent of the total volume of concrete. The crushed stone aggregates were collected from the local quarry. The properties of coarse aggregate were evaluated as per the procedures given in IS:383-1970 and IS:2386-1963 (part- I, II and III).

![Particle size distribution](image)

**Figure 2.** Particle size distribution

3.3. Water

Water is an essential concrete element as it strongly engages in cement chemistry. The volume and consistency of water must be closely controlled in order to shape the strength-giving cement gel. Portable water is used for mortar production. The pH of the water is between 6 and 8, suggesting that the water is free of organic matter.

3.4. Steel properties

The reinforcement cage was prepared using 10mm and 8 mm diameter steel bars tested in tension to determine their yield strength, ultimate strength and elastic modulus. For each bar type, three tensile specimens were tested and the test results are summarized in Table.1.

| Bar diameter (mm) | Yield strength (MPa) | Ultimate strength (MPa) |
|------------------|----------------------|-------------------------|
| 10               | 480                  | 672                     |
| 8                | 450                  | 612                     |

**Table1.** Properties of steel reinforcement

3.5. Super plasticizer

Conplast SP430 is compatible with IS: 9103:1999 and BS: 5075 Part 3 and ASTM-C-494 Type 'F' as a high-dose water mixture reducer and Type G as a high-dose mixture reducer. Conplast SP430 (G) is
supplied as a brown liquid instantly dispersible in water. Conplast SP430 has been specially designed to offer up to 25 percent high water reduction without lack of workability or to manufacture high-quality concrete with decreased permeability.

3.6. Epoxy resin

The technique of strengthening relies critically on the efficiency of the adhesive used. Epoxy resin, composed of two parts, a resin and a hardener, was the adhesive used in this research. The resin possesses low viscosity and Bisphenol-A based crystallization free resin, modified with reactive diluents, having attractive processing properties, and reduced resistance to organic solvents. The hardener used was a high viscosity polyamidamine for the formulation of flexible coatings, trowelable screeds and grouting mortar with excellent adhesion properties. The epoxy adhesive is a solvent free low viscosity system and can take high filler loadings. Properties of the resin and hardener which the producer supplies [12, 13].

4. Testing of textile fabric

4.1. Samples preparation

Wrapping of beam is made with the help of epoxy resin. Fiber is initially dipped in epoxy resin and it is allowed to dry at the room temperature for about 7 days. Then it is carried out for wrapping process.

4.2. Testing of samples

A thin flat strip of textile fabric of rectangular section 150 mm x 100 mm was mounted between the grips of fabric testing machine so that the direction of force applied to the specimen should coincide with the longitudinal axis of the specimen. It was loaded in tension by the driving mechanism of testing machine imparting constant speed to movable grip with respect to the fixed grip and tested fabric is shown in Fig. 3.

![Tested jute fiber](image)

Figure 3. Tested jute fiber

4.3. Results of fabrics

| S.No. | Type of Specimen | Tensile Strength Without Epoxy (MPa) | Tensile Strength With Epoxy (MPa) |
|-------|------------------|-----------------------------------|----------------------------------|
| 1.    | Flax             | 450                               | 540                              |
The Fig. 4 shows the characteristics of three FRP textile reinforcement i.e., Jute, Flax and Kenaf with epoxy.

![Graph showing stress-strain behavior of the fabrics](image)

**Figure 4. Stress-strain behavior of the fabrics**

5. **Test specimens**

32 columns have been constructed to investigate the performance FRP wrapped columns consisting of two groups. One group consists of 16 circular columns of 100mm diameter and another group consists of 16 square columns of dimension 100mmX100mm. And both group of columns are constructed with same slenderness ratio of 6 having height of 600mm.

For building, M30 grade concrete and Fe 415 grade steel were employed. Initially, the compressive strength of the mixing design was tested and development began. After construction, 28 days of curing were carried out. Columns are then strengthened by fibres. Fig. 5 shows the detailing of circular and square columns respectively. Fig. 6 shows the wrapping of concrete specimens[14].

![Detailing of Circular and Square column](image)

**Figure 5. Detailing of Circular and Square column**

|   |   | Jute | 230 | 280 |
|---|---|------|-----|-----|
| 2 |   |      |     |     |
| 3 | Kenaf | 190  | 230 |     |

|   |   | Jute with epoxy | Flax with epoxy |
|---|---|-----------------|-----------------|
| 2 |   |                 |                 |
| 3 | Kenaf with epoxy | Jute with epoxy  | Flax without epoxy |
|   |                 | Jute without epoxy | Kenaf without epoxy |
6. Results & discussion

Table 3. Test Results

| S.No. | Type of specimen | Failure load(kN) | Peak deflection(mm) | Increase in compressive strength(%) |
|-------|------------------|------------------|----------------------|------------------------------------|
|       |                  |                  | circular | Square |                                    |
| 1     | Conventional     | 303              | 2.6      | 2       | -                                  |
| 2     | Flax             | 375              | 3.0      | 2.5     | 22.9                               |
| 3     | Jute             | 345              | 3.5      | 2.9     | 13.1                               |
| 4     | Kenaf            | 330              | 7.1      | 6.8     | 8.2                                |

The results (shown in table 3) occurred from the axial compression test show that the circular and square are well strengthened by FRP.

Figure 7(a). Displacement curve of circular column
It above graphs Fig.7 (a) & Fig.7 (b) Shows the deflection curve of conventional, Flax, Jute and Kenaf fibers wrapped column respectively. It is observed that in all the columns as the load increases deflection also increases.

- From all the above collected data the following results are obtained:
  - The strength of FRP wrapped columns (Flax, Jute and Kenaf) is found to be increased than the strength of conventional column.
  - In these three FRP wrapped columns Flax fiber wrapped column is having more strength and is having 22.9% more compressive strength than the conventional column.
  - Then comparing Jute and Kenaf fiber wrapped columns. Jute wrapped column is having more strength and have 13.1% more compressive strength than the conventional column.
  - Even though the strength obtained by Kenaf wrapped column is less when compared to Flax and Jute wrapped columns it obtained 8.2% more compressive strength than the conventional column.

Figure 7(c). Displacement curve for square column
The above graph Fig.7(c) shows the FRP strengthened columns shows better performance than the unwrapped i.e conventional columns. The Flax is better than all other fibers. The jute is better than kenaf fiber. The flax fibers have good compressive behavior. All the three fibers are interpreted to find the good performer. The x axis has the displacement values and y axis takes the load. The least count of the dial gauge is 0.01mm.

![Deflection curve](image)

*Figure 7(d). Deflection curve of square column*

This graph Fig.7 (d) shows the relation between load displacements. Here varies fibers are used to find the better one. In this graph also the flax fiber has better performance than other fibers. The fibers flax, jute, kenaf are tested and shows in same graph for betterment of interpretation.

The results of axial compression testing show deflection and displacement in the column. Comparing both results of deflection and displacements the fiber shows better performance than conventional column. The flax fiber has higher tensile strength and good performance than other fiber. The kenaf shows least performance and low tensile strength.

The table shows that strength of flax is 33% jute, 30% and kenaf is 27% higher than conventional column strength. Comparing flax fiber and jute fiber flax is 5% higher than jute likewise jute is 3% greater than kenaf and kenaf is 27% higher than conventional. The flax fiber is 33% higher performance than conventional. The performance of kenaf is 8% less than flax fiber.

The jute performance is 30% higher than conventional column. The reason for the high strength in flax is its tensile strength. the tensile strength of the flax fiber is higher than other fiber. The fiber strength get increased with used with epoxy resin. The strength of fiber get increased by 20% when used with epoxy resin. The epoxy resin helps in good bonding which increases the strength to the fiber.

### 7. Conclusion

The result discussion shows that the fiber reinforced polymer yield good tensile strength. It protects the concrete structure from failure. Among the three fiber used namely flax, jute, kenaf, the flax fiber is a best performer. In specimens under broad eccentricity loading, the strain of transverse FRP wraps is higher relative to specimens under minimal eccentricity loading.
This is due to the ductile nature of the former specimens, which allows greater concrete dilation. The test program is mainly chosen to study the comparison of FRP wrapped strengthened column and normal conventional column. The wrapping expands the life time of the structure.

It can be used to strength the old conventional and also used in repair works like strengthening the old and damaged columns. It is not that flax fiber is the best one when compared to other fibers (jute, kenaf) this fiber is good in performance. Even though jute is behind the flax fiber it is ahead the kenaf. Fiber Reinforced Polymer wrapping increases the axial load carrying capacity by providing addition confinement to the concrete without increasing the original column size. Control and FRP wrapped square columns undergo higher axial deformation as compared to that for circular columns.

Overall, the strength gains obtained were marginal with an axial load. Realistically the additions of FRP as an external confinement to concrete structures would effectively increase column strength and enhance moments of resistance formed in a situation incorporating axial loads and bending moments. Strength of FRP confined columns is found to have increased strength than the unconfined columns.

It seems to be one of the effective technique in strengthening of columns. But the cost of fibers namely Glass, Sisal, Carbon, Aramid, etc., used for it is more costly hence considered uneconomical. The circular and square columns are then strengthened with natural fibers namely Flax, Jute and Kenaf and is tested under axial compression to see their performance.

The strength of the circular column is more than square column when compared. The strength in the FRP wrapped columns are found to be increased by significant percentage when compared to conventional RC columns especially Flax fiber wrapped column has more compressive strength than the Jute fiber wrapped column which has more compressive strength than the Kenaf fiber wrapped column. Increase in percentage of compressive strength of Flax, Jute and Kenaf fiber wrapped column by the conventional column is 22.9%, 13.1% and 8.2% respectively.

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