I-81 EXPERIMENTAL AND THEORETICAL STUDY ON THE STRENGTH OF CONCRETE-FILLED THIN-WALLED STEEL BOX COLUMNS

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1. Introduction: Recently, composite structures consisting of steel plate and filled concrete have been increasingly popular in civil engineering structures. This is because of their excellent earthquake-resistant properties, namely high stiffness, strength, ductility and energy absorption capacity. In this study, experimental and theoretical study has been carried out on the strength of concrete-filled steel box columns. Tested and analyzed results and discussions are presented in this paper.

2. Outline of Experiment: A total of 10 specimens were tested to failure under concentric compression, of which six were concrete-filled square box stub-columns and four were steel square box stub-columns. Details of test specimens are shown in Figure 1 and the measured dimensions are listed in Table 1. In Table 1, the specimen designations starting with "U" refer to columns without stiffeners, and those starting with "S" refer to columns with stiffeners. The figures following "U" or "S" are related to the value of plate width-thickness ratio. In each test specimen, the last character "S" and "C" represent steel square box columns and concrete-filled square box columns repectively, and the character "HC" means that the filled concrete was a sort of high strength concrete called *high-performance concrete* instead of ordinary concrete. The values of R listed in Table 1 are computed from measured values of dimensions and material properties. The rigidities of longitudinal stiffeners used in this study are decided by coinciding its relative flexural rigidity, γ_l, with the required minimum value, γ_{req}, as well as with $0.35\gamma_{req}$. The diaphragms were designed to form the stiffened plates with aspect ratio a/b=3.0 for columns without stiffeners and a/b=2.0 for columns with stiffeners. In addition, the ends of the concrete-filled column specimens are filled with cement mortar so that uniform compression would be applied to the specimens.

Table 1 Measured Dimensions of Test Specimens and Maximum Loads

Specimen	R	b (mm)	L (mm)	γ_l / γ_{req}	t_s (mm)	b_s (mm)	f_c (kgf/mm^2)	P_u (tonf) Test	P_u (tonf) Analysis
U9-S	0.844	197	592	-	-	-	-	84	74
U9-C	0.839	196	592	-	-	-	3.993	188	206
U12-S	1.126	263	789	-	-	-	-	82	79
U12-C	1.126	263	790	-	-	-	4.126	313	335
U12-HC	1.126	263	789	-	-	-	4.920	408	382
U15-S	1.409	329	988	-	-	-	-	82	85
U15-C	1.409	329	988	-	-	-	4.147	334	488
S75-S(1)	0.702	328	1316	1.11	4.36	38.1	-	163	175
S75-C(1)	0.702	329	1316	1.11	4.36	38.0	4.147	513	-
S75-C(0.35)	0.705	329	1317	0.35	4.34	25.1	4.137	526	-

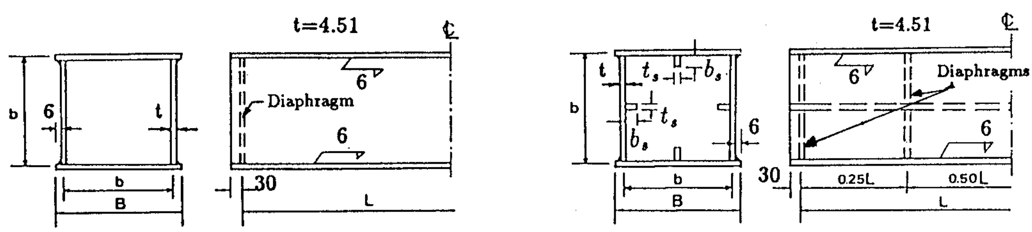

Figure 1 Box Specimens with and without Stiffeners

3. Outline of Theoretical Study: As shown in Figure 2, one eighth of the part between two di-

aphragms of the column is taken for the analysis because of symmetry. The discrete Kirchhoff thin shell element for the plate combined with the isoparametric cubic element for the concrete and a contact element (true distance gap element) for the interface is employed in this analysis. In addition, the measured initial out-of-flatness of the column and the residual stress are also considered. To account for the material nonlinearity, the von Mises yield criterion with normality flow rule is adopted for steel while a hardening-softening model developed by Wu & Tanabe[2] is adopted for concrete. Throughout the numerical study, a displacement control, in which incremental uniform edge displacements are applied to the structure's edge cross sections, is used. The MARC research program is employed in this study.

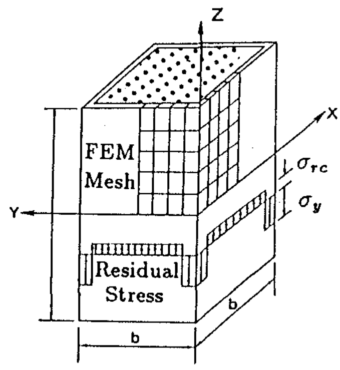

Figure 2 Analytical Model

4. Results and Discussions: Only part of experimental and theoretical results are presented here. Maximum loads of both the experiment and the analysis are given in Table 1. It could be observed that the maximum loads resulted from the analysis are closer to that of the experiment with a exception of the specimen U15-C. Figure 3 shows a typical example of computed average stress-strain curves of the specimens U15-S and U12-C with experimental results. For steel columns, the analytical results generally agree well with the experiments. For concrete-filled columns, the computed ultimate strength is generally in good agreement with the test results, though the analysis may not predict well the load-deformation characteristics. This may be because of the limitation of the hardening-softening model used for concrete material. Moreover, the phenomenon that the experimental curves are deviating slightly from the linear behavior as early at start of loading will be due to the measurement error of dial gauge device.

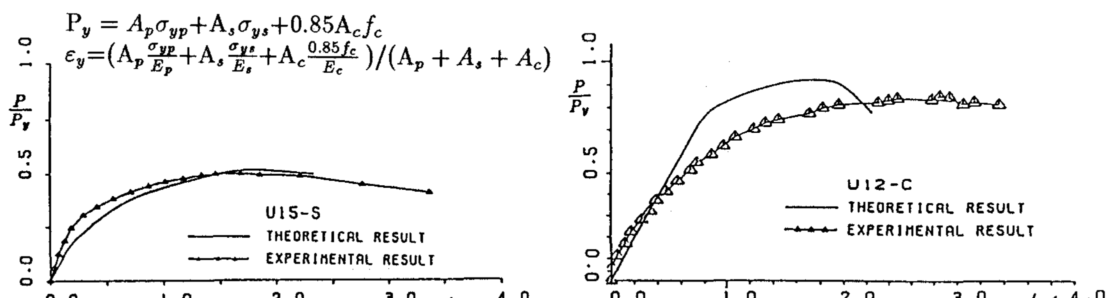

Figure 3 Comparison of Computed Average Stress-strain Curves with Experimental Results

5. Conclusions: It may be concluded that the concrete-filled column has the advantages of earthquake-resistance such as higher strength than the steel column. More details will be reported at presentation.

6. References:

(1) Hanshin Expressway Highway Public Cooperation : "Recommendation of Design and Construction of Steel Bridge Piers with Composite Columns (Concrete Filled Structures)," Draft, March, 1986.

(2) Z. S. Wu, T. Tanabe: "A Hardening-softening Model of Concrete Subjected to Compressive Loading," *J. of Struct. Engng., AIJ*, Vol.36, pp.153–161, 1990.