Behaviour of Circular RC Column Confined with Textile Reinforced Mortar under Compression Load

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Abstract. The effectiveness of a new structural material, namely textile-reinforced mortar (TRM), was investigated experimentally in this study as a means of confining circular RC columns with two layers at different wrapping design. Four circular columns with size 600 mm height and 150 mm diameter were wrapped with glass fibre mesh at different types of wrapping design was prepared and tested under compression load. This study aims to establish an in-depth understanding on the effect of wrapping material and the design as a contributing factor in increment of load capacity. This research come into conclusion that wrapping the circular columns with TRM has increased the load capacity for the columns as compared to unwrapped columns, the best design is 100% wrapping with 14% increment in strength. Moreover, multiple researches have proven the efficacy of TRM wrapping design with different type of materials used in their studies. Based on the contemporaneity researches, this study was the first in term of studying the behaviour of circular RC column confined with various types of glass fibre design.

1. Introduction

In strengthening field there are multiple types of strengthening systems that have been tested experimentally on different structural elements to study the behaviour of the retrofitting materials under different types of loads. In the study by [1], non-woven steel fibre was tested, while [2] used Self-compacting concrete as a strengthening system.

The most common strengthening material that have been used to retrofit the structural element it is fibre- reinforced polymer (FRP) due to its’ benefit as it is light weight, has high strength, thermal insulation, radiation-resistant, corrosion-resistant, and low temperature. On the contrary, the disadvantages of FRP is the material's strength decreases and deflection increases if it exposed to high temperature. These materials will continue to deflect under heavy, sustained loads. Impact loading during collisions can damage these materials, and it also cost higher compared with other materials. As a result of all those disadvantages, the researchers used an alternative material trying to avoid FRP disadvantages; [3] used the fibre reinforced cementitious matrix (FRCM) as an alternative material to FRP because FRP composite materials use epoxy resin to bond concrete with external composite reinforcement, FRCM instead uses composite jacket embedded in mineral mortar for applications in elevated temperatures. In another study by [4] a strengthening material which consists from steel fibre combined with inorganic matrix; cementitious grout matrix (SRG) were used as an alternative material to FRP. SRG material according to experiments will work as a retrofit solution for reinforced concrete confinement, they found that the SRG increase substantially both compression strength and deformation capacity and the behaviour of the low density type it was more effective than the FRP.
Another material that has been used as an alternative is the textile-reinforced mortar (TRM). Moreover, TRM is an effective material that can be used as an enhancing solution because it integrates the outstanding properties of composite materials (high strength, low weight, corrosion resistance, fire resistance, low cost, ability to apply on wet surfaces, air permeability of the substrate) and other properties which cannot be found in resins. [5] used TRM as a strengthening material to increase the deformation capacity of old-type RC columns subjected to simulated seismic loading and to increase the shear and flexural resistance of RC members, as evaluated by comparing it with equivalent fibre-reinforced polymer (FRP). The results presented in this study showed that TRM jacketing of RC is nearly as effective as FRP jacketing. As studied by [6] on the shear bond between TRM and masonry, it was observed that the failure was due to slippage within the mortar itself and synchronized to fibre rupture. [7] studied behaviour of glass-TRM strengthened RC column. They observed only slight increase in load capacity due to the significant concentration of stresses in the corners of column.

Therefore, in the light of previous researches done by other fellow researchers and the favourable results of adapting TRM as the strengthening materials as compared to alternatives materials; TRM has been employed in this study as a strengthening system to measure the increment of load capacity for circular RC columns that subjected to compression load.

2. Methodology
The concrete strength that was adopted in this study is 15 MPa. Based on ACI 318-14 Ordinary Portland Cement (OPC), crushed limestone with nominal maximum aggregate size of 10 mm and local sand with size in between (0.1-0.2) mm have been used in the concrete mixture. The sand and aggregate have been dried in the oven for one day at 120°C. Mixture content were as illustrated in Table 1.

In terms of the reinforcement, 6 bars for the longitudinal reinforcement with 6 mm diameter (ACI 318-14) [8] and 6 stirrups for the transverse reinforcement with 4 mm diameter. Referring to experiment of [9], the stirrups were located at the first 10 cm in the top and the bottom of the column.

Five columns were prepared with multiple wrapping design, the first column namely Tc is designed with no strengthening wrapping to be employed as reference for other specimens. The second column, T4.1 were wrapped with 100%. Followed by wrapping of 70% for specimen column T4.3, where it was wrapped from the centre with 35% length covering each the top and bottom region. Next is T6.2 at 50%, of which from the centre, 25% of the top and bottom region were covered. Lastly, for column T6.4 with (50+10+10) %, the 50% part shared the same wrapping method as specimen T6.2 but were varied with additional wrapping of 10%+10% at the first 60 mm of the top and bottom.

### Table 1. Concrete mixture content.

| Mixture design  | Cement (kg/m³) | Aggregate (kg/m³) | Sand (kg/m³) | Water (kg/m³) |
|----------------|----------------|------------------|--------------|---------------|
| For one specimen (kg) | 475.9 | 753.5 | 787.22 | 228.4 |

| For one specimen (kg) | 4 | 13.5 | 9.5 | 2.5+0.7 |

2.1. Casting of columns
In this experiment, 600 mm height and 150 mm diameter of circular moulds were used, and the specimens were divided into batches to ensure the concrete quality. Each batch contains four specimens that were casted in the same day in order to make sure that the various TRM design specimens to be broken under compression load will have the same mix design. In the subsequent stage, curing, the batches were soaked for 14 days. It was then taking out of the water to wrapped it with two layers of woven glass fibre mesh covered with mortar and soaked again for another 14 days to accumulate 28 days. The columns were then tested by compression machine under compression load.
3. Results and discussion

3.1. Failure pattern
Four columns were tested under compression load as illustrated in Figure 1. Specimen T4.1 (100%) failed on fully compression mode and the other specimens labelled (T4.3 70%, T6.4 50+10+10%, T6.2 50%) was observed that the failure happened because of two types of failure mode, compression and buckling failure which caused the damage that started at the bottom of the columns. Buckling failure can be observed by the transverse line on the columns. Moreover, all the specimens clearly failed from inside to outside which means that the first damage happened to the concrete and followed by TRM rupture.

To be more specific about the failure types, specimen T4.1 wrapped with 100% of TRM has a longitudinal cracking lines, that type of lines appears when the failure type is a compression failure. For columns that are partially wrapped with TRM namely T4.3 at 70%, T6.4 at (50+10+10%) and T6.2 wrapped with 50% it was observed that the required bonding was achieved hence causing a heterogeneity in the shape of the columns. Therefore, those columns can be considered as change section columns, that heterogeneity formed a weakness spots on both sides of the column. Even so, for this type of accrued failure all the four specimens gave higher results than the control specimen Tc.

![Figure 1. Specimens cracking.](image)

3.2. Strength increment
The result of the four compressed tested columns are presented in Figure 2 and Table 2. Specimen T4.1 at 100% gave the highest reading for compression load at 395.37 kN with an increment in load of 14% compared to the control specimen by this highest increment in load is because T4.1 had a full wrapping of TRM, specimen T4.3 recorded a load increment of 9.6% at 376.37 kN. Specimen T6.4, marked an increase of 7% at 365.8 kN while the lowest result of load increment can be seen in T6.2 at 359 kN with only 5.2% increment. It can be induced from the results that specimens which were wrapped with lower percentage of TRM has shown lower increment in their load reading against the fully wrapped specimen.
Table 2. Strength increment

| Specimen with Wrapping Percentage | Compression Load (kN) | Load Increment (%) |
|----------------------------------|------------------------|--------------------|
| Tc 0%                            | 340.37                 | -                  |
| T4.1 100%                        | 395.37                 | 14%                |
| T4.3 70%                         | 376.53                 | 9.6%               |
| T6.4 (50+10+10) %                | 365.8                  | 7%                 |
| T6.2 50%                         | 359                    | 5.2%               |

Figure 2. Load- deflection curve.

4. Conclusion

The result recorded in the research has shown a significant increase of compression strength for circular columns by wrapping the specimens with two layers of glass fibre. The highest increment of compression strength achieved in this study was marked at 14 % increment compared with the control specimen that was not wrapped with TRM. This increment result was acquired by specimen T4.1, that employed the highest percentage of wrapping at 100%. On the contrary, specimen T6.2 that was wrapped with only 50% of TRM shown the lowest, yet notable increment of strength at only 5.2 %. Thus, it can be concluded that textile reinforce mortar (TRM) used as a strengthening material on circular column indicates a contribution as enhancing solution against compression load. However, wrapping the specimens with a higher percentage of TRM will enhance the strength of columns contrasted to lower percentage wrapping or with no adapted strengthening system.

5. References

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