ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

EXPERIMENTAL INVESTIGATION ON LOCAL AND POST – LOCAL BUCKLING BEHAVIOUR OF STEEL - CONCRETE COMPOSITE COLUMN

R. Thirugnanam[1], A. Sattainathan Sharma[2], R. Anjughap Priya[3]

[1] ME Structural Engineering Student, Department of Civil Engineering, Valliammai Engineering College, Kancheepuram.
Email: yoursthirugnanam@gmail.com Mobile: +91-9585745511

[2] Assistant Professor, Department of Civil Engineering, Valliammai Engineering College, Kancheepuram.
Email: livic.nathan@gmail.com Mobile: +91-8098293038

3 Assistant Professor, Department of Civil Engineering, Valliammai Engineering College, Kancheepuram.
Email: anjughappriya@gmail.com Mobile: +91-8438336924

ABSTRACT

The objective of the study is to analyse the experimental behaviour of steel-concrete composite columns under axial compression and the mode of failure under ultimate failure and yield point. As far as the past researches are concerned, the composite concrete and steel structural system combines the rigidity and formability of reinforced concrete with the strength and ductility of structural steel, which is a necessary prerequisite in earthquake resistant structures. The economic considerations of the composite members are extremely satisfactory for large scale productions such as in the case of tall structures. The foreseeable advantage of steel being encased within the concrete is attributed for two significant reasons viz., Corrosion resistance and fireproof nature (resistivity to fire at higher temperatures) which are imparted into the member. These two reasons are the serious limitations of any steel structure amalgamated in an earthquake resistant structure. The prominent area of our interest is the noteworthy residual strength offered. It is an excellent feature offered by composite members (i.e.) after the initiation of failure of concrete (propagation of crack), the load is handled by the steel, until the stage of ultimate collapse is reached. This type of load handling capability is highly favourable for earthquake structures, rather than a conventional steel structure.

Keywords: *Steel-Concrete Composite Columns, Structural Steel, Buckling Behaviour, Local and Post-Local Buckling.*

I. INTRODUCTION

A. GENERAL

Composite construction governs the non-residential multi-storey building sector. This has been the circumstance for over twenty years. Its success is due to the strength and stiffness that can be achieved, with minimum use of materials.The reason why composite construction is often so good can be conveyed in one simple way - concrete is good in compression and steel is good in tension. By joining the two materials together structurally these strengths can be exploited to result in a lightweight and highly efficient design. The reduced self-weight of composite elements has a knock-on effect by decreasing the forces in those elements supporting them, including the foundations. Composite systems also offer benefits in terms of speed of construction. The floor depth decreases that can be achieved using composite construction can also provide significant benefits in terms of the costs of services and the building envelope.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

The composite structure comprises of composite beam, composite slab, and composite columns, also the connections may be of composite. The design of composite beams are traditionally been carried out by BS 5950-3-1, and the composite slabs are designed using BS 5950-4. The composite columns are designed with the help of EN 1994-1. The plastic distribution of composite beams shows that the plastic neutral axis lies within the concrete and all the steel therefore in tension. Concrete is a material that works well in compression but has insignificant resistance in tension. Hence for structural purposes it conventionally relies on steel reinforcement to carry any tensile forces (this is the role played by the steel part of a composite cross section, which is effectively external reinforcement), so that even when subject to tension, an element is in net compression.

B. COMPOSITE COLUMNS

A composite column is a combination of concrete, reinforcing steel and structural steel to afford an adequate load carrying capacity of the member.Thus, such composite members can provide inelasticity; usable floor areas and cost economy for mid-to-high buildings. During the past few decades, several composite steel–concrete structural systems have been used in the construction of tall buildings. One such system employs composite columns that consist of steel shapes encased in concrete and composite girders that use metal deck between the steel section and concrete slab. This system combines the rigidity and formability of reinforced concrete with the strength and speed of construction associated with structural steel to produce an economic structure. The concrete used for encasing a structural steel section not only increases its strength and stiffness, but also protects it from fire damage. As a result, the use of such columns is on the rise in building construction in addition to applications in marine structures.

In older days, the steel stanchions in steel frames were encased in concrete to protect them from fire, and they were still designed for the applied load as if uncased. It was then realised that encasement reduced the effective slenderness of the column and so increases it's buckling load. The concrete encasement also carries its share of both the axial load and the bending moments.

They are mainly constrained of two types. They are namely,

- Concrete encased Composite Column
- Concrete In filled Composite Column

C. CONCRETE ENCASED COMPOSITE COLUMN

Concrete encased steel columns are one type of composite columns used in composite structures. The concrete encased steel composite column consists of structural steel section encased in reinforced concrete. The structural steel is rolled or built-up shape. Deriving benefits from combining the structural steel and reinforced concrete, the composite columns possess great load-carrying capacity and stiffness owing to composite action. Further, the concrete encasement can serve for fire protection. Therefore, the use of the composite columns in medium-rise or high-rise buildings has been increased significantly in recent decades. Due to the traditional separation of structural steel and reinforced concrete design and construction, concrete encased composite steel-concrete columns have not received the same level of attention as steel or reinforced concrete columns. This is evident by incomplete and sometimes conflicting provisions for concrete encased composite columns in current design codes and standards.

For concrete-encased composite structural members, an additional benefit is that the concrete used for encasing a structural steel not only increases its stiffness, but also protects it from fire damage and local buckling failure. A new type of steel and concrete composite column consisting of thin-walled, I-shaped steel section with concrete being poured between the flanges of the steel section has recently been. The steel section features very slender plates exceeding the width to thickness ratio limits for non-compact sections. Transverse links between the flanges are spaced at regular intervals to enhance the resistance of the flanges to local buckling. The proposed composite column is intended to carry only axial loads in multi-story buildings, the lateral loads being resisted by other structural systems such as shear walls.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

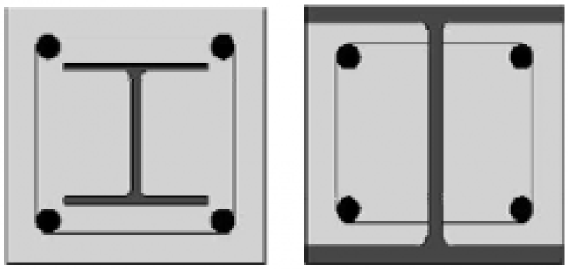

Fig 1.1 Example of Concrete Encased Composite Columns

D. CONCRETE IN FILLED COMPOSITE COLUMN

Concrete-filled steel tube columns have been increasingly used in many modern structures. Their usage provides high strength, high ductility, high stiffness and full usage of construction materials. In addition to these advantages, the steel tubes surrounding the concrete columns eliminate permanent formwork which reduces construction time. Furthermore, steel tubes not only assist in carrying axial load, but also provide confinement to the concrete. However, concrete confinement depends on many factors such as the column diameter, the thickness of the steel tube, the concrete strength and the yield stress of the steel tube.

Recently, the use of composite structures consisting of steel plate and filled concrete has become increasingly popular in civil engineering structures. This is because of their excellent earthquake-resistant properties, namely high stiffness, high strength, high ductility, and large energy-absorption capacity. In the concrete-filled columns, there is a mutual enhancement of ductility, because the steel plate provides confinement for the concrete, which in turn prevents the inward buckling of the plate. Moreover, this form of composite column offers additional advantages such as high impact resistance. Traditional concrete filled steel columns employ the use of hot rolled steel sections filled with concrete. These columns have been used widespread as they speed up construction by eliminating formwork and the need for tying of longitudinal reinforcement.

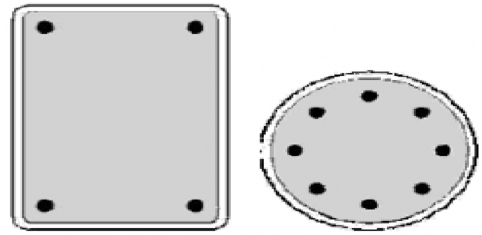

Fig 1.2 Example of Concrete In Filled Composite Columns

E. OBJECTIVE

- ❖ To determine the compressive strength of a proposed composite column section.
- ❖ To observe and determine the buckling behavior of Composite column section.
- ❖ To study the failure occurred in the composite column with axial load.

F. SCOPE

- ❖ By using this type of composite system, reduction in weight and increase in strength of steel permits the use of smaller and lighter foundations.
- ❖ This type of composite system plays a vital role in resisting the sway and lateral deflection.

II. SUMMARY OF LITERATURE REVIEW

- ❖ The concrete region which were encasing steel sections give better strength and stability to the section, which was earlier believed to be only advantageous over fire protection and corrosion protection.
- ❖ The presence of a large steel core provides a favourable residual strength following concrete crushing that leads to improved ductility.
- ❖ The additional longitudinal and transverse reinforcements, with the configuration used, improved the ductility and post-peak response of the column.
- ❖ Compressive strength of concrete and its corresponding compressive strain are the most effective parameters on the ultimate strength capacity of column members.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

III. MATERIAL TESTING

Following materials were used for the study is described in the following sections.

i. Ordinary Portland Cement (OPC)

ii. Aggregates

iii. Water

TABLE I
PROPERTIES OF RAW MATERIALS

TEST	Cement	Fine aggregate	Coarse aggregate
Consistency	33%	-	-
Initial Setting Time	42mins	-	-
Final Setting Time	275mins	-	-
Specific Gravity	3.15	2.6	2.65
Fineness	2.9	3.07	7.3

A. Mix Ratio

Cement	Fine Aggregate	Coarse Aggregate	W-C Ratio
1	1.6	2.56	0.45

B. COMPRESSIVE STRENGTH TEST

Out of many test applied to the concrete, this is the utmost significant which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Compressive strength of concrete depends on many elements such as water-cement ratio, cement strength, quality of concrete material, and quality control during production of concrete etc. Test for compressive strength is carried out either on cube or cylinder. For cube test cubes of 15 cm × 15 cm × 15 cm are used.

TABLE II
RESULTS OF COMPRESSION STRENGTH TEST

Days	Load (kN)	Stress (N/mm^2)
7 Days	580	25.76
14 Days	803	35.64
28 Days	892	39.6

C. SPLIT TENSILE TEST

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to define the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete progress cracks when subjected to tensile forces. Thus, it is necessary to evaluate the tensile strength of concrete to determine the load at which the concrete members may crack.

TABLE III
RESULTS OF SPLIT TENSILE TEST

Days	Load (kN)	Stress (N/mm^2)
7 Days	115	1.62
14 Days	138	1.96
28 Days	153	2.18

IV. MANUAL DESIGN

Manual theoretical calculations have been worked out for proposed steel-concrete composite column and conventional RC and Steel columns. The design work is calculated with the help of Eurocode 4, IS-456, IS-800 for proposed steel-concrete composite column, Conventional RC and Steel Columns respectively.

A. Proposed Column

i) Plastic resistance of composite column

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

$P_p = \frac{A_a f_y}{\gamma_a} + \frac{0.85 \times A_c f_{ck}}{\gamma_c}$

A_a = Area of structural steel

f_y = yield stress of structural steel

γ_a = partial safety factor of steel

A_c = Area of concrete

f_{ck} = characteristic compressive strength of concrete at 28 days

γ_c = partial safety factor of concrete.

$P_p = \frac{A_a f_y}{\gamma_a} + \frac{0.85 \times A_c f_{ck}}{\gamma_c}$

$= \frac{1460 \times 250}{1.10} + \frac{0.85 \times 21040 \times 30}{1.5}$ = 689.75 kN

ii) Effective flexural Stiffness

$(EI)_x = 1.1742 \times 10^{12}$ Nmm^2

$(EI)_y = 7.768 \times 10^{11}$ Nmm^2

iii) Non-Dimensional parameters

$\lambda_x = 0.144 < 0.8$

$\lambda_y = 0.178 < 0.8$

iv) Resistance of composite column under axial compression

Reduction factor $\chi_x = 1.021 \sim 1$

Reduction factor $\chi_y = 1.011 \sim 1$

Thus the Plastic resistance of the composite column = 689.75 kN

B. Conventional RC Column

Length = 600mm, breadth = 150 mm, depth = 150 mm

$\frac{l_e}{D} = \frac{600}{150} = 4 < 12$, Hence Short column

A_c = Area of concrete

f_{ck} = Characteristic compressive stength of concrete at 28 days

A_{sc} = area of steel in compression

f_y = yield stress of steel

$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

$= (0.4 \times 30 \times (150^2 - 314.15)) + (0.67 \times 415 \times 314.15)$

Ultimate Axial Load = 353.57 kN

C. Conventional Steel Column - ISMB 150

$\frac{b}{T} = 5.26 < 9.4$, $\frac{d}{t} = 28.08 < 42$. Hence Plastic section.

$A_e = 1900$ mm^2, L = 600 mm

Non-Dimensional parameter, $\lambda = 0.406$

$\phi = 0.617$

Reduction factor, $\chi = 0.92$

$F_{cd} = 170$ N/mm^2

Factored Axial Load, $P_d = A_e . F_{cd}$

$= \frac{1900 \times 170}{1000}$

Factored Axial Load = 323 kN

V. EXPERIMENTS

This section outlines the experiments conducted on proposed steel concrete composite columns and conventional columns. The proposed steel concrete composite column is of dimension 150mm x 150mm, in which ISMB 100 was encased by concrete. Further more conventional column of same dimension 150mm x 150mm was casted with a nominal reinforcement of 12mm dia main bars and 8mm lateral ties. Also another conventional section of Steel column of designation ISMB 150 is proposed. All these specimens are tested for compression, while the corresponding deflection and strain readings are attained. Thus to determine the local and post local buckling, Load vs Shortening and Load vs Axial Strain curves being plotted.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

Fig 5.1 Test Specimens (a) Proposed Composite column, (b) Conventional RC Column,(c) Conventional Steel Column

A. FAILURE MODES

The Specimens were prepared and tested in compression testing machine. The proposed composite column was failed by crushing but further load was taken care by structural steel present in it. The ultimate load occurred when local buckling attained in the structural steel. The conventional RC concrete failed due to crushing at the ends followed by spalling of concrete. While the conventional steel column buckled at the mid portion and attained its ultimate load.

Fig 5.2 Failure pattern of Steel-Concrete Composite column

Fig 5.3 Failure pattern of Conventional RC Column

Fig 5.4 Failure pattern of Conventional Steel Column

B. Load-Axial Shortening

The load-axial shortening behaviour provides information on the maximum load and apparent ductility of each specimen. The load-axial shortening results for each series of tests are compared. The results show that there was a better development in the initial buckling load of proposed steel concrete composite columns than conventional columns. The results are being shown below.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

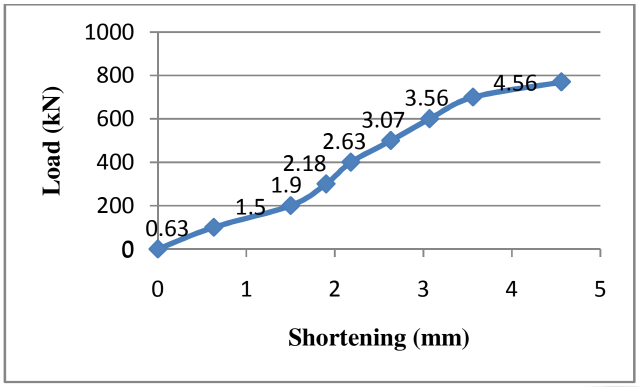

Fig 5.5 Load – Axial Shortening Curves for proposed composite sections

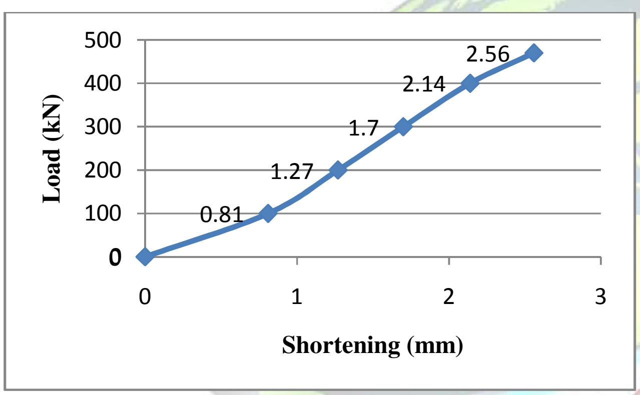

Fig 5.6 Load – Axial Shortening Curves for Conventional RC Column

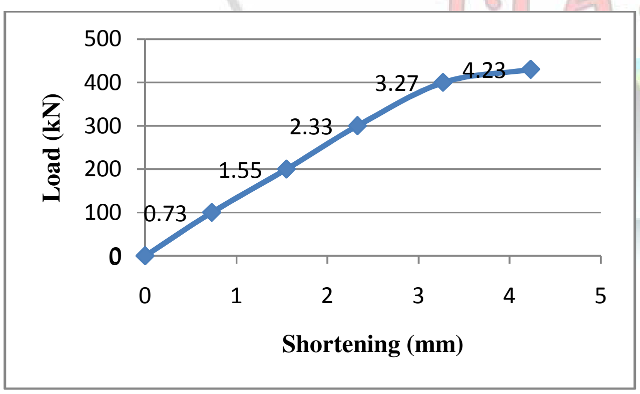

Fig 5.7 Load – Axial Shortening Curves for Conventional Steel Column

Thus the above charts show that the stiffness and strength of proposed composite column is greater than that of conventional RC and Steel columns. Through this curve we could find the ultimate load of proposed column, conventional RC and Steel Columns as 770kN, 470kN, 430kN respectively. [10] presented a short overview on widely used microwave and RF applications and the denomination of frequency bands. The chapter start outs with an illustrative case on wave propagation which will introduce fundamental aspects of high frequency technology.

C. Stress - Average Strain

The stress-strain curves, which monitor the membrane strains, provide information on the progression of local buckling and the redistribution of stress commonly known as post-local buckling. The load-average strain results for each series of tests are compared. The results show the initial buckling load and post- local buckling behaviour of proposed steel concrete composite columns and conventional columns. The results are being shown below.

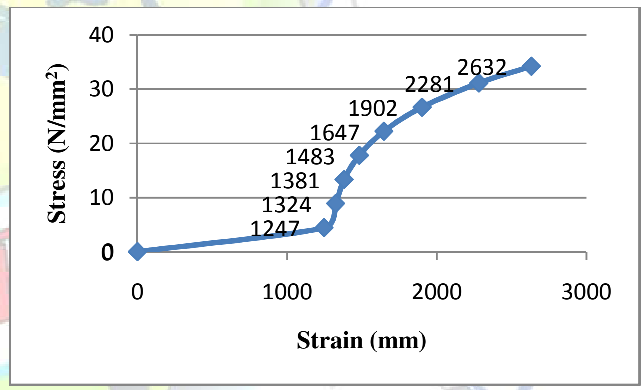

Fig 5.8 Stress – Average Strain Curve for proposed composite sections

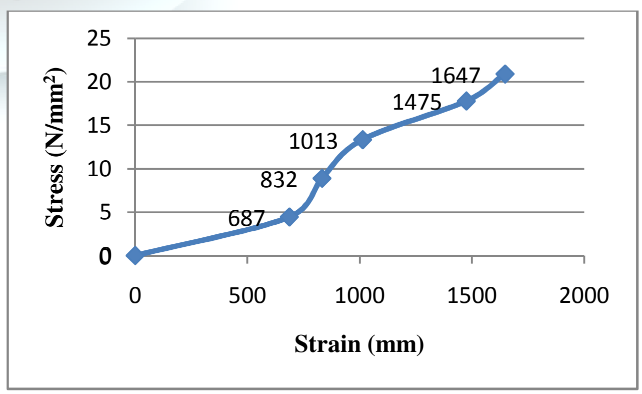

Fig 5.9Stress – Average Strain Curve for Conventional RC Column

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

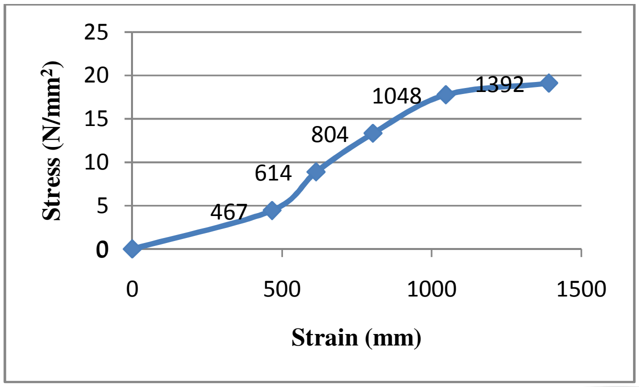

Fig 5.10Stress – Average Strain Curve for Conventional Steel Column.

These diagrams are very useful in the determination of the initial local buckling load and stress for each specimen. Furthermore, they also allow the reduction in stiffness to be traced and the stress redistribution to be determined after initial local buckling has taken place. The local buckling stresses were determined from these curves by noting changes in the stiffness. Through this curve we could find the Local buckling load of proposed column, conventional RC and Steel Columns as 400kN, 200kN, 200kN respectively.

VI. FINITE ELEMENT ANALYSIS

In order to accurately simulate the actual behaviour of concrete encased steel – concrete composite columns, the main three components of these columns have to be modelled properly. These components are the confined concrete, the Structural steel and the interface between the concrete and the structural steel. In addition to these parameters, the choice of the element type and mesh size that provide accurate results with reasonable computational time is also important in simulating structures with interface elements.

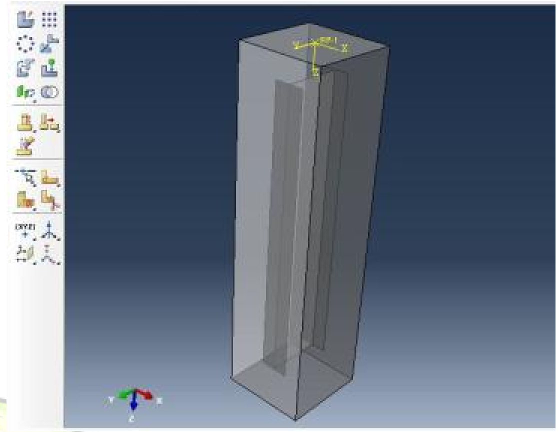

Fig6.1. Model of Proposed composite Column

The above model is being modelled, meshed and then analysed through ABAQUS software. The Results obtained were shown below.

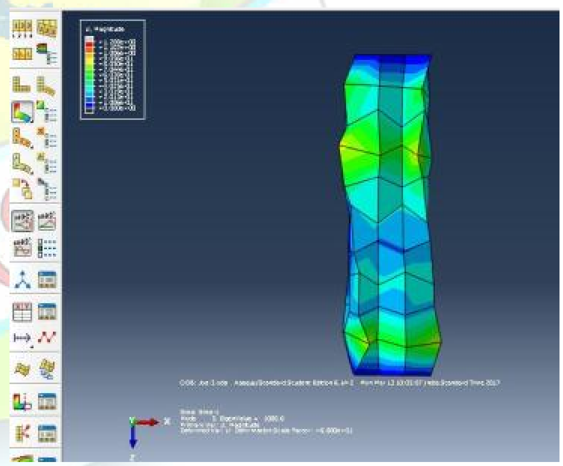

Fig6.2. Failure pattern of proposed composite columnfrom ABAQUS

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 9, April 2017

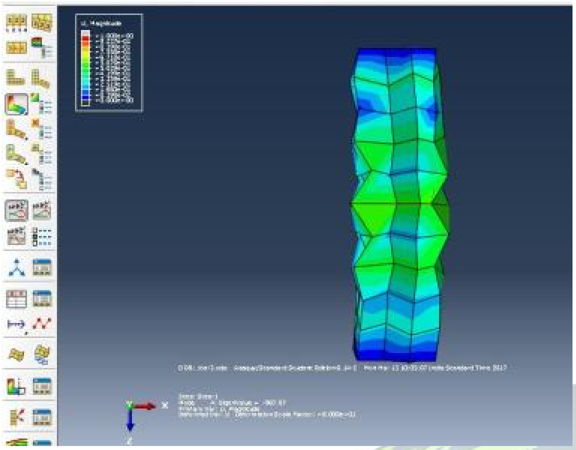

Fig6.3. Failure pattern of Conventional RC column from ABAQUS

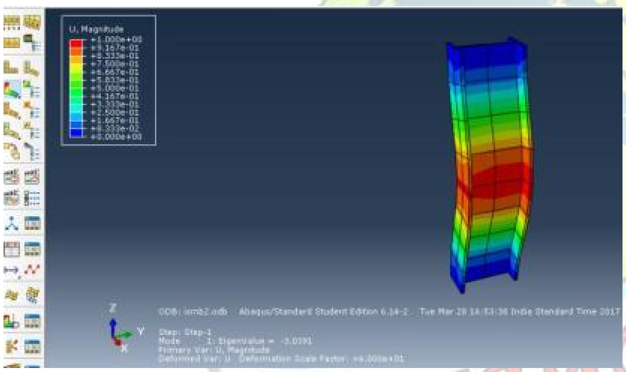

Fig6.4. Failure pattern of Conventional Steel column from ABAQUS

The above Shown figures represents the failure modes possible occurred during the experimental investigation.

VII. CONCLUSION

Experiments have been undertaken for Proposed and conventional column sections. These tests have illustrated the potential increase in both the initial local buckling load and ultimate load. A theoretical model developed is calibrated with these tests for initial local buckling.

The subject specimen was casted to study the behaviour of various possibilities of failure.

- Steel concrete composite column (ISMB 100) – Specimen 1

These were relatively compared with conventional steel column (ISMB 150) and reinforced concrete column and the results were studied.

Specimen-1 yielded the highest value among the tested specimens which is 64% greater than the conventional reinforced concrete and 79% greater than steel column.

This study explains the load carrying capacity of the composite column, which proves it to be a good one when compared to other type of columns.

REFERENCES

[1] Brian,*"Local and Post local Buckling of Fabricated Steel and Composite Cross Sections"*, Journal of Structural Engineering, Vol. 127, June, 2001.

[2] CengizDundar, SerkanTokgoz, Kamil Tanrikulu, Tarik Baran*"Behaviour of reinforced and concrete-encased composite columns subjected to biaxial bending and axial load"*, Building and environment, Vol. 43, 2008.

[3] Chang-Soo Kim, Hong-Gun Park, Kyung-Soo Chung, and In-Rak Choi,*"Eccentric Axial Load Capacity of High-Strength Steel-Concrete Composite Columns of Various Sectional Shapes"*, Journal of Structural Engineering, Vol. 140(4), 2014.

[4] Chen.S.F, Teng.J.G, and Chan.S.L,2001, *"Design Of Biaxially Loaded Short Composite Columns of Arbitrary Section"*,Journal of StructuralEngineering, Vol. 127, No. 6, 2001.

[5] Cheng-Chih Chen and Nan-Jiao Lin.,2006, *"Analytical model for predicting axial capacity and behavior of concrete encased steel composite stub columns"*, Journal of Constructional Steel Research Vol. 62, 2006.

[6] EhabEllobody, Ben Young, and Dennis Lam*"Behaviour of normal and high strength concrete-filled compact steel tube circular stub columns"*, Journal of Constructional Steel Research Vol.62, 2005.

[7] Jaehong Lee, HuuThanh Nguyen, and Seung-Eock Kim, *"Buckling and Post Buckling of Thin-walled Composite Columns with Intermediate-stiffened open Cross-section under Axial Compression"*, International Journal of Steel Structures, Vol 9, 2009.

[8] Mirza.S.A, and Lacroix.E.A,*"Comparative Strength Analyses of Concrete-Encased Steel Composite Columns"*, Journal of Structural Engineering, Vol. 130, December 1, 2004.

[9] MohamadMursi, and Brian, *"Strength of Concrete Filled Steel Box Columns Incorporating Interaction Buckling"*, Journal of Structural Engineering, Vol. 129, May 1, 2003.

[10] Christo Ananth, [Account ID: AORZMT9EL3DL0],"A Detailed Analysis Of Two Port RF Networks - Circuit Representation [RF & Microwave Engineering Book 1]", Kindle Edition, USA, ASIN: B06XQY4MVL, ISBN: 978-15-208-752-1-7, Volume 8, March 2017, pp:1-38.

[11] Thierry Chicoine, Robert Tremblay, Bruno Massicotte, James M. Ricles, and Le-Wu Lu."*Behavior and Strength of Partially Encased Composite Columns with Built-up Shapes*", Journal of Structural Engineering, Vol. 128(3), 2002.

[12] Weng.C.C, Yen.S.I, and Chen.C.C.,2001, *"Shear Strength Of Concrete-Encased Composite Structural Members"*, Journal of StructuralEngineering, Vol. 127, No. 10, 2001.

[13] Weng.C.C, and Yen.S.I,*"Comparisons of concrete-encased composite column strength provisions of ACI code and AISC specification"*, Engineering Structures, Vol. 24, 2002.

[14] Wright.H.D., 1995, *"Local Stability of Filled and Encased Steel Sections"*, Journal of Structural Engineering, Vol. 121(10), 1995.

[15] A textbook on "*Composite Structures of Steel and Concrete Volume 1"*, by R.P. Johnson, Blackwell Scientific Publications.

[16] EN 1992-1-1 – Eurocode 2 – "Design of concrete structures - Part 1-1 General rules and rules for buildings".

[17] EN 1994-1-1 – Eurocode 4 – "Design of composite steel and concrete structures – Part 1-1 – General rules and rules for buildings".

[18] IS 11384:1985 "Code of Practice for composite construction in Structural Steel and Concrete".

[19] IS 10262:2009 "Concrete Mix Proportioning – Guidelines"