STUDY ON AXIAL COMPRESSIVE BEHAVIOUR OF CONCRETE FILLED HYBRID TUBULAR COLUMNS

A THESIS

Submitted by

SHARMILA S

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

FACULTY OF CIVIL ENGINEERING

ANNA UNIVERSITY

CHENNAI 600 025

FEBRAURY 2024

ABSTRACT

Composite structural columns are often used in construction to improve performance through the efficient use of various materials, such as concrete, steel, and fiber-reinforced polymer (FRP). Fiber-reinforced polymer (FRP)-steel double skin tubular columns have emerged as a promising innovation in the field of civil engineering. These composite columns improve structural performance and durability by combining the lightweight, corrosion-resistant characteristics of FRP materials with the high stiffness and strength of steel. The FRP tube with fibres at different orientations provides effective confinement to the concrete, high strength to weight ratio and good corrosion resistance–which enables it to possess greater advantage over steel tube. Hence, the current study is focused on Hybrid FRP steel double skin tubular columns subjected to axial compressive loading focused on structural applications.

The materials used in this study are Ordinary Portland Cement (OPC-53) conforming to IS 12269:2013, Glass fiber reinforced polymer (GFRP) tube and steel tube. The GFRP tube used in this study have three different orientations of fibers of 0º, 45º and 0º/90º.The diameters of the steel tube are 26.9 mm, 33.7 mm and 42.4 mm with all the tubes having thickness 2.8/2.6 mm. The concrete mix is designed according to IS 10262: 2019 - Concrete Mix Proportioning-Guidelines.

Steel-Steel double skin tubular columns (SCDST)and concrete filled GFRP steel tubular stub (GSDST) columns are casted and tested under axial loading. Eight numbers of Steel- concrete-steel (SCDST), 64 numbers of GFRP – concrete – steel double skin tubular columns(GSDST) and 32

numbers of CFFT stub columns . The parameters considered for the investigation are hollow cross section ratio (χ) to vary the confinement thickness, GFRP fiber orientation with respect to length of columns, Diameter-to-thickness ratio of the outer GFRP tubes. The load strain behavior of Steel-steel double skin tubular columns (SCDST) and GFRP steel double skin tubular columns specimens indicates that hollow cross section ratio (χ)-0.3 gives better confinement than 0.25. A higher number of FRP layers can provide better confinement, leading to improved load-carrying capacity and ductility. Higher-grade concrete often provides better bonding with FRP, improving the overall load transfer and performance of the GSDST stub column. FRP tubes with the fiber orientation of 0°,0°/ 90° gives significant confinement in concrete and load carrying capacity than the fiber orientation of 45°. The experimental results indicate that improvement in GFRP confinement thickness, improves the axial compressive strength of Concrete filled FRP tubular (CFFT) columns.

Experimental investigation was carried out on GFRP Steel double skin tubular (GSDSTC) short columns having outer diameter of 114.3 mm and specimen length of 1m with include hollow section ratio(χ) of 0.24, 0.31 and 0.39. The experimental results are indicated in terms of load Vs axial displacement relationship, load carrying capacity and failure modes of the column specimen. As the hollow section ratio χ increases, the load-bearing area of the annular concrete reduces, which reduces the load-carrying capacity of the specimens. Additionally, as the inner tube diameter increases/ the hollow section ratio χ increases, the inner tube will become more prone to local buckling, which lowers the load carrying capacity of the specimens. The thickness of the GFRP tube have significant impact on the load deflection behavior. The failure phenomena like concrete crushing, bucking of the inner steel tube and rupture as well as delamination of the GFRP tube especially for specimens with thinner GFRP tube.

The experimental investigation on concrete filled FRP tubular columns (CFFT) short columns consisting of Glass fiber reinforced polymer tube (GFRP) filled with concrete. The parameters considered for this study are the thickness of the GFRP tube (2, 3 and four layers), the orientation of fibers (0/90°, 0° and 45 º) and the Grade of concrete (M30, M40 and M50). From experimental investigation, it is observed that the GFRP tube is improving the axial compressive behavior concrete filled tubes, in terms of both ductility and the load carrying capacity and also provides confinement to concrete. The local buckling of the fiber reinforced polymer tube specimens is suppressed by steel plates.

Studies on axial behaviour of Concrete Filled GFRP steel double Skin Tubular (FSDST) columns with l/d ratios from 2 to 8.75 was carried out . The load vs axial displacement plots are made from the experimental investigation on FSDSTC columns with different length to diameter ratios. From the load axial displacement behaviors, the specimens with a l/d ratio of 2.01 have the highest stiffness. As the angle of orientation of the fiber increases, the Axial displacement and the lateral deflection of the fibers decreases. When the axial load is gradually increased, the slenderness ratio affects the lateral deflection significantly. The columns with higher slenderness ratio exhibited high lateral deflection. The increase in the l/d ratio leads to the reduction in load carting capacity of the column. The load carrying capacity increases with increase in GFRP layer and decreases with increase orientation to 45° with respect to axis of column. The columns oriented along hoop direction have high stiffness and load carrying capacity.

The analytical study includes modelling and finite element analysis of the columns using the software ABAQUS. Non-linear static analysis is performed under the application of displacement-controlled loading. The results obtained from this analytical study is validated with the experimental

investigation in terms of the ultimate load-carrying capacity and load axial displacement relationship. The maximum discrepancy of 10 % to 20% was observed in the ultimate load carrying capacity of experimental study when compared with analytical investigation for two layered specimens and the minimum discrepancy of 7% was obtained for the four-layered specimens. The discrepancy between the experimental and analytical could potentially be due to certain assumptions made in the finite element modelling such as mesh size, analysis procedure adopted, interactions between steel and concrete and FRP and concrete and the interaction properties.

The parameters of the confining outer GFRP tube such as orientation of fibre, hollow section ratio, diameter-to-thickness ratio were varied to determine the axial behaviour of the GSDST, FSDST columns and CFFT short columns. The finite element modelling was carried out to validate the experimental investigation. GFRP tube steel double skin tubular columns with fibers oriented along the hoop direction improved the strength of inner concrete by passive confinement. The adequately confined concrete exhibited high ductile characteristics in load-deflection behavior. Fiber efficiency reduces when the orientation of fibers is away from the hoop direction, especially when the fibers are oriented along 45°. Hence the composite columns can be used in structures where high load carrying capacity is desired.

.