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An Experimental Investigation on Concrete Filled Steel Tube Columns Under Axial Compression

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Abstract. This paper presents an experimental investigation on the behaviour of concrete filled steel tube columns under axial compression. The steel columns were filled with self-compacting and self-curing concrete instead of normal conventional concrete. A test program consisting of square column, circular column and rectangular column was firstly conducted. The behaviour of three concrete filled steel tubular sections (CFSTs) under axial load is presented. The effect of steel tube dimensions, shapes and confinement of concrete are also examined. Measured column strengths are compared with the values predicted by Euro code 4 and American codes. Euro code 4, gives good estimation of self-compaction concrete. However, lower values as measured during the experiments were predicted by the American Concrete Institute (ACI) equation. Also, the effect of thickness of steel tubes, concrete cube strength and steel percentage is also studied. In addition to CFST column the steel tube also acts as confinement for concrete.

Introduction

For earthquake resistance structures, concrete filled steel tube (CFST) columns can provide good structural properties. The steel member has more advantages such as high strength, high ductility and large absorption capacity. In this steel tubes using in civil and offshore construction like bridges, offshore platforms, high rise buildings, and airport structures [1]. The concrete members have some advantages such as high compressive strength and fire resistance. In this column combine both steel and concrete and the steel tubes are stiffened by the concrete core. It is applicable value for repairing damaged or enhancing the capacity subjected to increase the load [2]. These are well-known tensile stress and has influenced by their constituent material properties, such as compressive strength, the steel ratio and the yield strength of the steel moreover, in this column due to provide the supporting effect by the core concrete, the inward buckling of steel tube can be prevented, resulting in the higher buckling resistance [3]. The self-compacting concrete possesses high deformability, high workability. It does not need vibration (or) tamping after pouring [4]. This reduced the noise level while manufacturing plants and reduction in labor cost. Therefore, there is an excellent potential for using CFST with SCC in structure. Hence, the Self-curing possesses more durability when comparison of conventional water cured concrete. It reduces permeability, protects reinforcement steel.

Self-Compacting Concrete (SCC)

The social problem concerning the durability of concrete structures that evolved in Japan around 1983 was the motive for the development of SCC. It is used in new buildings due to its compact size, flexibility, ease of manufacture and good mixing consistency [3]. As a result, there is a single solution for achieving durable concrete structures, independent of the quality of the construction work, which could be compacted into each corner of the shell, by its own weight by itself [5].

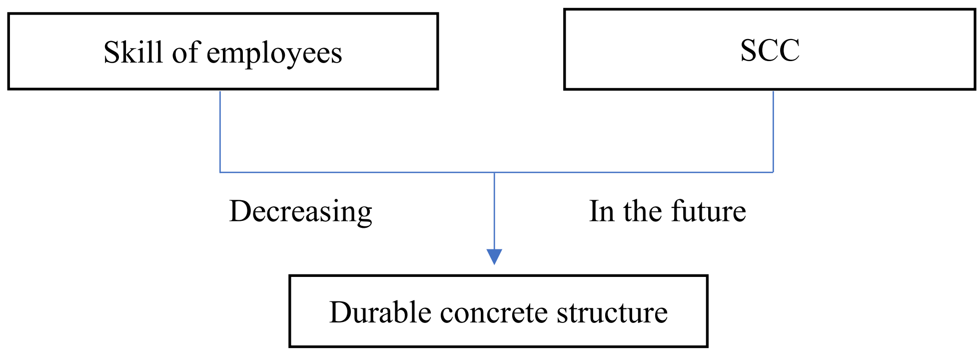

Fig. 1, Necessity of SCC

- *Passing capacity:* The capacity is to flow without segregation such as spaces between steel reinforcement bars. The mix is testing by the slump flow, V funnel and increased by having a suitable w/p ratio. Super plasticizers help to develop the feasibility.
- *Filling Ability:* This fresh concrete property is entirely relevant to the flexibility of. By addition of super plasticizers and by optimizing the packing of fine particles by adding fillers is carried out.
- *Resistance to Segregation:* Under high flow conditions, the mixture must preserve its equilibrium, i.e., it should not be separated and should remain homogeneous in composition during transport and homogeneity. A proportion of coarse aggregate is replaced by fine aggregate as the standard concrete mix shows signs of segregation. The consistency is preserved in this analysis by the use of cementation fines, fly ash instead of coarse aggregate.

Self-Curing

The proper curing of the concrete framework enables hydration of cement and it also gain strength to the concrete the curing is the process of applying water to the concrete externally after the concrete was being put, blended and finished. It provides the most productive cement hydration with additional concrete moisture and to minimize self-desiccation. In construction industry requires more amount of water while in the curing process. The days later that all the construction industry has to switch into an alternative curing system, not only to save water for the environment, because of in some case pf indoor and outdoor construction activities areas where there is scarcity of water. The hydration of cement and self-evaporation is not required as an internal curing [6]. The advantages of self-curing are such as self-curing are increased hydration process and developed the strength to concrete., reduced permeability and self-curing increased durability.

Mechanism of Internal Curing

The evaporation of water reduces from the concrete surface by using poly-ethylene glycol (PEG) and also helps to increase the effectiveness of the protection of the concrete environment. Due to a difference in chemical potential between the vapour and the liquid states, constant evaporation of moisture takes place from the exposed surface [7]. Hydrogen bonds with particles are mainly formed by the composites applied to the mix which reduce the chemical ability of the particles by decreasing the moisture and reducing the evaporation from the surface of the concrete.

Experimental of Fresh Concrete

Materials used and properties

In this study were OPC 53 grade, river sand, coarse aggregate with maximum size 12.5mm high range water reducing admixture type master Glenium sky 8233 and Polyethylene Glycol (PEG). OPC 53 grade was used in this cement have been tested. River sand with fraction passing through 4.75 sieve [8]. The improvement properties tested for fine aggregate. Crushed granite coarse aggregate of passing through 12.5mm and retained on 10mm. the important properties tested for coarse aggregate were given below [9].

Table 1, *Properties of Sand*

Properties	Values
Specific gravity	2.67
Fitness modulus	2.87
Size	Passing through 4.75mm sieve

Mix Composition

The output standards for concrete are obtained by the composition of the blend in both fresh and brittle environments. The specifications of EN 206 are satisfied in the hardened state.

Table 2, *Mix Composition*

Material	Proportion by Weight	Weight in Kg/M3
Cement	1.35	400 kg/m3
Fine aggregate	2.63	780
Coarse aggregate	2.53	750
W/c ratio	0.54	160
Master glenium sky 8233	1.2%	1.2%
Polyethylene glycol	1%	1%

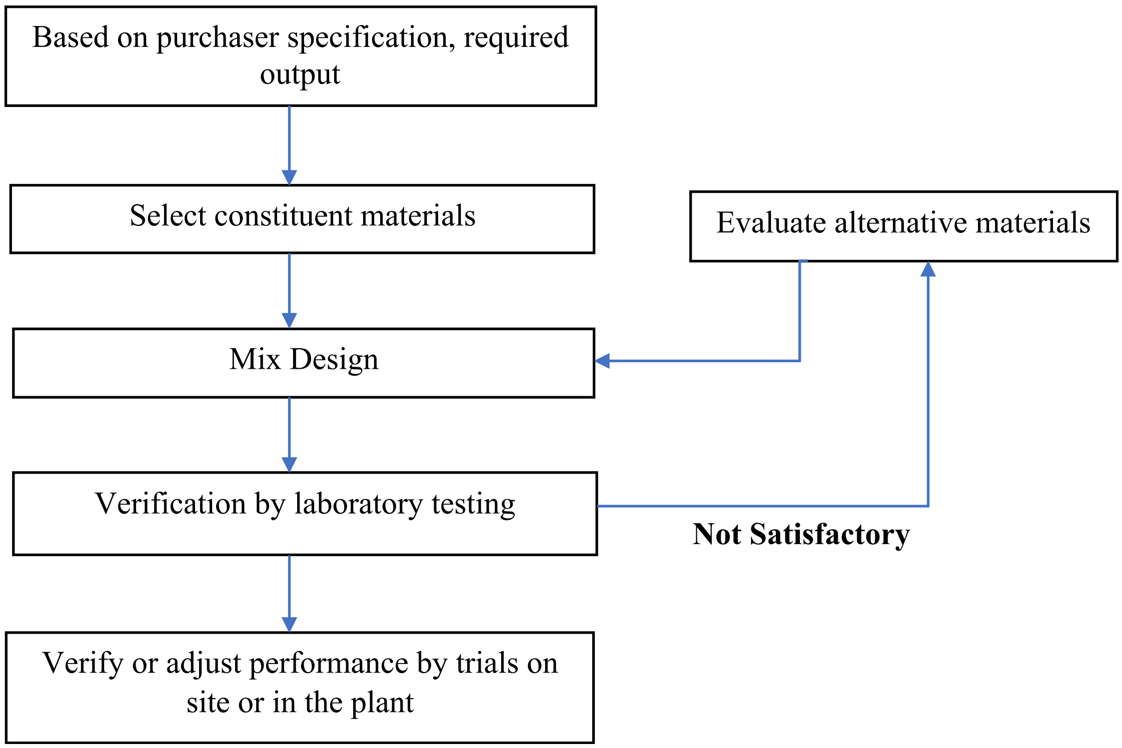

Fig. 2, *Mix Design Procedure*

Experimental Procedure

In general, the specification, preparation of mould, the method of casting and curing are briefly described. The number of column specimens are casted and moulded specification are square with the size of 87.7mm diameter with 600mmlongand 4mm thickness, circular with the size of 87.5mm diameter, 600mm long and 4mm thickness, rectangular section with the size of 87.5mm length and 50mm breadth, with 600mm long and 2mm thickness. The composite structures and steel reinforced concrete can improve the workability [3]. For the advanced research, twelve specimens were examined. It is divided into three different groups, each group consists of four specimens, three are filled with self-compacting concrete and the continuation of one column was tested for reference processes as hollow sections (designated as HS) [10]. In one CFT column as a benchmark [11]. Both the specimens were made of, circular, rectangular and square filled in self-compacting and self-curing aggregate concrete. The durability of the columns improved and compared with conventional concrete [11]. For the steel conduct, calculated ultimate load values and flexural stress values were 260 and 320 MPa. Elasticity modulus Es observed to be 20 x 105 MPa. In the modern research investigation, the parameters of the research samples were particle form, sample height, concrete strength and column D/t ratio. Each of the parameters chosen within the realistic limits of the context. The steel with local buckling is to stop hollow column section, ACI (1995) allows the steel sections of length (B/t) ratio to be not greater than the maximum $\sqrt{}$ (3Es /fy). And tested in circular column L/D = 7 with B/t = 17.5, and for square column L/D = 7 with B/T = 21.8 and rectangular column L/D = 12 with B/t = 25. B/T has been identified to be less than the mentioned limit ($\sqrt{}$ (3Es /fy) = 48.04). The strain and axial shortening of separate interval has been maintained [3] Tests of slenderness ratio and were designed the parameters [12].

***Table 3,** Column Detail*

Type	Diameter	Length	Thickness
Square	87	600	4
Circular	87	600	5
Rectangle	87	600	2

***Table 4,** Testing methods of SCC*

Method	Acceptance Criteria		Properties
	Minimum	Maximum	
Slump flow test (mm)	650	800	Filling abilities
V-funnel test (sec)	6	12	Filling abilities
L-box test (h_2/h_1)	0.8	1.0	Passing abilities
T_{50} slump flow	2	5	Passing abilities

Curing of Specimen

Self-curing is a process to supply concrete with extra moisture for more efficient cement hydration and decreased self-desiccation. After 28 days of curing, the specimen is taken out. then the specimen is tested.

***Fig. 3,** Self-Curing of Concrete*

Experimental Results and Discussions

Failure Modes

The failure mode on circular column of 600mm short column as subjected to bending to the supports by each column. Failure mode and specimens are not affected by cement ratio and leads to destruction [2]. Local buckling near the supports, as shown by circles in each section, is the failure mode on a square column of 600 mm short column. It indicates the failure mode on the 600 mm short column rectangular column is by local buckling near to the supports, as shown by circles with substantial lateral deflection in each column and total buckling closer to the mid-height of the column. Elongation at peak is also known as fracture strain. The elongation at break can be determined by tensile testing is given in below.

Fig. 4, *Failure mode of Cicular Specimen (600 mm Short Columns)*

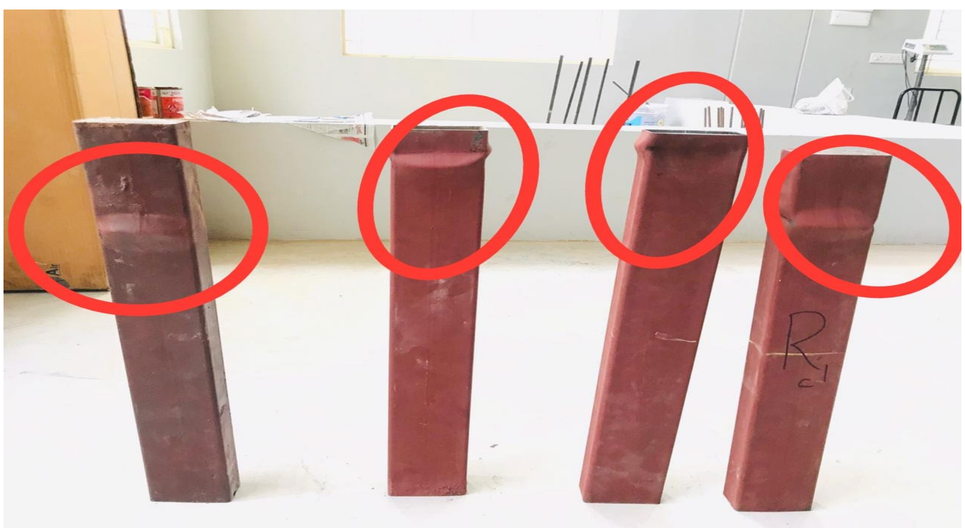

Fig. 5, *Failure mode of Rectangular Specimen (600 Mm Short Columns)*

Fig. 6, *Failure mode of Rectangular Specimen (600mm Short Column)*

Table 5, *Specimen properties*

Specimen	D (mm)	T (mm)	D/t	Length L(mm)	L/D	Steel strength fy (mpa)	Load at peak (KN)	Elongation at peak (mm)	Compression strength (N/mm^2)
C1-HS	87.5	5	17.5	600	6.8	260	624.590	19.840	1022.71
C2-scc$_1$	87.5	5	17.5	600	6.8	260	911.870	15.100	95.95
C3-scc$_2$	87.5	5	17.5	600	6.8	260	949.030	12.580	99.86
C4-scc$_3$	87.5	5	17.5	600	6.8	260	906.980	12.680	95.43
S1-HS	87.5	4	21.8	600	6.8	260	295.220	0.630	1035.86
S2-scc$_1$	87.5	4	21.8	600	6.8	260	707.160	8.960	1964.33
S3-scc$_2$	87.5	4	21.8	600	6.8	260	707.160	8.960	1964.33
S4-scc$_3$	87.5	4	21.8	600	6.8	260	745.920	4.340	2072
R1-HS	90	2	45	600	6.6	260	118.240	7.430	117.2
R2-scc$_1$	90	2	45	600	6.6	260	190.750	0.00	706.48
R3-scc$_2$	90	2	45	600	6.6	260	321.210	2.300	1189.66
R4-scc$_3$	90	2	45	600	6.6	260	491.170	12.740	89.76

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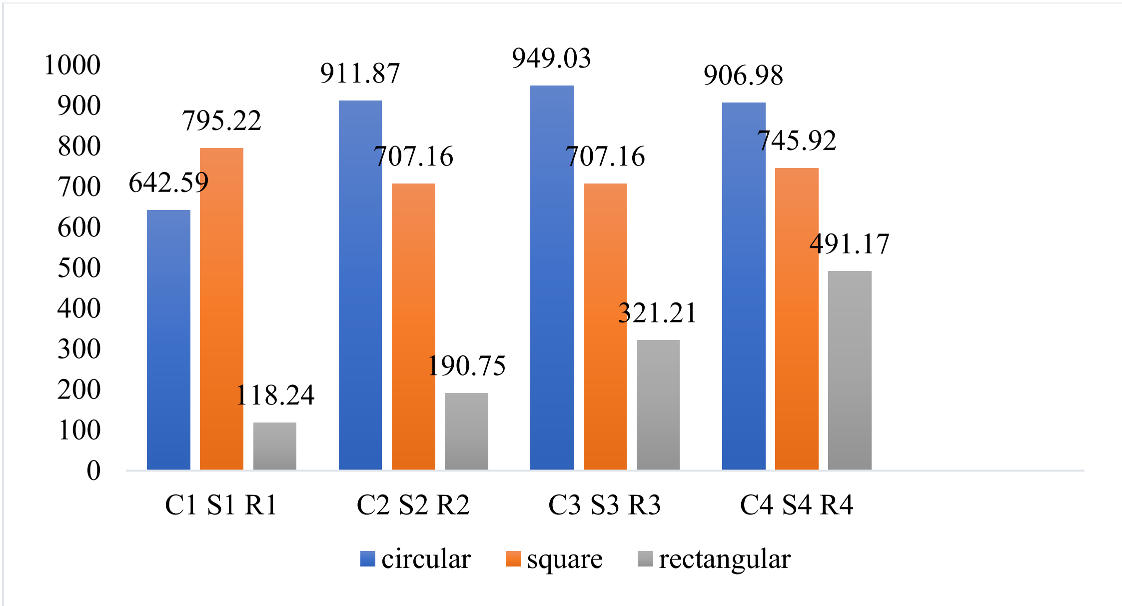

***Fig. 7**, Comparison of Load Carrying Capacity of all columns*

Test Results

Fig. 8,9,10 shows it filled with self-compacting concrete, the axial load of circular, square and rectangular columns. And it occurs the axial deflection produced by the transvers load. The axial compression in a bending moment and deflection of beam is more serious type of axial load is given below. Fig. 11,12,13 shows that hollow as well as packed with self-compacting concrete of lateral displacement, the load bearing capacity of square columns of all sizes. In all columns shows that in rectangular, the load carrying of all sizes, both solid and reinforced with self-compacting concrete. This test occurs high load and stresses and it was investigated [13]. From the fig. 7, shows that comparison of all columns is in load bearing capacity. The graph shows that the hollow square column performs better and rectangular columns as well. It can be observed that the self-compacting of circular columns performs better than the self-compacting concrete of square and rectangular columns.

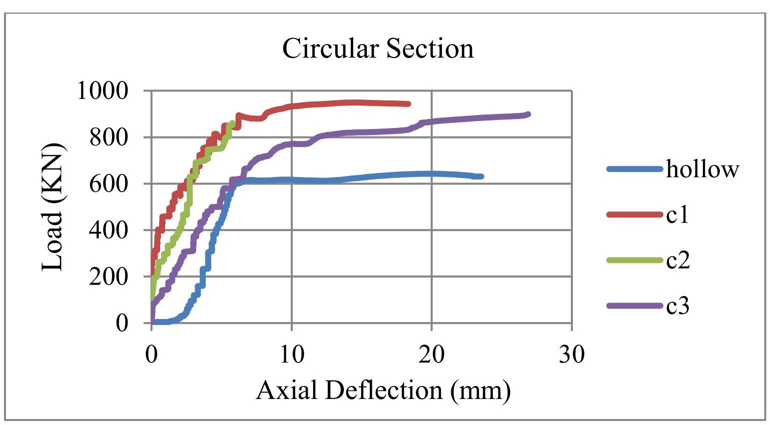

***Fig. 8,** Comparison of Axial load*

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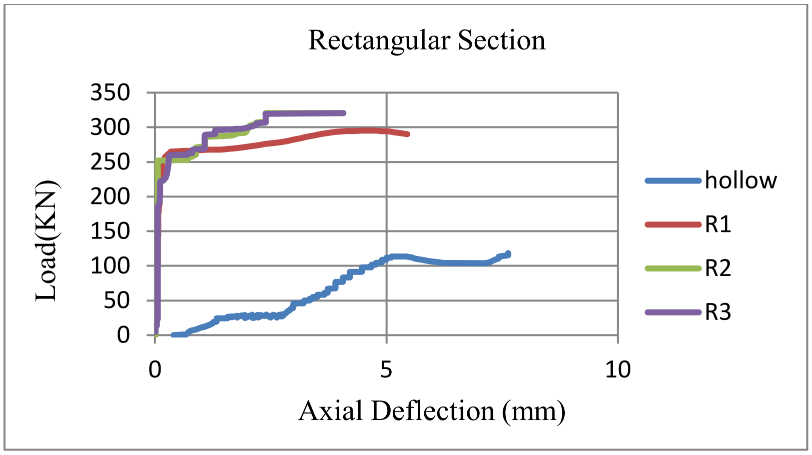

Fig. 9, *Comparison Axial Load.*

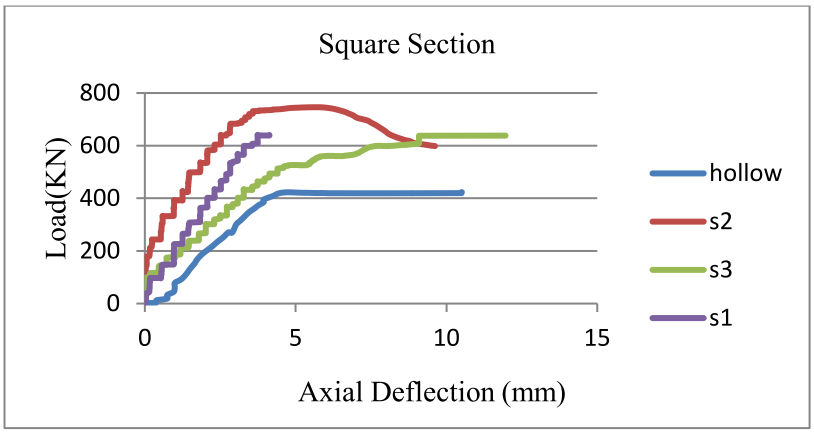

Fig. 10, *Comparison Axial load.*

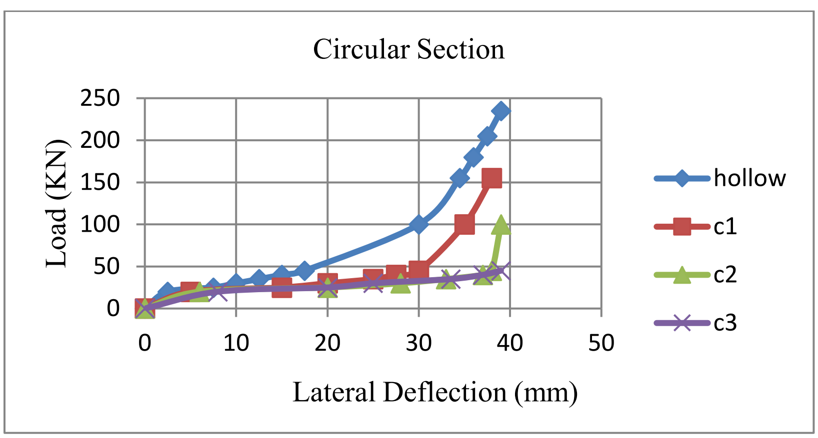

Fig. 11*, Load at Lateral displacement.*

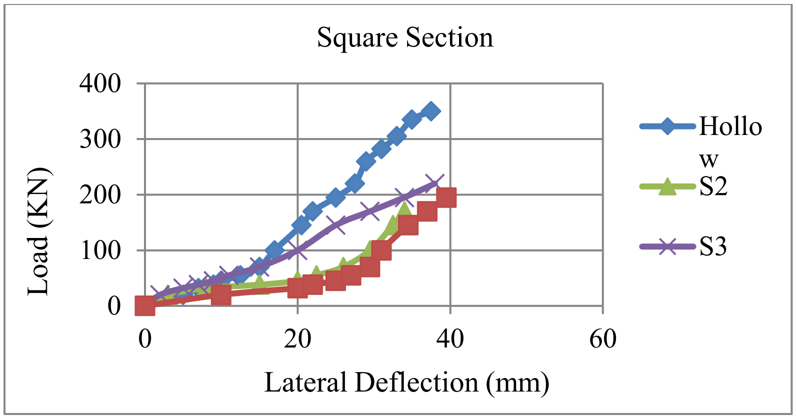

Fig. 12, *Load at Lateral displacement.*

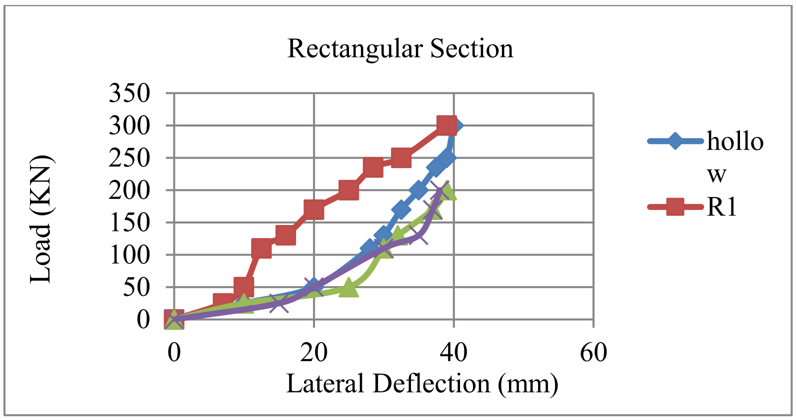

Fig. 13, *Load at Lateral displacement.*

Conclusion

Twelve columns were tested under axial compression. Four specimens were hollow structure columns and remaining eight are self-compacting concrete. Columns were ranged in shape, including circular, square and rectangular sections, lateral load deflection, failure mode. Concrete column strength has been tested against the efficiency of current concrete models and a model is proposed to fit various types of concrete, column forms and slenderness ratio.

- The failure modes the radial expansion, columns with a lower slenderness ratio are failed. Local buckling caused rectangular columns to collapse more frequently. Shear is failed by higher strength concrete than lower strength concrete.
- Column stiffness and concrete toughness also had an impact on the force reaction. Higher-strength concrete columns showed higher peak load characteristics. In general, an improvement in axial strength and an increase in column slenderness, with the exception of a few columns, has been observed.
- Biaxial stress factors were mainly based on cross-sectional, as the lateral stress factor for circular was higher for square and rectangular columns. In circular CFST subjected greater transverse stress development, providing a more confining effect. Thus, size reduction is necessary for square columns.
- The use of SCC greatly shortened the time between the steel tubes for in-filling the concrete. With an increase in the CFST column diameter, the load carrying capability of concrete filled steel tube columns has been raised. It was found that the load bearing capacity of the CFST

columns was exactly the same when the thickness of the outer steel tube was increased from 4 mm to 5 mm.

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