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# Non-linear Finite Element Analysis of Short Tapered Composite Square Box Columns

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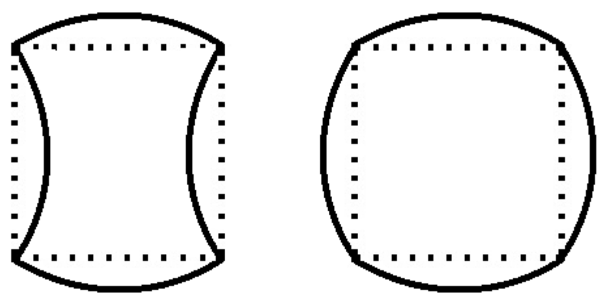
*Abstract*— **This study is concerned with the analysis of short tapered composite square box columns subjected to the action of axial load. 9 models were analysed using finite element simulations. Results obtained are presented in the form of load-deflection diagrams, charts and tables. The finite element package, LUSAS has been used to carry out non-linear analyses of models to study the behaviour and ultimate load-carrying capacity of the columns. The effect of taper angle and thickness of steel plate on the axial stiffness and ultimate axial load capacity have been examined. It was concluded that taper angle and steel plate thickness have significant influence on the behaviour and strength of columns.**

***Keywords*—short columns, finite element, non linear, ultimate load capacity**

## I. Introduction

CFT columns expose the effect of concrete in delaying local buckling of steel tube and the confinement of the concrete core by steel tube. Concrete delays local buckling of the steel tube by changing deformation mode as shown in Figure 1. This paper describes non-linear analysis of short tapered composite box columns subjected to axial loading to understand the behaviour of such columns (as shown in figure. 2). The authors' proposed non-linear finite element model of the columns was verified to be accurate by experiment conducted by Hossain [15] on uniform square composite box column. A parametric study was then conducted to understand the behaviour of the columns by varying taper angle and thickness of steel plate to discover theoretically their effects on column behaviour and ultimate load capacities [1, 6], [9, 19].



(a) Hollow Section (b) CFT Section
**Fig.1.** Deformation modes

## II. Finite Element Modelling and Verification

Finite element software, LUSAS Version 14 was used to carry out the non-linear analyses in the study. The short CFT composite box columns tested in the past by other scientist Anwar Hossain in 2003 are shown in the figure 2. The columns were modelled with real length and cross-section size. A typical finite element mesh adopt for the short composite columns is shown in Figure 3. Incremental displacement load with adopted for the 1 mm was applied in the negative Z direction and the load acts vertically to the column, simulating the load applied to the columns in experiments. Thin shell and solid elements were chosen for the steel tube plates and concrete, respectively [7, 8].

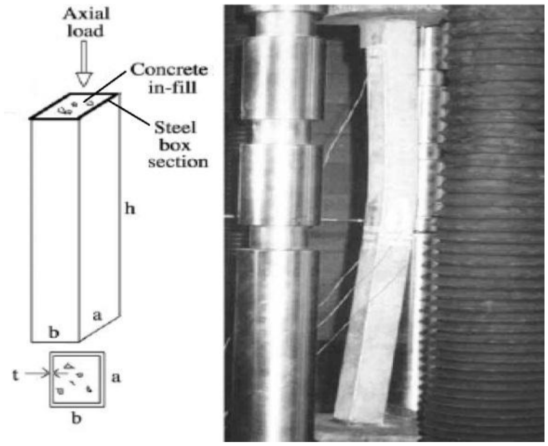



**Fig.2.** Cross-sections of short composite columns which tested by Anwar Hossain

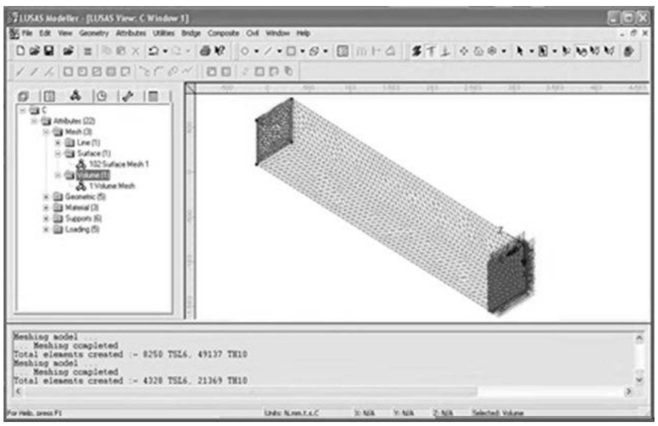
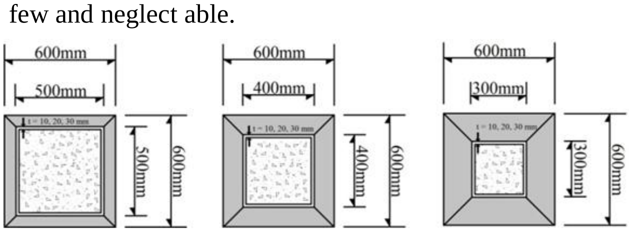


**Fig.3.** Typical finite element mesh used in current study.

## III. Numerical Investigation

Material properties of steel and concrete for composite columns were used in finite element simulation are summarised in Table 1. Column sections studied are shown in Figure 4. All the columns have the same cross-sectional area at the base of 360,000 mm$^2$, while at the top, the area varies from 250,000 mm$^2$ to 90,000 mm$^2$. The plate thickness is changed from 20 mm to 30 mm and the column length is 4 and 6 m. Furthermore, for verification study specimen S2nc which already tested in 2003 was reanalysed again by FE Method are comprised and presented in figure 5. As shown the difference between the results is a little few and neglect able.




a) CFT1 b) CFT2 c) CFT3

**Fig.4.** short tapered composite box columns sections

**Table 1.** Material properties for the composite column

| Properties | Values |
|---|---|
| **Steel** | |
| Modulus of Elasticity, $E_s$ | $209\times10^3$ N/mm$^2$ |
| Poisson's Ratio, $\upsilon$ | 0.3 |
| Yield Stress, $f_y$ | 275 N/mm$^2$ |
| **Concrete** | |
| Modulus of Elasticity, $E_s$ | $33\times10^3$ N/mm$^2$ |
| Poisson's ratio, $\upsilon$ | 0.2 |
| Compressive strength, $f_c$ | 25 N/mm$^2$ |

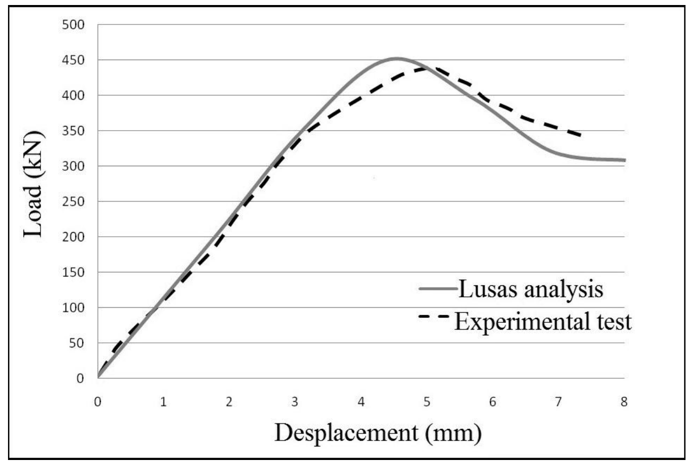



**Fig.5**. Load-deflection response for S2nc

The verification study showed that the finite element model is able to predict the behaviour of composite box columns with sufficient accuracy. Hence, the finite element method was used to investigate the effects of change in taper slope, steel tube thickness and columns length on ultimate load carrying capacity of steel tapered box columns. [7, 8].

Table 2 lists the analyzed ultimate load capacities of the modeled columns subjected to pure axial load. The table categorized the columns into two heights of 4 m and 6 m long with width at the top of the column varying from 300 mm to 500 mm. The column width is fixed to 600 mm at the bottom with steel tube thicknesses of 20 mm to 30 mm.

**Table 2.**Ultimate load of uniform and tapered columns

| Top side<br>Bottom side | 500 mm<br>600mm | 400mm<br>600mm | 300mm<br>600mm | |
|---|---|---|---|---|
| Thickness | | | | Height |
| 20mm | 985 kN | 847 kN | 651kN | 4m |
| 25mm | 1069 kN | 930 kN | 733 kN | 4m |
| 30mm | 1161 kN | 1022 kN | 820 kN | 4m |
| | | | | |
| 20mm | 932 kN | 797 kN | 591kN | 6m |
| 25mm | 1008 kN | 860 kN | 684 kN | 6m |
| 30mm | 1101 kN | 997 kN | 728 kN | 6m |

Figure 6 is plotted deflection against the applied load in the figure for columns of 6 m long with thickness varying from 20 mm to 30 mm. During the initial stages of loading all the curves show a linear relationship between the load and the axial-deflection. As the applied load increases and exceeds the critical buckling load, the columns enter the crushing range in which the resistance to applied load is predominantly governed by nonlinear behaviour. At the ultimate load, the columns failed and lost its ability to carry further loading. The figure shows that increase in thickness results in increase of lateral stiffness, hence it causes growth in load carrying capacity of column and rate of increasing will increase.

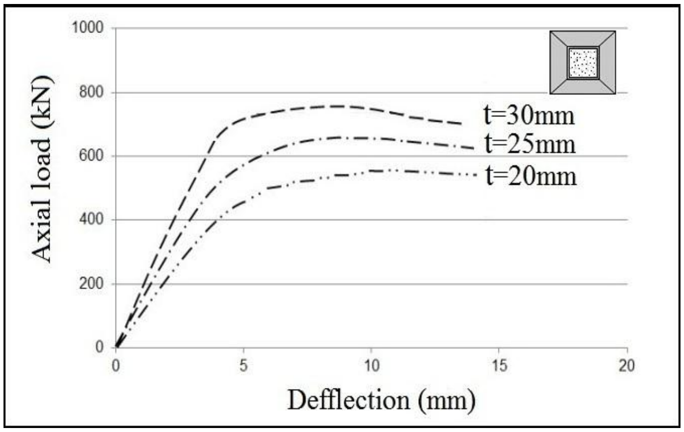



**Fig. 6:** Load- axial deformation plots for tapered composite box columns

Figure 6 and 7 shows the ultimate load carrying capacity of composite columns in relation to thickness of plate tube.

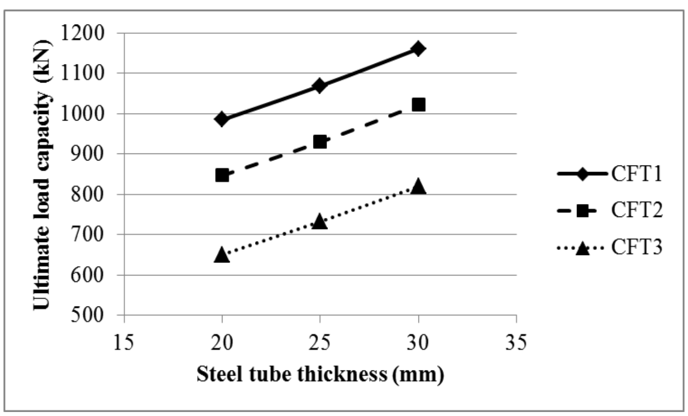



**Fig.7.** Ultimate axial load for taper composite columns with 4 m long.

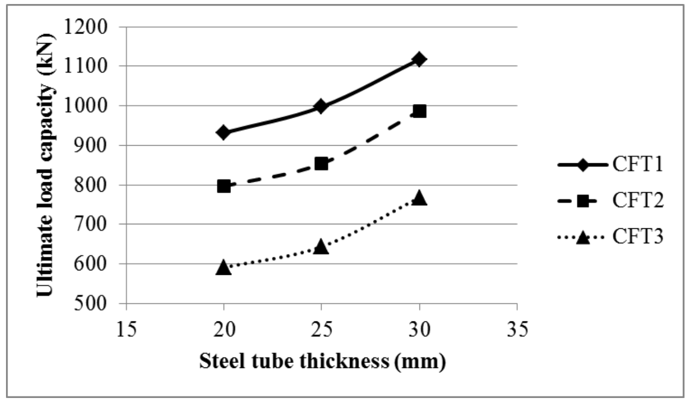



**Fig.8.** Ultimate axial load for taper composite columns with 6 m long.

According to the Figure 6 and 7, by reducing the thickness of steel tube cover, strength of column will be decreased. Hence, there is a direct relationship between the thickness and strength of the column. Moreover, the changes of top side wide of the column are proportional with the changes of column strength.

The bar charts in Figs. 9 to 11 were plotted to compare the ultimate loads of composite box columns with same cross-section in 4 and 6m lengths and various steel tube thickness.

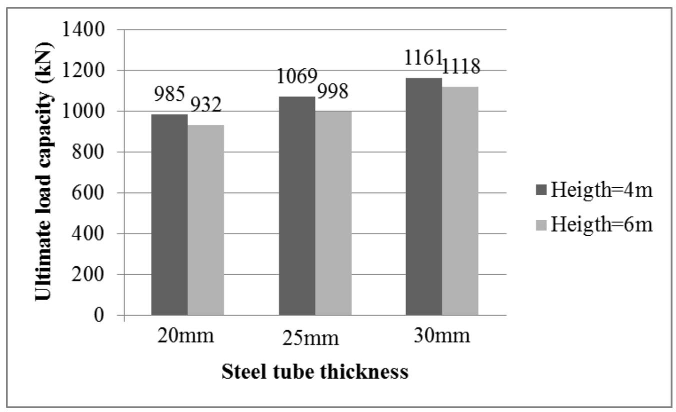



**Fig.9.** CFT1 columns

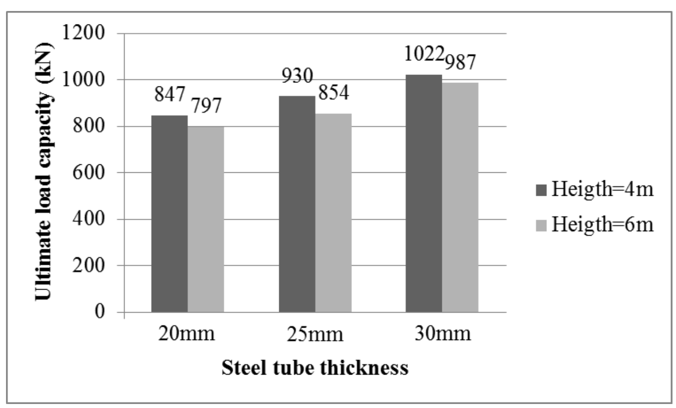



**Fig.10.** CFT2 columns

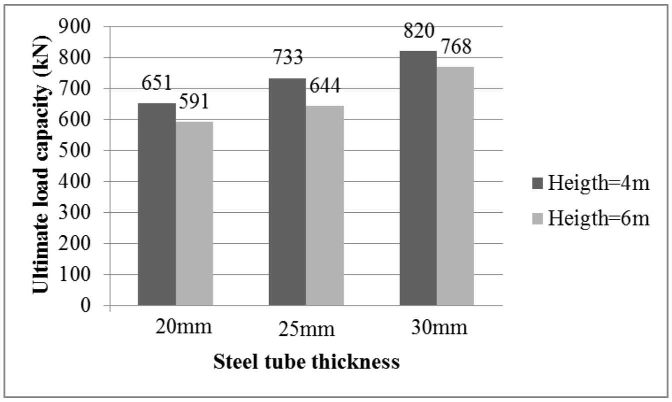



**Fig.11.** CFT3 columns

# IV. Conclusion

Finite element verification analysis of the composite box column behaviour has been carried out by comparing results with an earlier experimental study. The verification exercise concluded that the proposed three dimensional finite elements modelling by the authors employing LUSAS software is sufficiently accurate in predicting the ultimate load capacity and behaviour of the uniform composite box columns. The predicted ultimate load capacity and behaviour of the short tapered composite box columns with various taper angles, steel plate thicknesses and column lengths have been modelled by non-linear finite element analyses. It is concluded that the length, taper angle, the thickness of steel plate play important role in influencing failure modes and the ultimate load capacity of the short tapered composite box columns.

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