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ISSN (PRINT): 2454-9762
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International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
Vol. 3, Special Issue 8, March 2017

COMPARATIVE STUDY ON BUCKLING BEHAVIOUR OF REINFORCED COMPOSITE COLUMN WITH CONVENTIONAL COLUMNS

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ABSTRACT – Composite sections are found to be a novel technique in modern day scenario of construction. This stands tall than the ordinary and conventional type of constructions. Columns as a structural element play a vital role in structural frame. This research comments on the buckling behaviour of different sections of composite columns. As far as past research is concerned the composite concrete and steel structural system combines the stiffness and formability of reinforced concrete with the strength of structural steel to produce an economic structure. Thus the composite columns are found to be more efficient in terms of providing better strength and stability to the structure. In this present study, a comparative analysis of the local and post local buckling behaviour of different sections of composite column sections and conventional sections has been studied and the column sections are designed according to Eurocode 4 (ENV 1994). Base materials are tested for their natural properties. Thus the material testing for Cement, Fine aggregate, and Coarse aggregate has been conducted and a mix design for concrete has been proposed.

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

I. INTRODUCTION

A. 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 stiffness 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 raises its strength and rigidity, 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.

Composite columns may take a range of forms. As with all composite elements they are attractive because they play to the relative assets of both steel and concrete. They also exhibit particularly good performance in fire conditions. Design rules for composite columns in structural frames are given in BS EN 1994-1-1. Composite columns requiring formwork during execution tend not to be viewedas cost-effective. Concrete infill adds significantly to the compression resistance of the bare steel section by sharing the load and inhibiting the steel from buckling locally. Infill concrete retains free water which in other situations would be lost; its latent heat of evaporation significantly delays temperature rise. Rectangular sections have the advantage of flat faces for end plate beam-to-column connections. Ordinary fin plates can be employed with either shape.

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

B. 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. Deriving benefits from combining the structural steel and reinforced concrete, the composite columns possess great load-carrying capacity and rigidity 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 considerably 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 contradictory provisions for concrete encased composite columns in current design codes and standards.

The composite column with cross-shaped steel section is widely used in an inner column to link four steel beams in orthogonal directions. The cross-shaped steel section is usually fabricated by welding two H-shaped steel sections together. The composite column with T-shaped steel section is usually designed for an exterior column. There is very little research regarding the effect of various shapes of steel section on the axial compressive behaviour of concrete encased steel columns.

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.

C. 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.
- To compare the ultimate loads obtained from tests and finite element analysis and deformed shapes after failure of different proposed composite column sections.

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.

III. MATERIAL TESTING

Materials testing were done for materials like ordinary Portland cement (OPC), Fine aggregate, Coarse aggregate which were used for concrete. Then the concrete cube and cylinder were casted in order to perform compressive

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IJARMATE
International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
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strength test and Split tensile strength test respectively. A mix Ratio of M30 grade concrete is proposed.

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. 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 I
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 II
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

This chapter deals with 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

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

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.

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

$$= \frac{771 \times 250}{1.10} + \frac{0.85 \times 21040 \times 30}{1.5} + \frac{314.14 \times 415}{1.10} = 657.78 \text{ kN}$$

ii) Effective flexural Stiffness

$$(EI)_x = 9.51 \times 10^{11} \text{ Nmm}^2$$

$$(EI)_y = 7.09 \times 10^{11} \text{ Nmm}^2$$

iii) Non-Dimensional parameters

$$\lambda_x = 0.157 < 0.8$$

$$\lambda_y = 0.182 < 0.8$$

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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 = 657.78 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

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

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

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 = 600mm

Non-Dimensional parameter, $\lambda = 0.406$

$\phi = 0.617$

Reduction factor, $\chi = 0.92$

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

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

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

Factored Axial Load = 323 kN

V. 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.

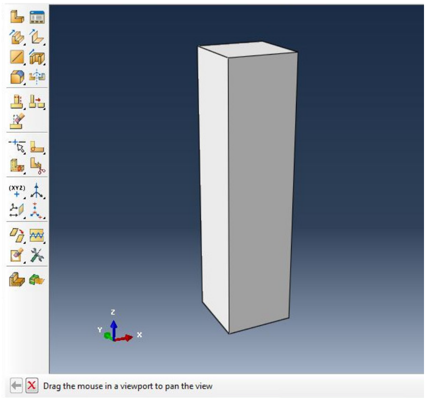

Fig1. Model of Proposed composite Column

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

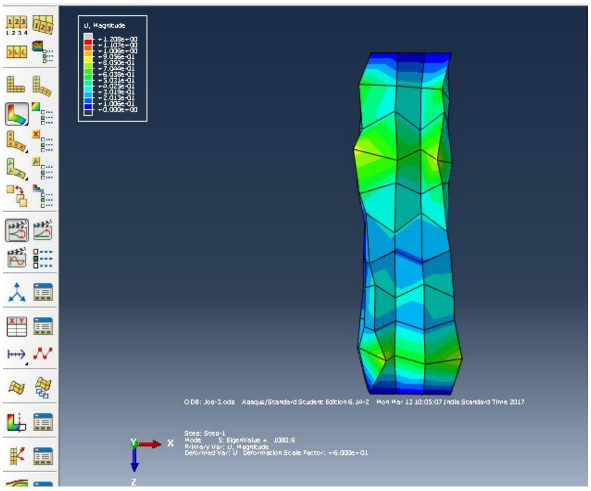

Fig2. Failure pattern of proposed composite columnfrom ABAQUS

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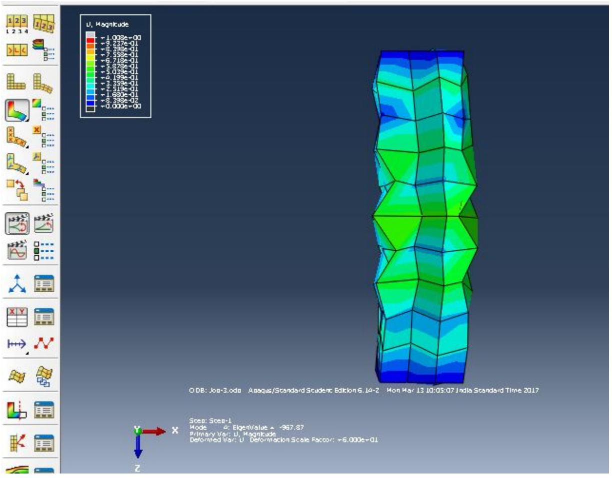

Fig3. Failure pattern of Conventional RC column from ABAQUS

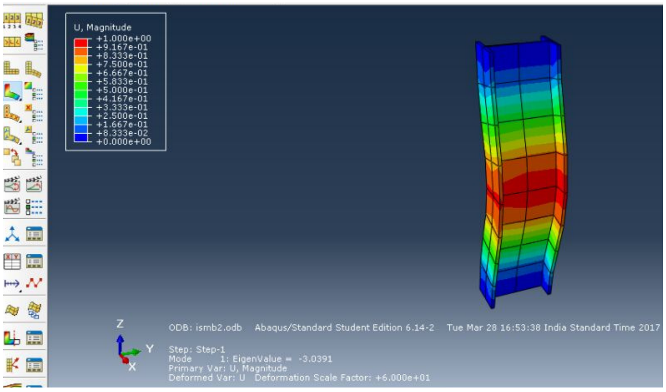

Fig4. Failure pattern of Conventional Steel column from ABAQUS

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

VI. 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 ISLB 75 was encased by concrete also with a nominal reinforcement of 12mm dia main bars a 8mm lateral ties. Another Composite Column 150mm dia Circular section 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 Stress vs Axial Strain curves being plotted.

(a) (b) (c)

Fig5. 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 Square composite column was failed by crushing but further load was taken care by structural steel and the reinforcement existing 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.

(a) (b) (c)

Fig6. Failure Pattern (a) Proposed Composite column, (b) Conventional RC Column, (c) 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

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ISSN (PRINT): 2454-9762
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Vol. 3, Special Issue 8, March 2017

steel concrete composite columns than conventional columns. The results are being shown below.

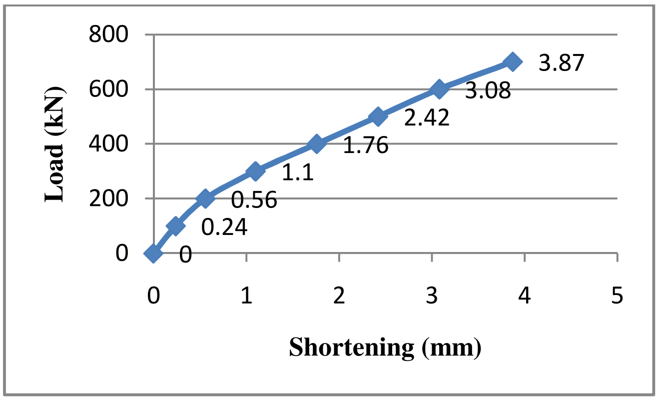

Fig7. Load – Axial Shortening Curves for proposed composite section

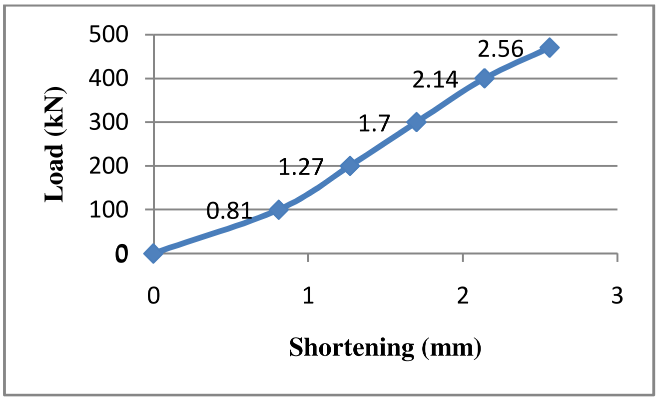

Fig8. Load – Axial Shortening Curves for Conventional RC Column

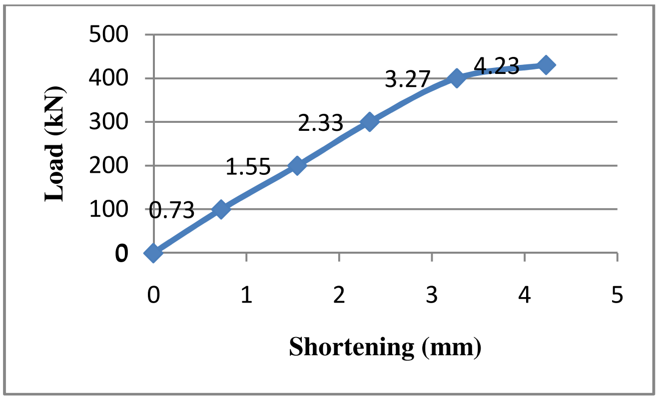

Fig9. Load – Axial Shortening Curves for Conventional Steel Column

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 700kN,470kN, 430kN respectively.

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 being shown below.

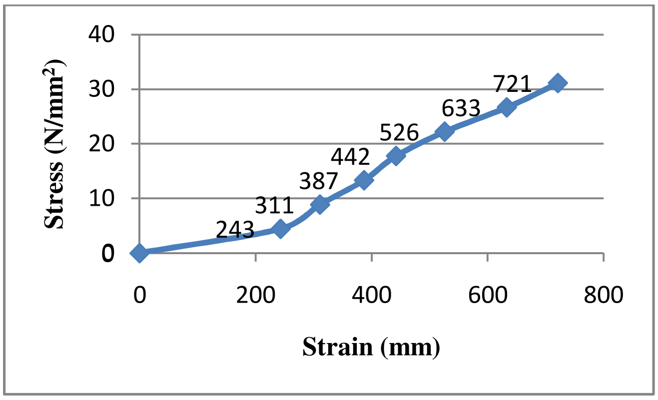

Fig10. Stress – Average Strain Curve for proposed composite section

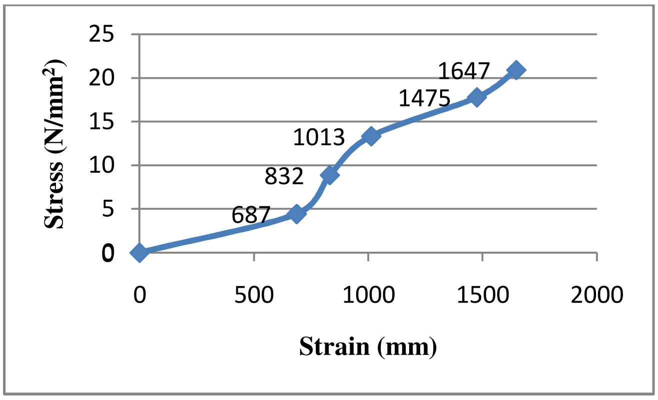

Fig11. Stress – Average Strain Curve for Conventional RC Column

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ISSN (PRINT): 2454-9762
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International Journal of Advanced Research in Management, Architecture, Technology and Engineering (IJARMATE)
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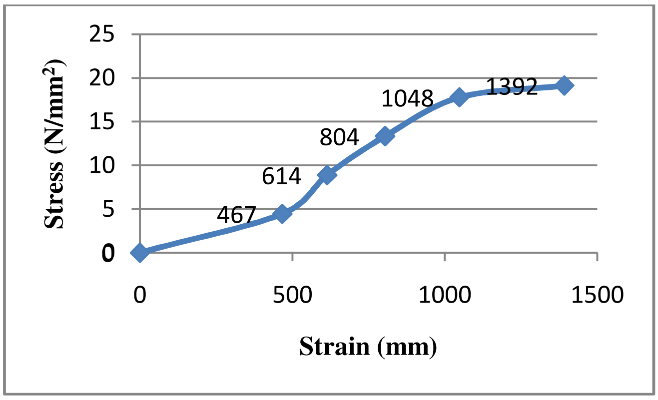

Fig12. Stress – Average Strain Curve for Conventional Steel Column.

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 350kN,200kN, 200kN respectively.

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 (ISLB 75 & Reinforcement rods-10mm dia) - Specimen 1

It was 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 49% greater than the conventional reinforced concrete and 63% greater than steel column.

Thus, 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.

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