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Analytical and Experimental Investigation on Steel Encased Composite Column Using Alccofine Concrete

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Abstract: **This paper presents the results of analytical, numerical and experimental work of steel encased composite column using Alccofine concrete. In practice, most of the composite columns are relatively slender in nature. In composite column there is no requirement to provide additional reinforcing steel for composite concrete filled tubular sections and in composite column both the steel and concrete would resist the external loading by interacting together by bond and friction. In order to increase the strength, durability of the column and used to reduce the water content for the concrete mix, Alccofine a new type of a mineral admixture is added with the concrete mix. In this paper comparisons will take place between the conventional column with the steel encased composite column with Alccofine which results in higher strength and resist the sudden failure when axial load acts on the specimen. The sections are arrived by using the code IS 808:1989. The finite element software (Using ABAQUSE software) is used to determine the numerical analysis of the composite column under axial load and finally, the ultimate plastic resistance of the composite column is compared with analytical, numerical and experimental works.**

Keywords: **Alccofine, steel encased composite columns, Mineral admixture, strength and durability, friction**

1. INTRODUCTION

Composite construction is a generic term to describe any building construction involving multiple dissimilar materials. Composite construction is often used in building aircraft, watercraft, and building construction. There are several reasons to use composite materials including increased strength, aesthetics, and environmental sustainability. Composite construction dominates the non-residential multi-story building sector. This has been the case 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 expressed 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 highly efficient and lightweight design. The reduced self-weight of composite elements has a knock-on effect by reducing the forces in those elements supporting them, including the foundations.

Composite systems also offer benefits in terms of speed of construction. The floor depth reductions that can be achieved using composite construction can also provide significant benefits in terms of the costs of services. The most important and most frequently encountered combination of construction materials is that of steel and concrete, with applications in multi-story commercial buildings and factories, as well as in bridges. These materials can be used in mixed structural systems. 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. The demand of better concrete is increasing day by day. Improved quality of concrete will only perform better if concrete improves workability, durability, flow ability & resistance to chemical attack/corrosion and reduce w/c ratio, heat of hydration & segregation mainly

Yatin H Patel,Dr.B.K. Shah(1) presented durability study of high performance concrete with Alccofine and flyash The performance of concrete mixture in terms of Compressive strength, Chloride Attack tests, Sea water test and Accelerated corrosion test at age of 28 and 56 days is considered. The author concluded that- Result show that concrete incorporating Alccofine and fly ash have higher compressive strength and Alccofine enhanced the durability of concretes and reduced the chloride diffusion. An exponential relationship between chloride permeability and compressive strength of concrete is exhibited. Siddharth P Upadhyay, Prof. M.A.Jamnu [2] Studied the Effect on compressive strength of high performance concrete incorporating Alccofine and fly ash. In this Paper the Compressive strength of high performance concrete with their placement of cement with Alccofine and Fly ash, and also with natural sand to manufactured sand. The concrete specimens were cured on normal moist curing under normal atmospheric temperature. The ternary system that is Ordinary Portland cement fly ash Alccofine concrete was found to increase the compressive strength of concrete on all age when compared to concrete made with fly ash and Alccofine alone.

Saurabh Gupta, Dr. Sanjay Sharma, Er. Devinder Sharma [3] Studied on Alccofine as a supplementary cementitious material from the experimental results the author concludes that-The Alccofine being use as mineral admixture in a concrete mix increase the initial strength of the concrete than the ordinary concrete. The concrete possesses high workability and retain the workability for sufficient time. Alccofine is easy to use and can be added directly with cement, ultrafine particle of Alccofine provide better and smooth surface finish. For high strength concrete the cost of the concrete mix prepared with Alccofine is lesser than the concrete without Alccofine. It also lowers the water/binder ratio. Rajesh Kumar S, Amiya K Samanta, Dilip K. Singha Roy [4] proposed the experimental study on the mechanical properties of Alccofine. The cement replacement by 10% of alccofine gives higher values of all other mix. It is clear from the results that the alccofine material increases the strength only at the addition of 10% replacement of cement. If the percentage level of alccofine is increased beyond that level it acts as a filler material and yields good workability to the concrete. Ansari U.S, Chaudhri I.M, Ghuge

N.P, Phatangre R.R. [5] studied some experimental work cement is partially replaced by alccofine and fly ash for M70 grade of concrete. The compressive strength of concrete of OPC concrete and with alccofine and fly ash is compared and it has-been found that the strength of concrete got increased by 20% with partial replacement of cement by alccofine. DevalSoni Suhasini Kulkarni, Vilin Parekh [6] Alccofine has better performance compares to other slag materials and micro silica Alccofine helps to increase strength in both compressive and flexural strength upto certain limit (6%, 7%, 8%). M.S. Pawar , A.C. Saoji [7] The study focuses on comparison of the properties of SCC with flyash and Alccofine to that of standard one, with flyash .The main variable is proportion of Alccofine keeping cement, flyash, water, coarse aggregate, fine aggregate and super plasticizer contents constant. The primary objective of this study is to study the axial stress-strain characteristics of alccofine concrete composite column, to evaluate the effect of alccofine concrete on the strength and deformation of the composite column and to compare the experimental results with the predictions of analytical results.

2. FINITE ELEMENT ANALYSIS

In order to accurately simulate the actual behavior 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. ABAQUS is a software application used for both the modelling and analysis of mechanical components and assemblies (pre-processing) and visualizing the finite element analysis result. Here steel encased composite section column models of 150*150*600mm are designed in the finite element software ABAQUS/CAE, provides a complete modelling and visualization environment for ABAQUS analysis products. With direct access to CAD models, advanced meshing and visualization, and with an exclusive view towards ABAQUS analysis products, ABAQUS/CAE is the modelling environment of choice for many ABAQUS users. In finite element software ABAQUS the columns are analyzed by defining the following part, property, assembly, step, load, mesh.

- **Pre-processing or modelling**: This stage involves creating an input file which contains an engineer's design for a finite-element analyzer (also called "solver").
- **Processing or finite element analysis:** This stage produces an output visual file.
- **Post-processing** or generating report, image, animation, etc. from the output file: This stage is a visual rendering stage.

2.1 Part Module

The first step in the finite element modelling is defining the part. The Parts Module is where you make all the basic definitions of Parts (shapes, sections, etc. not boundary conditions or any analysis) the defining part means the creation of model shapes, section in this study it is steel encased composite column of cross section 150 x 150 mm as shown in Fig.1. The height of the column is 600mm. the shell shape, extrusion type section is created for this elliptical hollow section column.

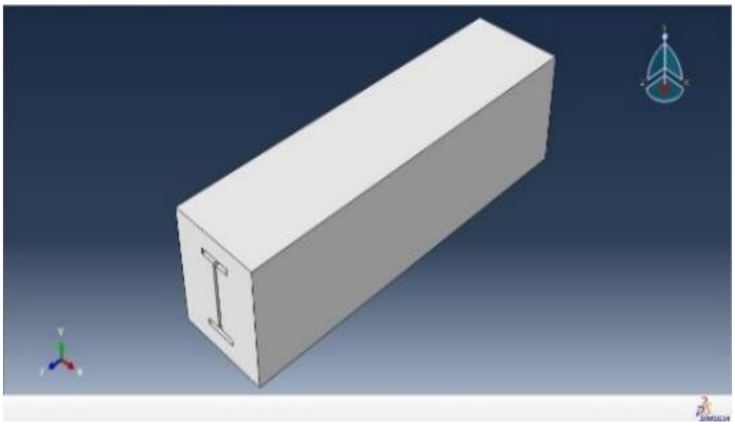

Fig.1 Column part module

2.2 Property Module

In the finite element modelling, defining the property is an important step. The defining the property means the defining the material and section properties. Composite column is made of concrete and structural steel, with a Young's modulus of 200 GPa, a Poisson's ratio of 0.3. Defining the section properties involves the assigning the section thickness. And all the material properties used for the analysis are presented in the Table I.

TABLE I: MATERIALS PROPERTY

Materials	Density (N/m^3)	Young's Modulus (Mpa)	Poisson's ratio
Concrete	24000	2.0E04	0.15
Steel	78500	2.0E05	0.30

2.3 Step Module

In finite element modelling, step module is for setting the type of analysis we needed and the analysis procedure. In this study, composite column section buckling analysis has been done. The step module is used for setting the buckling analysis. Buckling analysis calculates buckling load magnitudes that cause buckling and associated buckling modes. FEA programs provide calculations of many buckling modes and the associated buckling-load factors (BLF). The BLF is expressed by a number which the applied load must be multiplied by (or divided) depending on the FEA package) to obtain the buckling-load magnitude. The step module for the corresponding column is shown in Fig.2.

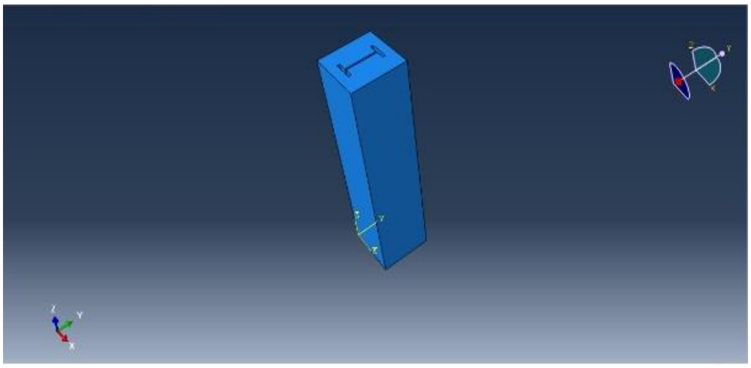

Fig.2. Step Module

2.4 Load Module

The step sequence provides a convenient way to capture changes in the loading and boundary conditions of the model, changes in the way parts of the model interact with each other, the removal or addition of parts, and any other changes that may occur in the model during the course of the analysis. The initial step allows defining boundary conditions, predefined fields, and interactions that are applicable at the very beginning of the analysis. In finite element modelling, load module is used for assigning the boundary condition and loading point. In this study, hinged- hinged boundary condition is assigned as shown in Fig 3. The boundary condition is assigned Mechanical – Displacement/Rotation type to be the type of step. Apply the boundary conditionU1, U2, U3, UR1, UR2, UR3 and specify U3 as -1. The load type is specified as concentrated force. The corresponding module is shown in fig. The steel encased composite section columns 150 x 150 x 600mm are in this same manner for all.

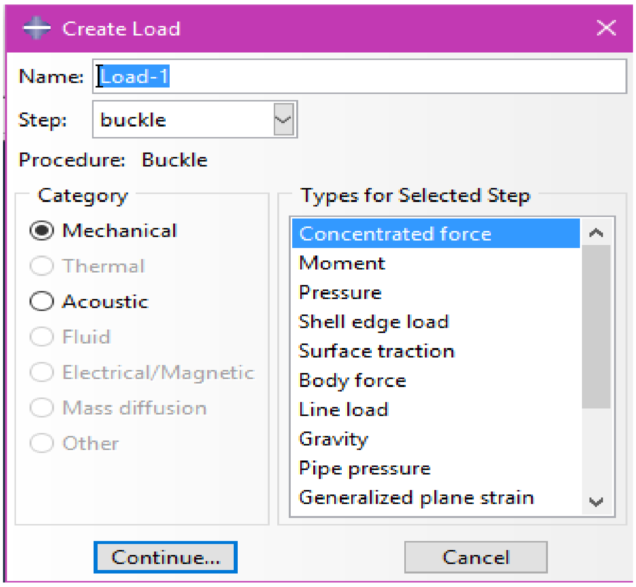

Fig. 3. Load module

2.5 Mesh Module

Meshing technique is the most easily access able meshing mechanism in Abaqus that requires no pre-established mesh pattering (e.g. partitioning). The process of meshing a part with complex geometry can be either highly rewarding or, as is more often the case, highly frustrating. Creating a clean, uniform mesh for a structural analysis has gotten easier as meshing algorithms and tools have improved. The focus of this post is the use of partition (or divide) tool sets to improve mesh quality. In this study, for composite columns 150 x 150 x 600mm are meshed in ABAQUS software. The 1050 mesh elements are created for each composite column section. The meshed result is shown in fig.4.

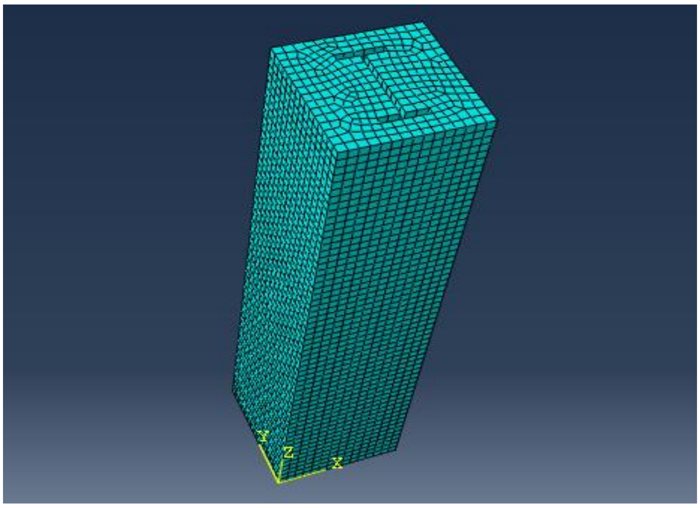

Fig.4. Meshed composite column section

2.6 Post Processing

The two no's of steel encased composite column and one conventional RC column specimens under axial loading were analyzed using ABAQUS finite element code. The results pertaining to the objectives of the study are presented and discussed in this section. Finite element analysis successfully according to the prompt in the log tag of job monitor, you can choose the results button in job manager window to enter visualization module to view the result in different methods. The Visualization module provides graphical display of finite element models and results. It obtains model and result information from the output database; you can control what information is placed in the output database by modifying output requests in the step module i.e. the type of analysis. The results for the column specimens are shown in Fig 5,6,7. The obtained ultimate loads are tabulated in table II.

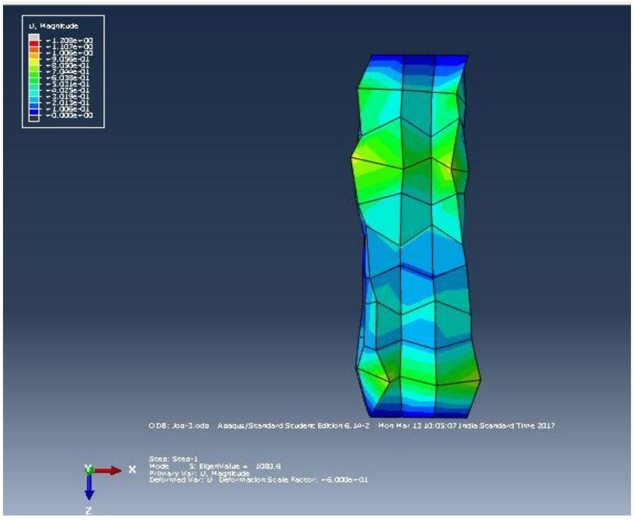

Fig 5. ABAQUS Result for PC – 1

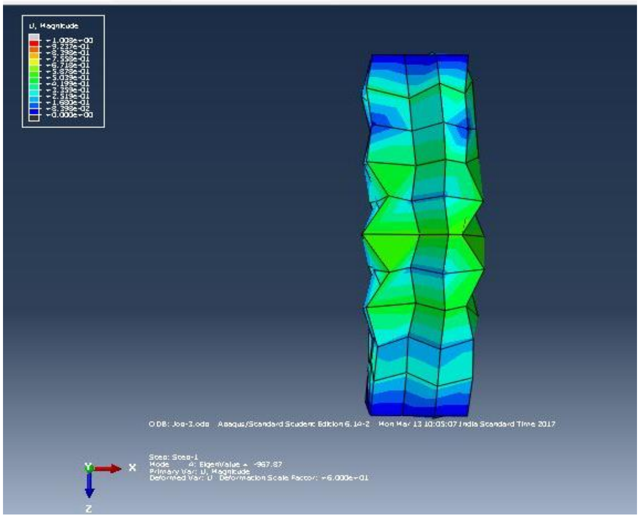

Fig 6. ABAQUS Result for PC– 2

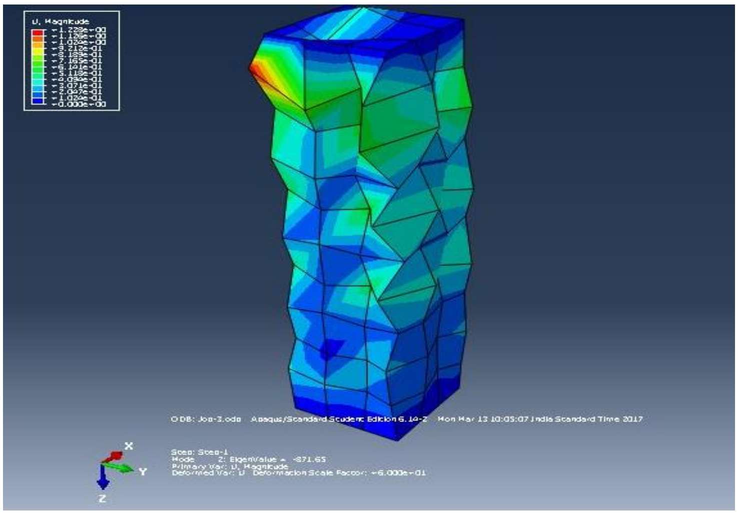

Fig. 7 ABAQUS Result for Conventional RC column

TABLE II. LOAD - SHORTENING RESULT

Column ID	Ultimate Load (KN)	Deformation(mm)
PC-1	907	4.87
PC-2	670	3.05
CC	520	2.56

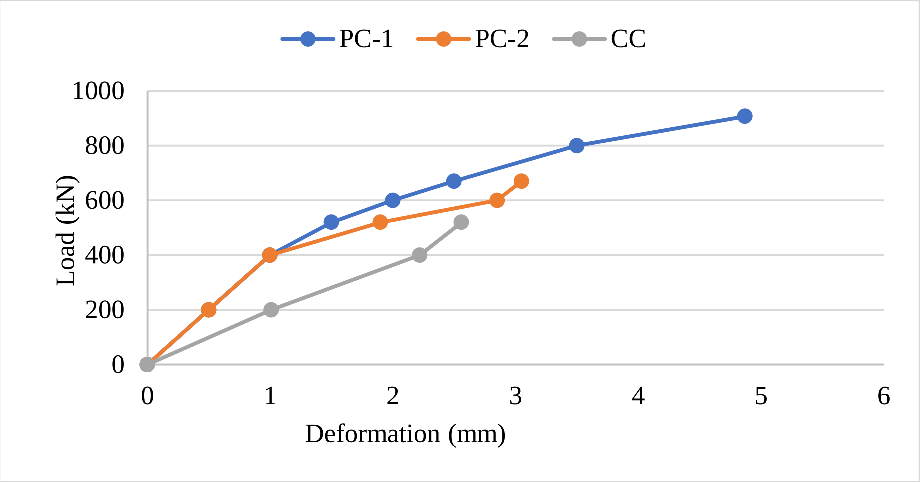

Fig 8. Axial stress -strain behaviour- comparison

3. EXPERIMENTAL PROCEDURE

3.1 Material properties

3.1.1 Steel I-Beam

I-beams are commonly made of structural steel but may also be formed from aluminum or other materials. The horizontal elements of the "I" are known as flanges, while the vertical element is termed the "web". The web resists shear forces, while the flanges resist most of the bending moment experienced by the beam. Beam theory shows that the I shaped section is a very efficient form for carrying both bending and shear loads in the plane of the web.

3.1.2 Alccofine

Alccofine is a new generation, micro fine material of particle size much finer than other hydraulic materials like cement, fly ash, silica etc. being manufactured in India. ALCCOFINE is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. The raw materials are composed primary of low calcium silicates. The processing with other select ingredients results in controlled particle size distribution. The computed blain value based on PSD is around 12000cm/gm. and is truly ultra-fine, thus resulting in a material of better structural performance. It is a micro finer cementitious grouting material for soil stabilization and rock anchoring. The performance of Alccofine is superior to all other admixtures used in India. Due to high calcium oxide (Cao) content. Alccofine 1203 is a slag based Alccofine 1203 provides reduced water demand for a given workability, even up to 70% replacement level as per requirement of concrete performance. having ultra-fineness with optimized particle size distribution. The alccofine 1203 admixture is shown in Fig 9.

Fig 9. Alccofine

3.2 Test Specimens and Its Details

The main purpose of this experimental study is to evaluate the buckling behavior of the composite column under axial loading. A total of 4 columns have been casted with two numbers of composite columns proposed column-1, proposed column-2 (PC-1, PC-2) and one column with reinforcement cages by using alccofine (CC(A)) and another column without using alccofine (CC). The column dimensions are similar for all the columns 150 mm x 150 mm. All the columns were 600mm long. The reinforcement cages are four numbers of 12mm diameter bars as longitudinal reinforcement and 8mm diameter bars as lateral reinforcement. The columns were made of concrete of strength 59.81 Mpa and provided with HYSD bars of yield strength 415.63 Mpa. For all the test columns, the study parameters included ultimate load, yield load, deformation, number of cracks, ductility and failure modes. The column specimens were casted using Ordinary Portland cement, well dry and clean natural gravel aggregate with a maximum size of 12mm, tap water and alccofine maintains good workability. The column specimen was cast horizontally in a steel mould in the Structural Laboratory. The specimens were carefully compacted using taming rod in order to prevent honey combing in the columns. The details of the columns are shown in Table III.

TABLE III. DETAILS OF TESTED COLUMNS

Column ID	Top bar	Bottom bar	Stirrups Spacing (mm)	Dimensions (mm)
PC-1	-	-	-	150 x 150
PC-2	-	-	-	150 x 150
CC(A)	2-12Ø	2-12Ø	125	150 x 150
CC	2-12Ø	2-12Ø	125	150 x 150

3.3 Test Setup and Instrumentation

The columns were tested in compression testing machine of capacity 3000 kN. The experimental set up is shown in Fig 2. Earlier to apply loading, the specimens were positioned on the support and also centered to make sure that the two supporting ends were parallel to each other and at right angles to the loading axis. The load was applied to the column by hydraulic jack and monitored by using 1000 kN capacity load cell. Axial deformation of the column was measured using linear voltage displacement transducer (LVDT) which was kept at top of the jack. The load cell and LVDT were connected with the 16- Channel Data Acquisition System to store the respective data. The load was applied slowly and the column was tested to failure by applying the concentric compressive load in small increments and the observations such as axial deformation and ultimate load were carefully recorded. The load at which the column starts rupturing and the nature of failure were also noted for each column and it was tested to failure by applying the concentric compressive load and the observations such as ultimate loadings, the deformation was carefully recorded and tabulated which also include the stress, strain and percentage of change in length of the specimens. The test setup is shown in Fig 10.

Fig.10. Test setup and instrumentation

3.4. Experimental Results &Discussions

In the tests, the composite columns mainly exhibited required experimental behavior. The test results exposed that the composite column with alccofine provides significant resistance. The tensile cracks occurred in the tension zone and the concrete crushing was observed in the compression zone of the columns. The inclusion of the alccofine definitely improved the ductility and deformability of the composite columns and reinforced columns. The experimental test results are shown in table IV.

TABLE IV. TEST RESULTS FOR COLUMNS

Column ID	Load (kN)	Deformation (mm)	Stress (N/mm^2)	Strain
PC-1	980	4.09	43.33	0.00341
PC-2	825	3.05	36.67	0.00743
CC(A)	690	2.50	30.67	0.00416
CC	575	1.69	25.56	0.00186

3.4.1 Failure modes of column specimens

During the tests, the axial load was applied to the column specimens, the inner cracks were appeared for both the type of columns generally at mid-height or close to mid-height on the tension region at almost 40% of failure load. At the time of failure, the cover concrete spalled highly and the longitudinal bars buckled in the compression zone for the reinforced concrete columns. In addition, premature cover spalling was prevented by the addition of alccofine. At failure, the local buckling failure was observed near the specimen mid height. Typical failure mode of the column specimens is shown in fig.11.

Fig 11. Typical failure mode of the column specimens

3.4.2 Effect on Strength

The test results show that the load carrying capacity varied with different column specimens. In proposed column (PC-1), the yield load increased by 50% when compared with the proposed column (PC-2). In column with light weight beam (PC-2), the yield load increased by 75% when compared with conventional column with alccofine(CC(A)). In columns with alccofine reaches the yield load increased by 62.5% when compared with conventional reinforced column(CC). As a result, the yield load increased higher for the composite column with medium standard I- beam (PC-1). In columns with medium standard beam (PC-1), the ultimate load increased by 77.5% when compared with proposed column (PC-2). In columns with light weight beam (PC-2), the ultimate load increased by 67.5% when compared with conventional column using alccofine(CC(A)). In columns with alccofine reaches the ultimate load increased by 57.5% when compared with conventional reinforced column(CC). The effect on strength for the four columns specimens are shown in below figure 12.

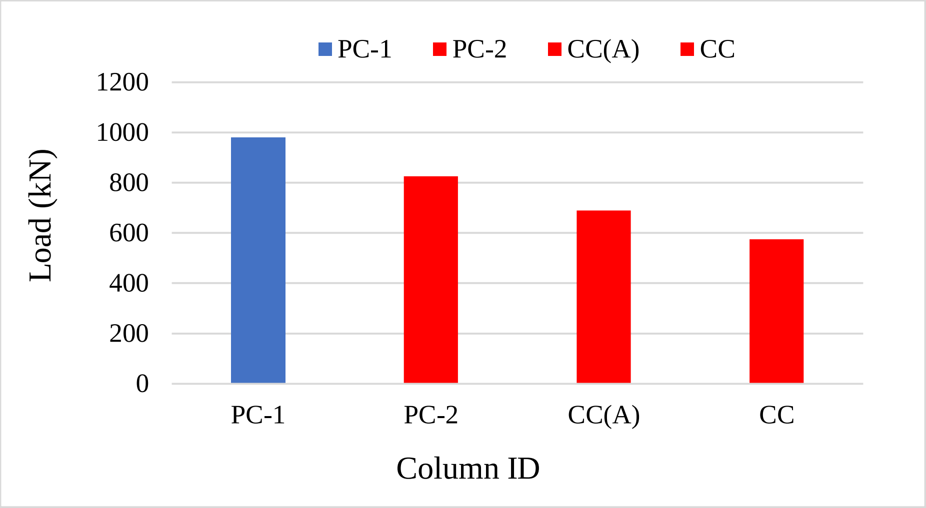

Fig 12. Effect on Strength of all column specimens

3.4.3 Load- Deformation Behaviour of Column

The load-deformation curves are a standard method of quantifying the energy which a column absorbs during its load induced deflection. In the experimental investigation, all column specimens behaved in a similar manner until crushing of concrete occurred. It was observed that the tensile crack in the tension zone is and the concrete crash in the compression zone is located nearly in the middle height of the column specimens. Experimental load-deflection diagrams for the specimen's PC-1, PC-2, CC(A), CC are presented in Fig. 13. As can be seen in the diagrams, the column specimens behaved in a ductile manner in both sides. The specimens deflected until reaching the peak load and tensile crack observed on the convex side of the specimens at that stage. After that, a sudden drop occurred in load resistance and lateral displacements increased. Because of the confinement provided by lateral ties, the maximum strain value for the column specimen shown in the figure exceeded the maximum compressive strain value obtained experimentally.

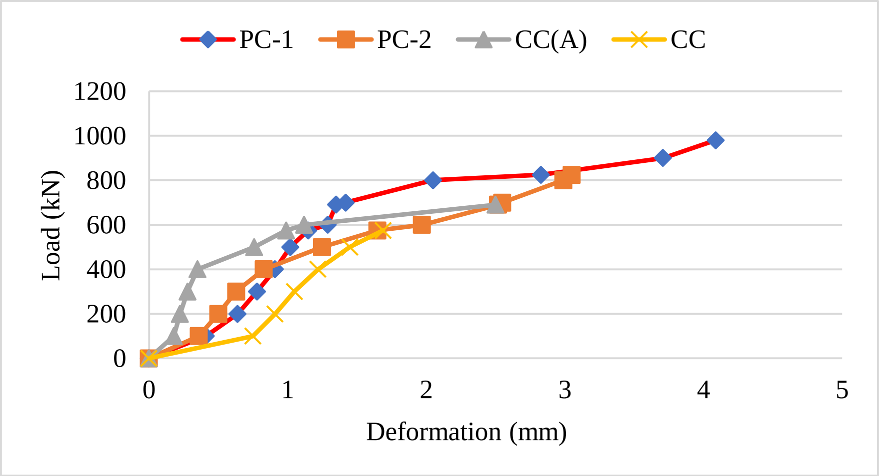

Fig 13. Load- Deformation Behaviour of columns

3.4.4 Effect on Deformation

Deformation control is one of the important parameter to be considered here the deformation are compared for all the column specimens. The ultimate deflections are denoted in the below figure. In tested column PC-1 reaches ultimate deflection 1.17% decrease when compared with PC-2. In column testing, the ultimate deflection for PC-2 increased by 0.43% when compared with CC(A). In columns testing, for CC(A) the ultimate deflection decreases by 0.32% when compared with CC. The effect on deformation for all the column specimens are shown in below fig 14.

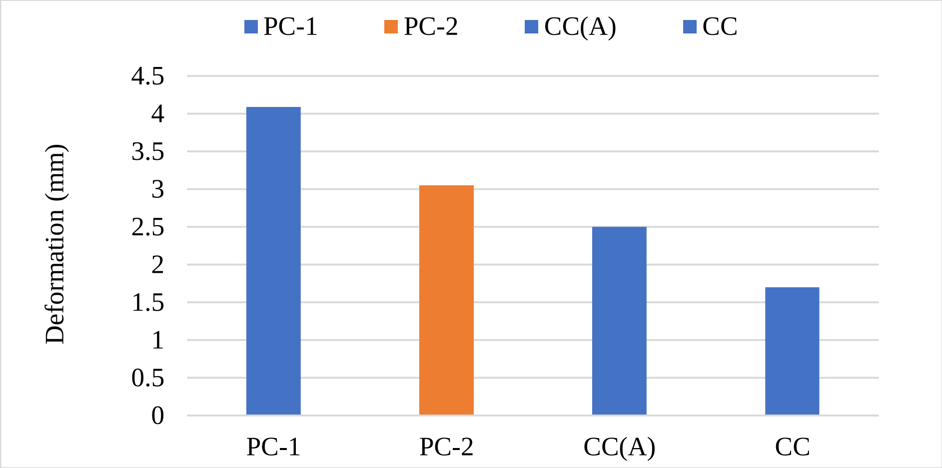

Fig 14. Effect on Deformation for all column specimens

4. CONCLUSIONS

Composite constructions are nowadays widely used in the multi-storey buildings. The advantage of using the composite section is due to its increased strength and stiffness. Since concrete is good in compression and steel in tension, the combination of these two materials result in efficient and lightweight design. The tests were conducted on base materials like cement, fine and coarse aggregates. In which the fineness modulus and specific gravity of cement, fine and coarse aggregate were 2.9 and 3.15, 2.6 and 3.07, 7.3 and 2.65 respectively. A mix design for M_{50} grade concrete has been chosen for better performance. The compressive strength and split tensile tests were conducted on hardened concrete and the values were found to be 59.03N/mm^2 and 3.53 N/mm^2 respectively. After these preliminary base materials tests are done and results are obtained, the specimens were casted and tested. A theoretical manual design was adopted for all four specimens the results obtained from Theoretical, experimental for Proposed Composite Column – 1 were 927.94 kN, 980 kN, For Proposed Composite Column – 2 790 kN, 825 kN, for conventional RC Column with alccofine 550.53 kN, 690 kN, for conventional column without alccofine – 531.05 kN, 575 kN, Respectively.

Although, the experimental results obtained are almost identical to the theoretical values and thus, showing the Proposed Composite Column – 1 to be superior when compared to other specimens. Based upon the results it can be concluded that supplementary cementitious materials like Alccofine, play a significant role in strength development of the concrete mixes. The reduction in w/c ratio considerably increases the strength of the mix. High density of the mix was achieved and subsequently higher packing. Cube failure was dumb bell showing aggregate crushing dominantly. The addition of 10% Alccofine tends to give better strength results.

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