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Review Article

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Amplifying Column Resilience and Retrofitting of Nano Defects: A Profound Review of Advanced Wrapping Methodologies

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Abstract: In order to sustain the vertical load and guarantee the stability of various constructed environments, structural columns are essential. These columns can lose their integrity over time as a result of things like age, corrosion, seismic activity, or modifications in the conditions under which they are loaded unlike designed results in nano defects. If this is the case, conventional techniques of rehabilitation and strengthening might not be adequate to help them return to their prior levels of performance. Nowadays, wrapping techniques have become one of the most efficient and cutting-edge methods for improving the load-bearing capacity, ductility, and longevity of columns. The numerous wrapping techniques used to strengthen and refit columns to lengthen their useful lives are thoroughly analyzed in this paper. The objective is to provide a complete understanding of the concepts, elements, and practical uses related to different wrapping strategies. Steel, fiber-reinforced polymers (FRP), soft computing methods, and hybrid materials are some of the strategies that are currently being looked at. The fundamental physics of column wrapping, such as stress redistribution, confinement, and interactions between the material used for wrapping and the host column's structure are listed. The review additionally emphasizes how important suitable design, material selection, installation strategies, and quality control methods are to the successful implementation of column wrapping techniques. Numerous kinds of factors, such as the environment, loading patterns, and long-term performance, have been taken into account to shed light on the resilience and sustainability of wrapped columns. The detailed examination of wrapping techniques in this article offers a comprehensive picture of the most significant present progress and potential in the field of column strengthening, improving the overall toughness and resilience of built structures.

Keywords: Retrofitting, Jacketing, Partial wrapping, Soft computing, Ductility improvement, Structural enhancement, Nano cracks

1. Introduction

Structural columns provide support and stability for a wide range of structures, including housing developments, bridges, and commercial and industrial buildings. Structural columns are very vital architectural components. But with time, factors including aging, environmental damage, and increased weight requirements can impact how well these columns' function. It is now essential to use effective repair and strengthening procedures (Figure 1) to maintain the safety and sturdiness of existing structures [1]. The ideal column wrapping techniques depend on the exact project requirements and conditions. The item may be covered in steel or concrete, epoxy, or fiber-reinforced polymer, among other common techniques [2]. Traditional column rehabilitation techniques including jacketing, encasing, and external post-tensioning are frequently used to solve performance issues [1]. However, these techniques frequently come with drawbacks such added weight, a restricted range of adaptation, and trouble ensuring uniform confinement [2]. Wrapping techniques have become an effective and creative way to improve the load-bearing capacity, ductility, and longevity of columns in response to these limits [3].

Using wrapping strategies, specialized substances are applied to the surface of columns in the form of sheets, strips, or grids, such as fiber-reinforced polymers (FRP), steel the sheets or hybrid combinations [4]. These components are attached to the column surface either externally or inside, near to the column perimeter. In order to improve the structural performance of columns, the wrapping procedure seeks to effectively limit stresses, redistribute them, and increase their flexural and shear behaviour wisely [5]. One of the wrapping methods used to reinforce columns that have been damaged by earthquakes, fire, or other catastrophes is called jacketing. Additionally, it can be used to reinforce columns that are potentially unable to carry the loads for which they were intended. A number of different Reinforced concrete columns can be strengthened using one of the adaptable approaches known as jacketing [6].

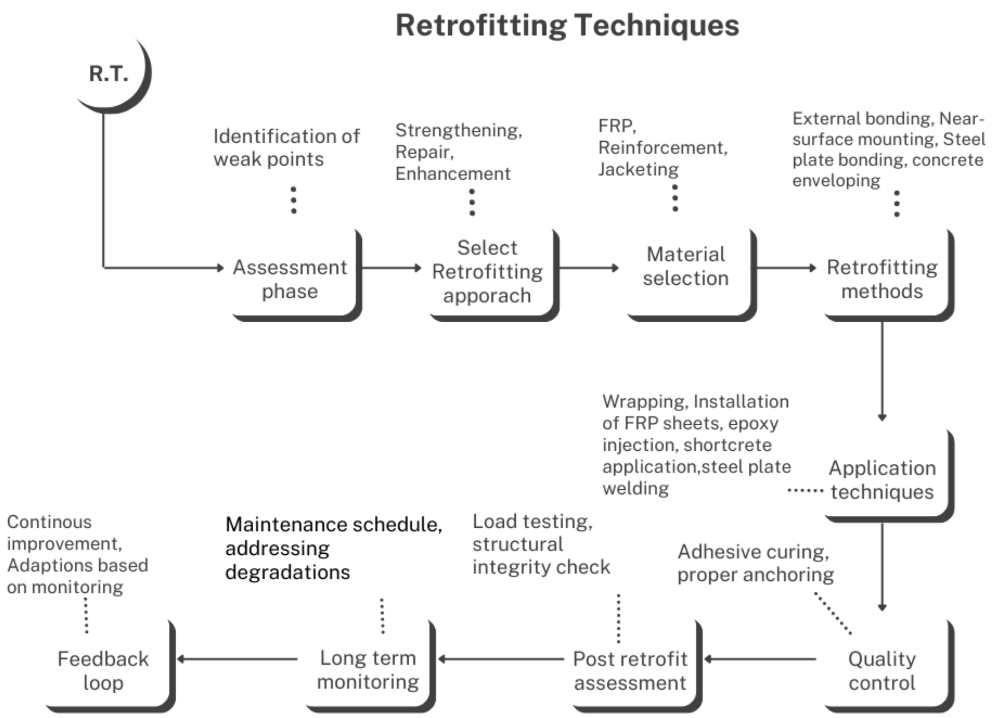


Figure 1. Work flow of Retrofitting techniques [8].

Figure 2. Before wrapping of specimen [8]

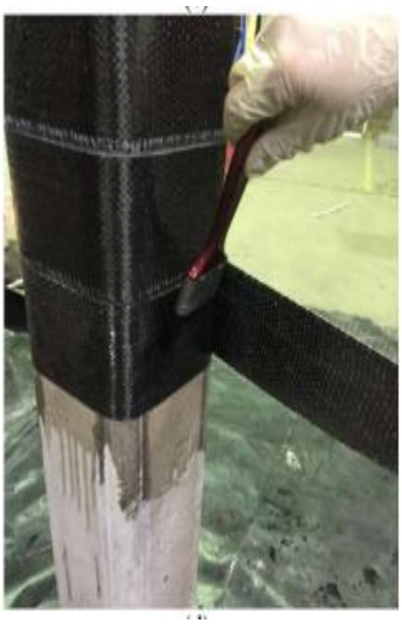


Figure 3. Wet lay-up technique for wrapping [8]

By restricting the lateral expansion of concrete by transversely wrapping the columns with FRP, the structure's strength and ductility are significantly increased [7]. a number of accessible research papers looked at the efficiency of complete wrapping. Despite this, there aren't many studies on FRP-wrapped columns, which examined the behaviour of partly FRP-wrapped structures. The RC's ductility and strength were allegedly enhanced by the partial FRP covering, constructions with columns [8]. Wrapping only partially offers many advantages, compared to totally wrapping. Partial wrapping can prevent the formation of potential air gaps between the FRP and the concrete surface. It is less expensive because less adhesive and FRP are needed [8]. Figure 2 shows before wrapping of specimen and wet lay-up technique in figure 3.

2. Fundamental Mechanics of Wrapping

The fundamental mechanics of wrapping a structural column involve the application of an external material, typically Fiber-Reinforced Polymer (FRP) or similar composite materials, around the column's perimeter [9]. This wrapping process is aimed at enhancing the column's load-carrying capacity, ductility, and overall performance.

a) *Confinement Effect:* Wrapping the column with FRP creates a confining effect on the concrete core. This confining pressure restricts the lateral expansion of the concrete when subjected to axial loads or lateral forces. As a result, the confined concrete experiences an increase in compressive strength, allowing the column to bear higher loads before reaching failure [9].

b) *Redistribution structural Stress:* Within the column, the FRP wrapping redistributes stresses. Due to the structure's confinement, whenever the column is subjected to external stress, the stresses are more equally distributed across the cross-section. This redistribution aids in postponing the start of column buckling or concrete crushing [5].

c) *Enhancement of shear:* Wrapping may additionally render columns more resistant to shear. The FRP material adds a second layer of support, strengthening the column's ability to withstand shear stresses. This is crucial in earthquake-prone areas where shear failure can be a serious problem [10].

d) *Enhancement of Axial Load:* The column's ability to support axial loads is increased by the constraining effect of FRP wrapping. It shields the concrete from early failure mechanisms including crushing and spalling, allowing the column to withstand greater axial forces.

e) *Improvement of ductile property:* Wrapping increases the column's ductile property, which is defined as its capacity to flex under load without abrupt collapse meeting the structural failure criteria. The column may experience bigger deformations before it reaches its maximum capacity because to the confining pressure generated by the FRP, which increases the structure's overall durability also.

f) *Strengthening of flexure property:* Wrapping not only increases the capacity to withstand axial loads but additionally improves flexural strength too. It upgrades the column's resistance to bending moments, which is particularly advantageous in constructions that experience lateral loads or moments.

g) *Bonding at the Interfacial Layer:* A successful wrapping depends on a strong connection between the FRP material and the concrete surface of the structural member. In order for the FRP to work together with the concrete, right preparation of the surface and adhesive coating must be made to establish a strong connection between concrete and the wrapping material [5-9].

In conclusion, a structural column's behaviour is changed by the confinement, stress redistribution of shear and axial weight augmentation, increased ductile behaviour of the structural member, and flexural strengthening that FRP or related materials provide. Together, these mechanics provide a more robust and load-bearing column, enhancing the overall functioning and security of the structure.

3. Effect of wrapping technique on flexural and shear behaviour of structural columns

3.1 Flexural Behaviour

Higher Flexural Performance: By enclosing the concrete core, wrapping increases the flexural capacity of columns significantly [13]. The aforementioned limitation limits the concrete's lateral expansion, enabling it to withstand greater bending moments before failing. Particularly in columns subjected to large loads or lateral stresses, the greater capacity is advantageous thus results in sound structural member.

Slow cracking: Flexural nano cracks may form and spread more slowly as a result of the wrapping. The FRP material functions as an exterior reinforcement that spans and supports cracks, narrowing them, and preventing premature cracking [10].

3.2 Shear Behaviour

Improved Shear Strength: Wrapping columns considerably increases their shear resistance. The FRP material's increased exterior confinement strengthens the column's capacity to withstand stresses caused by shear [12]. This is especially important for buildings with high dynamic loads or those situated in seismic zones.

Improved Shear Ductility: Similar to flexural behaviour, wrapping enhances the shear ductility of columns. The confinement effect prevents shear failure from occurring suddenly, allowing the column to undergo larger deformations before shear failure ultimately takes place [9].

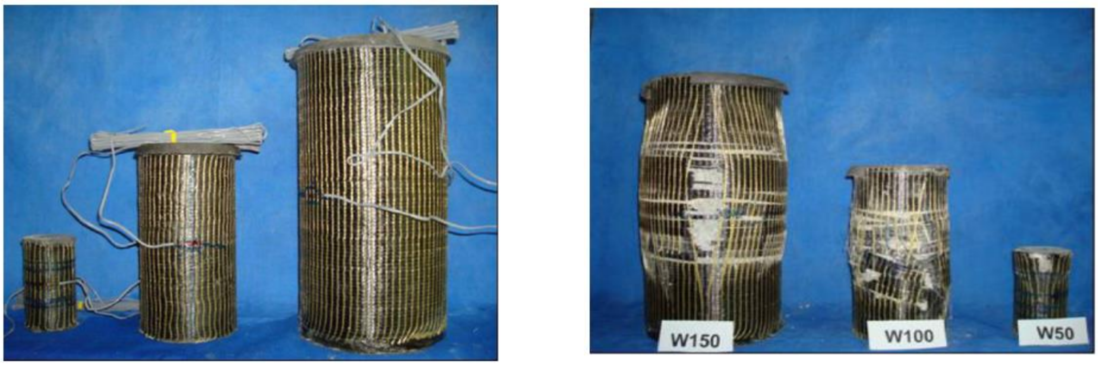
Crack Control: Wrapping helps control shear cracks and prevents their widening. The FRP material limits the opening of shear cracks, reducing the potential for degradation of shear strength due to crack propagation [4-10].

Table 1. Quantities of ingredients used [7]

Ingredients	**Quantity per m3**
Cement	350 kg
Fine aggregate	195 kg
Silica fine aggregate	585 kg
Aggregate size of 10 mm	315 kg
Aggregate size of 20 mm	735 kg
H_2O	175 kg
Admixture	06% by cement weight

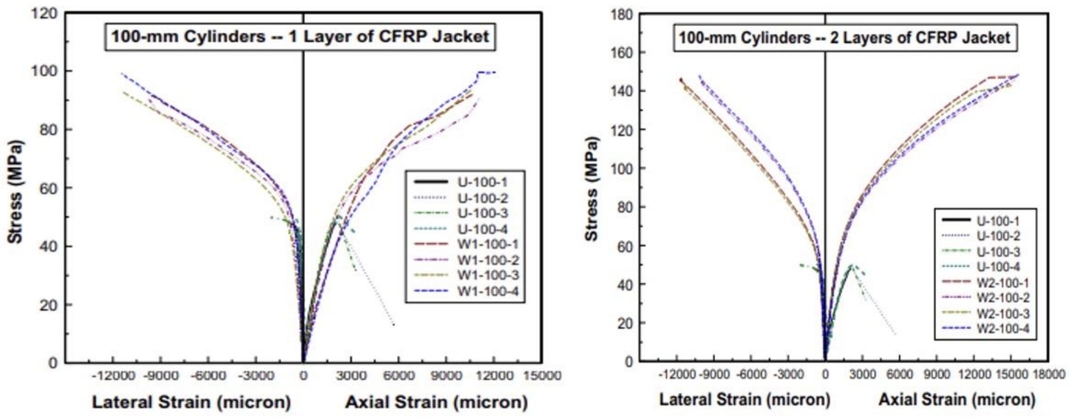
(a) **(b)**

Figure 4. Unwrapped cylindrical specimens before (a) and after (b) testing [7]



(a) **(b)**

Figure 5. Wrapped cylindrical specimens before and after testing [7]



(a) Specimens with 1 layer of CFRP jacket (b) Specimens with 2 layers of CFRP jacket

Figure 6. Stress strain curve of different wrapping thickness [7]

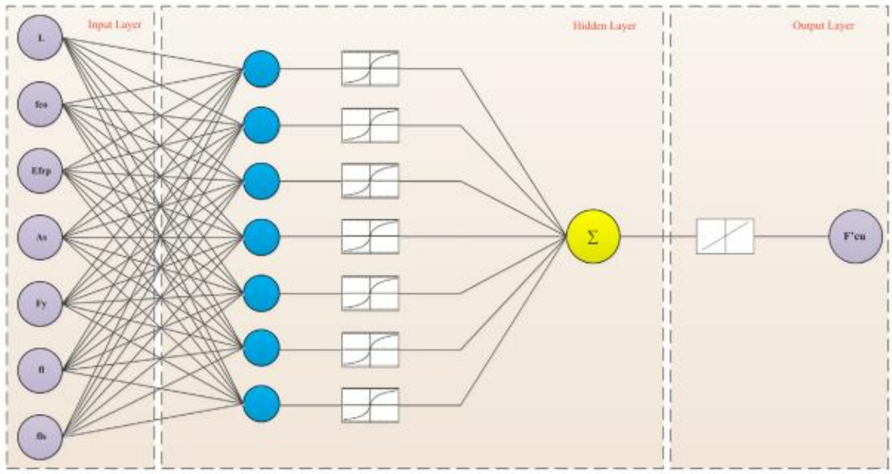


Figure 7. Illustrative depiction of ANN model structure [11]

4. Laboratory inquiry or Empirical investigation

4.1 Wrapping on different sizes of specimens

Elsanadedy et al. [7] investigated by using a nomenclature made up of four-character codes has allowed for the differentiation of test specimens. The primary two characters, U and W, signify for wrapped and control specimens, respectively. The number of CFRP layers is indicated by the first numerical digit in the nomenclature. The next digit represents the test specimens' diameter (measured in millimeter), and the last digit is the specimen's sequential number. For instance, the symbol W3-100-2 designates a specimen with a 100 millimeter diameter and three layers of CFRP jacketing. The specimen can be recognized as the second of its kind by the terminal character in the code. The absence of this attribute suggests that the average value generated from all of the specimens is taken into account. Figure 4 & 5 depicts before and after testing of wrapped and unwrapped specimens. Figure 6 shows the variation of stress-strain curve for different thickness of wrap for 100 mm diameter cylinders.

4.2 Soft computing methods of structural member

Using soft computing techniques (ANN,GEP and GMDH), Naderpour et al. [11] investigated and forecasted the compressive strength of circular reinforced concrete columns contained by FRP (Figure 7). 95 experimental data sets were chosen from a sizable database for the development of models. Using a total of seven input parameters for the first time shows how accurate the ANN method is in predicting outcomes when compared to other approaches. Finally, it may be said that approaches to soft computing have the bonus of being easily implemented in parallel architectures, which would significantly shorten processing time compared to other methods while producing equivalent results.

4.3 Wrapping technique by varying the thickness

Vijayan et al. [2] The experimental investigation executed by the authors primarily dealt with evaluating the performance of reinforced polymer glass fiber-infused concrete columns. The empirical learnings from external E-glass fiber composite-reinforced concrete column studies showed observable improvements in load-bearing capacity and strain performance. Comparing the 3 mm and 5 mm wrapped samples in the setting of M40 grade concrete demonstrated a significant 5.2% increase in favour of the latter. Comparing the no wrapping, 3 mm and 5 mm wrapped specimens, it was found that the 5 mm wrapped type significantly outperformed its 0 mm counterpart by 2.47%, using wrapping material of 5 mm resulted in the achievement of the highest structural strength.

5. Research Significance

The in-depth study of wrapping methods demonstrates their potential to increase load-bearing capacities as well as to reduce probable failure mechanisms, strengthen structural resilience, and prolong the useful life of constructed assets. The conclusions drawn from the published articles demonstrate the value of wrapping techniques as a key tactic for overcoming structural flaws and safeguarding infrastructure against various loading situations.

6. Conclusions

The studied corpus of research emphasizes the wrapping techniques' certain effectiveness as a workable option for strengthening the load-bearing capacity of structural columns. As cited, numerous studies have repeatedly shown how using different wrapping materials and configurations can significantly improve both flexural and shear performance.

Collectively, the study results in the publications under review demonstrate that partial wrapping, in particular, is a practical alternative to full wrapping, striking a careful balance between improved performance and cost-effectiveness.

The application of wrapping techniques crosses geographic limits, as shown by the wide range of research taken into account, and finds importance in a variety of structural situations, including structures such as bridges and buildings and industrial facilities. These discoveries have important consequences for strengthening infrastructure all across the world, which will improve the durability and general security of constructed environments.

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Conflict of interest

The Authors declares that there is no conflict of interest anywhere.

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Yes