

# Cost And Aesthetic Assessment of RC Columns Retrofitted with Reinforced Concrete Jacketing and FRP Wrapping.

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*Abstract- Existing reinforced concrete (RC) structures often require retrofitting due to deterioration of infrastructure, rising service loads, and the need to meet modern structural design standards. Reinforced concrete (RC) jacketing and fiber reinforced polymer (FRP) jacketing are two popular strengthening procedures for enhancing the performance of subpar RC columns. The structural behavior of these methods has been the subject of several research, but their cost-effectiveness and aesthetic implications both crucial factors in rehabilitation projects have received relatively little attention. The cost and aesthetic performance of RC and FRP jacketing systems are compared in this study. Using a Bill of Quantities (BOQ) cost analysis, the cost of identified retrofitting options was estimated by analyzing direct costs associated with labor, materials and equipment for each retrofitting technique. The analysis showed that the average total cost of RC jacketing would be approximately ₹23,998/column, whereas the average total cost of FRP jacketing would be approximately ₹36,964/column, indicating that RC jacketing is more cost effective than FRP jacketing, as RC jacketing is done using conventional materials. The aesthetic assessment was undertaken using several criteria, including column proportion change, surface finish quality, architectural compatibility, reduction of spaces, and finishing specifications. The aesthetic performance results indicate that FRP jacketing has superior aesthetic performance than RC jacketing due to the preservation of the original geometry of the structural member and the minimal increase of the column dimensions. Therefore, when selecting an appropriate retrofit option, both economic implications, and architectural requirements must be considered.*

*Keywords - RC Jacketing, FRP Jacketing, Column Retrofit, Cost Analysis, Aesthetic Assessment.*

## I. INTRODUCTION

To increase safety in buildings with aged infrastructure, poor environmental conditions, heavier loads being placed on them, and the continuous threat of earthquakes, it is necessary to strengthen existing reinforced concrete (RC) structures. Many of the buildings that were built prior to the adoption of a seismic design code are likely to be deficient in either strength or ductility or both when subjected to large loads. Strengthening methods offer an opportunity to enhance the strength of existing structures and prolong the life span of the structure without having to demolish or completely rebuild them [1]. Reinforced concrete columns are important structural components of buildings that provide vertical support and keep them standing. However, their load-bearing capacity may decline over time as a result of increased service loads, construction flaws, corrosion of reinforcement, and design restrictions that were imposed at the outset. To help restore both the structural capacity and long-term durability of reinforced concrete column retrofitting by means of various techniques such as: steel jacketing, FRP (fibre-reinforced polymers) wrapping, and RC (reinforced concrete) jacketing has been developed [2]. FRPs (Fiber Reinforced Polymers) have become an excellent material Used to enhance the strength of structures due to their low weight, high strength, resistance to corrosion, and ease of installation. When applied as an external wrap

for reinforced concrete columns (RC), confinement with FRP increases both the load capacity and ductility of the column. Experimental research has shown that retrofitting weak RC columns with FRP can significantly improve their performance when loaded with axial loads [3]. RC jacketing is a typical method of strengthening columns and has been used for some time. The primary purpose of using this type of jacketing is to increase the size of the column cross-section along with adding reinforcing to the column. The majority of use is in retrofitting buildings to improve seismic performance and increase building stiffness or load carrying capacity overall [4]. There are multiple types of strengthening methods to select; the selected retrofitting technique will depend on structural performance, construction, and cost. Additionally, how the selected solution will ultimately affect the aesthetics of the building must be taken into consideration [5]. Most existent literature evaluates and provides an analysis of retrofitting techniques based on their structural and seismic performance with little consideration given to other aspects, such as the cost of the technique, and the aesthetic impact. Therefore, when developing a suitable strengthening solution, comparative analysis of the two viable jacketing techniques based on these factors is necessary to determine which technique to employ [6].

## II. OBJECTIVES OF THE STUDY

Previous research into retrofitting columns has predominantly concentrated on assessing the structural & seismic performance of methods used to strengthen columns, such as RC jacketing and fibre reinforced polymer (FRP) wrapping. Conversely, cost effectiveness and effects on the architectural aesthetics have been largely unexamined. Thus, this paper seeks to fulfil this knowledge gap by achieving the following objectives:

1. Assess the cost-effectiveness of using either RC or FRP jacketing techniques for strengthening existing reinforced concrete columns.
2. Evaluate the aesthetic impact of using either RC or FRP jacketing techniques on an existing building structure.

## III. LITERATURE REVIEW

3.1 Structural Retrofitting methods- Structural retrofitting methods are often used to enhance the strength, stiffness, and durability of existing reinforced concrete (RC) structures that have deteriorated due to age, environmental conditions, increased loads, or seismic activity [1]. Reinforced concrete column retrofitting (RC jacketing) is one of the newest and most common existing methods for providing additional strength to existing reinforced concrete columns. The method consists of increasing the size of the original column by adding a new layer of reinforced concrete and providing longitudinal and transverse reinforcement [7]. Moreover, RC jacketing offers better confinement to the existing concrete core, which helps improve the overall load-carrying capacity of the column [8]. Owing to its reliability and ease of application using conventional construction practices, RC jacketing is widely used for strengthening and rehabilitating deficient RC structures [7]. Although effective, RC jacketing may enlarge the column dimensions and involve more construction time and labour owing to the requirements of formwork and concrete casting. [9]. During recent years, FRP wrapping has gained attention as an efficient alternative technique for improving the strength of RC columns [10]. In this method, sheets of carbon, glass, or aramid fibre reinforced polymer are wrapped around the column to confine the concrete core and improve its performance [11]. Research experiments indicate that columns strengthened with FRP confinement perform better when subjected to axial loads as well as seismic forces [12]. As a result of these benefits, FRP wrapping has received growing attention in recent years as a modern technique for strengthening reinforced concrete structures [10].

3.2 Cost Assessment for Retrofitting- While deciding on a suitable retrofitting method for reinforced concrete structures, it is important to consider economic factors such as material cost, labour requirements, and construction time. Retrofitting is usually chosen instead of doing a complete tear-down of a building because it tends to be much less expensive yet still preserves both safety and functionality of the original building design [13]. In general, the material selections made for retrofitting

have a major impact on the overall cost of retrofitting, including the specific types and amounts of materials selected [14]. In general, it has been found that the construction costs of traditional rehabilitation methods, such as reinforced concrete jacketing, do significantly increase as a result of addition of concrete, detailing of steel reinforcement, types and arrangements of formwork, and curing methods used in construction [15]. Reinforced concrete jacketing is also labour-intensive requiring that the rehabilitation methods associated with reinforcement of a structure would involve additional construction time and an increase in the amount of labour required for the construction of the project than would generally be required to construct using modern retrofitting technology [10]. Because of the lightweight characteristics, ease of installation, and faster construction times associated with using FRP wrapping, its use has become increasingly common [10]. FRP materials tend to be more expensive than conventional materials; however, the speed of installing FRP materials can significantly lower skilled labour rates and total project time. Comparative analyses have shown that RC jacketing is often seen as being more economical with respect to material cost (especially in developing nations) when compared with the more readily available traditional materials and skilled labour. [16]. FRP retrofitting may be a comparatively lower cost option than traditional materials (such as steel or concrete) where a fast-strengthening approach is necessary, without disrupting the normal activities of the building [10]. In addition to material cost associated with FRP retrofitting, construction time and labour productivity are also key factors in evaluating retrofitting options. All of these factors impact the total cost of the project. The selection of the best option for the retrofitting of reinforced concrete columns is based on a thorough cost analysis which includes material costs, labour requirements, and installation time [17].

3.3 Aesthetic aspects of Structural Rehabilitation- When selecting retrofitting methods for a building's structure, in addition to structural performance and cost efficiency, there are aesthetic implications to consider; this is especially true for buildings with significant architectural desirability. In order for retrofitting techniques to successfully add strength to

the structure of a building, they need to increase the strength of the building's structural system without diminishing the building's visual aesthetic quality [6]. The resulting enlargement of the cross-section can, in some instances, disrupt the internal architectural design of the building [18]. Increasing column size can occupy a larger area of usable floor space and potentially impact the visual proportions of the structural elements in the building [19]. In particular, when minimal modifications to the building's architecture are preferred, fibre-reinforced polymer strengthening techniques are frequently chosen due to their light weight and very thin profile [18]. When using FRP Wrapping versus Conventional Retrofitting Techniques, there is substantially More Surface Preparation Required for Conventional Retrofitting Techniques [14]. In addition to the issues of No Finishing Work and Directly Applying FRP Wrapping to the Surface of the Old Columns, Newer Methods for Strengthening the Concrete E.g., NSM FRP Reinforcement also reduce the Visual Impact of These Repairs by Putting the Reinforcing within Grooves in the Concrete Cover [20]. In many cases, surface treatments/finishes will influence how a retrofitted structural member looks. This is especially true for buildings that have exposed structural elements in their architectural design. Therefore, when selecting a retrofitting solution for reinforced concrete columns, it is important to consider the architectural compatibility of the proposed retrofit method, any potential changes to column dimensions, finishing requirements and the surface treatment of the retrofitting method [21].

#### IV. DESCRIPTION OF RETROFITTING TECHNIQUES

##### 4.1 RC Jacketing-

Reinforced concrete jacketing is one of the most commonly used methods for strengthening weak reinforced concrete columns. It consists of installing a new layer of reinforced concrete around the existing column and providing new longitudinal and transverse reinforcement. The additional reinforcing cage installed around the existing concrete core provides increased confinement of the core, as well as improved loading capacity and stiffness. The 400 mm x 700 mm original column was reinforced in this

study by enlarging to a new section of 600 mm x 1000 mm using higher strength concrete and added reinforcing bars. The enlarged cross-section provides the column with significant improvements to its structural stiffness and axial load capacity; however, as a result of RC jacketing, the self-weight and diameter of the column increase as well. Following the RC jacketing process, the new surface is typically finished with some type of surface treatment (plastering or finishing) to match up with the existing architectural features and restore the column's appearance.

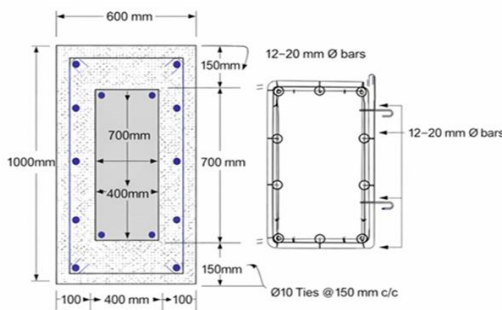


Fig 1: RC jacketing details.

#### 4.2 FRP Jacketing-

External wrapping of existing reinforced concrete columns with high-strength fibre sheets is an example of modern technology using a fibre reinforced polymer (FRP) jacketing technique. Epoxy resin is used as the bonding agent to attach the high-strength fibre sheets to the concrete core. The lateral confinement provided by the FRP jacketing increases the ductility, compressive strength, and deformability of the column, thereby improving its ability to carry loads and resist damage due to lateral forces. Since carbon fibre reinforced polymer (CFRP) provides superior confinement efficiency, high tensile strength, and excellent corrosion resistance compared to other fibre types, it was chosen as the subject of this study. The use of fibre reinforced polymer (FRP) jacketing to provide high-strength external wrapping of existing reinforced concrete columns using epoxy resin as the bonding agent, increases the ductility, compressive strength and deformability of the column due to the lateral confinement provided to the concrete core by the FRP wrap.

Wraps of carbon fibre-reinforced polymer (CFRP) were used to provide confinement and to enhance the

strength of a weak column, thereby improving the overall performance of the concrete structure. The CFRP was externally bonded to the surface of the column using epoxy resin; this created sufficient mechanical bonding between the two materials. Because the fibre layer is so thin, FRP wrapping results in a little increase in column dimensions as opposed to RC jacketing. As a result, the technique may be used for structures when increasing the member size is not feasible due to architectural or spatial constraints. The installation process mainly comprises surface preparation of the concrete, epoxy resin application, fibre sheet wrapping, and a protective surface coating to extend lifespan and maintain the appearance of the reinforced column.

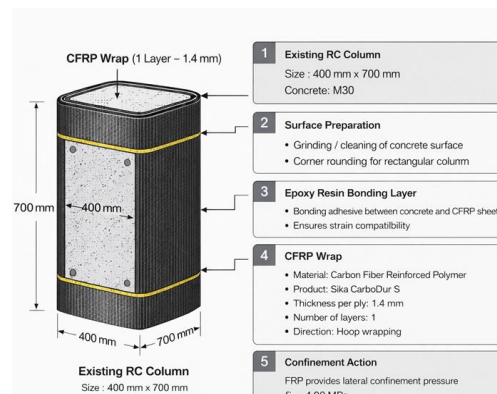


Fig 2: FRP jacketing details of Existing RC Column (400 × 700 mm).

## V. METHODOLOGY FOR COST EVALUATION.

### 5.1 Cost Evaluation for RC Jacketing.

#### 5.1.1 Column Details and Material Properties

The cost estimation was performed for Column C3, which was identified as structurally deficient during seismic analysis. The existing column dimensions and retrofitted dimensions used for cost evaluation are given below.

Existing Column- Width (B) = 0.4 m, Depth (D) = 0.7 m

Jacketed Column- Width (B') = 0.6m, Depth (D') = 1.0m

Height (H) = 3.5 m

Material Properties

- Concrete grade = M35

- Steel yield strength ( $f_y$ ) = 500 MPa
- Longitudinal reinforcement = 12 bars of 20 mm diameter
- Lateral ties = 10 mm diameter @150 mm spacing

### 5.1.2 Quantity Estimation

The quantities of concrete and reinforcement required for RC jacketing were determined using geometric relationships based on the difference between the original and jacketed column sections.

#### a) Volume of Concrete in Jacket

The gross volume of the jacketed column was calculated as:

$$V_g = (B' \times D' \times H) - (B \times D \times H)$$

$$V_g = 1.12 \text{ m}^3$$

#### b) Volume of Reinforcement

The total reinforcement volume consists of longitudinal bars and lateral ties.

##### Longitudinal Reinforcement

Volume of longitudinal reinforcement:

The RC jacket was provided with 12 longitudinal bars of 20 mm diameter along the height of the column.

The volume of reinforcement was calculated using:

$$V_{\text{long}} = n \times A \times L$$

$$V_{\text{long}} = 0.01596 \text{ m}^3$$

##### Lateral Ties

Tie spacing: 150 mm.

Number of ties:  $n = 24$

Perimeter of jacketed column:  $P = 2(B' + D')$

$$P = 3.2 \text{ m}$$

Volume of ties:

$$V_{\text{ties}} = n \times A_{\text{bar}} \times \text{Lone tie} = 0.00603 \text{ m}^3$$

Total Reinforcement Volume

$$V_r = V_{\text{long}} + V_{\text{ties}}$$

$$V_r = 0.02199 \text{ m}^3$$

#### c) Net Concrete Volume

The actual concrete required for jacketing was obtained by subtracting the reinforcement volume from the gross concrete volume.

$$V_c = V_g - V_r$$

$$V_c = 1.098 \text{ m}^3$$

### 5.1.3 Mass of Reinforcement

The mass of reinforcement steel was calculated using the density of steel.

Density of steel:  $\rho = 7850 \text{ kg/m}^3$

$$MR = \rho \times V_r$$

$$MR = 172.68 \text{ kg}$$

### 5.1.4 Concrete Mix Proportion

Concrete mix ratio adopted: 1:1.5:3

Water-cement ratio: 0.45

Maximum aggregate size: 20 mm

### 5.1.5 Quantity of Concrete Materials

For  $1.098 \text{ m}^3$  of concrete, the material quantities calculated.

Cement-

Required cement:  $C = 408.456 \text{ kg}$

Number of cement bags = 8.17 bags.

Fine Aggregate-

FA = 694.38 kg

Volume of sand =  $0.408 \text{ m}^3$

Coarse Aggregate-

CA = 1347.90 kg

Volume of coarse aggregate =  $0.817 \text{ m}^3$

### 5.1.6 Cost of Concrete.

Table:1 Total cost of Concrete for RC Jacketing.

	Cement	Fine Aggregate	Coarse Aggregate
Rate	350Rs/bag	882 Rs	2258 Rs
Quantity	8.17bags	$0.408 \text{ m}^3$	$0.818 \text{ m}^3$
Cost	2859.19 Rs	360.26Rs	1844.59 Rs
Total Concrete Cost = 5064.04 Rs			

### 5.1.7 Cost of Reinforcement

Steel rate: 50 Rs/kg

Cost steel =  $172.7 \times 50 = 8633.99 \text{ Rs}$

### 5.1.8 Formwork (Shuttering) Cost

Formwork area was calculated using the perimeter of the jacketed column.

Area =  $P \times \text{Area}$

$$\text{Area} = 3.2 \times 3.5 = 11.2 \text{ m}^2$$

Formwork rate: 500 Rs/m<sup>2</sup>

Cost formwork = 5600Rs

5.1.9 Total Cost

Total Cost = Cost concrete + Cost steel + Cost formwork  
 =5064.04+8633.99+5600

Total Cost=19298.03Rs

5.1.10 Labour Cost

Labour cost was estimated considering the construction activities involved in RC jacketing, which include:

- surface preparation of the existing column
- fixing reinforcement cage
- installation of formwork
- concrete casting
- curing and finishing

The labour requirement assumed for jacketing one column is given below.

Table:2 Total cost of Labour for RC Jacketing

Labour type	No. Workers	Daily Wages (₹)	Cost (₹)
Mason	1	900	900
Helper	2	600	1200
Bar bender	1	800	800
Carpenter	1	800	800
Total Labour Cost = 3700 Rs			

5.1.11 Equipment Cost

Equipment used during RC jacketing includes tools required for concrete preparation and placement.

Table:3 Total cost of Equipment for RC Jacketing.

Equipment	Equipment cost
Concrete mixer	400
Vibrator	300
Cutting and drilling tools	300
Equipment cost = 1000 Rs	

5.1.12 Total Cost of RC Jacketing

The total cost of RC jacketing was obtained by summing the material, labour, and equipment costs.

Total Cost =Material Cost+ Labour Cost+ Equipment Cost

Total Cost = 19298 + 3700 + 1000

Total Cost of RC Jacketing = ₹ 23,998

5.2 Cost Evaluation for FRP Jacketing

The cost of FRP jacketing for the deficient RC column was evaluated using a material quantity and unit-rate based approach. The total cost was calculated by estimating the quantities of FRP sheets, epoxy adhesive, surface preparation work, and anchoring systems required for strengthening the column. These quantities were then multiplied by the corresponding market rates to obtain the total retrofitting cost

5.2.1. Column Geometry and FRP Parameters.

Column considered for FRP strengthening:

- Width (b) = 400 mm
- Depth (D) = 700 mm
- Height (H) = 3.5 m

a) Perimeter of column:  $P = 2 \times (b + D) = 2(0.4 + 0.7) = 2.2m$

b) Number of FRP layers:  $n = 1$

c) Width of FRP strip = 0.1m.

5.2.2. Quantity of FRP Material.

The quantity of FRP sheet required was calculated based on the perimeter of the column and the height of wrapping.

Quantity = Perimeter × Height

Quantity=2.2×3.5 =7.7m

Unit rate of CFRP laminate = ₹2950/m

Cost of FRP laminate = 7.7×2950 = ₹ 22,715

5.2.3. Surface Preparation Cost.

Proper bonding between FRP and concrete requires surface grinding and cleaning.

Surface preparation quantity = 7.7m

Rate = ₹ 120/m

Cost = 7.7×120Cost = ₹ 924

5.2.4. CFRP Anchors.

Anchors are used to prevent premature debonding of the FRP sheets.

Number of anchors = 17.5

Rate per anchor = ₹ 550

Cost = 17.5×550 = ₹ 9625

5.2.5. Total Cost of FRP Jacketing.

The total cost of FRP retrofitting was calculated as the sum of FRP laminate, surface preparation, and anchoring costs.

Total Cost = 22715 + 924 + 9625 = ₹ 33,264  
 Thus, the total cost of FRP jacketing for column C3 is approximately ₹33,264.

### 5.2.6 Labour Cost for FRP Jacketing.

FRP jacketing requires skilled technicians for fibre wrapping and epoxy application, along with helpers for surface preparation and handling materials.

Table:4 Total cost of Labour for FRP Jacketing.

Labour type	No. Workers	Daily Wages (₹)	Cost (₹)
Skilled technician	1	1200	1200
Mason	1	900	1200
Helper	1	600	800
Total Labour Cost = 2700 Rs			

### 5.2.7 Equipment Cost for FRP Jacketing.

The equipment used in FRP retrofitting mainly includes tools for surface preparation and installation.

Table:5 Total cost of Equipment for FRP Jacketing.

Equipment	Equipment cost
Grinding machine	400
Air blower/ cleaning tool	200
Mixing equipment for epoxy	200
Safety equipment	200
Equipment cost = 1000 Rs	

### 5.2.8 Total FRP Jacketing Cost.

The total cost of FRP jacketing was obtained by summing the material, labour, and equipment costs.

Total Cost=Material Cost+ Labour Cost +Equipment Cost

Total Cost = 33,264 + 2700 + 1000

Total Cost of FRP Jacketing = ₹ 36,964

### 5.3. Aesthetic Evaluation Criteria.

The visual and architectural impact of retrofitting techniques is a significant factor in choosing a suitable strengthening approach, in addition to structural efficiency and economic concerns. In order to evaluate the impact of FRP and RC jacketing on the enhanced column's architectural look, aesthetic assessment criteria were established. The first factor

taken into account was the change in column dimensions because conventional methods like RC jacketing greatly increase the cross-sectional size of the column, which may have an impact on the structure's useable internal space and aesthetic proportions. Another aspect looked at was the surface finish of the column. Since the FRP wrap produces a very uniform surface available for painting or coating immediately, and the RC jacketing (typical way of retrofitting) may need to have exterior texture materials applied (plaster or other finishing layers) to create a smooth finish, the surface finish was examined as a criterion. In addition to the surface finish, whether or not the altered column matched with the outside and inside architectural elements of the building was evaluated as compatibility with the original geometry of the building (the original structural design) because many of the retrofitting methods do not alter the original structural design [20]. When evaluating the effects of space loss due to structural retrofitting, it is necessary to consider the physical alterations that may occur within a building, such as the construction of concrete jackets around columns. These jackets may result in greater diameters of the column, thereby affecting the usable area of the floor above. Another aspect to evaluate is the amount of architecturally required finish treatment, such as additional protective coatings or surface preparations, necessary to maintain the building's aesthetic appearance after retrofitting has occurred. Together, these factors create an integrated method for assessing the visual impacts caused by various types of retrofitting and determining which methods of strengthening structural integrity will provide continued structural performance.

## VI. RESULTS AND DISCUSSION.

Based on cost calculation and aesthetic performance criteria, a comparison of RC and FRP jacketing procedures was conducted. The following displays the outcomes of the cost computations and qualitative evaluation criteria.

6.1 Cost Evaluation Results - The total cost of retrofitting for the selected column was estimated by accounting for the cost of labour, materials, and equipment for both approaches. According to the results, RC jacketing is less costly than FRP

jacketing. While RC jacketing was expected to cost ₹23,998 per column, FRP jacketing was expected to cost ₹36,964 per column. The main factor driving up the cost of FRP jacketing is the increased unit costs of CFRP sheets, epoxy resin, and anchoring materials specialized composite materials used for strengthening purposes. Construction operations that prolong the building process include concrete casting, curing, formwork installation, and reinforcement fixing. Conversely, RC jacketing uses conventional materials like concrete, reinforcing steel, and formwork that are readily available and economically priced. However, RC jacketing requires additional construction labour, such as formwork installation, concrete casting, curing, and reinforcement fixing, all of which add time to the building process.

jacketing gives a rather smooth surface that may be painted or coated right away. Consequently, FRP jacketing requires minimal additional finishing work.

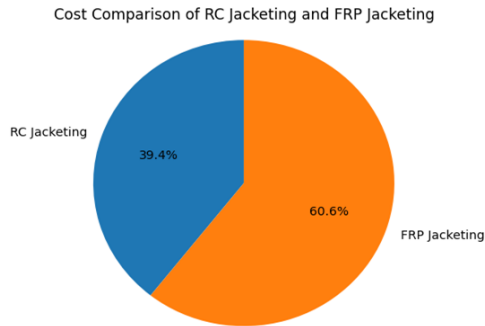


Fig 3: Cost Comparison

6.2 Aesthetic Evaluation Results -The aesthetic performance of both retrofitting techniques was evaluated based on predefined criteria, including modified column dimensions, surface finish quality, architectural compatibility, space reduction, and finishing standards. The results demonstrate that RC jacketing greatly improves column dimensions as the cross-sectional size of the column increases from 400 mm × 700 mm to 600 mm × 1000 mm after jacketing. This enlargement may reduce the quantity of usable floor space and have an effect on the architectural style of the structure. However, FRP jacketing results in very little change in column dimensions since FRP sheets are thinner than concrete jackets. This allows the original geometry of the column to be preserved without substantially altering the layout of the structure. In terms of surface finish, RC jacketing typically requires further plastering or finishing treatments, whereas FRP



Fig 4: Comparison of columns after RC jacketing and FRP jacketing retrofitting techniques.

### 6.3 Comparative Result

A comparative summary of the evaluated parameters is presented in Table

Table:6 Aesthetic Evaluation Criteria for Retrofitting Techniques

Criteria	RC Jacketing	FRP Jacketing
Column size change	High	Very low
Surface finish	Requires plastering	Smooth wrap surface
Architectural compatibility	Moderate	High
Space reduction	Significant	Negligible

Additional finishing	Required	Minimal
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## VII. CONCLUSION

Based on the comparative evaluation of RC jacketing and FRP jacketing techniques in terms of cost and aesthetic considerations, the following conclusions can be drawn:

1. RC jacketing is a more cost-effective method of retrofitting that uses conventional building materials including concrete, rebar, and formwork, which are commonly available and not so costly.
2. The thin wrap provided in FRP jacketing helps to maintain the visual appearance of the structural elements which, therefore, provides an additional aesthetic quality.
3. By using FRP jacketing, the column retains its original shape with a minimal increase in size, thereby reducing the impact on usable space.
4. In contrast to FRP, RC jacketing adds to the thickness of the columns; therefore, creating architectural disruption and reducing useful area in tightly packed buildings.
5. Based on this study, FRP jacketing is advantageous when considered for aesthetic characteristics and available space; however, RC jacketing should be the solution of choice when financial restrictions prevail.
6. To ensure a retrofitting solution is practical and attractive, it must address structural needs while respecting the architectural character of the building.

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