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Theoretical Study on Strength of Segma Composite Columns

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ABSTRACT

A combination of steel and concrete in structural members and components of load-bearing structures appears very efficient due to the advantageous properties of both materials complementing each other. It leads to design of highly effective and cost-saving structures. The cold formed steel sigma section has recently used as an alternative to the channel section. This is because the sigma shaped section having an intermediate web return and multi stiffeners. Concrete-filled hollow steel sigma sections are more and more frequently used as compression members in structures nowadays. This paper presents an theoretical investigate the strength of double sigma cold formed section placed face to face composite columns subjected to axially loaded. The parameters were the wall thickness (t), cross sections, the eccentricity (e), and the columns length (L). An equation is proposed based on the obtained results to predict the ultimate load capacity of the columns. It was found that the proposed equation could give closer predictions than the others could.

Introduction and Background

Recently there are many researchers who have studied the composite columns, some of them focused on strength. A group of them discussed concrete filled tubes with un-stiffened square or rectangle cross section under axial loading such as An He studied the behavior and load-carrying capacities of concrete-filled steel tube (CFST) stub columns and presented by experimental and numerical investigation was used outer tubes from high-chromium grade EN 1.442 stainless steel. And tested 15 specimens experimentally with different cross-section sizes and concrete infill as a parameters and was defined ultimate loads, load–deformation histories and failure modes and was supplemented by a numerical modelling study and then utilized to perform parametric studies for the purpose of expanding the limited test data pool over a wider range of cross-section sizes [1]. Yong Ye studied the effects of square composite columns subjected to axial loading. The tubes were made by comprised an outer layer made of stainless steel and an inner layer made of carbon steel. 200-mm square carbon steel columns (wall thickness tsc = 3.30 mm) were manufactured first, then the bimetallic tubes were fabricated by cladding the carbon steel columns with stainless steel sheets. Was conducted an experimental program on fourteen CFBT columns and two conventional concrete-filled steel tubular (CFST) counterparts were tested to failure under axial compressive loading. Using different parameters included the stainless steel grade (Grade 316, 304, and 202), steel thickness of the stainless steel tube layer (tss = 0.84, 1.32, and 1.88 mm), and cube compressive strength of concrete (fcu = 54.5, 68.4, and 80.5 MPa). A finite element analysis (FEA) model was conducted and verified against the experimental measurements. and was defined ultimate loads and effects of the square CFBT stub columns were then discussed and compared with those of the conventional CFST columns. Lastly, the ultimate loads obtained from the experiments were compared to those predicted by the available design codes [2]. Yu, Ran presented an experimental program on flexural behavior of concrete-filled tube made of stainless steel with square and rectangular hollow cross section (SHS and RHS) tubes subjected to uniaxial bending. The ultimate strengths, failure modes, ductility, flexural stiffness, bending moment-midspan deflection curves, overall deflection curves and strain distribution curves of test specimens were then defined. The test parameters included the thickness of the

SHS and RHS tube and filling concrete. It was demonstrated that the ultimate strength, initial ductility and stiffness of empty stainless steel SHS and RHS flexural members were significantly improved by filling the concrete in the specimen along its full length.

The improvement was increased with the increase of the thickness of the SHS and RHS tube. Also shown that, the concrete strength has little influence on the ultimate strength, initial stiffness and ductility of concrete-filled stainless steel SHS and RHS flexural members [3]. And anther researches studied circular composite columns as Yuncheng studied the properties of the eco-concrete so produced and the influence of using such eco-concrete on the axial performance of CFSTs, Results demonstrate that at same water/ cement ratio, the eco-concrete had large compressive strength and the CFSTs in filled with the Eco concrete had good axial performance. However, at same concrete strength level, the CFSTs in filled with the Eco concrete had similar axial performance. Finally, the test results obtained from the experiments were compared to those predicted by the available design codes. Based on the results the available design equations may also be applied to CFSTs in filled with like this eco-concrete [4]. Peng Daia and Lu Yanga studied the behavior of CFSST stub columns through a comprehensive experimental and numerical investigation used in parametric study to generate a on a larger scale of data and investigated the effects of the test parameters such tube thickness and concrete strength on the ultimate loads of CFSST stub columns. Based on results of the analysis were indicated that the current Chinese and European standards for Concrete-filled steel composite columns carbon tubes under-estimate the resistances of CFSST columns improved. To this end, new calculation methods proposed based on these Chinese and European design equations have been illustrated, which were provide information for improved strength predictions for both the austenitic and duplex CFSST columns [5]. Zongping and Jinjun described a series of tests on steel tube short columns of circular cross section full with concrete (NA) and recycled aggregate concrete (RAC), from 0% to 100% with 10% increasing. Based on the results both types of RACFST specimens and normal Concrete-filled steel composite columns failed due to oblique shear pressure failure with a drum-like. Comparisons are established with predicted bearing capacities of RACFST specimens using the existing theories, same as Unified Strengthen theory (I), Confinement theory (II) and Superposition theory (III).

The equation for axial compressive stress-strain curves of the whole Processing are discussed Through experimental investigation for RACFST short columns, which can be directly used in theoretical and numerical program in addition to practical engineering design and evaluation of RACFST structures [6] and anther researchers investigated behavior of other cross sections like Pouria Three-dimensional FE simulations of circular, square, hexagonal, and octagonal stub columns under axial compressive loading were established and evaluated through the experimental investigation. Based on the results full load-displacement histories, ultimate axial load, and failure modes are demonstrated. The behaviors of hexagonal and octagonal CFST specimens were generally similar to that of the square CFST specimens as their overall structural performance was relatively enhanced [7]. Wang and Han developed Three-dimensional FE models and compared to against experimental results in terms of failure modes, load-deformation curves and ultimate strength, where circular, triangular, Fan-shaped, D-shaped, 1/4 circular and semi-circular sections are considered. A finite element analysis (FEA) model was established the composite actions between the special-shaped steel tubular and concrete cores have been discussed through load-deformation and interaction stress-deformation histories [8]. Consequently, many different optimization approaches have been proposed in the near past to optimize these structures. In addition, many other structural systems were considered and analyzed to determine the optimum structural selection for the steel pedestrian bridges [9] [10] [11] [12] [13] [14] [15].

Research Methodology

Now a days Some new types of CFST columns have been investigated as for Ren and han (17) made an Experimental on triangular, fan-shaped, D-shaped, 1/4 circular and semi-circular sections CFST stub columns under the effect of axial compression by testing 44 specimens and the failure mode was towards the local buckling as for square CFST stub columns. However, there is currently a lack of information on cold formed composite columns with sigma section. It is expected that these columns could provide an alternative solution to the design engineers [16]. In this paper Samples were taken from the columns, which were practically tested, and the maximum value of the resistance was calculated by the method of interaction diagrams.

Theoretical Analysis

For background and familiarity purposes, a brief review of the determination of CFT column strength is provided as follow. The ultimate strength was calculated theoretically using ACI code formula by using interaction diagram columns method

1- Define section properties of each specimens in program SAP.

To get the interaction diagram for double sigma section there are need to using a software engineering program. the program “SAP” was adopted. The used concrete was assumed to be an isotropic material with compressive strength of 220Kg/cm2. Poisson’s ratio was assumed to be 0.20, modulus of elasticity, E = 212 ton/cm2 and specified concrete compressive strength, fc`= 0.184 ton/cm2 and the used steel with properties of 2150 ton/cm2 for modulus of elasticity, E, poisson, U = 0.3 , yield stress, Fy = 3.9 ton/cm2 and tensile stresses, Fu = 5.4 ton/cm2 then draw the composite columns to define sigma section to get their properties Aeq, rx and ry to mange

for calculate the buckling for long columns in both direction to calculate displacement (e) as follow :

2- Get rx and ry form properties of section after define sigma section in sap as shown in fig.1 & 2.

3- Calculate ƛ in and ƛ out of plan

ƛ in= L / rx and ƛ out= L / ry

4- Identify the columns short or long in each direction

All columns are braced.

If ƛ < 50 the column is small and if ƛ>50 the column is long

5- For long columns calculate Δ

Take all ƛ that are large of 50 to calculate Δ

Δ = ƛ^2*b/30000

Identify if specimens under single or double moment and normal force. If the column under double moment and normal then need to get angle of the resultant moment. The angle that makes with double moment and load we can calculate from the slop in a relationship with two moment tan angle= My/Mx.

Get interaction diagram for each of the specimens as shown in Figure 3. Then we can get the ultimate load from the interaction diagram by using a equivalent eccentricity as shown in Figure 4.

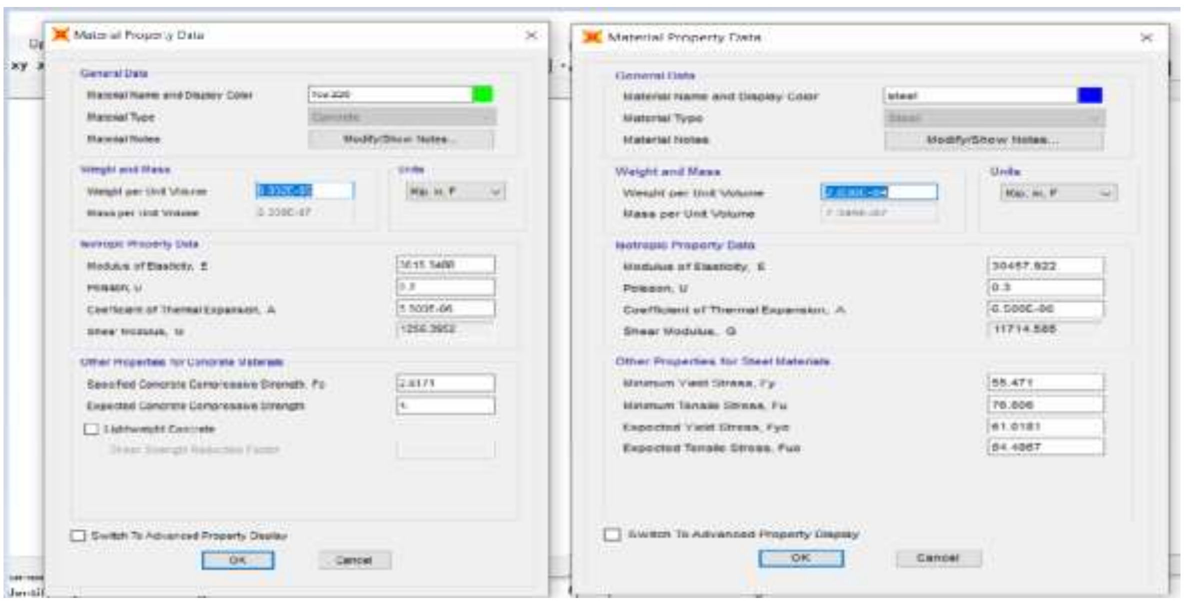

Fig.1: Material properties

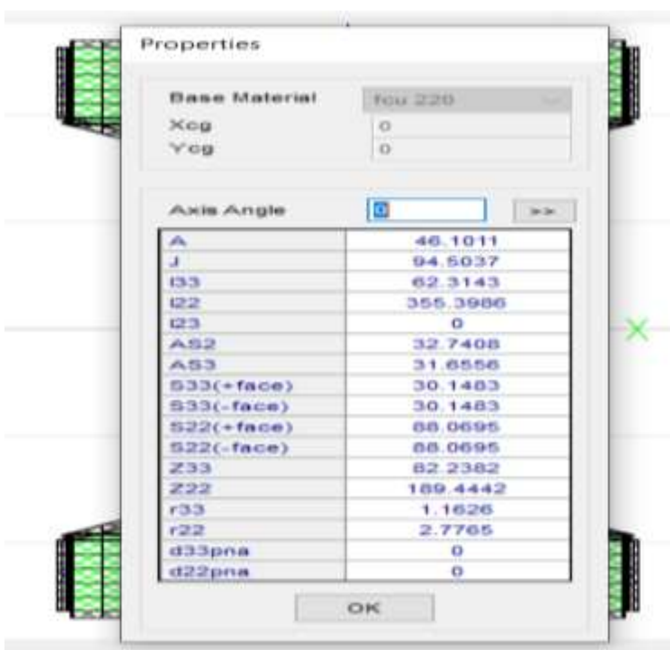

Fig.2: rx and ry

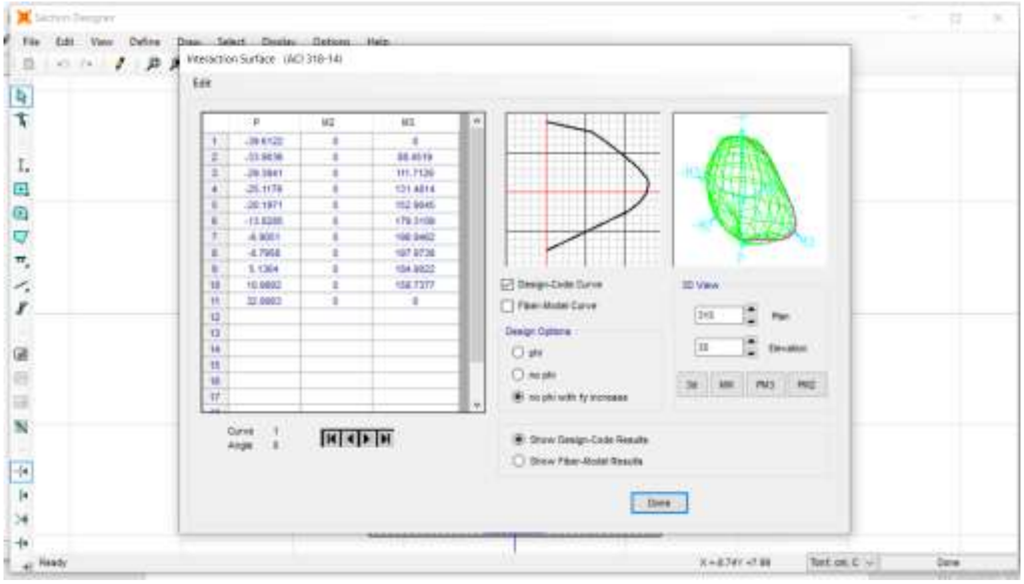

Fig.3: interaction diagram columns

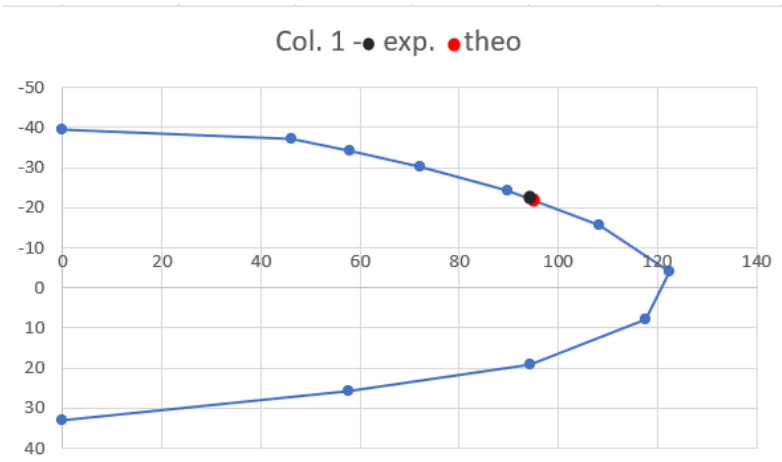

Fig.4: Pu for column 1

The comparison between the predicted and measured cross-sectional strength is listed in Table 3 and as shown in Fig. 5 for all columns, Egyptian code give average mean values of 1.05 and mean standard deviations of 0.056. These results clearly show that the method given in code could be used to predict the cross-sectional strength of the sigma section composite column. the numerical investigation is important in the research on behavior of sigma section specimen. A finite element analysis will be carried out in future research, and the experimental results presented will provide verification to the numerical model.

Table 1 : Theoretical result

No.	L (cm)	e (cm)	b/d	t (cm)	r x	r y	ƛ in	ƛ out	Δ1 tot	Δ2	angle	Pu (tons)	exp. Result
1	248	3.75	1.5	0.15	5.26	2.92	47.12	84.80	4.86	2.40	26.53	22.5	22.567
2	248	1.25	1	0.2	3.59	3.30	69.04	75.27	2.84	1.89	33.81	19.3	23.26
3	248	0	2	0.2	7.02	2.91	35.32	85.36	0.00	2.43	90	30.00	39.4
4	248	0	1.5	0.25	5.39	3.09	46.03	80.25	1.06	2.15	63.73	38.50	46.374
5	198	2	1.5	0.15	5.26	2.92	37.62	67.70	2.00	1.53	37.93	31.00	24.309
6	198	2.5	2	0.15	6.93	2.77	28.57	71.36	2.50	1.70	34.71	35.90	35.319
7	198	0	1	0.2	3.59	3.30	55.12	60.09	1.00	1.20	49.92	25.15	28.49
8	198	3.75	1.5	0.2	5.33	3.02	37.12	65.63	3.75	1.44	21.3	30.00	38.309
9	198	1.25	1	0.25	3.63	3.30	54.50	60.08	2.25	1.20	28.5	33.00	44.161
10	198	0	2	0.25	7.05	2.95	28.07	67.01	0.00	1.50	90	55.00	58

11	98	2.5	1	0.15	3.53	3.14	27.77	31.25	2.50	0.00	0	20.00	27.83
12	98	2	1.5	0.15	5.26	2.92	18.62	33.51	2.00	0	0	34.80	34.964
13	98	0	1	0.2	3.59	3.30	27.28	29.74	0.00	0	0	29.70	32.36
15	98	1.25	1	0.25	3.63	3.30	26.97	29.74	1.25	0	0	40.00	45.149
16	98	0	2	0.25	7.05	2.95	13.89	33.17	0.00	0	0	58.60	58.55

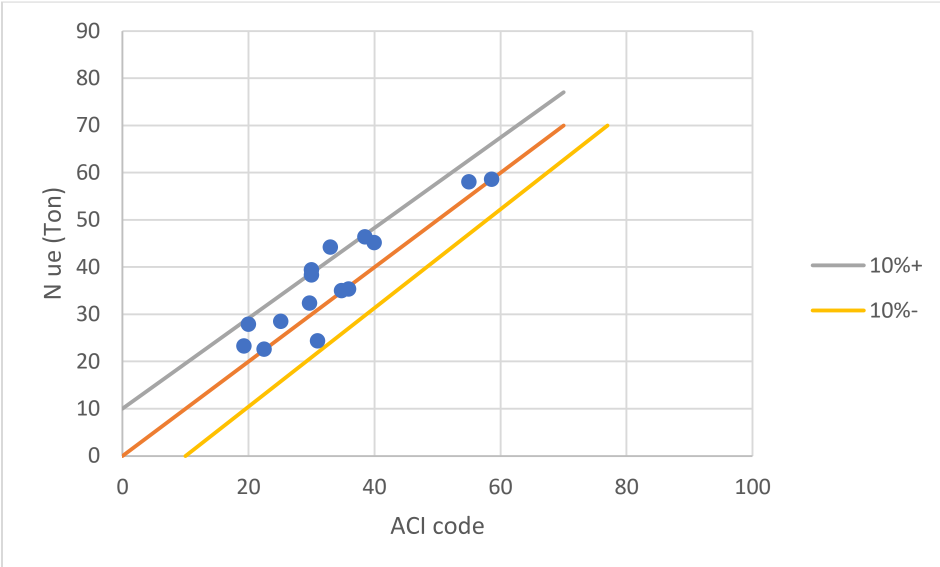

Fig. 5: Comparison between the predicted and measured cross-sectional strength

Conclusion

This paper investigates the strength of sigma cold formed section composite columns under axial and eccentric compression loading. The experimental result strength of the composite columns were compared with the predicted results using equations of composite cross-sectional strength in Eurocode 4and ACI. Both of these codes provide a reasonable estimate for the cross-sectional strength of sigma section composite columns under axial and eccentric loading. The typical failure modes of these sigma composite columns were outward local buckling near the middle section owing to the outward bulging of the crushed concrete. Theoretical calculations have proved that the composite structures between steel sigma section and concrete are effective and the bond between them is cohesive and that they can work together strongly. Composite sections contributed to improvement the weakness in filled concrete in resistance the tensile forces and steel columns provided an effective confinement improved steel in strength of buckling.

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