Finite Element Behaviour of Innovative Multi Cellular CFST Column Shapes under Axial, Eccentric and Dynamic Performance

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Abstract - *The concrete-filled steel tube CFST is a type of steel-concrete composite construction, and has an increasing trend in being used in high-rise building and bridge structures. This paper studies the behavior of concrete-encased concrete filled steel tube (CFST) columns under different loading condition. In this study four square columns fabricated using concrete-filled steel tubes connected via vertical connecting plates were tested under different loading cases. A finite element analysis (FEA) is used to analysis the behavior of the composite columns. In this paper three methods are used to connect the columns. Three main base models are used for connecting the columns, the axil load, lateral load and biaxial load with 30% and 60% are applied. Among the three methods the worst model is selected and strengthened by using horizontal plates. Among the different methods the best and suitable methods will be selected. The failure modes, load–deformation relationship, strain distribution, ductility, and strength index of the columns were studied. This study is to conduct an evaluation of strength behavior, ductility behavior, stress distribution and load-deflection by FEA for different connection methods. The influences of the different connections, and strength of the column were studied, and the failure mode and mechanism of the connection were obtained.*

Key Words: Concrete filled steel tube, lacing plate connection, plate connections with perforated holes, lacing with horizontal plates, plate connections, finite element analysis, ANSYS 16.1.

1. INTRODUCTION

The concrete filled steel tube (CFST) is a type of steel concrete composite section, which consists of inner concrete and outer steel tube. This composite structure has many applications compared to the reinforced concrete structures CFST columns, the CFST columns have higher fire resistance and better durability under corrosive environment due to the protection from the outer steel tube of the CFST. The CFST columns can be inserted into walls, and thus helps avoid column protrusion, and which is beneficial from an architectural-design viewpoint, and also helps to increase the indoor space.

CFST column has a significant role in the physical properties such as strength, stiffness, and ductility. This study is to conduct an evaluation of strength behavior, ductility behavior, stress distribution and load-deflection by FEA with four columns that are used to connect by different means. In this study mainly three base models are used as the interconnecting members. Among these three models the weak connection is identified and that is strengthened by providing a horizontal plate in an equal interval. The lateral loading, axial loading and eccentric loading are applied on all the cases. By analyzing the load-deflection, find out the performance of the different connecting plates.

The load applied on the structure is as follows 1. Axial Load (AL), 2. Lateral Load (LL), 3.BI-axial load 30% and Bi-axial load 60%.

This paper is focused on the comparison of different models. The models used for connecting of columns are plate connection, lazing connections, plates with perforations and the lazing with horizontal plates and to conduct study on the strength, ductility, stress distribution, and load deflection. The aim of this paper is to investigate the bearing performance of the connecting plates used for column-to-column connections under lateral loads, axial loads and eccentric loading by means of a method that takes into account the possibility of displacement of column by using different connections. By analyzing the load-deflection, find out the performance of the different modes of connection of columns.

1.1 Objectives

The project focused on the performance study of CFST columns under the applied load and identifying the deflections occurring on different load due to the applied load. An extensive parametric study was conducted on this finite element models to compare the models on the basis of load-deflection chart, the load-deflection chart is obtained by testing the models under the influence of the loads. The ductility behavior, load deflection and stress distribution of columns where identified and compared. The finite element analysis on concrete-encased CFST columns and the column to column connections are developed. Full-range response of the load versus deformation relation is analyzed. Parametric studies are studied. The model with ultimate strength is selected. The objective of the project is to determine the effect of different models used for column to column connections under different loading conditions like lateral load, axial load and bi-axial load.

2. MODELLING AND ANALYSIS

The general layout and dimensions of elements are given below. The verification of finite element model of section size of each column is 100x100.The elements used in this project are high strength steel and concrete. The specimens were made from IS961 steel and m30 concrete. The connecting plate distance is 100mm, single plate system is used. The connecting plates used are of for types vertical steel plate, vertical steel plate with perforations, vertical steel plates with lacings, all the connecting plates used in the projects having same dimensions. The finite element model is created in ANSYS using different element Types, Real Constants and Material Models and is assigned to respective elements of the model. The loads and boundary conditions are then applied. Next, the material properties are defined. The materials consist of structural steel used in the connecting of columns and the concrete is used in the CFST columns, their engineering data are assigned.

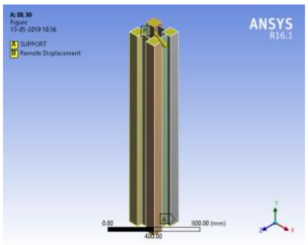


Fig-1a: vertical plate connection

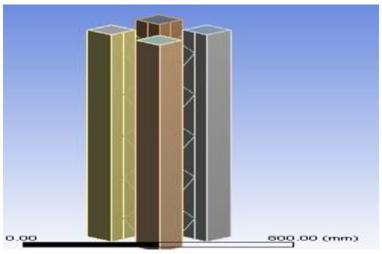


Fig-1b: vertical lacing connection

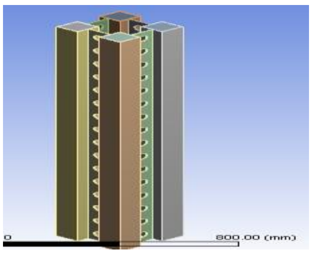


Fig-1c: vertical plate with perforations

2.1 Boundary Condition, Contact Interactions and Loading

The columns are fixed at the bottom. The vertical connecting plates in between the columns are connected to the columns by means of welding. The connection has possessed a friction in reality. In the software as well, they are connected to each other frictionally with a friction coefficient of 0.2.

2.2 Selected Parameters

The models used in this paper are generally classified into two main categories, they are the models without strengthening and the models with strengthening. The first category includes three models 1. Vertical steel plate connection, 2. Vertical steel plates with lacings, 3. Vertical steel plates with perforations. The second category consists of the weaker model, and which is strengthened by providing horizontal steel plates in a particular interval and the model included in this category is 1. Vertical lasing with horizontal plate. The dimensions of the columns, vertical connecting plates and stiffeners are the same in all connections.

The first parametric study was selection of different models. Secondly three different loadings such as lateral loading, axial loading and eccentric loading were selected for the performance evaluation like strength behavior, ductility behavior and stress distribution of different column models. The analysis was done in ANSYS software.

Finally, the strength of every model is compared and evaluated. The difference in the strength of different models. On the basis of this the weaker model is selected and some additional arrangements are added to increase the strength.

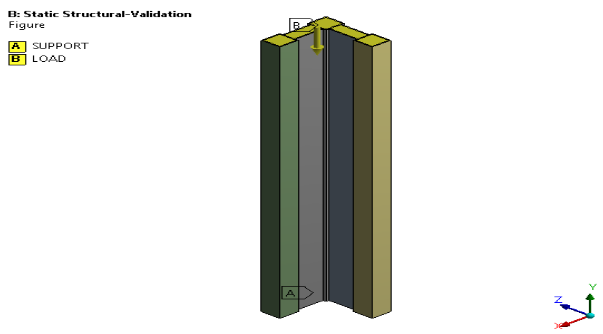


Fig -1: Boundary conditions and lateral loading

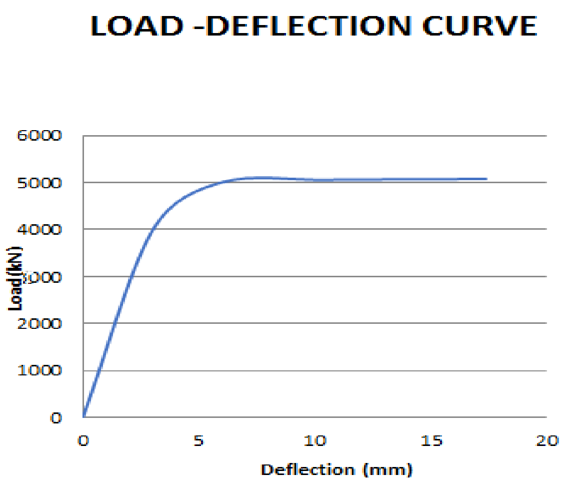


Chart -1: Load deflection curve

In the finite element software, loading was applied statically which a displacement control loading is to the top of the column up to the final loading step. Then analysis the model in ANSYS Workbench 16.1.

3. RESULTS AND DISCUSSION

3.1 The Performance of Columns due to Axial Load for different models

In this study, there are four columns, they are arranged in a square shape. The box shape arrangement is symmetrical and it has high load carrying capacity. Each model has same overall weight. The dimensions of the connecting plates are the same in all connections. The models are different only in the connecting plates. The total deformation on different models are shown in the fig-2

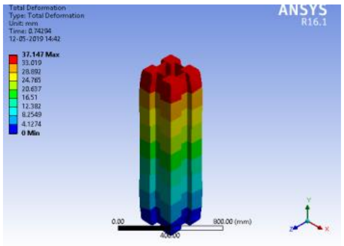
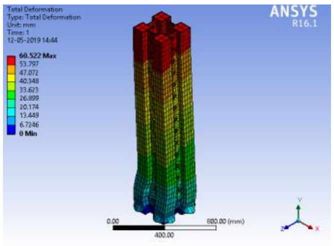


Plate connection – AL



Perforated connection-AL

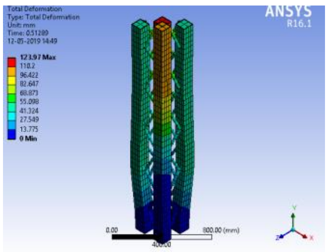
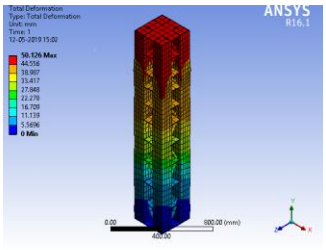


Plate with Lacing connection - AL



Lacing with horizontal plate - AL

Fig -2: Columns under the influence of AL

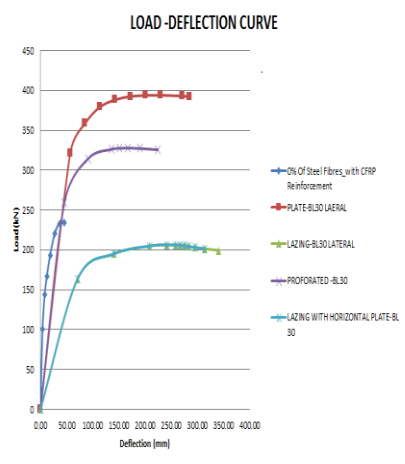


Chart -2: Load deflection curve

fig. 2 shows the load-deflection diagram obtained from the FEA analysis of different models using ANSYS 16.1. the first figure shows the deflection diagram of a vertical plate connection. The second figure shows the deflection of vertical plate connections with perforations. The third figure implies the deflection happened to the vertical lacing plate connection. From the third figure it is identified that the deflection is minimum for this type of connection. Thus, arriving into a conclusion that this model cannot be practicable for the connection of columns in high raised building. By the use of horizontal plate in the plates with lacing connection, there will be a reduction in the deflection. The figure four shows the deflection occurred when the axial load is applied to the lacing with horizontal plate. According to this graph the. The lacing with horizontal plate connection carry 14% of additional lateral load than the normal lacing connection.

Chart. 2 shows the load-deflection graph of the four models when it is subjected to axial load. According to this graph the vertical plate connection carries maximum load. The perforated plate carries a slightly less load with the plate section.

The figure 2(a) shows the percentage of load of the different models. It is clear from the chart that the plate section carries high load. . The vertical plate connection carry 26% of additional lateral load than the normal lacing connection.

Figure 2(b) shows the vertical plate with lacing starts to deform at first. The vertical plate connection withstands the load to the maximum value when compared with the other models.

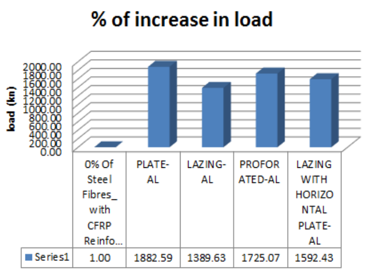


Fig-2(a): Percentage of increase in load

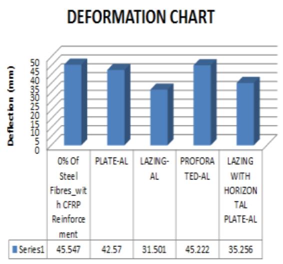


Fig-2(b): Deformation chart of axial load

3.2 The Performance of the column due to lateral load for different models

In this study, there are four columns, they are arranged in a square shape. The box shape arrangement is symmetrical and it has high load carrying capacity. Each model has same overall weight. The dimensions of the connecting plates are the same in all connections. The models are different only in the connecting plates. In this case all the models are subjected to lateral load and the models are subjected to deformation. The total deformation on different models are shown in the fig-3

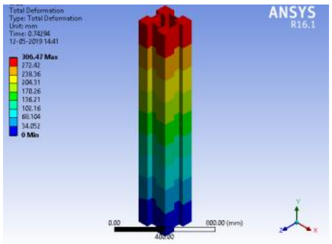
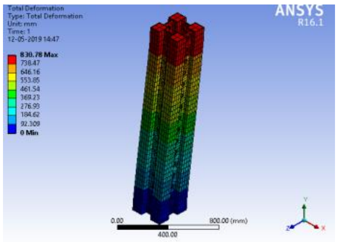
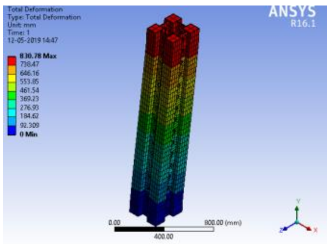


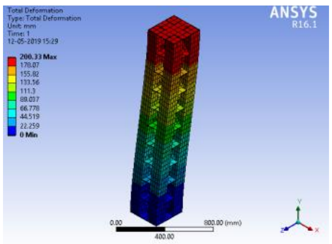
Plate – LL



Perforation - LL



Lazing - LL



Lazing with horizontal plate - LL

Fig -3: Columns under the influence of LL

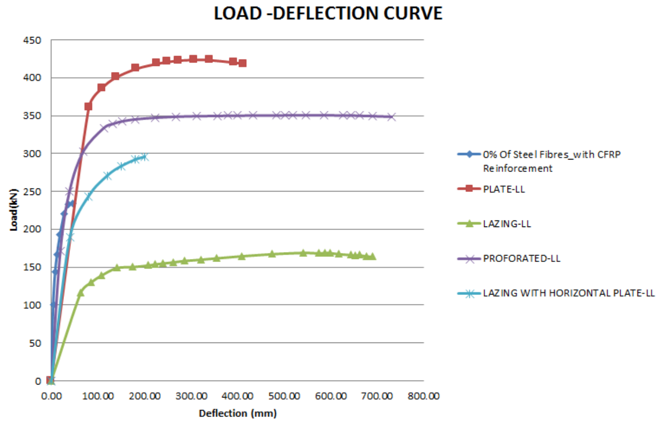
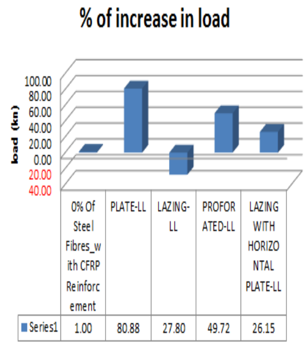


Chart -3: Load deflection curve

fig. 3 shows the load-deflection diagram obtained from the FEA analysis of different models using ANSYS 16.

Chart.3 shows the load-deflection graph of the four models when it is subjected to lateral load. The graph shows that the vertical plate connection carries the maximum load. load- deflection of lacing plate connection is the weak section in the terms of load carrying capacity under lateral loading.



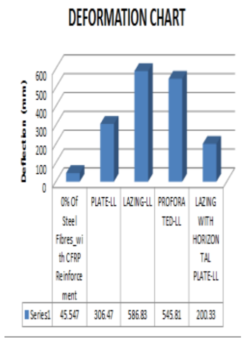


Fig-3(a): Deformation chart of lateral load **Fig-3(b)**: Deformation chart of lateral load

The figure 3(a) shows the percentage of load of the different models. It is clear from the chart that the plate section carries high load. . The vertical plate connection carry 64% of additional lateral load than the normal lacing connection.

Figure 3(b) shows the vertical plate with lacing starts to deform at first. The vertical plate connection withstands the load to the maximum value when compared with the other models.

3.3 The Performance of Columns under biaxial load for different models

In this study, there are four different models. The models are selected on the basis of the strength they possess. In each model have same dimensions according to their shapes. The dimensions connecting plates are the same in all connections. The bottom column is fixed on its base. The columns are fixed only at one end. In this case all the models are subjected to bi-axial load. In this case the bi-axial load applied on the models will have influence in the deformation in both the X direction and the Y direction. Certain effort should be taken to find out the total deformation which compresses both the deformations in X and Y directions. The bi-axial loading is taken in 30% and 60%. The bi-axial loading of both the X and Y directions are shown in the figure 4.

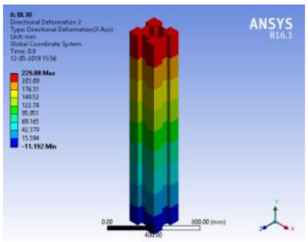


Plate-BL-30X

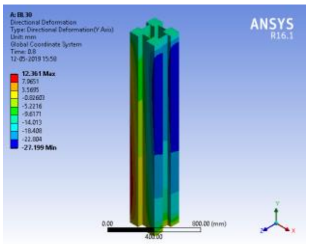


Plate-BL-30Y

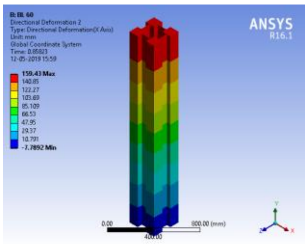


Plate-BL-60X

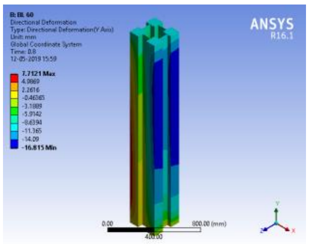
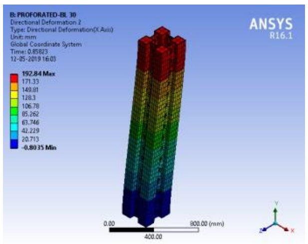
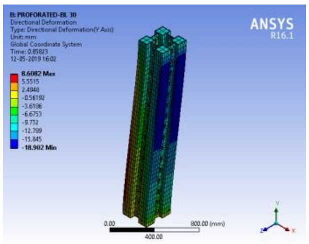


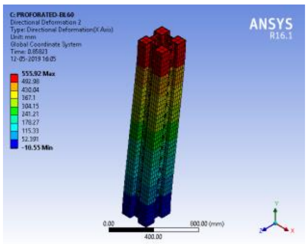
Plate-BL-60Y



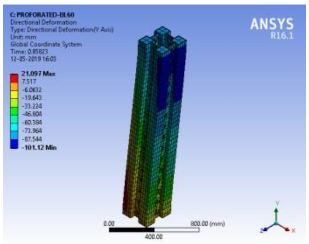
PRO-BL-30X



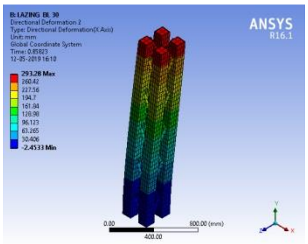
PRO-BL-30Y



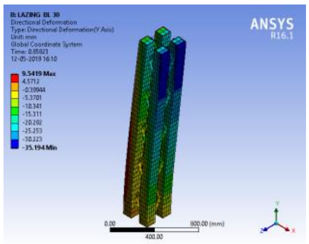
PRO-BL-60X



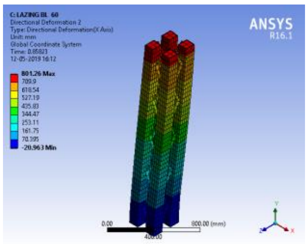
PRO-BL-60Y



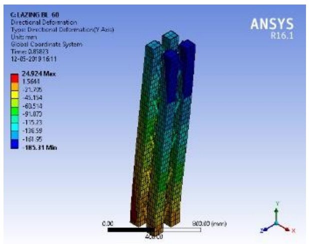
LAZING-BL-30X



LAZING-BL-30Y



LAZING-BL-60X



LAZING-BL-60Y

Fig -4: Columns under the influence of Bi-axial load in X & Y direction

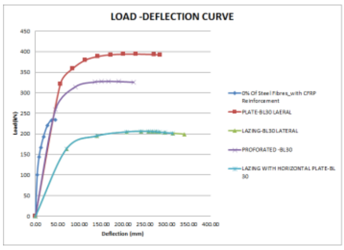


Chart.3(a): BL-30X

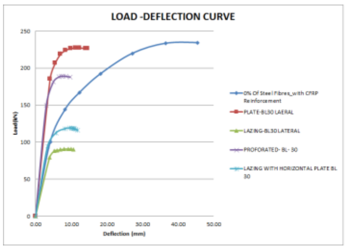


Chart.3(b): BL-30Y

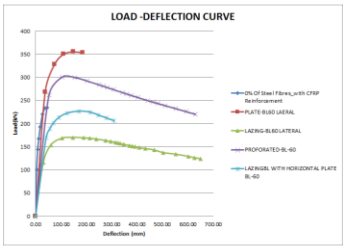


Chart.3©: BL-60X

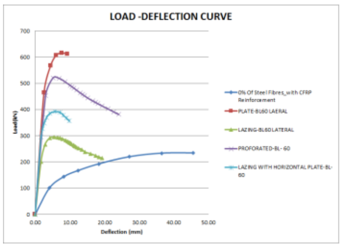


Chart.3(d): BL-60Y

Chart -4: Load deflection curve

Chart. 3(a) shows the load-deflection of bi-axial load 30% in the X direction. The plate connection carries high load. Lacing connection carries the minimum load.

Chart. 3(b) shows the load-deflection of bi-axial load 30% in the Y direction. The plate connection carries the maximum load and lacing connection carries the minimum load. The deformation of lazing gradually starts increasing with the applied load.

Chart. 3© shows the load-deflection of bi-axial load 60% in the X direction. The plate connection carries high load. Lacing connection carries the minimum load.

Chart.4(d) shows the load-deflection graph of the models subjected to bi-axial load 60% in Y direction

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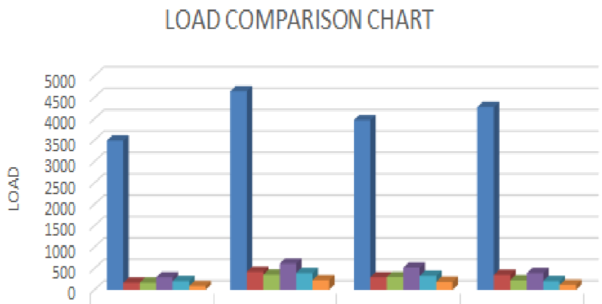
4. COMPARISON OF RESULTS

A total of four models were analyzed under different loading conditions such as lateral loading, axial and bi-axial loading. In each model have same dimensions according to their shape. The comparison of load and deflection curve of different models under the application of axial load, lateral load, bi-axial load let to know the best model in the total system. The comparison of deflection and load and the percentage of increase in the strength of the weaker section shown in chart

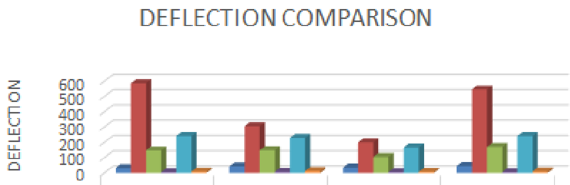
4.1 The Effect of Columns in different Load

Chart-5: Clearly gives the comparison of different models with different loads applied on to it. Chart 5 shows the load comparison of all models. From the chart we can see that the axial load is maximum for the plate connection, this helps the connection to withstand the maximum load compared to the other connections. The vertical plate with perforations has the second largest load carrying capacity. The lacing vertical plates has the minimum amount of load carrying capacity and the load bearing capacity of the lacing connection is ha improved from the base model. So, by applying the horizontal plate in the lazing connection the model has strengthened. On the same way the, this procedure can use to improve the strength of every models. The result will be much higher than the base models



	LAZING	PLATE	L&P	PRO
AL	3490.5	4645.6	3965.7	4276.5
LL	169.18	423.83	295.6	350.82
BL-60-AP	169.96	354.96	300.44	226.52
BL-60-LP	294.38	614.80	520.38	392.34
BL-30-AP	205.99	393.67	327.83	205.99
BL-30-LP	90.904	227.29	189.27	118.93

Chart.5: Comparison of Loads



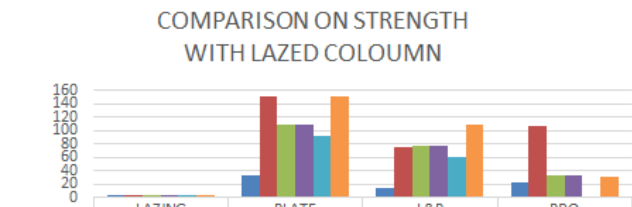
	LAZING	PLATE	L&P	PRO
AL	31.501	42.57	35.256	45.222
LL	586.83	306.47	200.33	545.81
BL-60-AP	147.41	148.7	104.41	170.09
BL-60-LP	5.3732	7.71	5.1181	5.6354
BL-30-AP	241.97	229.88	166.71	241.97
BL-30-LP	9.1563	12.36	7.6967	9.5208

Chart.6: Comparison of Deflections

Chart-6 shows the comparison of deflection under different loading cases. According to this figure the vertical lacing plate connections have a larger deflection than all other models that are used in the column to column connection of a CFST columns. So, it has more brittle behavior than other columns.

4.2 Comparing the strength of base models with respect to the strength of the lazing with horizontal plates

Chart-7 presents the comparison of axial load, lateral load, and bi-axial load of the vertical lacing plate and the lacing plate with an additional horizontal plate is added in a regular interval. This comparison is mainly done to find out how far the strength of the lacing with horizontal plate increased with vertical lacing plate. From the chart it is clear that in the case of axial loading the strength increased by 33% and in the case of lateral loading the strength is increased by 150% and for bi-axial loading the strength increased by more than 100%. From this chart it is understood that the strength increment of lacing plate has achieve a satisfactory result and this procedure can be followed in the remaining models to improve the strength.



	LAZING	PLATE	L&P	PRO
AL	1	33.093	13.690	22.510
LL	1.000	150.520	74.725	107.365
BL-60-AP	1.000	108.849	76.771	33.278
BL-60-LP	1.000	108.846	76.772	33.277
BL-30-AP	1.000	91.111	59.149	0.000
BL-30-LP	1.000	150.033	108.209	30.830

Chart-7: Comparison of strength with the lazed columns

5. CONCLUSIONS

The following conclusions may be drawn from the Finite Element Analysis (FEA) performed on four different models.
The increased in the strength of one of the weaker base models is achieved. The following conclusions were obtained by using finite element analysis software ANSYS Workbench 16.1. Different connecting patterns were tested to find out the models with maximum load bearing capacity.

• On the performance evaluation of four different models used for the inter connection the CFST columns lead to a conclusion that vertical plate section has the maximum strength than all other three base models.
•The square shape of the column is more symmetrical and helps to improve the load bearing capacity.
•The load bearing capacity is minimum for the lacing connecting pattern.
•The deformation occurs early in lacing connecting pattern.
•The performance of different models are different.
Among the CFST columns with four different connecting patterns, the column with vertical steel plates and the vertical steel plate with perforations performs more and achieves higher load bearing capacity.
• The strength of the lacing plate is increased by provide the horizontal plate.
• For the lacing with horizontal plate axial loading the strength increased by 33% and in the case of lateral loading the strength is increased by 150% and for bi-axial loading the strength increased by more than 100%.
• The horizontal plate is used to improve the strength of the lacing connecting pattern, the following method can be adopted to improve the strength of the other models.

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