ANALYTICAL AND EXPERIMENTAL STUDY ON COMPOSITE FRAMES

ARCHANA P[1], ANJUGHAP PRIYA R[2], SARANYA M[3]

[1]PG Student, Dept. of Civil Engineering, Valliammai Engineering College, Chennai, Tamil Nadu
[2] Assistant Professor, Dept. of Civil Engineering, Valliammai Engineering College, Chennai, Tamil Nadu
[3]Assistant Professor, Dept. of Civil Engineering, Valliammai Engineering College, Chennai, Tamil Nadu

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Abstract – *This paper investigates the behaviour of Composite frames with Concrete Filled Steel Tubular Column with Steel beam by welded connections. A CFST Column is formed by filling a steel tube with Self Compacting Concrete. The steel lies at the outer perimeter which is effective in tension and in resisting bending moment. Circular Concrete filled Steel tubular column is preferred in Composite Frames. Self-compacting concrete is filled in Concrete filled Steel tubular column because it is a flowing concrete mixture that is able to consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in difficult conditions. The Composite frame specimen consists of two CFST Columns and Steel I beam. The design specifications and standards by Euro Code 4 are addressed. Steel I –Beam is used since it can withstand very heavy loads. Hot rolled steel is preferred for composite frames. The obtained Composite frames are tested under half Cyclic loading. Abaqus Software is used to analyze the Composite Frames. Stress analysis is conducted by using this model to investigate the failure mode and mechanism of the composite joint. The obtained results from the Abaqus Model are compared with the experimental results.*

Key Words: Composite Frames, Concrete filled steel tubular Column (CFST), Steel I-beam, Self Compacting Concrete, Welded Connections.

1. INTRODUCTION

The Composite frame consists of two Concrete filled steel tubular columns (Self Compacting Concrete) with steel I-beam connected by weld connections.

1.1 CFST Column

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 a steel concrete composite column both the steel and concrete would resist the external loading by interacting together by bond and friction. Use of composite column has increased stiffness, reduced slenderness, increased strength and good fire resistance. The CFST Column is advantageous where the columns are subjected to large compressive forces and it is shown in Fig .1.1.

1.2 Steel I-beam

The horizontal elements of the "I" are known as flanges, while the vertical element is termed the "web". I-beams are usually made of structural steel and are used in construction and civil engineering. The web resists shear force, while the flanges resist most of the bending moment experienced by the beam.

Beam theory shows that the I-Shaped section is very efficient for carrying both bending and shear loads in the plane of the web .The I beam consists of two horizontal planes, known as flanges, connected by one vertical component, or the web. The steel I-beam is shown in below Fig.1.2.

1.3 Self-compacting concrete

Self-compacting concrete is a flowing concrete mixture that is able to consolidate under its own weight. Self-compacting concrete produces resistance to segregation by using mineral fillers or fines and using special admixtures.

Self-compacting concrete is placed or poured in the same way as ordinary concrete but without vibration. It is very fluid and can pass around obstruction and fill all the nooks and corners without the risk of mortar or other ingredients of concrete separating out, at the same time there are no entrapped air. The admixture used in SCC is Setcrete - Liquid integral water proofing admixture and it is shown in Fig .1.3 as below,
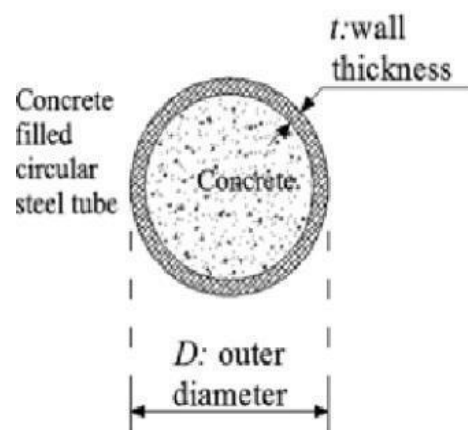

Fig.1.1 Circular CFST Column

Fig.1.2 Steel I-beam

Fig.1.3 Setcrete

1.4 Connections

The CFST Column with Steel I- beam is connected by welded connections and it is shown in Fig.1.4. Welding is a process of joining two pieces of metal by creating a strong metallurgical bond between them by heating or pressure or both. Welding enables direct transfer of stress between members eliminating gusset and splice plates necessary for bolted structures. Hence the weight of the joint is minimum.

Fig.1.4 Weld connections

The following are the objectives of this study,

- To study the behaviour of Composite Frames under cyclic loading.
- To study the modes of failure of the Composite Frames.
- To study the load vs. deflection, stiffness and the stress-strain characteristics relationship of the Composite frames under half cyclic loading.
- To analyze the model by using Abaqus Software.
- To compare the results of Abaqus Model with the experimental results.

2. SCOPE

- For high rise buildings the steel concrete composite construction is cost effective.
- It has much scope for the use of composite structures in seismic areas.
- The CFST column has increased strength for a given cross sectional dimension, increased stiffness, increased buckling resistance.
- The use of Self Compacting Concrete has superior strength, durability, improved constructability, improved structural integrity, uniform surface finish.

3. ABAQUS SOFTWARE

The Abaqus suite of software for finite element analysis (FEA) is known for   its high performance, challenging

simulations than any other software. The Abaqus does not have built –in units. The user must use consistent units.

3.1 GENERAL

The Abaqus modeling is capable of Pre-processing, processing and Post-processing. The pre-processing stage is also called as "Solver".It involves creating an input file, the processing stage produces an output visual file and the third stage of Post-processing generates report, images etc.,

3.2 Specifications

1. Steel I-beam is used and the width of steel I-beam is 1.2 m and the beam is kept below 500 mm from the column height.

2. The CFST column height is 1.3 m and the diameter of CFST Column is 100 mm.

3.   The Composite frame is connected by welded connections. The AutoCAD plan is shown in below Fig.3.1
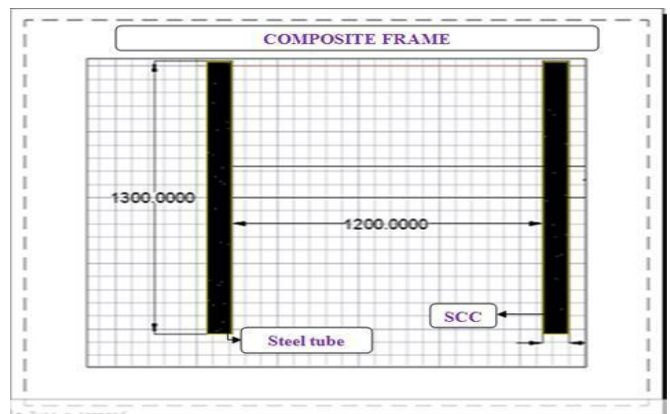

Fig.3.1 AutoCAD Plan

3.3. Procedure

The Composite frame is analyzed by using ABAQUS Software and the procedure is shown below as follows,

STEP 1: Creating a part

Parts define the geometry of the individual components of the model and, therefore parts are the basic building blocks of an ABAQUS/CAE model. It is shown in Fig .3.2 and 3.3.
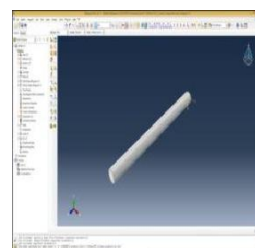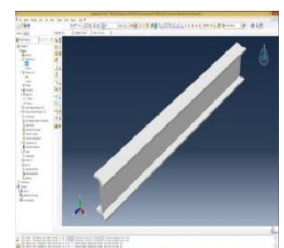

Fig .3.2 CFST Column

Fig. 3.3 Steel I – Beam

STEP 2: Creating the materials

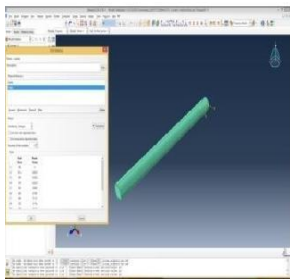The material for CFST Column and Steel I-beam is been created and it is shown in Fig 3.4 and 3.5 respectively.
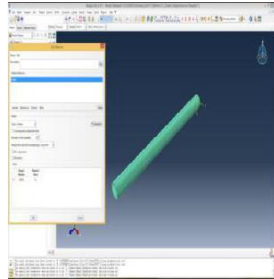

Fig. 3.4 Plastic   **Fig .3.5 Elastic**

STEP 3:Defining and Assigning Sectional Properties

(i)After creating the part the material has been specified. The material has been defined for the following CFST Column and Steel I-Beam and sectional properties is also assigned. The CFST Column consists of outer steel tube of 2.5 mm diameter and it is filled inside with Self compacting concrete and ISMB 150 is been defined for Steel I-Beam. The Steel I-Beam and CFST column is viewed in Fig.3.6 and 3.7 respectively.
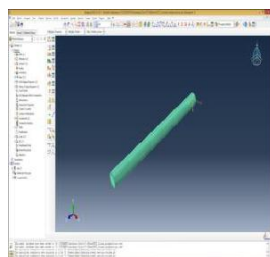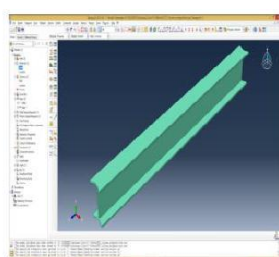
(ii)The CFST Column and Steel I-beam region has been selected and it is been assigned.

Fig 3.6 Column   **Fig 3.7 Steel I-beam**

STEP 4: Assembly

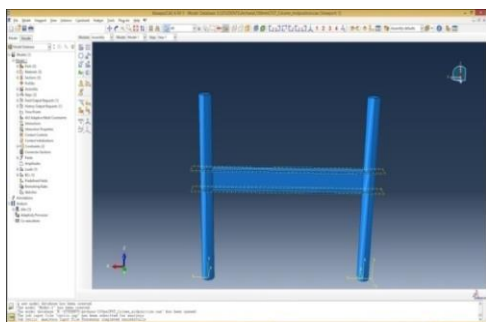Here the CFST Column and Steel I-beam is assembled and it is shown in Fig.3.8.

Fig 3.8 Assembly

STEP 5: STEP AND INTERACTIONS

(i)In Step, the analysis type is of Static General Type and it is shown in below Fig.3.9

(ii) The surface to surface interactions is given in an Composite Frame. The interactions between CFST Column with Steel I-beam is shown in Fig.3.10 as below as follows,
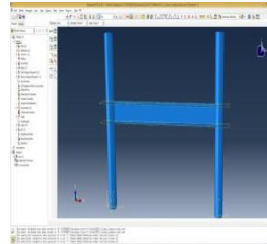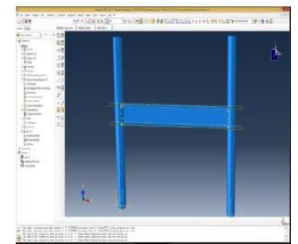

Fig 3.9 Step   **Fig 3.10 Interaction**

STEP 7: Loads and Boundary conditions

(i) The load plays an prominent role in the Composite frames. The half cyclic load is given in an composite frames and it is shown in Fig .3.11 respectively.

(ii) To apply the boundary conditions, a node set needs to be created. Here the condition used is both ends are fixed and it is shown in Fig.3.12
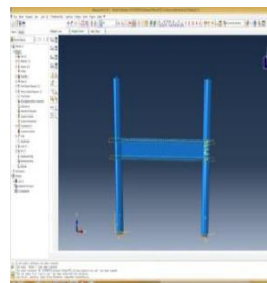

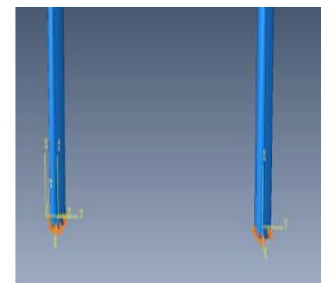**Fig .3.11 Cyclic load**   **Fig. 3.12 B.C**

STEP 9: Mesh

(i)Hyper meshing is used where it is able to divide the model into number of nodes and elements for a solver to apply the mathematical functions on it. It is shown in Fig.3.13 as below,
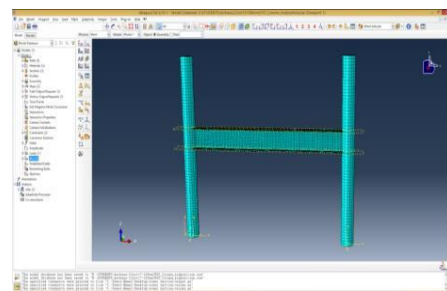

Fig .3.13 Mesh

STEP 10: VISUALIZATION

The Visualization will helps us to overlay plot to display plots of substructure data in the same viewport as a plot of the rest of the assembly. The final step of analysis is about getting the analyzed structure to be visualized and it is shown in Fig .3.14 as below as follows,
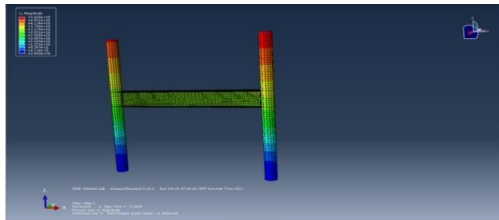

Fig .3.14 Deformed displacements for Composite frame

It is visualized that Composite frame starts to yield at 44kN.

4. EXPERIMENTAL STUDY

This chapter discusses the Experimental study of the composite frame, materials used and testing of composite frames under half cyclic loading. The load vs. deflection and stress - strain characteristics relationship is also studied.

4.1 Composite Frame-Coated with primer

The Composite frame consists of two CFST Column with steel I- beam by weld connections. The Composite frame is coated with primer coating to protect the steel from corrosion. For steel coatings, primer is used and it is the key to preventing the formation of rust. This primer has rust preventive properties. They will stop any rust from adhering to the surface or will kill the rust. Composite frame is coated with primer coating and it is shown in Fig 4.1 as below as follows,

Fig. 4.1 Composite frame coated with primer

4.2 EXPERIMENTAL SETUP

An experiment is set up to test the behaviour of the composite frame. The CFST Column has an diameter of 100 mm. The Self compacting concrete is used inside CFST Column. The hydraulic jack is fixed properly at 575 mm distance. Both ends are fixed at the bottom.

A Linear Variable Differential Transducer (LVDT) is a displacement based transducer. LVDT is placed at two positions in composite frame set up. The first LVDT is placed at top of column. Two LVDT is fixed to find out the deflections.

Strain is the amount of deformation of a body due to an applied force. More specifically, strain (å) is defined as the fractional change in length. Strain gauge is a device used to measure strain on an object. Two Strain gauge is used at two positions to find out the strain value by using an instrument termed to be "Strain indicator". The Experimental setup for the composite frames is shown below in Fig.4.2.

Fig .4.2 Experimental Setup

5. RESULTS AND DISCUSSIONS

The load vs Deflection values ,graph and stiffness values are shown below and the results has been discussed.

5.1 Analytical Results

The Composite frame is analyzed by using Abaqus software under half cyclic loading. The load vs Deflection graph is also plotted.

5.1.1 Load vs Deflection

At first cycle, for 12 kN it attains with an deflection of 13.55 mm. At Second cycle, for 24 kN it attains with an deflection of 22.88 mm. Similarly for the third cycle, for 36 kN it attains with an deflection of 68.82 mm. Finally for the fourth cycle of 44kN load it attains with an deflection of 98.02 mm and it is shown in Table 5.1.

Table 5.1 Load vs Deflection for Composite frame - Analytical

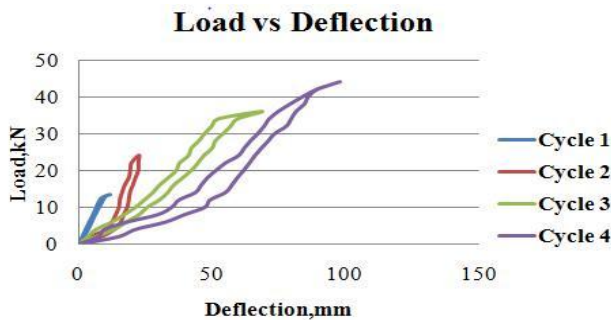| Cycles	Load, kN	Deflection, mm
Cycle 1	12	13.55
Cycle 2	24	22.88
Cycle 3	36	68.82
Cycle 4	44	98.02

Fig 5.1 Load vs Deflection graph for Composite frame

In analytical method, it is discussed that the composite frame yields at 44 kN with an deflection of 98.02 mm and is shown in Fig 5.1 respectively.

5.1.2 Stiffness for Composite frame

The load yields at 44 kN with a deflection of 98.02 mm and the stiffness value is evaluated to be 448.88 N/mm and it is shown in Table 5.2.

(i.e.,) Stiffness = load /Deflection

= 44kN/98.02 = 448.88N/mm

Table 5.2 Stiffness for Composite frame –Analytical

Load, kN	Deflection, mm	Stiffness, N/mm
44	98.02	448.88

5.2 Experimental Results

The Composite frame is tested under half cyclic loading conditions.The load vs Deflection graph is also plotted. The stiffness value is also noted.

5.2.1 Load vs Deflection at Top

The half cyclic loading is given in an composite frames. At first cycle, for 12 kN load,it attains with an deflection of 17.49 mm. At Second cycle, for 24 kN load, it attains with an deflection of 41.18mm.Similarly for the third cycle, for 36 kN load it attains with an deflection of 62.22. Finally for the fourth cycle of 48 kN load ,it attains with an deflection of

103.8mm.The results of Load vs Deflection at top is shown in Table 5.3

Table 5.3 Load vs Deflection at Top –Experimental

Cycles	Load, kN	Deflection, mm
Cycle 1	12	17.49
Cycle 2	24	41.18
Cycle 3	36	62.22
Cycle 4	48	103.8

From Experimental results, the load vs Deflection at Top graph are drawn and it is shown in Fig 5.2. From the graph it is said that Cycle 1 represents the 12 kN load, Cycle 2 represents the 24 kN load, Cycle 3 represents the 36 kN load and finally Cycle 4 represents the load at 48 kN. From the above table it is said that the composite frame yields at 48 kN.
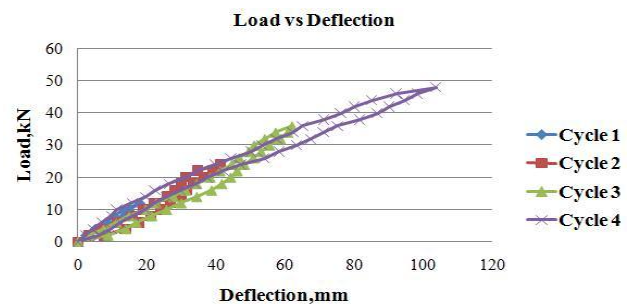

Fig 5.2 Load vs. Deflection graph at top

5.2.2 Load vs. Deflection at joints

The half cyclic loading is given in an composite frames. At first cycle, for 12 kN it attains with an deflection of 14.22 mm. At Second cycle, for 24 kN it attains with an deflection of

35.12 mm. Similarly for the third cycle, for 36 kN it attains with an deflection of 49.86.Finally for the 48 kN load for the fourth cycle it attains with an deflection of 95.49 mm. The results of Load vs Deflection at joints is shown in Table 5.4.

Table 5.4 Load vs Deflection at joints –Experimental

Cycles	Load, kN	Deflection, mm
Cycle 1	12	14.22
Cycle 2	24	35.12
Cycle 3	36	49.86
Cycle 4	48	95.49

From Experimental results, the load vs Deflection graph at joints are drawn and it is shown in Fig 6.3. From the graph it is said that Cycle 1 represents the 12 kN load, Cycle 2 represents the 24 kN load, Cycle 3 represents the 36 kN load and finally Cycle 4 represents the load at 48kN .The load vs deflection graph at joints is shown in Fig 5.3,
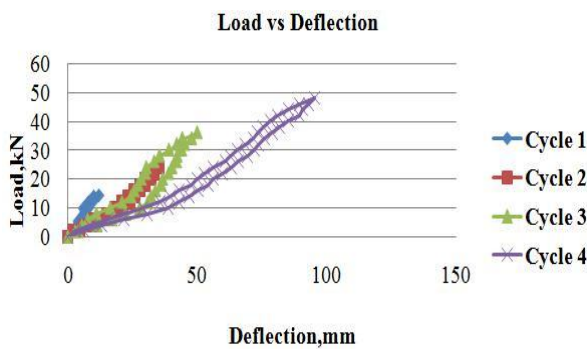
Fig 5.3 Load vs. Deflection graph at joints

It is also discussed that the load vs Deflection at top is greater than the load vs Deflection at joints.

5.2.3 STIFFNESS

The stiffness, k of a body is a measure of the resistance offered by an elastic body to deformation. It is the rigidity of an object (i.e.,) the extent to which it resists deformation in response to an applied force.

Stiffness = Force/Displacement.

5.2.3.1 Stiffness at Top

The load yields at 48 kN with a deflection of 103.8 mm and the stiffness value is evaluated to be 462.427 N/mm and it is shown in Table 5.5 as below,

(i.e.,) Stiffness = load /Deflection
           =48kN/103.8
           =462.427 N/mm

Table 5.5 Stiffness at Top –Experimental

Load , kN	Deflection, mm (at top)	Stiffness ,N/mm
48	103.8	462.427

5. 2.3.2 Stiffness at Joints

The load yields at 48 kN with a deflection of 95.49 mm and the stiffness value is evaluated to 502.670 N/mm and it is shown in Table 5.6.

(i.e) Stiffness = load / Deflection

= 48kN/95.49 = 502.670 N/mm

Table 5.6 Stiffness at Joints – Experimental

Load, kN	Deflection, mm (at joints)	Stiffness, N/mm
48	95.49	502.670

It is also discussed that the stiffness value at joints is greater than the stiffness value at top.

5.3 STRAIN

The strain value is found at mid-span of beam and at joints by using strain gauge and it is explained below,

5.3.1 Strain at mid span

The strain gauge is kept at the mid span of the Steel I-beam to find out the strain value of the composite frame. At first cycle, for 0.52 N/mm 2 stress, the attainment of strain is of 0.0087. At Second cycle, for 1.16 N/mm 2 stress, the attainment of strain is of 0.0278 Similarly for the third cycle, 1.82 N/mm2 stress, the attainment of strain is of 0.0408. Finally for the 2.35 N/mm 2 stress, the attainment of strain is of 0.0742 .
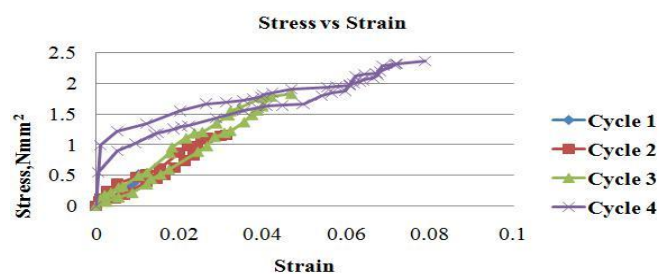

Fig 5.4 Stress vs. Strain graph @ mid -span of beam

From the graph, it is shown that the load gets released at 48 kN and it has an strain of 0.0742 mm and it is shown in Fig 5.4

5.3.2. Strain at joints

The strain gauge is kept at beam column joints to find out the strain value of the composite frame At first cycle, for 0.52 N/mm2 stress, the attainment of strain is of 0.0102. At Second cycle, for 1.16 N/mm2 stress , the attainment of strain is of 0.0312 Similarly for the third cycle, 1.82 N/mm 2 stress, the attainment of strain is of 0.0468. Finally for the 2.35 N/mm 2 stress, the attainment of strain is of 0.0789.
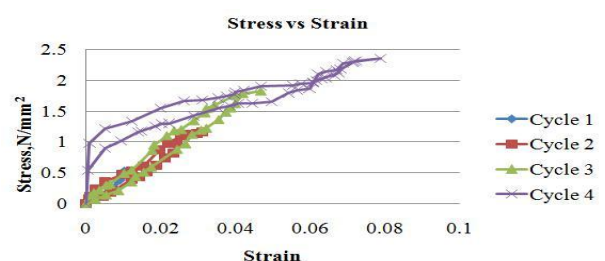

Fig 5.5 Stress vs. Strain graph at joints

From the Fig 5.5, it is shown that the load gets released at 48 kN and it has an strain of 0.0789 mm. It is discussed that the strain at joints is greater than the strain at mid-span of beam.

From the above, it is studied that composite frame are analysed by using Abaqus software. The comparison between the Analytical and Experimental results of the composite frames is shown in Fig 5.6.
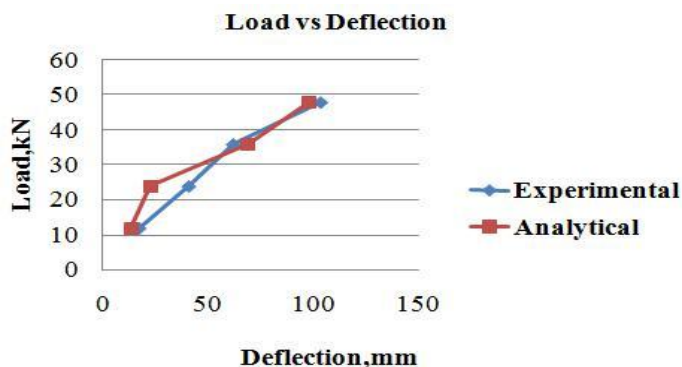

Fig 5.6 Comparison of Analytical vs. Experimental results

In analytical result, the composite frame starts to yield at 44 kN , but in experimental result, the composite frame starts to yield at 48 kN. The Analytical results for the stiffness of the composite frame is found out to be 448.88 N/mm for the load of 44 kN with a deflection of 98.02 mm.

The Experimental testing is also done for the composite frames. It starts to yields at 48 kN and load gets reversed with an deflection of 103.8 mm at top and 95.4 mm at joints. The stiffness of the composite frame at top is 462.42 N/mm and stiffness of the composite frame at joints is 502.67 N/mm. Two strain gauge is used and it attains an strain value of 0.0742 at mid-span of beam and 0.0789 at joints.

The Experimental results are higher than the Analytical results. Hence composite frames are more efficient.

6. CONCLUSION

This paper reported the behaviour of CFST Column with steel I-beam (Composite frame) by welded connections. The introduced FEA model was able to reasonably predict the lateral load Vs deflection (ä) and stiffness (k) of the Composite frame. The Composite frames is been analyzed by using Abaqus software.

From the above study it is concluded that the analytical study of the composite frame section i.e.,CFST Column with steel I-beam by welded connections yields by 44 kN .

The Experimental testing is also done for the composite frames. It starts to yields at 48 kN, whereas in software analysis it starts to yield at 44 kN.

The Composite frames can be preferred because the composite frames have both concrete and steel. The usage of Circular Concrete filled steel tubular column has efficient strength .The inherent buckling problem related to steel tube is either prevented or delayed due to the presence of the concrete core. Hence CFST Column type can be preferred in Composite Column. For further study it is concluded that the composite frames are preferred for high rise structures.

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