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Experimental and Numerical Investigation of Hollow Section With and Without Infill Under Compression and Flexure

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***Abstract*— A steel-concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled steel and is generally used as a load-bearing member in a composite framed structure. In the present study, an experiment is conducted on hollow structural steel with and without infill under compression and flexure. The Experiment is carried out on square hollow sections of dimension 75X75X1.6mm. For compression test; short, intermediate and long columns of length 300mm, 360mm, and 400mm are considered respectively. For flexure test, the composite specimen of length 350mm (effective length 310mm) is considered. The infill materials used in the hollow sections are design mix concrete and nofines concrete with chemical bond and mechanical bond. Compression and flexure tests are performed on the specimens and the behavior of the specimens are plotted. The behavior of hollow specimens with and without infill is observed from the experiment and also the effect of bonding between the concrete and steel is obtained. The percentage increase in the strength of hollow section is achieved from the experimental work. The results obtained from the experimental work are compared with numerical study by Finite Element Modeling using ANSYS.**

Keywords—composite section, chemical bond, mechanical bond compression, flexure, FEM.

I.INTRODUCTION

A steel-concrete composite structural member contains both structural steel and concrete elements which work together. There are many combinations between structural steel and concrete. For example, a concrete slab on a steel beam with mechanical shear connectors allows the slab and beam to resist bending moment together. Steel-reinforced concrete column (SRC), comprising a structural steel core surrounded by reinforced concrete, is used when an exposed concrete surface is required and when concrete is to protect the steel core from fire. Steel-concrete composite structures have become a popular choice for building construction due to their efficient and economic use of both steel and concrete construction materials. Most composite structures consist of structural steel frames with steel concrete composite columns to help control lateral drift. These composite columns may be circular or rectangular concrete-filled steel tubes (CFT) or steel shapes encased in reinforced concrete .In a concrete-filled steel tube column (CFT or CFST) the hollow steel tube is filled with concrete, with or without reinforcing bars. Here, the steel element contributes tensile capacity, provides confinement to concrete elements, and reduces concrete shrinkage while concrete element prevents steel from premature local buckling and fatigue.

Two types of composite columns, those with steel section encased in concrete and those with steel section in-filled with concrete are commonly used in buildings. Basic forms of cross-sections representative of composite columns are Concrete-encased steel composite columns Concrete-filled steel tubular columns

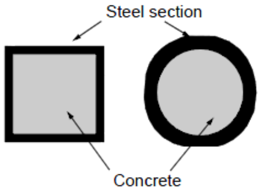

Figure 1- concrete filled steel columns

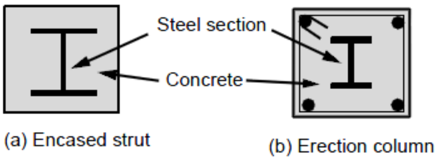

Figure 2- Encased composite section

A hollow structural section (HSS) is a type of metal profile with a hollow tubular cross section HSS is used as a structural element in buildings, bridges and other structures, and in a wide variety of manufactured products. It's produced in round, square and rectangular shapes in a broad range of sizes and gauges. HSS has many benefits: aesthetic appeal, high strength-to-weight ratios, uniform strength, cost effectiveness and recyclability. HSS is fire resistant and does not warp, twist, split, swell or shrink. It resists dry rot and mildew, termites and carpenter ants. For increased fire resistance, the exterior of the product may be sprayed with a fire retardant material, or boxed in with drywall. The interior can be filled with concrete.

Hollow sections are produced in circular, square and rectangular shapes in broad range of sizes and gauges. Fig shows the typical shapes of cross hollow sections.

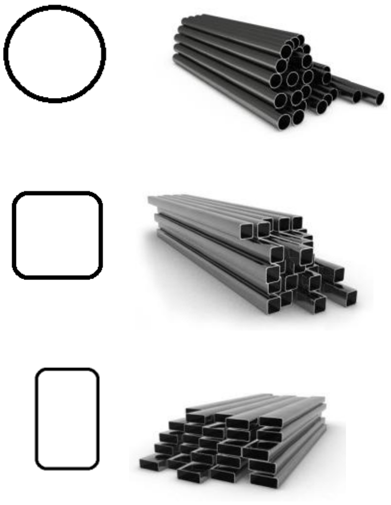

Figure 3- shapes of tube sections

A. *Finite Element Analysis*

The finite element method (FEM) of analysis is a very powerful, modern computational tool. The method has been used to solve very complex structural engineering problems, particularly in the aircraft industry, transient dynamic analysis, buckling analysis, nonlinear structural analysis, contact mechanics, fracture mechanics and composites analysis. It has gained wide acceptance in other disciplines such as thermal analysis, fluid mechanics and electromagnetics.

II. APPLICATIONS OF COMPOSITE CONSTRUCTION

Composite construction has been mainly applied to bridges and multistory buildings, with the more traditional forms of composite beams and composite columns. This section will look at the various applications of composite construction to both bridges and buildings.

A. *Bridges*

Composite construction with bridges allows the designer to take full advantage of the steel section in tension by shifting the compression force into the concrete slab in sagging bending. This is made possible through the transfer of longitudinal shear force through traditional headed-stud shear connectors. Headed-stud shear connectors not only provide the transfer of shear force, but also help to assist lateral stability of the section.

B. *Buildings*

In steel-framed buildings throughout the world, composite floors are essential in order to achieve an economic structure. This is for quite a few reasons. First, composite slabs allow reduced construction time by eliminating the need for propping and false work in the slab-pouring phase. Furthermore, composite beams are economical, as they reduce the structural depth of the floor and thereby increase the available floors in a given building.

C. *Other Structures*

In addition to bridges and buildings, composite slab and beam systems have seen considerable application in car park structures. Steel and steel–concrete composite construction provide a lighter structure with reduced foundation loads.

III. METHODOLOGY

The tests were performed in four series for each of the two tests each series consists of 9 specimens which are further subdivided as short column specimens, intermediate column specimens and long column specimens, consisting of 3 specimens respectively. Series 1 and 2 the specimens are casted with concrete and series 3 is casted with no fines concrete. Each column has cross sectional dimension as 75mmX75mm, and the length of specimens vary as 300mm, 360mm, and 400mm for short, intermediate and long column specimens respectively. the thickness of the hollow section used are 1.6mm. Table 1 and table 2 shows the tabulation of specimens used for compression and flexure tests

Table 1 specification of composite column for compression test

Series number	Concrete type	Bond type	COLUMN TYPE	Abbreviation used
Series I	Design mix concrete	Mechanical bond	Short column	RMSC1
				RMSC2
				RMSC3
			Intermediate column	RMIC1
				RMIC2
				RMIC3
			Long column	RMLC1
				RMLC2
				RMLC3
Series II	Design mix concrete	Chemical bond	Short column	RCSC1
				RCSC2
				RCSC3
			Intermediate column	RCIC1
				RCIC2
				RCIC3
			Long column	RCLC1
				RCLC2
				RCLC3
Series III	No fines concrete	Chemical bond	Short column	NCSC1
				NCSC2
				NCSC3
			intermediate column	NCIC1
				NCIC2
				NCIC3
			Long column	NCLC1
				NCLC2
				NCLC3
Series IV	Hollow section		Short column	HSC1
				HSC2
				HSC3
			Intermediate column	HIC1
				HIC2
				HIC3
			Long column	HLC1
				HLC2
				HLC3

Table 2 specification of composite beam section

Series number	Concrete type	Bond type	Abbreviation used
Series I	Design mix concrete	Mechanical bond	RMFC1
			RMFC2
			RMFC3
Series II	Design mix concrete	Chemical bond	RCFC1
			RCFC2
			RCFC3
Series III	No fines concrete	Chemical bond	NCFC1
			NCFC2
			NCFC3
Series IV	Hollow section		HFC1
			HFC2
			HFC3

IV. RESULTS AND DISCUSSION

A. *Observation on Compression Test*

Failure of short column under compression.

The height of the short column used in the experiment was 300mm. Initially the failure of concrete took place in no-fines concrete infill later composite action took place. In composite column yielding of steel is observed at the middle portion. The failure is as shown in the fig 4

Figure 4- failure of composite section under compression

Failure in intermediate column

Majority of the intermediate column failed due to buckling of the column either at the top or at the bottom. Especially in the no fines infill, failure took place at the top of the column, whereas in design mix concrete infill, failure took place at the bottom.

Figure 5- failure of composite section under compression

Failure of long column

Majority of the long column failed due to buckling of the column either at the top or at the bottom was observed. Especially in the no fines infill, failure took place at the top of the column, whereas in design mix concrete infill, failure took place at the bottom. In comparison with design mix concrete, nofines concrete infill showed maximum bending.

Figure 6- failure of composite section under compression

B. *Observation on Flexure Test*

The flexure test is performed in the universal testing machine by applying concentrated load at the center of the specimen. The failure of the flexural member took place at the bottom layer with formation of crack as shown in the fig 7

Figure 7- failure of composite beam section

C. *Load Deflection Relationship of Compression Test.*

The load- axial deformation curves for all the series are obtained. The variation for concrete filled short column specimens is shown in fig 8.

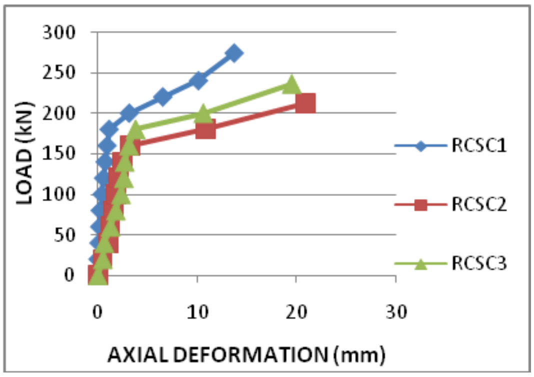

Figure 8 load - deformation curve for composite section

D. *Load Deflection Relationship of Flexure Test.*

The load deformation curve for flexure is as shown in fig 9

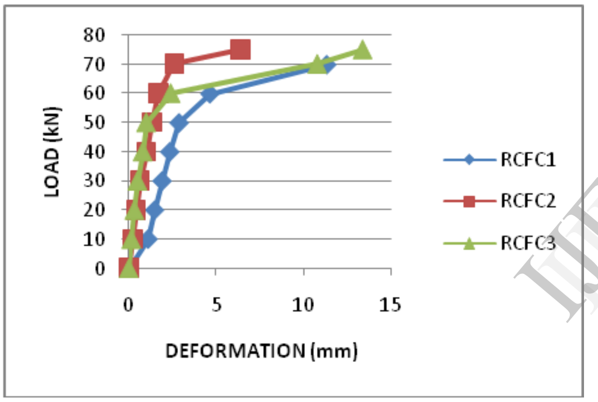

Figure 9 – load –deformation curve for composite section

The comparison of the hollow sections with and without infill is shown in the fig 10

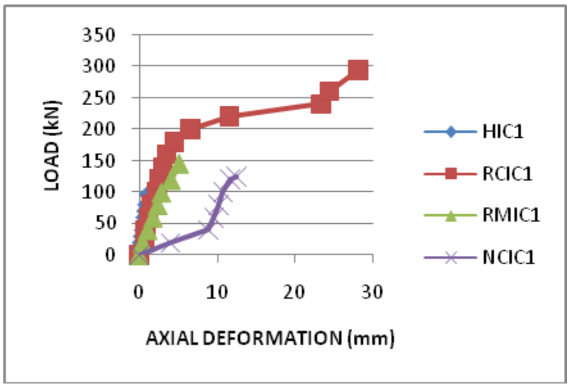

Figure 10- comparison of sections with and without infill

The ultimate load and deformation of the series of specimens used are tabulated as shown in the table

Table 3 – summary of flexure test results

Infill type	Bonding type	Beam specification	Ultimate load (in kN)	Maximum deformation (in mm)
Hollow		HFC1	15	8.59
		HFC2	14	9.3
		HFC3	14	9.08
Concrete	Chemical bonding	RCFC1	70	11.29
		RCFC2	75	6.4
		RCFC3	75	13.4
Concrete	Mechanical bonding	RMFC1	76	24
		RMFC2	70	17
		RMFC3	70	9
Nofines	Chemical bonding	NCFC1	35	20
		NCFC2	35	26.82
		NCFC3	30	10.8

Table 4 – summary of compression test results

Infill type	Bonding type	Column specifications		Ultimate load (in kN)	Maximum axial deformation (in mm)
Hollow		Short column	HSC1	104	1.25
			HSC2	106	1.1
			HSC3	106	2.25
		Intermediate column	HIC1	96	1.22
			HIC2	96	1.1
			HIC3	82	1.9
		Long column	HLC1	80	1.09
			HLC2	102	1.35
			HLC3	100	1.4
Concrete infill	Chemical bonding	Short column	RCSC1	274	13.7
			RCSC2	212	20.95
			RCSC3	236	19.47
		Intermediate column	RCIC1	294	28.17
			RCIC2	300	21.64
			RCIC3	284	22.85
		Long column	RCLC1	262	14.95
			RCLC2	260	12.61
			RCLC3	244	10.02
Concrete infill	Mechanical bonding	Short column	RMSC1	162	5
			RMSC2	214	4.8
			RMSC3	192	6.6
		Intermediate column	RMIC1	146	5.15
			RMIC2	172	3.96
			RMIC3	156	3.85
		Long column	RMLC1	206	12.3
			RMLC2	216	28.58
			RMLC3	206	24.03
Nofines	Chemical bonding	Short column	NCSC1	140	7
			NCSC2	140	8.3
			NCSC3	130	6.6
		Intermediate column	NCIC1	125	12.5
			NCIC2	110	12.5
			NCIC3	145	8.95
		Long column	NCLC1	116	14.1
			NCLC2	120	9.53
			NCLC3	118	11.45

The above experimental results are compared with the numerical analysis. The FEM model of the specimen subjected to compression and flexure are shown in figure 11 and figure 12.

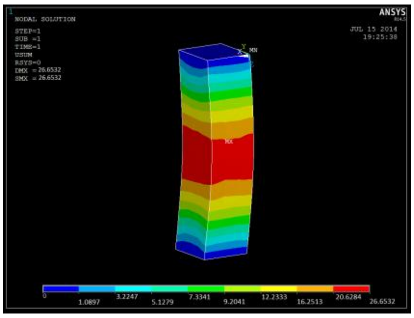

Figure 11 Model of composite section subjected to compression

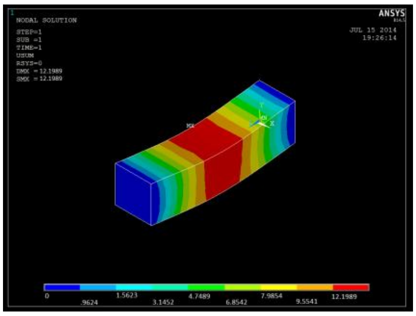

Figure 12 Model of composite section subjected to flexure

The numerical analysis in comparison with experimental results shows similar variations. The plot of numerical and experimental result is shown in figure 13.

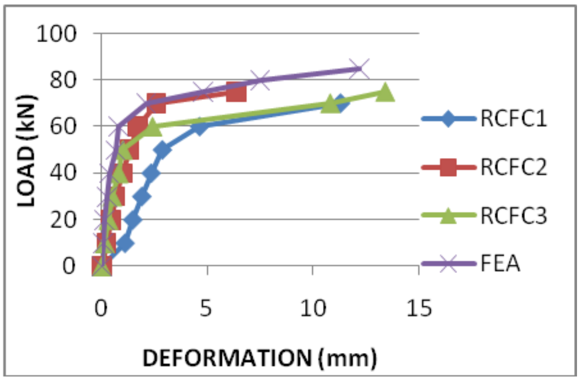

Figure 13 Comparison of experimental and FEA results under flexure

V. CONCLUSIONS

In the present study following conclusions are derived

1. The strength of the hollow section with infill were observed to be greater than the hollow section without infill in compression as well as in flexure.
2. Among the composite sections used the design mix concrete composite sections were shown better results than other forms of composite section.
3. The percentage increase in the compressive strength of the composite columns are as shown
    a. composite columns with chemical bonding - 60 to 70%.
    b. composite columns with mechanical bonding - 50 to 60%
    c. hollow columns with no fines concrete - 15 to 25%
4. The percentage increase in the flexural strength are as shown below.
    a. Composite section with chemical bonding and mechanical bonding - 80%
    b. hollow columns with no fines concrete - 57%
5. The above experimental results are compared with the numerical analysis of composite section. The results are compared for composite column section (RCIC) and composite beam section (RCFC).In comparison with the experimental results the numerical study shows similar variation.
6. There is an enhancement of ultimate load carrying capacity of specimen in numerical method than that of experimental results. It shows a deviation of 12% from experimental results for compression and the deviation under flexure is observed to be 15%.

REFERENCES

[1] K. Chithira and K. Baskar "Experimental and Numerical Investigation on Circular CFT Columns under Eccentric Load Condition with and without Shear Connectors" International Journal of Earth Sciences and EngineeringISSN 0974-5904, Vol. 05, No. 01, February 2012, pp. 169-179 (2012)

[2] Shehdeh Ghannam "Buckling of Concrete-Filled Steel Tubular Slender Columns"

[3] E. K. Mohanraj, Perundurai Dr. S. Kandasamy "Experimental Behavior of Axially Loaded Slender Hollow Steel Columns in-filled with Rubber Concrete" (2007)

[4] Anil Kumar Patidar" Behaviour of Concrete Filled Rectangular Steel Tube Column " IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684 Volume 4, Issue 2 (Nov. - Dec. 2012), PP 46-52 (2012)

[5] N.E. Shanmugam, B. Lakshmi "State of the art report on steel–concrete composite columns" Journal of Constructional Steel Research 57 (2001) 1041– 1080 (2001)

[6] Lin-Hai Han "Flexural behaviour of concrete-filled steel tubes" Journal of Constructional Steel Research 60 (2004) 313–337

[7] E. M. Lui "Structural Steel Design" 1999 by CRC Press LLC

[8] Brian Uy, J.Y. Richard Liew "Composite Steel–Concrete Structures" 2003 by CRC Press LLC