Seismic Behavior of Full-Scale Concrete Filled Steel Tubular (CFST) Columns with High Axial Load Effect

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ABSTRACT

The seismic behaviors of concrete filled steel tubular (CFST) columns were investigated experimentally and analytically in this research. An experimental program with a total of four full-scale square CFST column specimens using steel tubes with a width-to-thickness ratio (B/t) of 41.7 was carried out. The design compressive strength of concrete and yield stress of steel for the specimens are identical, respectively, being 35 and 345 MPa. These specimens were subjected to horizontal cyclic-reversal loads combined with three different constant axial compressive loads, 0.15, 0.35, and $0.55P_0$, and with cyclic varying axial compressive load, from 0.15 to $0.55P_0$, respectively, where P_0 is pure compression strength of the column specimen.

Test results revealed that higher axial compression applied to the CFST column degrades its strength response and deformation capacity. For the axial compressive loading greater than $0.35P_0$, the ultimate interstory drift ratio (IDR_u) of the column was less than 3% radian. It implies that the B/t limitations specified in ACI 318-14, AISC 360-16, AIJ-2008, EC4-2004, and Taiwan SRC codes, those are greater than 41.7, are not able to ensure the square CFST column providing 3% radian of IDR_u under a high axial compression exceeding $0.35P_0$. Additionally, the comparisons

of the CFST column flexural strength between experimental results and various codes' predictions indicate that the ACI 318-14 prediction is significantly underestimated, the AISC 360-16 one predicts reasonable underestimation and the EC4 2004 prediction is slightly overestimated for higher axial compression and underestimated for lower axial compression, and the AIJ 2008 prediction has a good agreement.

Numerical investigations of the CFST columns using finite element analysis (FEA) with ABAQUS were conducted and validated based on the experimental results. A new stress-strain confined concrete model to take an axial compressive loading account was proposed. According to this proposed model, the effective confined strength and ductility of concrete are degraded and reduced, respectively, when the axial compressive loading increases. The validated FEA models were further extended to conduct a parametric study for square CFST columns with parameters: axial compression ratio ($n=P/P_0$), B/t of steel tube, steel grade (f_y), and concrete strength (f_c'). Analytical results of the parametric study revealed that n and B/t significantly affected the seismic performance of the CFST column. The higher the n value or B/t value, the lower the shear strength, and the smaller the deformation capacity was. It was shown that the square CFST columns with B/t of 21 using steel yield stress of 345 MPa and concrete compressive strength of 35 MPa, respectively, satisfy the deformation demand of more than 3% radian under high axial loading (n=0.55). Besides, increasing f_y results in the enhancement of strength. It results in a reduction in deformation capacity for column specimens with higher B/t, but an increase in deformation capacity for specimens with lower B/t. Increasing f_c' results in a dramatic enhancement of shear strength for all specimens and an increase of deformation capacity for almost specimens having thinner steel walls. Moreover, a reasonable material strength combination between steel and concrete was observed to obtain better seismic responses.

Keywords: concrete filled steel tubular (CFST) columns, axial compression ratio, width-to-thickness ratio (*B*/*t*), ultimate interstory drift ratio (IDR_u), finite element analysis (FEA), concrete stress-strain confined model, deformation demand.