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BEHAVIOUR OF CONCRETE COLUMNS WITH GFRP CIRCULAR AND RECTILINEAR CONFINING REINFORCEMENT

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1. ABSTRACT

Glass Fibre-Reinforced Polymer (GFRP) bars are becoming a feasible alternative to steel bars to produce corrosion-free reinforced concrete structures. In an effort to assess the effectiveness GFRP spirals and GFRP rectilinear ties as internal reinforcement in columns, an extensive research program is underway at the University of Toronto. Fifteen 356 mm diameter full-scale circular columns and sixteen 305 mm x 305 mm cross-section square columns were constructed and tested under simulated earthquake loading. This extended abstract presents an example comparison of the experimental behaviour of circular and square concrete columns with internal reinforcement comprising of steel longitudinal bars and GFRP lateral spirals or ties. Results are presented in the form of moment vs. curvature response and shear vs. lateral deflection behaviour.

Keywords: GFRP, Columns, Hybrid, Seismic, Confinement, Reinforced Concrete

2. INTRODUCTION

Reinforced concrete structures with conventional steel reinforcement deteriorate quickly in aggressive environments, such as bridges with exposure to de-icing salts and marine environment, due to steel's inherent property of corrosion. Corrosion of lateral steel in columns causes not only the spalling of concrete cover, which results in a drop in load-carrying capacity, but further exposes the steel longitudinal bars to corrosion that may eventually lead to a structural collapse. The replacement of steel with a non-corroding material like glass fiber reinforced polymer (GFRP) bars is a feasible solution that can alleviate this problem.

Very limited studies can be found on the seismic performance of columns having GFRP as internal longitudinal and lateral reinforcement. The results from these few studies showed that columns with GFRP longitudinal bars have a softer response and lower energy capacity in comparison with steel-reinforced columns using circular sections (Tavassoli et al. 2015) or square sections (Ali et al. 2015). It was decided to investigate hybrid columns with steel longitudinal bars and GFRP lateral reinforcement. It was theorised that the hybrid columns with GFRP spirals/ties will prevent cover deterioration, since these bars do not corrode, and the steel longitudinal reinforcement will ensure a stiffer member response. In this study the performance of circular and square columns hybrid columns subjected to seismic loading was investigated.

3. EXPERIMENTAL PROGRAM AND RESULTS

Of the total 31 columns, four circular and four square columns reinforced longitudinally with steel reinforcement and laterally with GFRP reinforcement were comparable. They were all tested under constant axial load and cyclic quasi-static lateral load. The circular columns were confined with GFRP spirals and the square columns were confined by GFRP rectilinear ties made by the same manufacturer. Refer to Figure 1 for schematics of the specimens and the corresponding cross-sectional details.

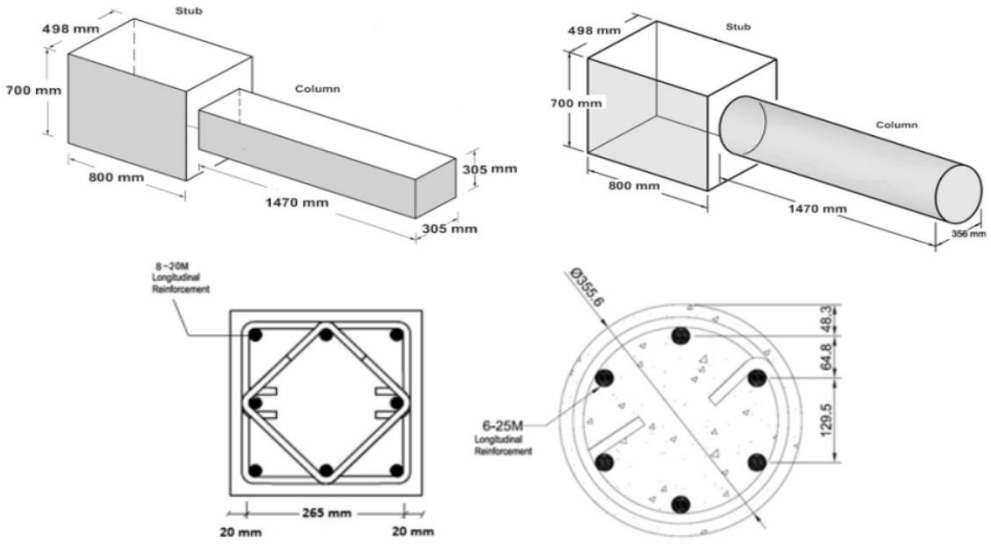

Figure 1: Square and circular column specimen schematic and cross-section

Results in terms of shear versus tip deflection and moment versus curvature from one square and one circular column are shown in Figure 2 to compare the effectiveness of using GFRP rectilinear ties and GFRP circular stirrups as confinement. Table 1 provides the general information regarding these two specimens. Both columns were subjected to 28% of their axial load capacity that remained constant throughout the test. Results show that both columns behaved in a very similar manner with almost equal ductility parameters. The amount of lateral reinforcement in circular column was a little more than half that of the square column. This indicates the higher efficiency of circular confinement compared with rectilinear confinement.

Table 1: Specimen Details

Column Shape	Specimen Name	*f'c* (MPa)	Axial load level, P/P_o	Axial load level, Load (kN)	Longitudinal Steel Reinforcement, No. & Size	Longitudinal Steel Reinforcement, Ps (%)	Lateral GFRP Reinforcement, Size @ Spacing (mm @ mm)	Lateral GFRP Reinforcement, Reinforcement Ratio, p_{fh} (%)
Square	TA-P28-S-10 (10)	42	0.28	1167	8 & 20M	2.58	12 @ 160	1.7
Circular	P-28-LS-12-160 (6)	40	0.28	1243	6 & 25M	2.96	12 @ 160	0.94

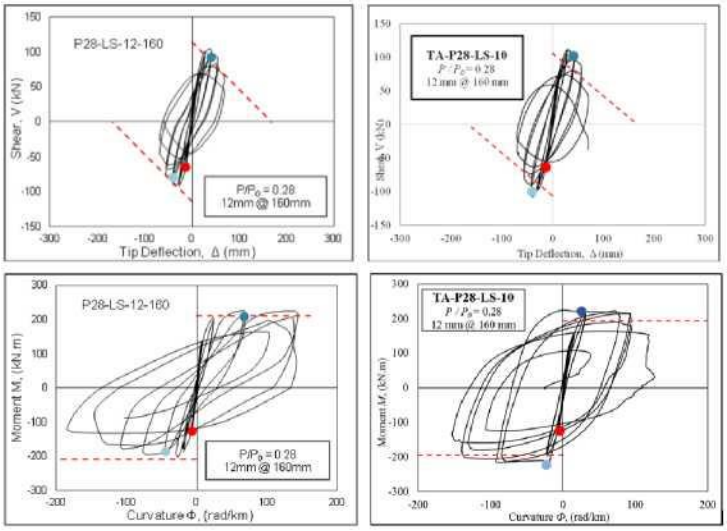

Figure 2: Shear vs. deflection and Moment vs. curvature relations

4. CONCLUSION

- It was observed that for circular columns, there was no redundancy after the rupture of GFRP spiral and confinement provided to the core concrete vanished as soon as the spirals ruptured. The loss of confinement in the square columns was found to be not quite as sudden. In most square columns, the failure was more prolonged due to the fact that there were two ties at each level and it took several cycles for the ties to unhook and they did not give way suddenly.
- The behaviour of square columns confined by GFRP ties was found to be very similar to with circular columns confined by GFRP spirals in terms of shear versus tip deflection and moment versus curvature when the spacing of the lateral reinforcement was large.
- The strength degradation before failure for both square and circular columns was found to be insignificant due to the well-confined concrete core. The drift capacity of the circular column at failure was 3.1%, and the drift capacity of the equivalent rectangular column at failure 2.9%, both of which satisfy the limitations of North American building codes. Hence, preliminary results from this research show that GFRP spirals and rectilinear ties can be used as primary lateral reinforcement for shear and confinement in concrete columns designed for seismic resistance.

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