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FINITE ELEMENT ANALYSIS OF CONCRETE FILLED STEEL TUBE COLUMN

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ABSTRACT

Reinforced cement concrete is one of the most versatile and most commonly used construction material and it's discovery has been a boon to mankind. It essentially consists of providing reinforcement in the form of twisted steel bars of varying diameter in the concrete element to enhance its tensile strength. Structural hollow sections made of steel make the most efficient compression members, filling them with concrete gives further advantages, some of which includes, higher load carrying capacity, reduced sectional dimensions resulting in slender members etc.

These hollow sections have an added advantage of not needing of any formwork during the casting and installation as well as there are no requirement of fabrication of the reinforcements which inturn reduce the labor work and cost.

Another advantage of such sections is that concrete, which is susceptible to fire hazards is not exposed to the environment but the drawback here is the exposure of steel to the environment can result in corrosion which can be easily tackled by coating the steel member with suitable anti-rust or anti-corrosive coatings.

In modern construction, especially in the housing sector use of precast elements has become increasingly popular. These elements can also be used as precast members for repair purpose in case of damage to the structure due to various reasons such as natural calamities like earthquakes, old and dilapidated structures of archeological importance etc, popularly known as retrofitting and rehabilitation of structures etc,.

In this project, we mainly aim in confining concrete into hollow steel tube, this confinement of concrete in the steel tubes also provides lateral stability to the elements which in turn increases the load carrying capacity, its flexural stiffness and rigidity. These specimen tubes are then compared with hollow specimens of same dimensions in terms of their flexural strength, compressive strength, finite element analysis is carried out and the corresponding graphs are plotted.

1 INTRODUCTION

1.1INTRODUCTION OF RCC

Reinforced cement concrete is one of the most versatile and most commonly used construction material and it's discovery has been a boon to mankind. It essentially consists of providing reinforcements in the form of steel TMT or HYSD bars of varying diameter ranging from 8mm to 32mm in the concrete element to enhance its tensile strength, The steel reinforcement is provided as we know that concrete isvery poor in resisting tensile stresses.

1.2 CONCRETE

Concrete basically consists of the 4 most important components. Particularly Ordinary Portland Cement(OPC), first-class mixture(IS 4.75mm to 600 microns), coarse aggregates(IS 12.5mm to 4.75 mm), potable water, and admixtures(mineral and chemical).

Self-compacting concrete, (hereinafter refers as SCC), a new composite material, which has the capacity to waft under its very own weight over an extended distance without segregation and to acquire consolidation without the usage of vibrators, appears to be one of the answers to clear up all those creation associated issues. The use of SCC has probably lessened the desired labors by greater than50%. [RILEM, 1999]

1.3 NEED FOR THIS STUDY

This study and experimentation on Concrete in-filled tubular sections are specifically because of the following reasons.

1. There is no formwork required throughout its casting
2. There is not any need for the fabrication of reinforcements
3. Concrete that is solid is not exposed to the surroundings
4. Concrete being prone to hearth risks is protected here, though the steel is uncovered, it gives better resistance while compared to concrete
5. This undertaking has much application in precast works, repair and protection works, rehabilitation and retrofitting packages, and so forth.

1.4 OBJECTIVE OF THE STUDY

Steel contributors have the advantages of high tensile power and ductility, while concrete members have the benefits of excessive compressive power and stiffness. Composite participants combine metal and concrete, ensuing in a member that has the beneficial features of both substances. Here the energy and elastic houses of such beams may be studied.

1.5 SCOPE OF THE WORK

The scope is limited to the materials used for the experiments, which are

- Hollow rectangular steel section of 1 gauge measure only.
- One grade of SCC concrete of M20
- Testing is restricted to only flexure and compression.
- Comparison between the experimental results and the analyticalresults

2 LITERATURE REVIEW

Brian Uy, Sr. Lect. In Civ. Engrg., School of Civ. And Envir. Engrg., Univ. Of New South Wales, Sydney, NSW 2052

"Concrete stuffed metal field columns have these days skilled a renaissance in their use for the duration of the arena. This has occurred because of the massive blessings that the construction approach can offer. This paper deals with the energy behavior of brief columns under the mixed actions of axial compression and bending moment. The paper addresses the effect of steel plate slenderness limits on this conduct. A substantial set of experiments has been achieved and a numerical model developed someplace else is augmented and calibrated with those effects. A simple version for the dedication of the strength-interaction diagram is also proven towards both the take a look at effects and the numerical model advanced in this paper. This model, based on the rigid plastic approach of evaluation, is existent in worldwide codes of practice, however does no longer account for the outcomes of nearby buckling, which are located to be giant with large plate slenderness values, in particular for large values of axial force. Thus a few advised modifications are proposed to permit for the inclusion of slim plated columns in the layout."

BEHAVIOR OF CENTRALLY LOADED CONCRETE-FILLED STEEL-TUBE SHORT COLUMNS

Kenji Sakino1; Hiroyuki Nakahara2; Shosuke Morino3; and Isao Nishiyama

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[4]Advanced Research Engineer, Dept. Of Production Engineering, Building Research Institute, Tachihara-1, Tsukuba, Ibaraki 305-0802, Japan.

"A five one year have look at concrete-filled steel tubular (CFT) column machine became achieved as a part of the fifth phase of the U.S.–Japan Cooperative Earthquake Research Program, and the checks of centrally loaded quick columns had been finished. The objectives of those checks have been to make clear the synergistic interaction among steel tube and filled concrete and to derive strategies to signify the load-deformation courting of CFT columns. A trendy of 114 specimens were fabricated and examined within the experimental section of investigations on centrally loaded hollow and CFT short columns. Parameters for the assessments are as follows: (1) tube form, (2) tube tensile strength, (3) tube diameter-to-thickness ratio, and (4) concrete energy. In determining the range of parameters, the emphasis changed into placed on obtaining a big variety of taking a observe records for establishing a normally relevant layout technique of CFT column systems. Design formulation to estimate the last axial compressive load capacities are proposed for CFT columns with each round and rectangular sections based totally on tests effects defined in this paper."

ANALYSIS OF CONCRETE-FILLED STEEL TUBULAR BEAM-COLUMNS

W. F. Chen [1] and C. H. Chen [2]

[1]Associate Professor of Civil Engineering, Lehigh University, Bethlehem, Pennsylvania.

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FLEXURAL AND CYCLIC BEHAVIOUR OF HOLLOW AND CONCRETE-FILLED STEEL TUBES

Arivalagan .S[1], Kandasamy.S[2]

[1]Dept.Of Civil Engg., Dr. M.G.R.Educational and Research Institute, Dept. Of Civil Engg., Dr. M.G.R.Educational and Research Institute, Dr. M.G.R.University, Chennai, TamilNadu, India.

[2]Dean, Anna University-Trichirappali,Ariyallur Campus, Ariyallur,TamilNadu,

"This paper offers a remark on the flexural and cyclic behavior of concrete crammed steel hole beam sections. The specimens in-full of regular blend concrete, fly ash concrete, quarry waste concrete, and low electricity concrete (Brick-bat-lime concrete), and hollow metal sections were examined. Measurements of lines and deflections had been made under two-issue loading. A theoretical model will become moreover superior to are anticipating instantaneous wearing capability. The capacities of the beams were in comparison with the final capacity acquired by the use of the global requirements EC4-1994, ACI-2002, and AISC-LRFD-1999. The stop result of the experimental research showed that the on-the-spot wearing potential will boom primarily based on the compressive strength of the filler substances. Energy absorption potential moreover boom due to infilled substances. Analytical outcomes display suitable agreements with experimental results."

NUMERICAL ANALYSIS OF CONCRETE-FILLED CIRCULAR STEEL TUBES

Yaohua Deng, University of Nebraska-Lincoln
Terri R. Norton, University of Nebraska-Lincoln
Christopher Y. Tuan, University of Nebraska-Lincoln,

"Concrete-filled metallic tubes (CFTs) are composite members proudly owning the tremendous attributes of each concrete and steel. The flexural conduct of CFTs and submit-tensioned CFTs became investigated analytically. Finite-detail evaluation (FEA) changed into carried out the use of the elastic - flawlessly plastic uniaxial cloth model for metal and the Drucker-Prager (DP) plasticity model for concrete. Theoretical sectional evaluation (TSA) becomes completed by the use of dividing the circulate segment of a round CFT member proper right into a massive wide kind of horizontal layers parallel to the axis of bending. The elastic perfectly plastic uniaxial fabric model became significantly utilized for the metal tube and restricted concrete idea became implemented to the concrete middle"

3 EXPERIMENTAL DETAILS

3.1 INTRODUCTION

This chapter deals with the materials used, procedure adopted in this study.

3.2 MATERIALS:

3.2.1 CEMENT:

All forms of cement complying with Indian Standards are appropriate for making concrete. The choice of the kind of cement and content depends on the energy requirements, the exposure class for durability and the minimum amount of fines required for the mix.

3.2.2 Coarse aggregates:

Concrete may be crafted from most regular concreting aggregates. Coarse aggregates vary in nature and shape depending on their extraction and manufacturing. SCC has been produced successfully with coarse aggregate of as much as 40mm.

3.2.3 Water

Potable water as obtained from Bore well was used for the preparation of concrete mix and for curing as per Indian Standards.

3.2.4 Admixtures:

Admixtures are critical in determining drift traits and workability retention. Superplasticizers are vital additives SCC to provide the necessary workability. Other sorts can be included as vital, which includes Viscosity Modifying Agents (VMA) for stability, Air Entraining Admixtures (AEA) to improve freeze-thaw resistance, retarders to manipulate of placing, and so forth. Other materials may additionally indicate the requirement for additional segregation manipulate admixtures such as extremely first-rate silica, polysaccharide gum, modifying polyether, or maybe simple air-entrainers.

3.3 Flexure specimens

- Two hollow specimens have been prepared for flexural testing.
- The gross length of the specimens was 1.2m and had a powerful length of 0.9m(Fig. 2)
- A thin steel strip changed into attached on the mid-span to facilitate for solving of the dial gauge required to file deflections for the duration of the loaded software.

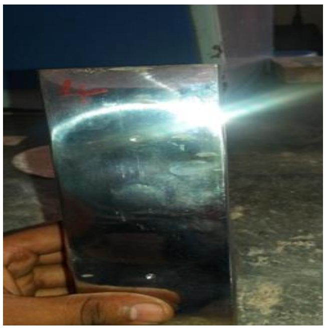

Figure 1 Specimen

Figure 2 Specimen

3.4 Concrete Mix Design

SCC Mix design adopted is based on Volume Fraction method.Notations used:

V - Volume of concrete 0.37 = Vc +Vfly + Vw

3.4.1 Preparation of In-filled Specimens

Stainless steel rectangular hollow tubes having the following characteristics is used for the all the experiments:

- Grade of steel : 202
- Tensile strength : 515M
- Elastic modulus : 207G
- Poisson's ratio : 0.27

The specimen was 6.5m factory made. This was later cut into four specimens of 1.2m length for flexure tests and 0.2m for compression tests.

3.5 Compression specimens

- Two-hole specimens have been organized for a compression check.
- The gross duration of the specimens was zero.2m and the gauge duration was fixed to 0.1m to accommodate the dial gauge(Fig. Three)

Figure 3 gauge duration was fixed to 0.1m to accommodate the dial gauge

3.6. Introduction

Many distinctive checks strategies had been in an attempt to characterize the homes of SCC so far no unmarried approach or combination of techniques has completed usual approval and maximum of them have their adherents. Similarly, no single strategy has been found which characterizes all of the relevant workability factors so each mix design need to be tested via more than one test method for distinct workability parameters. Typical reputation standards for SCC with a maximum mixture length of as much as 20mm are shown in Table.3.1

TABLE 3.1: List of Test Methods for Workability Properties of SCC.

SL.NO	METHOD	PROPERTY
1	SLUMP FLOW BY ABRAMS CONE	FILLING ABILITY
2	T50 cm SLUMP FLOW	FILLING ABILITY
3	J-RING	PASSING ABILITY
4	V-FUNNEL	FILLING ABILITY
5	V-FUNNEL AT 5 MINUTES	SEGGREGATION RESISTANCE
6	L-BOX	PASSING ABILITY
7	U-BOX	PASSING ABILITY
8	FILL-BOX	PASSING ABILITY
9	GTM SCREEN STABILITY TEST	SEGGREGATION RESISTANCE
10	ORIMET TEST	FILLING ABILITY

TABLE 3.2: Acceptance Criteria for SCC

SL. NO	METHOD	UNIT	MINIMUM VALUE	MAXIMUM VALUE
1	Slump Flow by Abrams Cone	mm	650	800
2	T50 cm Slump Flow	Sec	2	5
3	J-RING	mm	0	10
4	V-FUNNEL	Sec	6	12
5	V-FUNNEL AT 5 MINUTES	Sec	0	+3
6	L-BOX	h2/h1	0.8	1.0
7	FILL-BOX	%	90	100

3.6.1 Slump Flow Test and T_{50cm} Test:

The slump drift is used to evaluate the horizontal loose go with the flow of SCC inside the absence of obstructions. It became first advanced in Japan for

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use in the evaluation of underwater concrete. The test approach is primarily based on the test method for figuring out the slump. The diameter of the concrete circle is a degree for the filling capacity of the concrete.

3.7 EQUIPMENT:

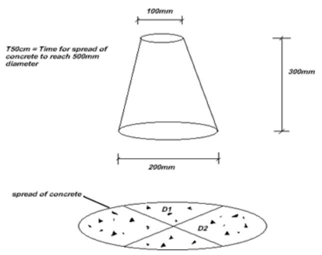


Fig. 4: Slump Flow and T_{50cm} Test

- Mould in the shape of a truncated cone with an internal dimensions 200mm diameter at the base, 100mm diameter at the top and a height 300mm, confirming to EN 12350-2.
- Trowel.
- Scoop.
- Ruler.
- Stop watch (optional).

3.7.1 Interpretation of Results:

The higher the stoop waft (SF) value, the extra is its capability to fill formwork beneath its own weight. A fee of a minimum of 650mm is needed for SCC. There is no typically everyday recommendation as to whatever the affordable tolerances about a precise fee are, although □ 50mm, as with the associated drift table test, might be appropriate.

The T50 time is a secondary indication of float. A lower time suggests greater flowability. The BriteEuRam studies suggested that a time of three to 7 seconds is appropriate for civil engineering programs, and a pair of to five seconds for housing packages. In case of intense segregation, most coarse aggregate will remain within the center of a pool of concrete and mortar and cement paste at the concrete periphery. In case of minor segregation, a border of mortar without coarse aggregate can arise at the threshold of the pool of the concrete.

3.7..2 J-RING TEST

The principle of J ring test may be from the Japanese, however, no references are recognized. The J ring takes a look at itself has been evolved at the University of Paisley. The take a look at is used to develop the passing capability of the concrete. The device includes a square phase (30mm x 25mm) open metallic ring, drilled vertically with holes to accept threaded sections of reinforcement bars. according to the regular reinforcement issues, in three instances the maximum mixture length can be appropriate. The diameter of the hoop of the vertical bars is 300mm, and the height is 100mm.

The J ring takes a look at can be used together with the hunch float take a look at, the Orimet take a look at, or ultimately even the V-Funnel test. These combinations test the flowing capability (the contribution of the J ring) and the passing potential of the concrete. The Ouimet time and or droop glide unfold is measured as regular to assess the glide traits.

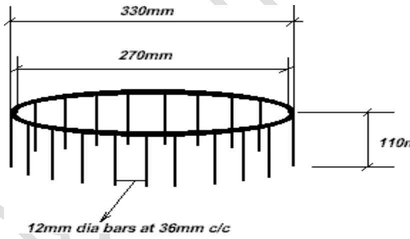
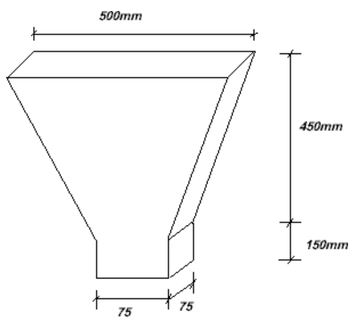


Fig.5 J-RING Apparatus

3.7.3 V-FUNNEL TEST AND V-FUNNEL TEST AT 5 MINUTES

The take a look at becoming advanced in Japan and utilized by Ozawa Et Al (5). The gadget includes a V-shaped funnel, proven in determine. An opportunity type of V-funnel, the O funnel, with a circular segment is likewise utilized in Japan.

The defined V-funnel take a look at is used to decide the filling capacity (flowability) of the concrete with the most mixtures size of 20mm. The funnel is filled with approximately 12 liters of concrete and the time taken for it to float thru the apparatus is measured.



` **Fig.6. V-Funnel Test Apparatus**

Equipment:

- V-Funnel.
- Bucket (12 liters).
- Scoop.
- Stopwatch.

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3.8 L-BOX TEST

This test, primarily based on a Japanese layout for underwater concrete, has been defined by way of Petersson [28]. The take a look at assesses the waft of concrete, and also the extent to which it is subjected to blocking off by way of reinforcements. The apparatus is as proven in the figure.

The equipment consists of a rectangular segment container in the form of an "L", with a vertical and horizontal section, separated via a movable gate, in front of which vertical lengths of reinforcement bars are fitted. The vertical segment is filled with concrete, after which the gate is lifted to allow the concrete to flow into the horizontal phase. When the glide has stopped, the height of the concrete at the give up of the horizontal phase is expressed as a percentage of that ultimate in the vertical segment (H2/H1 inside the diagram). It indicates the "slope" of the concrete while at rest.

3.8.1 Equipment:

- L box of a stiff and non-absorbing material.
- Trowel.
- Scoop.
- Stopwatch.

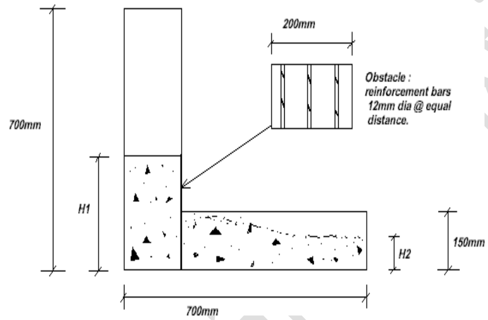


Fig.7: L-BOX Test Apparatus

4 EXPERIMENTAL PROCEEDINGS

4.1 Introduction

This chapter deals with the methodology adopted, and various tests conducted.

4.1.1 Preparation of Experimental Set-up - FLEXURE TEST

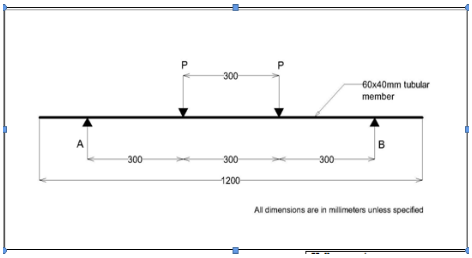


Fig. 8 FLEXURE TEST

Fig. 9: Flexure test set-up

4.2 Test Results

Specimen	Ultimate Load	Ultimate Stress	Ultimate Moment
Hollow specimens			
1.	25.05 kN	118.75 N/mm^2	3757.5 N-m
2.	27.05 kN	156.25 N/mm^2	4057.5 N-m
3.	22.18 kN	138.63 N/mm^2	3327 N-m
4.	26.97 kN	168.58 N/mm^2	4046 N-m
In-filled specimens			
1.	32.93 kN	205.81 N/mm^2	4939 N-m
2.	34.37 kN	212.5 N/mm^2	5155 N-m
3.	32.07 kN	200.42 N/mm^2	4810 N-m
4.	33.00 kN	206.26 N/mm^2	4950 N-m

Test results display that there may be consistency within the failure masses taken up by the specimens.

- It can also be seen that there is a growth within the load-wearing capability of the tubular sections whilst filled with concrete.

4.2.1 FAILURE PATTERN

- ✓ Hollow metallic tubes –Local buckling of the specimen at points of load application.
- ✓ Concrete in-filled metal tubes -Pure flexural failure with the improvement of cracks at the tensile face of the specimen.
- ✓ It can therefore be concluded that there may be bonding between the steel and urban and the inner surface isn't clean in place of the outer polished surface.

Fig. 10: View of the test set-up

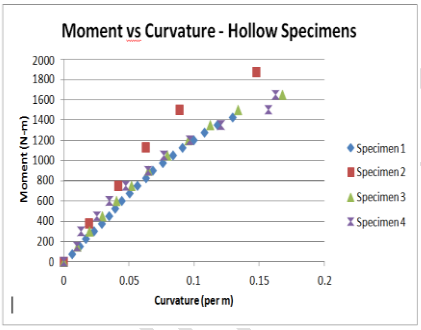
Fig. 11: Bending of the specimen.

Fig. 12 Bending of hollow specimen with slight crimping at pointsof application of load.

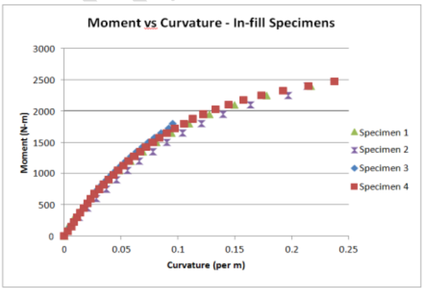
4.3 PLOT OF THE RESULTS

- The specimens, both, hole and In-stuffed have been subjected to flexure trying out as explained above and corresponding hundreds and deflections had been recorded(Appendix A).
- Using the received loads and deflections, the following plots of second- curvature, pressure pressure and cargo-deflection curves are plotted after calculations of the required parameters.

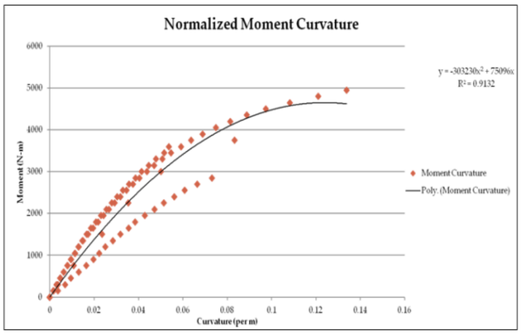
4.3.1 Moment vs. Curvature plots



Graph 1: Plot of moment

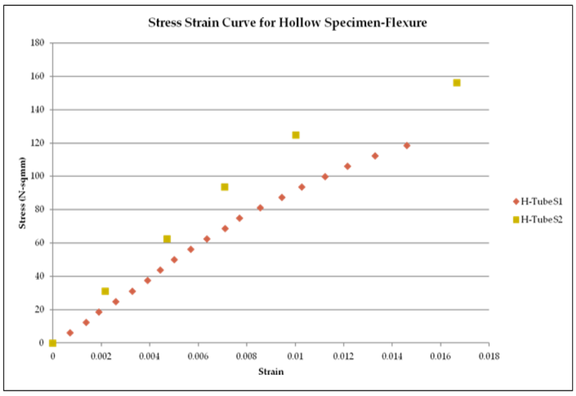


Graph 2: Plot of moment vs. Curvature for in-filled specimens subjectedto flexure loading.

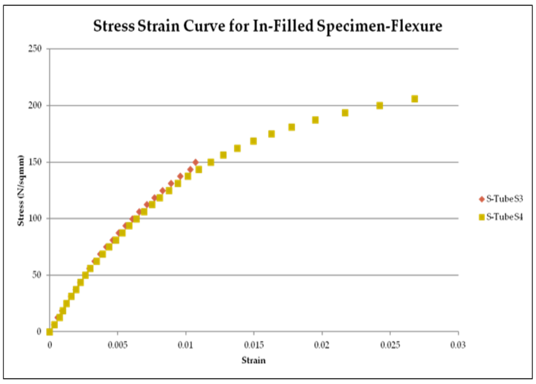


Graph 3 Plot of normalized moment vs. Curvature to flexure loading. The equationgives the flexural rigidity of the composite specimen.

4.3.2Stress vs. Strain graphs:



Graph 4 Plot of Stress Strain curve for hollow specimenssubjected to flexure loading



Graph 5 Plot of stress strain curve for in-filled specimens subjected to flexureloading

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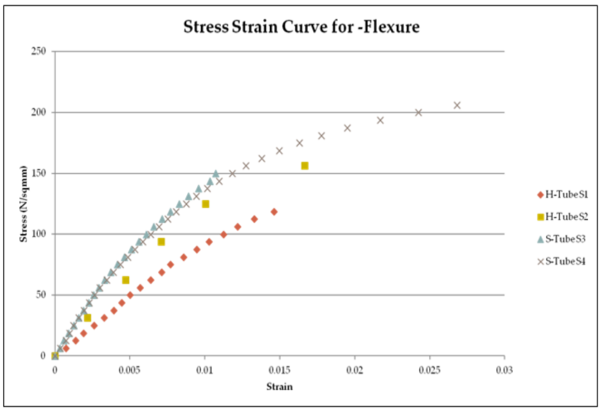
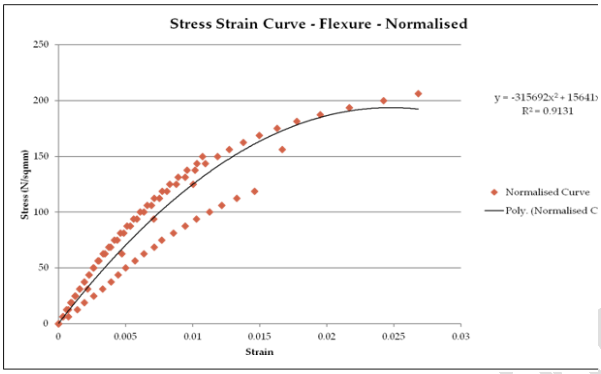
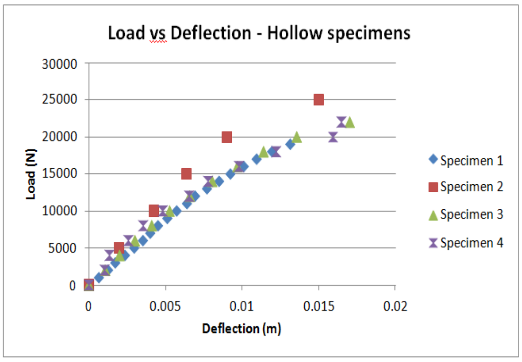


Graph 6 Comparison of plots of stress strain for all specimens subjected to flexureloading

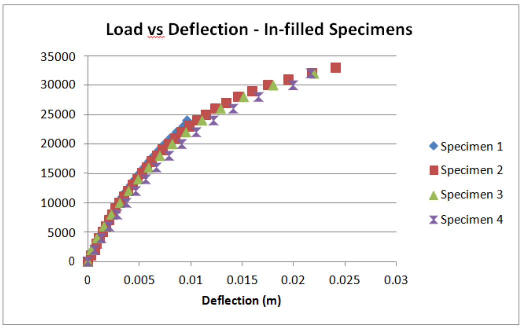


Graph 7 Normalized plot of Stress vs. Strain for the specimens subjected to flexureloading. The equation to the trend line gives the equivalent modulus of elasticity forthe composite specimen.

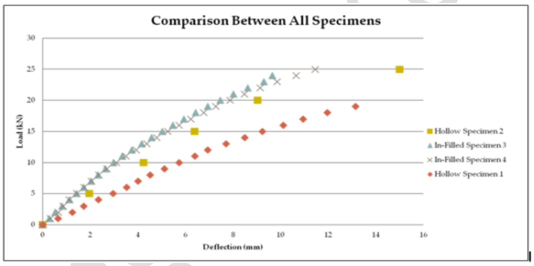
4.3.3 Load vs. Deflection plots



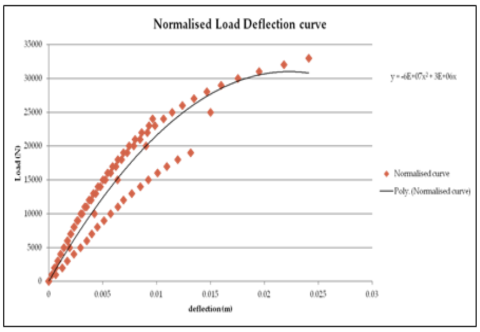
Graph 9: Plot of Load vs. Deflection for hollow specimens subjected to flexure loading



Graph 10: Plot of load vs. deflection for in-filled specimens subjected to flexureloading



Graph 11: Plot of load vs. deflection for all specimens subjected to flexure loading



Graph 12 Normalised load deflection curve

4.4 PREPARATION OF EXPERIMENTAL SET-UP - COMPRESSION TEST

- Fig.18 indicates the experimental set-up adopted for undertaking compression test to ascertain the compressive energy in addition to different parameters that are defined beneath.
- The set-up or arrangements worried leveling of the specimens to the true aircraft which will ensure that loading is along its axis or in other phrases to make sure that only axial loading is implemented.
- Two indents were made on one face of the specimen to facilitate for solving of the De-mech dial gauge as proven in Fig. 18.
- The masses and corresponding deflection were recorded and diverse parameters including strain, stress is calculated (Appendix B) and the following graphs are plotted.

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Stress vs. Strain graphs
Load vs. Deflection graphs.

Fig. 13 Experimental set-up for compression testing.

4.5 Test results

Specimen	Ultimate Load	Ultimate Stress
Hollow Specimen		
1.	120.00 kN	50.00 N/mm²
2.	123.43 kN	51.43 N/mm²
3.	147.50 kN	61.46 N/mm²
4.	156.00 kN	65.00 N/mm²
In-Filled Specimen		
1.	237.00 kN	98.75 N/mm²
2.	227.00 kN	94.58 N/mm²
3.	228.00 kN	95.00 N/mm²
4.	235.50 kN	98.13 N/mm²

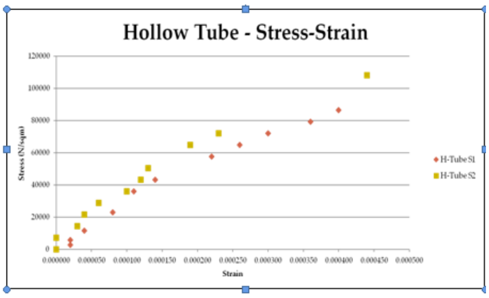
Failure pattern

Fig. 14 Failure in in-filled specimen.

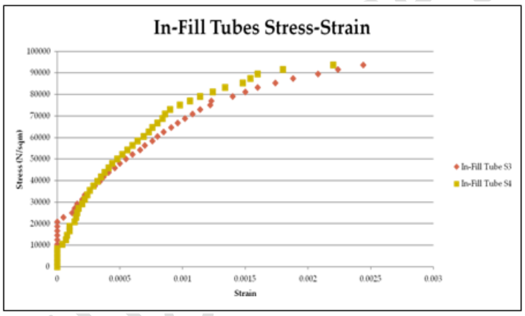
Fig. 15 Top view of failure of in-filled specimen, buckling near the top surface.

Plot of the results

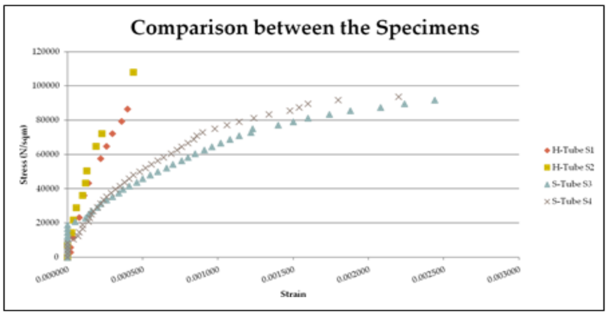
4.5.1 Stress vs. Strain Curves



Graph 13: Plot of Stress vs. Strain curve for hollow specimens subjected to axial compression loading.



Graph 14: Plot of Stress vs. Strain curve for in-filled specimens subjected to axial compression loading.



Graph 15: Comparison of plots of Stress vs. Strain curve for specimens subjected to axialcompression loading.

CHAPTER 5
FREE VIBRATION TEST

5.1 EXPERIMENTAL SET-UP

- The main objective of this test is to determine the natural frequency of the specimens which in turn is required to calculate the effective flexural rigidity and effective modulus of elasticity.
- It may be calculated as elaborated as follows:
- The formula used to calculate flexural rigidity for continuous systems is given by:

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$$\omega = \acute{a} * \sqrt{EI/mL^4}$$

Where,

ω – natural frequency of system = 2πf (where f is frequency in Hertz)
EI – flexural rigidity
– 3.516 for fundamental mode


Fig. 16 Fig. 17

- The accelerometers had been hooked up in this type of manner that they had been capable of report the vibrations at the edge in addition to inside the mid span of the element.
- The detail was subjected to cantilever boundary situations as proven within the figures.

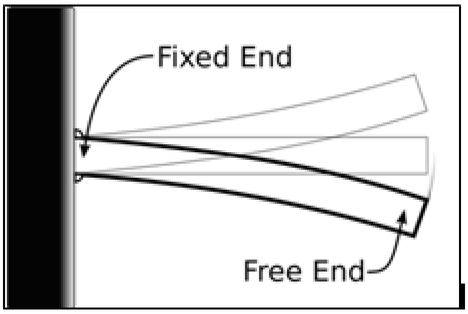


Fig. 18


Fig. 19 Fig.20

- It can observed in Fig. 29 that the element is clamped by fixing it to the Universal testing machine by applying just enough load sufficient to hold it firmly.

5.2 Results

The following plots were obtained through a platform called EZ-Analyst and the Fourier amplitude was determined.

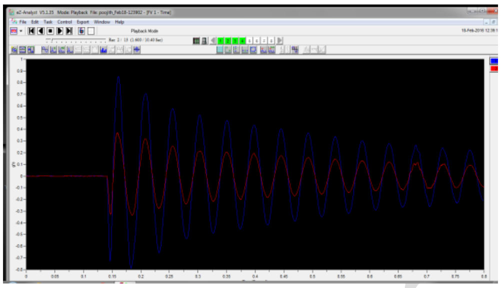


Fig. 21 Plot of time history data for hollow specimens.

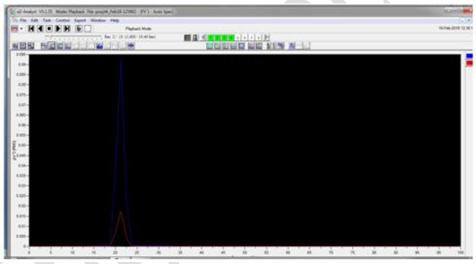


Fig. 22 Plot of Fourier amplitude.

Fundamental Frequency = 21.25Hz
Using this frequency, we can calculate the flexural rigidity and in turn we can determine the equivalent modulus of elasticity, using the formula stated above.

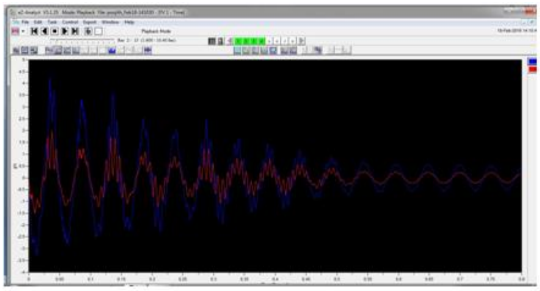


Fig. 23 Plot of time history data for in-filled specimen

It can be observed from Fig. 32 that apart from the fundamental modes, other modes have been excited as well, but the fundamental mode is distinguished from the peaks.

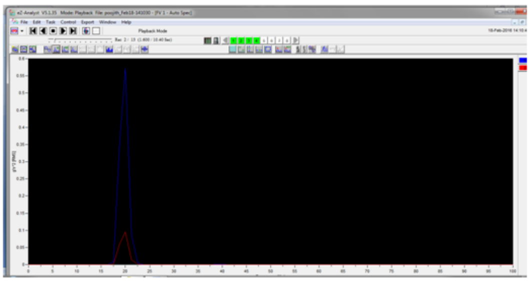


Fig. 24 Plot of Fourier amplitude for in-filled

specimens.

CHAPTER 6
FINITE ELEMENT ANALYSIS

6.1 INTRODUCTION OF FEM

- The finite element evaluation is a numerical method. In this approach all the complexities of the issues, like various form, boundary conditions and hundreds are maintained as they'll be.
- Because of its range and versatility as an evaluation device, it is receiving tons interest in engineering. Some of the famous programs are Staad-Pro, Gt-Strudel, NISA .
- Civil engineers use this method drastically for the evaluation of beams, space frames, plates, shells, folded plates, foundations, rock mechanics problems and seepage evaluation of fluid via porous media.
- Both static and dynamic troubles may be treated thru finite element evaluation.
- Free vibrations were simulated to the specimens with the aid of using modelling them on a Finite Element Analysis software program software, NISA – Display IV.

- Natural frequency of the specimens, traditional mass and Eigen charge evaluation have been acquired and consequences are confirmed in following slides

6.2 Results

Hollow Specimen

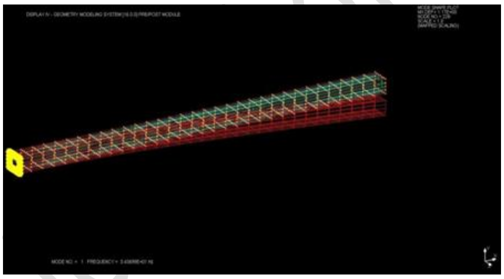


Fig. 25 Free vibration simulation of hollow tubular section.

GEOMETRIC PROPERTIES OF THE MODEL

TOTAL VOLUME = 3.24960E-03
TOTAL MASS = 9.81336E+00
X COORDINATE OF C.G. = 6.00000E-01
Y COORDINATE OF C.G. = 2.00000E-02
Z COORDINATE OF C.G. = 3.00000E-02

MASS MOMENT OF INERTIA WITH RESPECT TO GLOBAL AXES AT GLOBAL ORIGIN
IXX = 1.81709E-02 IXY = 1.17760E-01
IYY = 4.72289E+00 IYZ = 5.88802E-03
IZZ = 4.71611E+00 IXZ = 1.76640E-01

MASS MOMENT OF INERTIA WITH RESPECT TO CARTESIAN AXES AT C.G.
IXX = 5.41357E-03 IXY = 4.02456E-15
IYY = 1.18124E+00 IYZ = 7.97973E-17
IZZ = 1.17938E+00 IXZ = 2.94209E-15

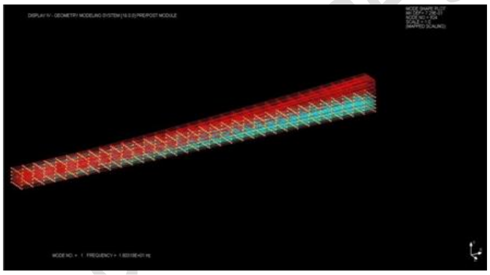
Fig. 26 Various properties of the specimen as obtained in NISA Display IV

****** E I G E N V A L U E A N A L Y S I S ******

	MODE NUMBER	****** FREQUENCY ****** (RAD/SEC)	(CYCLES/SEC)	PERIOD (SEC)	TOLERANCE
0	1	2.159527E+02	3.436993E+01	2.909520E-02	3.120348E-15
0	2	2.927242E+02	4.658850E+01	2.146453E-02	8.491277E-16
0	3	1.319594E+03	2.100198E+02	4.761455E-03	1.069670E-15
0	4	1.785494E+03	2.841701E+02	3.519019E-03	1.606742E-15
0	5	3.386860E+03	5.390355E+02	1.855165E-03	1.623812E-16
0	6	3.513019E+03	5.591143E+02	1.788543E-03	9.046611E-13
0	7	4.788279E+03	7.620782E+02	1.312201E-03	1.480161E-08
0	8	5.503861E+03	8.759666E+02	1.141596E-03	5.639207E-08
0	9	5.986742E+03	9.528196E+02	1.049517E-03	1.963465E-06
0	10	6.051318E+03	9.630972E+02	1.038317E-03	7.188866E-07

Fig.27 The frequencies of 10 modes obtained in NISA Display IV

In-filled specimen



$y = -9E+11x^2 + 7E+09x$

Fig. 37 Free vibration simulation of in-filled tubular section.

$y = -303230x^2 + 75096x$

GEOMETRIC PROPERTIES OF THE MODEL

TOTAL VOLUME = 3.24960E-03
TOTAL MASS = 9.81336E+00
X COORDINATE OF C.G. = 6.00000E-01
Y COORDINATE OF C.G. = 2.00000E-02
Z COORDINATE OF C.G. = 3.00000E-02

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IXX = 1.81709E-02 IXY = 1.17760E-01
IYY = 4.72289E+00 IYZ = 5.88802E-03
IZZ = 4.71611E+00 IXZ = 1.76640E-01

MASS MOMENT OF INERTIA WITH RESPECT TO CARTESIAN AXES AT C.G.
IXX = 5.41357E-03 IXY = 4.02456E-15
IYY = 1.18124E+00 IYZ = 7.97973E-17
IZZ = 1.17938E+00 IXZ = 2.94209E-15

Fig. 28 Mass characteristic of in-filled specimen

It can be observed that the frequency obtained within the free vibration check and that received in the finite element analysis is almost comparable.
The minor versions in the outcomes may be due to numerous conditions consisting of:

- Laboratory situations
- Boundary situations, and so on.

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GEOMETRIC PROPERTIES  OF  THE  MODEL
------------------------------------

TOTAL VOLUME                 = 3.24960E-03
TOTAL MASS                   = 9.81336E+00
X COORDINATE OF C.G.         = 6.00000E-01
Y COORDINATE OF C.G.         = 2.00000E-02
Z COORDINATE OF C.G.         = 3.00000E-02

MASS MOMENT OF INERTIA WITH RESPECT TO GLOBAL AXES AT GLOBAL ORIGIN
IXX = 1.81709E-02         IXY = 1.17760E-01
IYY = 4.72289E+00         IYZ = 5.88802E-03
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MASS MOMENT OF INERTIA WITH RESPECT TO CARTESIAN AXES AT C.G.
IXX = 5.41357E-03         IXY = 4.02456E-15
IYY = 1.18124E+00         IYZ = 7.97973E-17
IZZ = 1.17938E+00         IXZ = 2.94209E-15
```

7 RESULTS AND CONCLUSION

7.1 FLEXURAL TEST RESULTS:

$$y = -303230x^2 + 75096x$$

Moment vs. Curvature Plot

- The slope of Moment vs. Curvature gives the of the composite element in flexure and it can be calculated by using the equation of the trend line plotted.
- Therefore, by differentiating the equation
- we get, $\frac{dy}{dx}$, which is nothing but theat any given point on the trend line.

7.2 COMPRESSION TEST RESULTS:

Stress vs. Strain Plot

- The slope of the Stress vs. Strain plot gives the modulus of elasticity of the specimen in compression and this can be calculated by using the equation obtained from the trend line plotted for the normalised stress vs. strain graph.

$$y = -3E+10x^2 + 1E+08x$$

8 CONCLUSION

- ✓ It is found out that both hollow as well as in-filled specimens have their own merits as well as demerits.
- ✓ It can however be noted In-Filled specimens displayed higher load carrying capacity when compared to hollow specimens.
- ✓ Similarly In-Filled specimens has a higher Strain Energy capacity when compared to Hollow specimens.
- ✓ In-Filled specimens failed by cracking off of the tensile face when subjected toflexure testing, when compared to hollow specimens which failed due to local buckling at the points of loading as evident from the photographs taken during the esting process.

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