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Study of Mechanical Characteristics of Steel Tubular Sections Filled with High-Volume Rubberized Concrete

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ABSTRACT

This research manuscript presents a comprehensive investigation into the mechanical characteristics of steel tubular sections filled with high-volume rubberized concrete (HVRRC). The study aims to evaluate the structural behaviour, strength, and performance of such composite sections. Experimental study and numerical analysis were conducted to assess the key parameters, including load-carrying capacity, stiffness, energy dissipation, and deformation characteristics. The results contribute to the understanding of the feasibility and potential applications of HVRRC-filled steel tubular sections in various structural engineering fields.

Keywords: Steel tubular sections, high-volume rubberized concrete, load-carrying capacity, stiffness, energy dissipation, deformation characteristics.

Introduction

Steel tube sections are utilised extensively in a variety of structural applications due to its high stiffness and strength. Several benefits, including increased ductility, energy absorption, and sustainability, are provided by rubberized concrete, which is created by adding leftover tyre rubber particles to regular concrete. The combination of these two materials has the potential to enhance the mechanical properties of steel tubular sections, leading to improved structural performance and reduced environmental impact.

Several researchers have done some extensive work in this field, discussed as follows. Al-Akhras and Smadi (2004) found that the compressive strength increased when discarded tyre rubber was replaced with fine aggregate by 10%. Schneider (1998) looked at how the wall thickness and steel tube's form affected the compressive resistance of short composite columns that were concentrically loaded. Dong et al. (2013) studied the characteristics of concrete containing rubber that is not coated and concrete containing rubber that is coated with an aniline coupling agent were compared by. Ganjian et al. (2009) replaced cement with rubber powder resulted in a 20–40% drop in compressive strength while aggregate replacement with chipped rubber resulted in a 10–23% reduction. Chen et al. (2017) conducted experimental tests on circular steel tubes filled with rubberized concrete. The study found that the addition of rubberized concrete improved the ductility and energy dissipation capacity of the composite sections compared to empty tubes. Zhang et al. (2019) investigated the behaviour of steel tubular sections filled with rubberized concrete under different loading conditions.

The study revealed that the composite sections exhibited enhanced strength and stiffness, contributing to their improved load-carrying capacity. Wang and Huang (2020) conducted a numerical simulation which were employed to assess the mechanical characteristics of steel tubular sections filled with high-volume rubberized concrete. The results demonstrated that the composite sections exhibited favourable deformation characteristics and energy dissipation capacity. Siddique and Khatib (2018) investigated the mechanical properties of rubberized concrete used in filling steel tubular sections. Their research highlighted that the rubber content and particle size had significant effects on the compressive strength and elastic modulus of the composite sections. It was observed that, previous studies have shown that steel tubular sections filled with high-volume rubberized concrete offer improved mechanical characteristics such as enhanced ductility, energy absorption capacity, and load-carrying capacity compared to conventional steel sections. However, as per the authors best knowledge, further research is needed to explore the long-term behaviour, durability, and cost-effectiveness of these composite sections in different structural applications.

Materials used

Hollow mild steel tubes are made up of a specific yield strength of 255 MPa on the outside enclosure. Machine finished edges of the steel tubes eliminates any eccentricity that might cause during loading. The dimension of outside diameter was of 87.1 mm and that of wall thickness of 1.9 m. Cement of grade 43 as per the Indian Standard code was used, properties of which were tested in concrete laboratory and the test results are shown in table 1.

Results and Discussion

The load deformation curves are shown in Fig. 2 and 3. Series (1 and 2) shows that the slope of the axial load-deformation reactions decreases, with an increase in the cement replacement ratio in the original mix. It indicates that a rise in replacement level caused a decrease in stiffness of the CFST columns. It was found that axial deformation corresponding to the ultimate load increases with a increase in percent replacement level. It was found that the two series of CFST columns virtually had equal increase in axial deformation. The ultimate loads for 14.69%, 24.67%, and 34.23% replacement level were found to result in increases in axial deformations for series 1 specimens of 28.88%, 48.52%, and 89.90 concrete mixture. For the load deformation curves and the axial deformation corresponding to the ultimate load, have a same beginning slope. Series 2 CFST columns have somewhat lower ultimate capacity than series 1 columns. Table 1 shows the result of various test and comparison with the standard value as per the given Indian Standard code of practice. While, Table 2 shows the properties of super-plasticizer used in the concrete mix.

Table 1: Comparison of properties of cement with their standard code value.

Test Name	**Indian Standard Code used**	**Values obtained**	**Requirement as per Indian Standard**
Normal consistency (%)	IS: 4031(Part 4)-1988	28.4	-
Initial setting time (min)	IS: 4031(Part 5)-1988	57	30 (minimum)
Final setting time (min)	IS: 4031(Part 5)-1988	182	600 (maximum)
Compressive strength (MPa) 3 days 7 days 28 days	IS: 4031(Pt. 6) -1988	24.0 33.8 44.9	23 33 43
Soundness (mm)	IS 4031 – Part III	2.6	10 (maximum)
Fineness	IS: 460 (Part 1 and 3): 1985	231	225 m^2/ kg (minimum)
Specific gravity	IS: 4031(Part 11)-1988	3.12	-

Table 2: Properties of super-plasticizer

S.N.	**Property**	**Value obtained**
1	Specific gravity	1.1-1.2 at 25°C
2	Ph	8.5-9.5
3	Appearance	Brown liquid
4	Chloride content	Nil

Figure 1 shows the chemical properties of Ordinary Portland Cement of grade 43. Figure 25 shows the physical properties of fine aggregate. Figure 3 shows the physical property of coarse aggregate. Figure 4 shows the Mix proportion of different mixes of cement, rubber, fine aggregate, coarse aggregate and water.

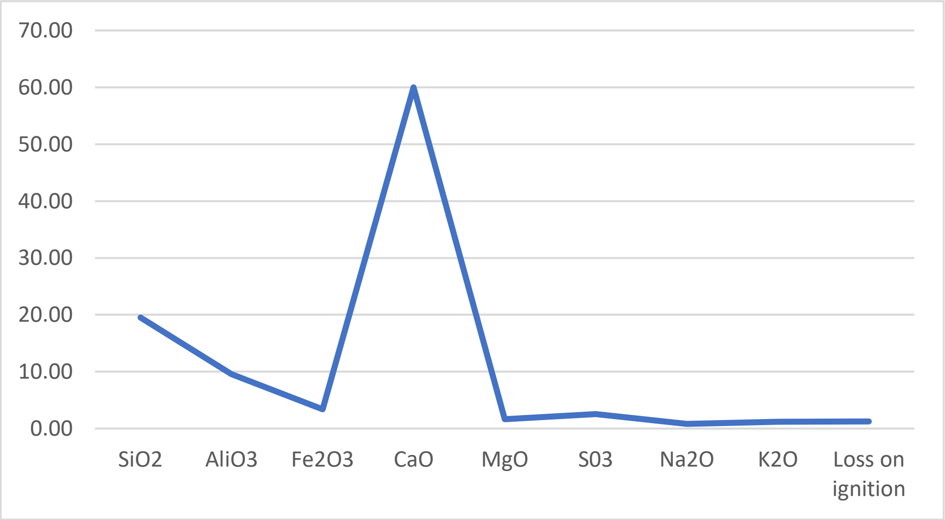

Figure 1: Chemical properties of Ordinary Portland Cement of grade 43

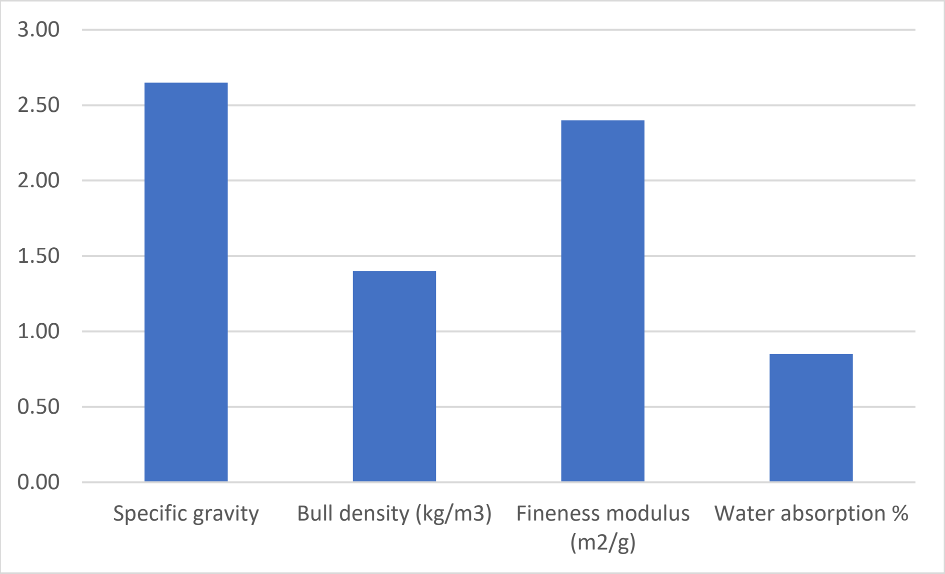

Figure 2: Physical properties of fine aggregate

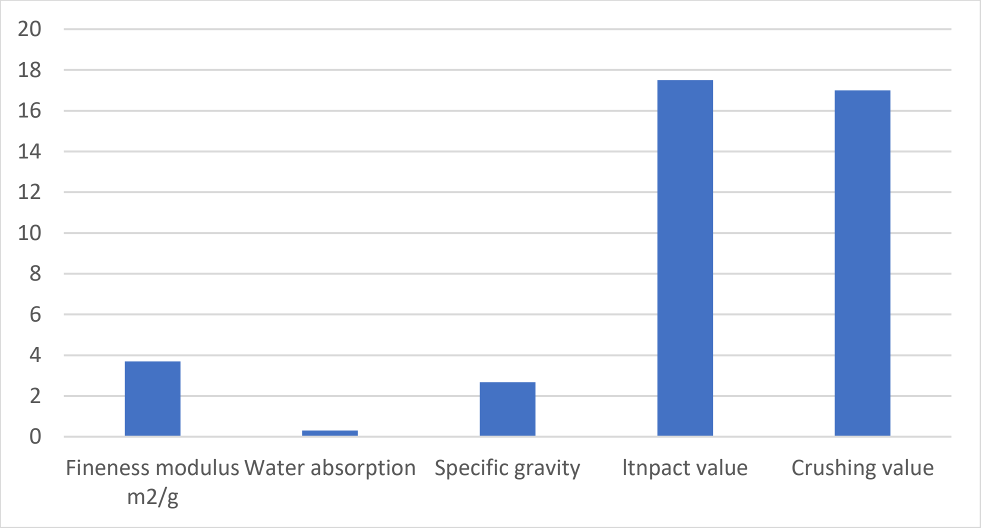

Figure 3: Physical property of coarse aggregate

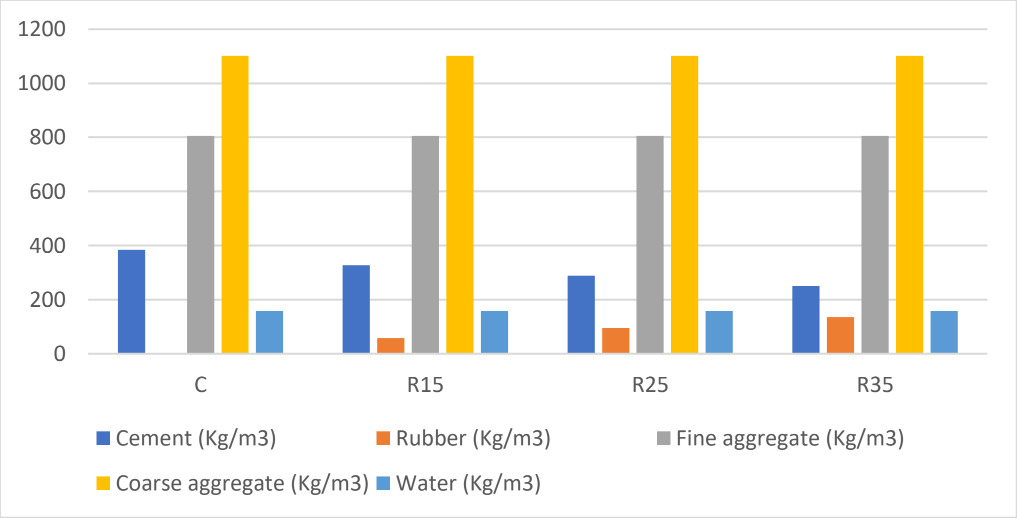

Figure 4: Mix proportion of different mixes

Where, **C** - Control mix (0% rubber powder), **R 15 -** 15% of cement replaced with rubber powder, **R 25 -** 25% of cement replaced with rubber powder, **R35 -** 35% of cement replaced with rubber powder.

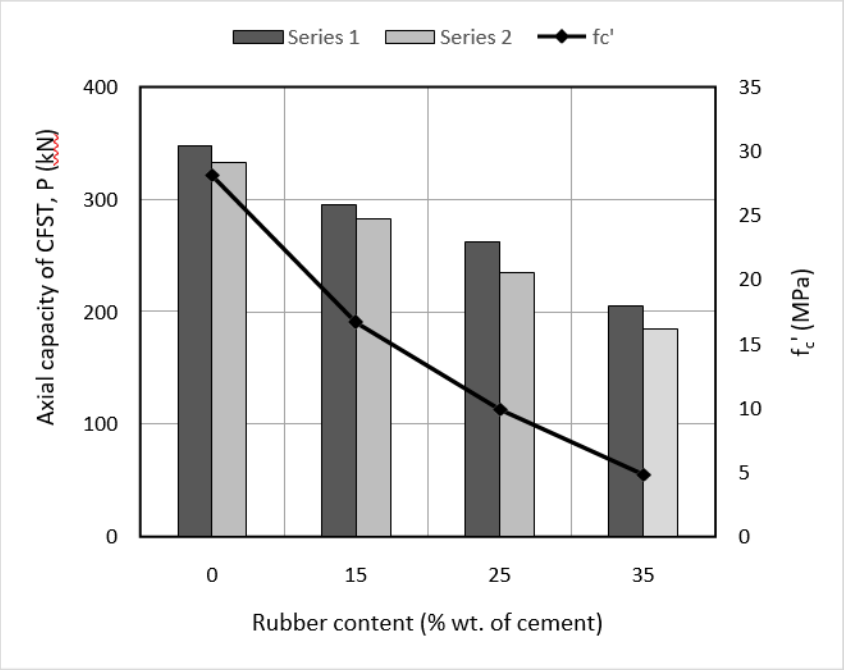

Fig.5. Reduction in concrete compressive strength and axial capacity of CFST columns with rubber content

Concrete might be replaced with ground elastic rubber that has a specific gravity of 1.1. The elastic particles have a size distribution between 0.075 mm and 0.15 mm. Elastic extracted from used elastic tyres using a two-step technique that involved appealing partition and was screening.

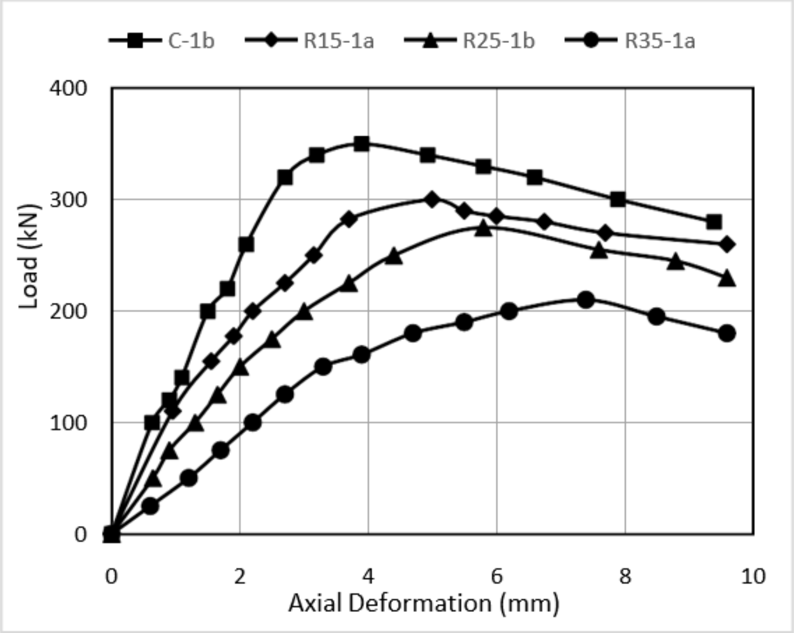

Fig 6 Load-deformation curves for series 1 CFSTs

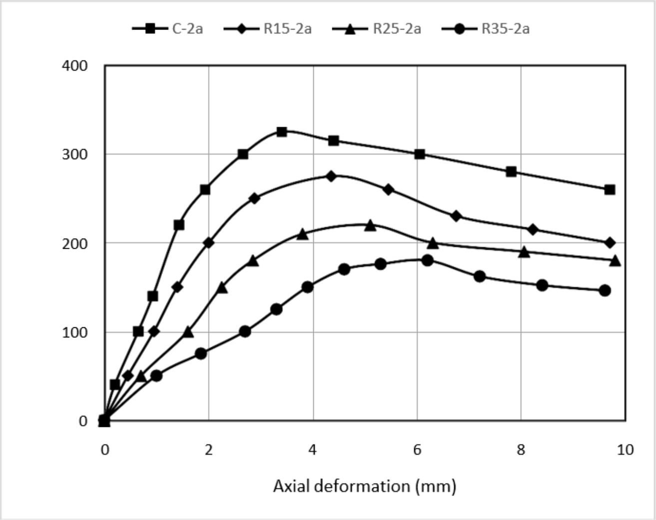

Fig 7 Load-deformation curves for series 2 CFSTs

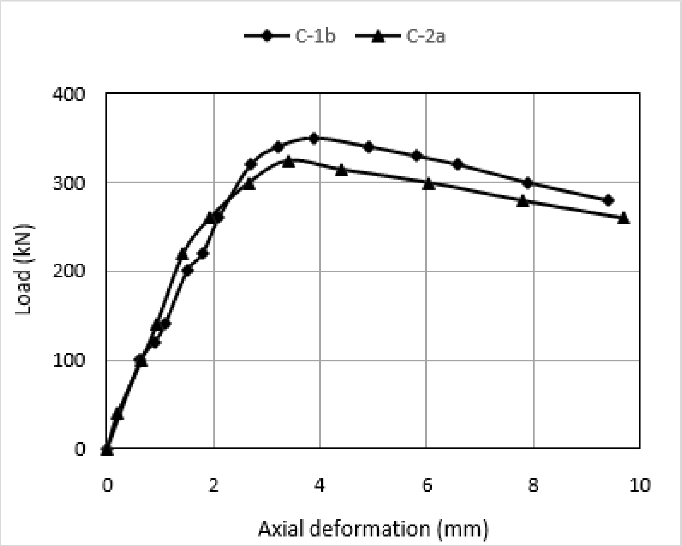

Fig 8 Comparison of Series 1 and 2 CFSTs of control mix

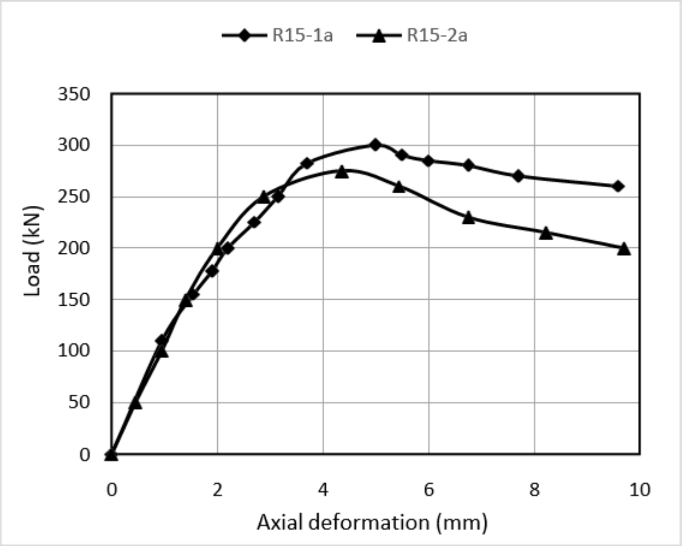

Fig 9 Comparison of Series 1 and 2 CFSTs incorporating rubber

Conclusions

Analyzing the results, following conclusions were drawn, the mechanical characteristics of steel tubular sections filled with high-volume rubberized concrete offer several advantages and considerations. The addition of rubber particles to concrete enhances its ductility, impact resistance, and energy absorption capabilities, making it an attractive option for structural applications.

Moreover, the combination of steel tubular sections and rubberized concrete enhanced the overall structural behavior. Steel tubes offer high strength and stiffness, while the rubberized concrete provides improved ductility and crack resistance. The confinement effect of the steel tube on the rubberized concrete can also enhance its load-carrying capacity and resistance to buckling, leading to a more robust and efficient structural system.

The use of steel tubular sections filled with high-volume rubberized concrete offers significant potential for improving the mechanical characteristics and performance of structural systems. It provides enhanced ductility, impact resistance, and energy absorption, making it a suitable option for mitigating dynamic loads. Further research and development efforts are needed to optimize the design and understanding of the long-term behavior of such composite structures.

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