BEHAVIOUR OF CONCRETE FILLED SATAINLESS STEEL COLUMN UNDER AXIAL COMPRESSIVE LOAD

by

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CERTIFICATE OF APPROVAL

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DECLARATION

It is hereby declared that, except where specified methodologies had been made to other investigation, the work embodied in the thesis is the result of investigation carried out by authors under the supervision Major Md. Soebur Rahman, Instructor Class ‘B’, Department of Civil Engineering, Military Institute of Science and Technology, Mirpur, Dhaka.

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ABSTRACT

Concrete filled stainless steel tubular columns (CFSST) is an improved and innovative version of composite structure due to better mechanical properties compared to mild steel such as higher strength and ductility, corrosion resistance, fire resistance, speedy construction and low maintenance cost. It exhibits a rounded stress-strain behaviour with significant strain hardening. This study presents experimental as well as extensive numerical investigations on concrete filled stainless steel tubular (CFSST columns under concentric and eccentric axial loads. The experimental program conducted with twenty-four (24) CFSST columns. Out of those eighteen (18) concretes filled and six (6) hollow columns were constructed with various size, shape and concrete strength. These CFSST columns were tested for concentrically applied axial loads to observe the failure behaviour, the ultimate load carrying capacity and axial deformation. Numerical simulations were conducted on CFSST columns under axial compression using finite element method. Both geometric and material nonlinearities were included in the FE model. A concrete damage plasticity model was used to simulate the concrete material behaviour. Static general solution strategy was implemented to trace a peak and post peak response of CFSST columns under various conditions of loading. To validate the model, simulations were conducted with exactly same geometric and mechanical properties of current experimental study and test specimens from published literatures. Comparisons were also made between the FE predictions and experimental results in terms of peak load and corresponding strain, load versus deformation curves and failure modes of the CFSST columns. In general, the FE model was able to predict the strength and load versus displacement behaviour of CFSST columns with the accuracy of 95 percent.

A parametric study was conducted using the numerical model to investigate the influences of geometric and mechanical properties of CFSST columns subjected to axial compression. The geometric variables were load eccentricity ratio (e/D), construction stainless steel ratio (D/t) and slenderness ratio (L/D) to generate more results to investigate the behaviour of CFSST columns. The concrete strength was varied from normal (30 MPa) to ultra-high strength (120 MPa) and steel strength 448 MPa to 707 MPa. In general, e/D ratio, D/t ratio, L/D ratio, strength of steel and concrete was found to greatly influence the overall carrying capacity and ductility of CFSST columns. The effects of ultra-high strength concrete (120 MPa) and high strength stainless steel of 707 MPa on column behaviour was also explored. The Numerical results are also compared with the code predicted capacities (AISC-LRFD 2010). Finally, on the basis of the parametric study a prediction co-relation $P_0 = A_s\sigma_{0.2} + (D/t)^{-0.014} A_c f'_c$. has been proposed to determine the sectional capacity with 98 percent accuracy for CFSST square columns.

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LIST OF SYMBOLS

Ac	Area of concrete,
As	Cross-sectional area of steel section
Asr	Area of continuous reinforcing bars
D	Depth of the column cross-section
L	Specimen length
B	Width of the square steel tube
Ec	Modulus of elasticity of concrete
E_0	Initial elastic modulus of stainless steel
E_s	Modulus of elasticity of steel
F_{cr}	Critical stress,
e	Eccentricity
e/D	Eccentricity ratio
σ	Stress
σ_u	Ultimate strength of structural steel
$\sigma_{0.2}$	0.2% Proof strength
F_y	Yield strength of structural steel shape
f'_c	Compressive stress of concrete
f_{ck}	Characteristic concrete strength (=0.67fcu for normal strength concrete)
f_{cd}	Design value of concrete compressive strength
P_{exp}	Experimental peak load
P_{num}	Numerical peak load
P_o	Nominal compressive strength
P_p	Nominal bearing strength
P_{FE}	Peak load of FE analysis
P_{AISC}	Peak load of AISC code
P_{CR}	Peak load of proposed prediction formula
λ	Slenderness parameter
λ_p	Limiting slenderness parameter for compact element
λ_r	Limiting slenderness parameter for noncompact element
K_c	Compressive meridian
ν	Poisson Ratio
ψ	Dilation angle

N	Axial load
r_i	Internal corner radius of the cold-formed section
n	Strain-hardening exponent
N_{uc}	FE predicted ultimate strength
N_u	Ultimate strength
α	Steel ratio (=As/Ac)
ε	Strain
ε_{cu}	Ultimate axial strain
ω_0	Amplitude of initial geometric imperfections
ξ	Confinement factor

LIST OF ABBREVIATIONS

ACI	American concrete institute
AIJ	Architectural institute of Japan
AISC	American institute of steel construction
BCA	Building code of Australia
BNBC	Bangladesh national building code
CC	Concrete crushing
CFBC	Concrete filled box column
CFST	Concrete filled steel tubular
CFSST	Concrete-filled stainless-steel tubular
CHS	Circular hollow section
COV	Coefficient of variation
EC4	Euro code 4
Exp.	Experimental
FE	Finite element
FEC	Fully encased composite
FEM	Finite element model
HSC	High strength concrete
HSS	High strength steel
HSC	High strength concrete
LRFD	Load and resistance factor design
NSC	Normal strength concrete
Num	Numerical
NZBC	New Zealand building code
PEC	Partially encased composite
SSLC	Structural specifications liaison committee
SHS	Square hollow section
SCC	Self-consolidating concrete