

# Experimental Study on the Confinement of Short Reinforced Concrete Columns Using Waste Tyre Tube as Internal Confinement Material

Ajay Rajput<sup>1</sup>, Mangesh Phad<sup>1</sup>, Rahul Potenavaru<sup>1</sup>, Diksha Ugale<sup>1</sup>, Atul P. Khatri<sup>2</sup>

<sup>1</sup>Student, Department of Civil Engineering, Marathwada Mitra Mandal's Institute of Technology, Pune, India

<sup>2</sup>Professor, Department of Civil Engineering, Marathwada Mitra Mandal's Institute of Technology, Pune, India

Email: [ajay.rajput22@mmmit.edu.in](mailto:ajay.rajput22@mmmit.edu.in) | [mangesh.phad23@mmmit.edu.in](mailto:mangesh.phad23@mmmit.edu.in) | [rahul.potenavaru22@mmmit.edu.in](mailto:rahul.potenavaru22@mmmit.edu.in)  
[diksha.ugale22@mmmit.edu.in](mailto:diksha.ugale22@mmmit.edu.in) | [atul.khatri@mmmit.edu.in](mailto:atul.khatri@mmmit.edu.in)

## ABSTRACT

This paper presents an experimental study on the use of waste tyre tube as an internal confinement material for short reinforced concrete columns subjected to axial compression. Conventional confinement methods such as steel jacketing and fibre reinforced polymer (FRP) wrapping are effective but expensive and depend on industrially processed materials. At the same time, the disposal of waste tyre tubes is a growing environmental problem. This study explores whether strips cut from waste tyre tubes can be used as a low-cost, sustainable alternative for confining concrete columns. M25 grade concrete and Fe550 steel reinforcement were used to cast nine column specimens of size 150 mm × 300 mm × 700 mm. The specimens were divided into three groups of three each — unconfined (control), single-layer confined, and double-layer confined — with tyre tube strips wrapped in polythene sheets placed internally around the reinforcement cage. After 28 days of water curing, all specimens were tested under axial compression in a Universal Testing Machine (UTM). The single-layer confined columns showed an average increase in load carrying capacity of 8.95 percent over the control columns, while the double-layer confined columns showed an increase of 11.80 percent. Confined columns also showed more gradual failure with less spalling compared to the sudden brittle failure of unconfined columns. The results show that waste tyre tube confinement is a workable, low-cost and eco-friendly method to improve the strength and ductility of short RC columns.

**Keywords:** Column confinement; waste tyre tube; ductility; sustainable construction; axial compression; Universal Testing Machine

## 1. INTRODUCTION

Reinforced concrete (RC) columns are one of the most important structural members in any building. They carry the load from beams and slabs above and pass it safely down to the foundation. Because of this, the strength and behaviour of columns has a direct effect on the safety of the whole structure. Plain concrete, however, is brittle in nature. When a column is loaded in compression, the concrete tends to crack and spall suddenly, often without much warning. This kind of failure is dangerous, especially in tall buildings where many floors depend on the same column.

To improve the strength and ductility of columns, engineers use different confinement methods. Closely spaced steel ties, steel jacketing and FRP wrapping are some of the common techniques used in practice. These methods do work well, but they are costly and usually need skilled labour and special equipment to install. This makes them less practical for everyday, low-budget construction.

At the same time, the disposal of waste tyres and tyre tubes has become a serious environmental problem. Tyres do not decompose easily, and burning them releases harmful gases. Because of their high elasticity and ability to absorb energy, waste tyre rubber has good potential for use in construction. If used properly, it can give some of the benefits of confinement at a much lower cost, while also reducing rubber waste.

This study looks at the use of waste tyre tube strips as an internal confinement material for short RC columns. The strips are placed inside the column, around the reinforcement cage, before the concrete is cast. This is different from most of the confinement methods reported in literature, which are applied on the outside of an already-built column. Nine column

specimens were cast and tested to compare the behaviour of unconfined columns with columns confined using one layer and two layers of tyre tube strips.

## 2. LITERATURE REVIEW

A number of studies have looked at different materials for confining RC columns, ranging from conventional steel and FRP systems to natural fibres and waste-based materials.

Kunjuvareed and Abhilasha [1] studied columns confined with bamboo sheet twinning tubes and found a clear improvement in compressive strength and ductility, showing that natural materials can work as a low-cost alternative to steel or FRP. Khatri and Hinge [2] compared several confining materials on rectangular RC short columns and reported strength gains in the range of 15 to 68 percent, along with more ductile failure compared to unconfined columns.

Susilorini and Kusumawardaningsih [3] tested columns confined with ultra-high-performance concrete (UHPC) and fibre-reinforced UHPC, and found large increases in load capacity, though at a much higher material cost. Yeon et al. [4] used internal Fe-SMA spirals that gave active confinement through shape memory effects, improving both strength and ductility, but this method needs special activation equipment and is still mostly experimental.

Hussain et al. [5] showed that even simple rope wrapping can improve the axial capacity and deformation behaviour of columns at very low cost. Bastami et al. [6] used hexagonal chicken wire mesh under cyclic loading and reported up to 22 percent increase in strength and 65 percent improvement in ductility, with only a small increase in cost, making it an attractive option for seismic retrofitting.

Several studies have also looked at natural fibres such as banana, jute, sisal and coir as confinement or reinforcement material [7–12]. These materials are cheap and widely available, and generally improve tensile strength, crack control and ductility, though the gains are usually smaller than what steel or FRP can give. Studies on recycled plastic fibres and mesh [13,14] reported similar trends — moderate strength improvement along with better crack control, while also reducing plastic waste.

Overall, the literature shows that confinement — no matter what material is used — generally improves both strength and ductility of RC columns. Very little work, however, has looked at waste tyre tube as an internal confinement material placed inside the column during casting, rather than as an external wrap applied later. This gap forms the basis of the present study.

## 3. MATERIALS AND METHODOLOGY

### 3.1 Materials Used

Ordinary Portland Cement (OPC) of 43 grade was used as the binder. Natural river sand of Zone II was used as fine aggregate, and crushed angular coarse aggregate of 20 mm maximum size was used as coarse aggregate. Clean potable water was used for mixing and curing. Fe550 grade TMT bars were used for both longitudinal reinforcement and lateral ties. Waste tyre tube, wrapped in polythene sheet, was used as the internal confinement material, and Fevicol Heat X adhesive was used to bond and position the strips during fabrication. A summary of the materials is given in Table 1.

| Material             | Specification   |
|----------------------|-----------------|
| Concrete grade       | M25             |
| Cement               | OPC 53 Grade    |
| Reinforcement        | Fe 550          |
| Confinement material | Waste tyre tube |
| Protective layer     | Polythene sheet |
| Adhesive             | Fevicol Heat X  |

Table 1. Materials used in the study

### 3.2 Mix Design

The concrete mix was designed for M25 grade as per IS 10262:2019 and IS 456:2000. The target mean strength was calculated as  $f_{ck} + 1.65S$ , taking  $f_{ck}$  as 25 MPa and  $S$  as 4 MPa, which gives a target mean strength of 31.6 MPa. A water-cement ratio of 0.42 was adopted based on the exposure condition and the required workability. The same mix was used for casting all nine specimens, so that concrete quality remained constant across the unconfined and confined groups.

### 3.3 Specimen Details

A total of nine short RC column specimens of size 150 mm × 300 mm × 700 mm were cast. Each specimen had four longitudinal bars of 12 mm diameter and lateral ties of 8 mm diameter, with a clear cover of 40 mm. The specimens were divided into three groups of three each: unconfined (control) columns, single-layer tyre tube confined columns, and double-layer tyre tube confined columns. The design parameters are summarised in Table 2.

| Parameter                  | Details                                          |
|----------------------------|--------------------------------------------------|
| Column size                | 150 × 300 × 700 mm                               |
| Grade of concrete          | M25                                              |
| Grade of steel             | Fe 550                                           |
| Longitudinal reinforcement | 4 bars of 12 mm diameter                         |
| Lateral ties               | 8 mm diameter                                    |
| Confinement material       | Waste tyre tube                                  |
| Loading type               | Axial compression (UTM)                          |
| Curing period              | 28 days, water curing                            |
| Total specimens            | 9 (3 unconfined, 3 single-layer, 3 double-layer) |

Table 2. Design parameters of column specimens

### 3.4 Specimen Fabrication and Testing

Waste tyre tubes were cleaned and cut into strips 95 mm wide, with length calculated as  $L = 2(A + B) \times 1.25$ , where  $A$  and  $B$  are the core dimensions after deducting clear cover, and the 1.25 factor provides sufficient overlap for secure tying. Each strip was wrapped in a thin polythene sheet to protect it from the alkaline cement environment before being bonded to the reinforcement cage using Fevicol Heat X adhesive, between the lateral ties, at four positions along the column height. For single-layer specimens one strip was placed at each position; for double-layer specimens two strips were stacked. The completed cages were placed centrally in formwork, and M25 concrete was cast in layers and compacted using a needle vibrator. Specimens were demoulded after 24 hours and water-cured for 28 days. After curing, all nine specimens were tested under concentric axial compression in a Universal Testing Machine (UTM) at a controlled loading rate until failure, with ultimate load and crack development recorded throughout.



Fig. 1. Reinforcement cages prepared for the three specimen groups — double-layer confined, single-layer confined, and unconfined control (left to right)



Fig. 2. Column specimens undergoing 28-day water curing



Fig. 3. Cured column specimens after 28-day curing, prior to axial compression testing

## 4. RESULTS AND DISCUSSION

### 4.1 Ultimate Load Carrying Capacity

Table 3 shows the ultimate axial load recorded for each of the nine specimens, along with the average value for each group.

| Specimen ID | Type         | Confinement | Ultimate Load $P_u$ (kN) | Average $P_u$ (kN) |
|-------------|--------------|-------------|--------------------------|--------------------|
| C1          | Control      | Unconfined  | 597.36                   |                    |
| C2          | Control      | Unconfined  | 602.88                   | 596.92             |
| C3          | Control      | Unconfined  | 590.51                   |                    |
| S1          | Single Layer | 4 strips    | 650.73                   |                    |
| S2          | Single Layer | 4 strips    | 658.86                   | 650.38             |

|    |              |          |        |        |
|----|--------------|----------|--------|--------|
| S3 | Single Layer | 4 strips | 641.51 |        |
| D1 | Double Layer | 8 strips | 680.89 |        |
| D2 | Double Layer | 8 strips | 662.46 | 667.28 |
| D3 | Double Layer | 8 strips | 658.43 |        |

Table 3. Ultimate axial load carrying capacity of all specimens

The unconfined control specimens (C1–C3) gave an average ultimate load of 596.92 kN. The single-layer confined specimens (S1–S3) showed a clear improvement, with an average of 650.38 kN, and the double-layer confined specimens (D1–D3) gave the highest average load of 667.28 kN. This shows a steady increase in load carrying capacity as the level of confinement increases, which matches the general trend reported for other confinement materials in the literature reviewed in Section 2.

#### 4.2 Percentage Increase in Load Carrying Capacity

Table 4 and Fig. 4 show the percentage increase in average load carrying capacity for the confined groups, compared to the unconfined control specimens.

| Specimen Type | Average Ultimate Load (kN) | % Increase over Control |
|---------------|----------------------------|-------------------------|
| Unconfined    | 596.92                     | —                       |
| Single Layer  | 650.38                     | 8.95                    |
| Double Layer  | 667.28                     | 11.80                   |

Table 4. Percentage increase in load carrying capacity due to confinement

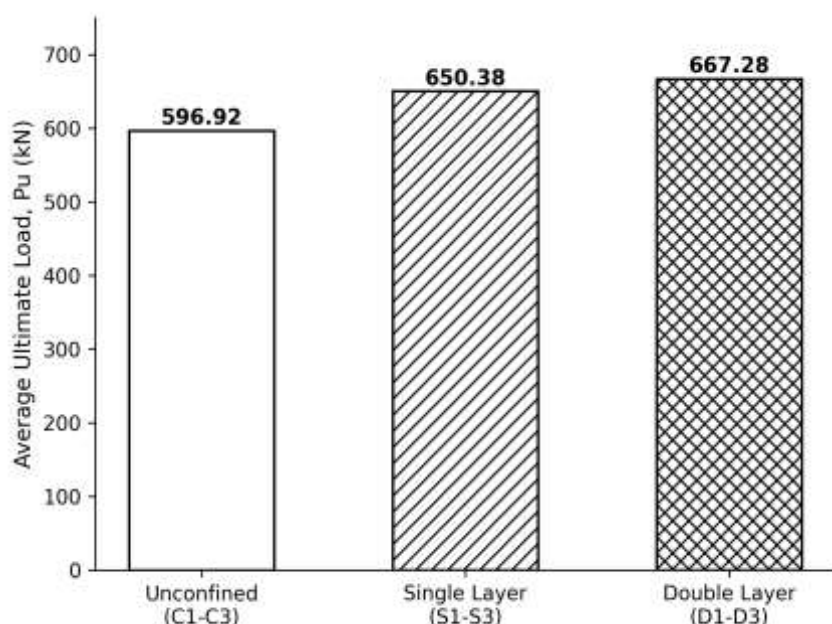


Fig. 4. Average ultimate load carrying capacity of unconfined, single-layer and double-layer confined columns

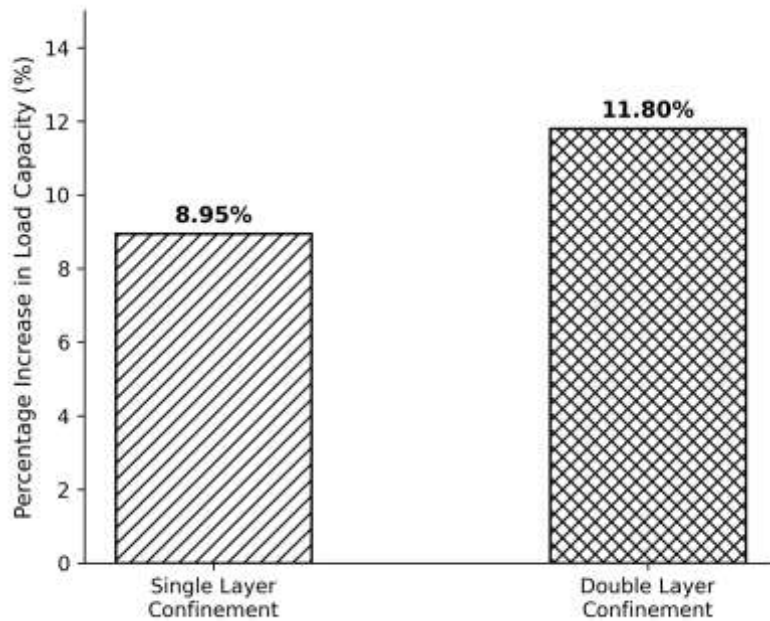


Fig. 5. Percentage increase in load carrying capacity over the unconfined control

Single-layer confinement gave an increase of 8.95 percent, while double-layer confinement gave 11.80 percent. The improvement is moderate compared to some of the high-performance confinement systems reported in literature (such as UHPC or Fe-SMA, which can give increases of 50 percent or more), but it is achieved at a very small fraction of the material cost, using a material that would otherwise be discarded.

### 4.3 Failure Pattern and Crack Behaviour

All specimens showed gradual crack development with increasing load, starting with fine hairline cracks near the top and bottom of the column. The unconfined control specimens failed in a brittle manner, with sudden crushing and noticeable spalling of the cover concrete once the peak load was reached. There was very little warning before failure in these specimens.

The single-layer confined specimens behaved better than the control specimens. Cracking was delayed and the cracks were generally smaller and more evenly spread along the column. The double-layer confined specimens performed the best among the three groups — cracking and spalling were noticeably reduced, and the columns continued to carry load over a larger deformation range before final failure. This shows that the tyre tube strips, even though they are much softer than steel, do provide a real restraining effect on the concrete core once it begins to expand sideways under load.

### 4.4 Discussion

The results confirm that waste tyre tube, when placed internally around the reinforcement cage, can act as an effective confinement material for short RC columns. The increase in strength is moderate but consistent, and the change in failure behaviour — from sudden brittle failure to a more gradual, ductile-type failure — is arguably the more important finding from a safety point of view. A column that gives some warning before failing is far more desirable in practice than one that simply snaps without notice, particularly under earthquake loading.

It is also worth noting that the confinement strips were placed only at a few discrete locations along the 700 mm height of the column, rather than continuously. This is likely one reason the strength gain is more modest than what is reported for some continuous wrapping systems in literature. A more closely spaced or continuous arrangement of tyre tube strips may give a larger improvement, and this is suggested as a direction for further work.

From a practical standpoint, the cost of the confinement material used in this study is very low, since it is sourced entirely from waste. Combined with the simple installation process — no special tools or skilled labour are required — this makes waste tyre tube confinement an attractive option for low-cost housing and small-scale construction, where conventional confinement methods are usually not economically feasible.

## 5. CONCLUSION

This study examined the use of waste tyre tube as an internal confinement material for short reinforced concrete columns under axial compression. Based on the experimental results, the following conclusions are drawn:

1. Internal confinement using waste tyre tube strips improves the axial load carrying capacity of short RC columns. Single-layer confinement gave an average increase of 8.95 percent, and double-layer confinement gave 11.80 percent, compared to unconfined control columns.
2. Confined columns showed more gradual, ductile-type failure with reduced spalling, compared to the sudden brittle failure observed in unconfined columns.
3. Double-layer confinement performed better than single-layer confinement in terms of both strength and observed ductility, confirming that the degree of confinement has a direct effect on column performance.
4. Waste tyre tube is a low-cost, locally available and eco-friendly confinement material. Its use also helps in reducing the environmental burden caused by tyre waste disposal.
5. The technique is simple to apply, requiring no special tools or skilled labour, which makes it a practical option for low-cost and small-scale construction.

## 6. FUTURE SCOPE

The present study was limited to short columns under concentric axial loading. Future work can look into the behaviour of tyre tube confined columns under eccentric and cyclic (seismic) loading, since this would give a clearer picture of their performance under real earthquake conditions. Long-term durability of the rubber inside the alkaline concrete environment, and the effect of a more closely spaced or continuous strip arrangement on confinement efficiency, are also worth investigating. A direct comparison with conventional confinement methods such as steel jacketing and FRP wrapping, along with a full cost analysis, would help establish the practical value of this technique more clearly.

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