



Axial compression behavior of CFRP confined UHPC encased Q690 steel stub columns

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ABSTRACT

High-strength steel (HSS) and ultra-high-performance concrete (UHPC) offer significant potential in structural engineering due to their superior strength. However, existing design codes often limit their use in steel-concrete composite columns due to the brittleness of UHPC and strain incompatibility issues between HSS and concrete. This study aims to improve the performance of both HSS and UHPC in concrete-encased steel (CES) columns by enhancing the strain capacity of UHPC and reducing its brittleness through the incorporation of steel fibers, while optimizing confinement with carbon fiber reinforced polymer (CFRP) and stirrups. The compressive behavior of CFRP-confined UHPC-encased Q690 HSS (CFRP UHPC-Q690 CES) stub columns was investigated, considering various parameters, including CFRP layers, stirrup spacing, steel fiber content, and steel section configuration (H and L sections). Results indicate that CFRP confinement enhanced the columns' strength by approximately 7–13 % and improved ductility by up to about 19 %, while its effect on ductility was negligible for specimens with L-shaped steel sections. The incorporation of steel fibers further increased the ultimate resistance by approximately 8–11 %. In addition, high stirrup volumetric ratios, combined with CFRP confinement, enabled UHPC-Q690 CES columns without steel fibers to achieve plastic sectional resistance, thereby enhancing axial resistance predictions in accordance with the EC4 and JGJ 138 design codes. An analytical model based on strain compatibility was developed to predict the axial behavior of CFRP UHPC-Q690 CES columns, showing close agreement with the experimental results.

1. Introduction

In recent years, CES composite columns have gained prominence in large-scale civil engineering projects due to their superior structural performance, including high strength, stiffness, enhanced ductility, seismic resilience, and potential for fast construction [1–5]. The reinforced concrete shell surrounding the inside steel section prevents local buckling of the steel, thereby improving the overall strength of the composite columns. As a result, CES columns are extensively utilized in high-rise buildings, as well as in long-span bridges and metro stations.

Ultra-high-performance concrete (UHPC) has garnered significant research attention due to its exceptional mechanical properties, including compressive strengths exceeding 120 MPa and enhanced

durability [6–8]. UHPC allows for the construction of structurally efficient designs with reduced cross-sectional dimensions. However, the inherent brittleness of UHPC under compression presents challenges for its use in compression members. Consequently, several design codes [9–11] impose restrictions on the use of high-strength concrete (HSC) in composite columns, as detailed in Table 1. To mitigate brittleness and enhance the ductility of UHPC under compression, incorporating internal reinforcement systems (such as spirals and stirrups) [12] and/or external confinement methods [13–16] are essential.

High-strength steel (HSS, yield strength > 460 MPa) is essential to modern structural engineering due to its high strength, making it ideal for high-rise buildings and long-span bridges. Despite its benefits, the use of HSS in composite columns introduces challenges, particularly

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