Analyzing the Effect of Cross-Sectional Change of Column on Symmetrical R.C.C. Frame Structure

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Abstract— **This paper presents the effect of different cross-section (i.e. rectangle, square & circular) of column on symmetrical R.C.C. frame structure. For this study, G+3, G+7, G+11 storey buildings were developed with different section of column and then it was analyzed by using Staad.pro for gravity loads as well as seismic forces by using the codal provisions given in IS-456:2000 and IS-1893:2002. After optimizing the structure in software, results are recorded in terms of cost of concrete and steel. The results of the analysis show that for G+3 storey building, total cost of building (i.e. total cost of concrete and steel) is minimum for Square cross-section. For G+7 storey building, total cost of building is minimum for square cross-section. For G+11 storey building, total cost of building is minimum for square cross-section.**

Keywords— *Seismic Analysis, Different Cross-section of Column, Short Building, Multi-Storey Stucture, Staad.Pro.*

I. INTRODUCTION

Analysis of a structure is only concerned with the behavior of a building when it is subjected to some forces and its stability. These forces can be in the form of dead load of the building and weight of people, furniture, snow, etc or some other excitation such as an earthquake, shaking of the ground due to a blast, etc.

"Taller the building more will be the forces generated in it."

Therefore, vertical members such as columns should be highly stiff in order to resist these forces. Column, being the vertical member, can carry axial load and bending moment and helps in transferring the load to the foundations. The cross-section, shape and the area of reinforcement depends on the actual load (vertical and horizontal load) acting on a column.

Shape of the column performs crucial role in any structure as we are concerned about only two things, surface-area and the cost of the column. More the cross-sectional area, more will be the surface area, less will be the reinforcement and vice-versa under same loading. More reinforcement implies more cost, but not in every case. Therefore, shape of a column should be chosen wisely and will vary with the type of building and its loading. There is a huge need for finding out which shape of the column suits best under same conditions. While designing, rectangular cross-section of the column is mostly used, as it is supposed to be the optimum shape of the column. But, sometimes, it's not true.

In this paper, study was carried out in Staad.Pro software to find out the optimum shape of the column with respect to the area and percentage of steel provided. Various models were developed and analyzed for vertical and horizontal loading with various load combinations.

Previously, many experiments were done using Staad.Pro for analyzing different types of building, such as analysis and design of high rise building frame, seismic effect on R.C.C. building for floor wise minimization of column cross-section, even comparative study of Ordinary Moment Resisting Frame (OMRF) & Special Moment Resisting Frame (SMRF) structural system for high rise building had been done, but no research work has been carried out with respect to the shape and cross-section of the column.

II. RESEARCH PROGRAM

The orientation for research program mainly focuses on:

- To study and compare the effect of different cross-section of the column (i.e. rectangle, square, circle) after optimizing the structure.
- To study and compare the area and percentage of steel provided in column for different cross-section of the column.
- To calculate and compare the total quantity of Concrete and Steel used in the different structures.
- To calculate and compare the total cost of building (i.e. total cost of concrete and steel)
- To study the results of different structures and different cross-section under same loading for best optimum cross-section.

For above study, following codes has been used:

- BIS:875-1987 (part-1) for Dead Load.
- BIS:875-1987 (part-2) for Live Load.
- BIS:1893-2002, for Seismic Loads.
- BIS:456-2000, for Reinforced Structures.

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Models:

Total 3 models as detailed below were designed using Staad.Pro software:

- G+3 with total height of 13m.
- G+7 with total height of 26m.
- G+11 with total height of 39m.

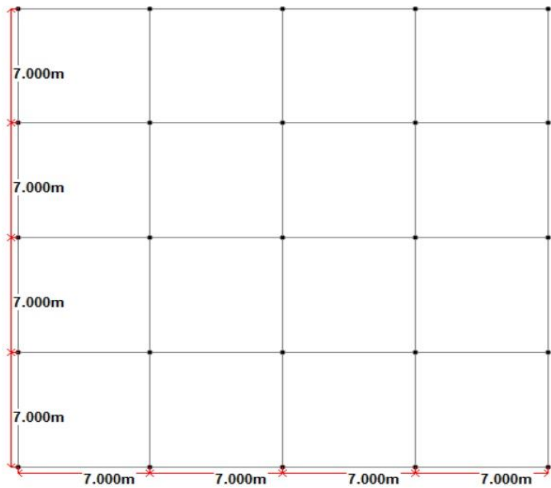The floor height taken is 3.25m each with total no of bays as 4 in both direction and panel size of 7 x 7m.
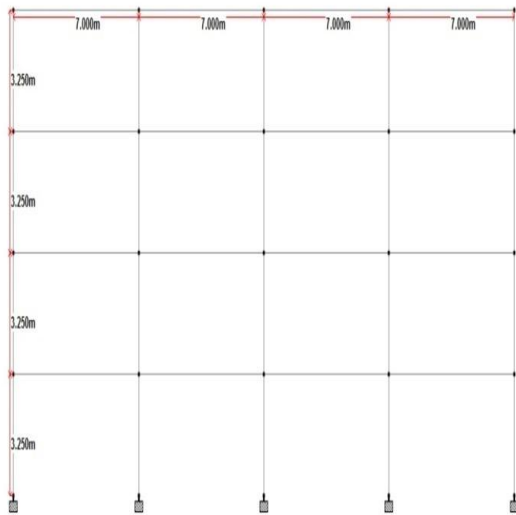

Fig. 1.   Plan of Building

Fig. 2.   Elevation of G+3 Storey Building.
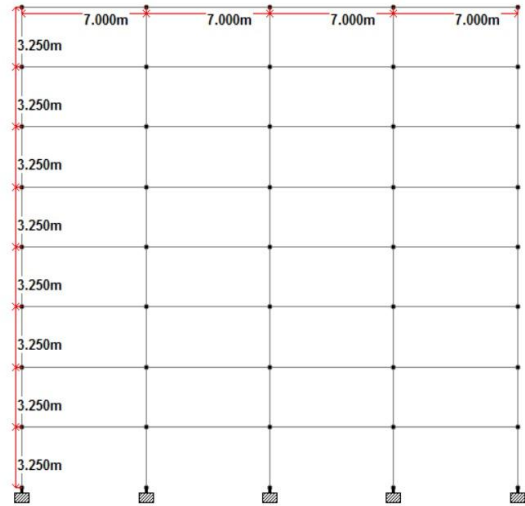
Fig. 3.   Elevation of G+7 Storey Building.
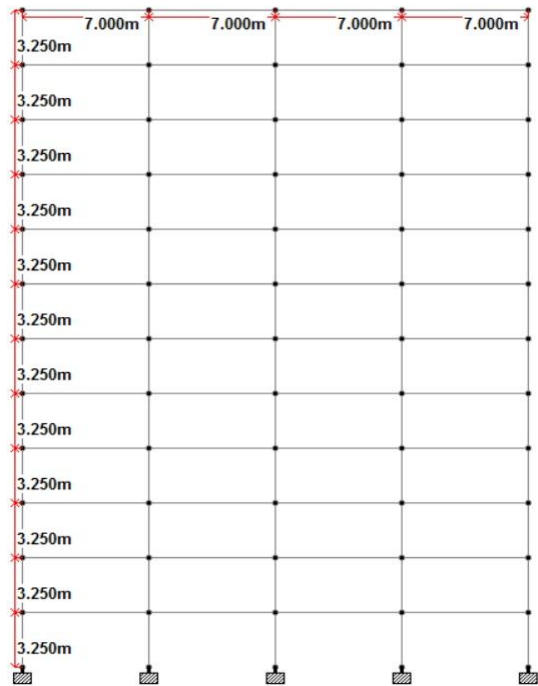
Fig. 4.   Elevation of G+11 Storey Building.

Input Data for modeling Structures:

I. Common data:

a. Design Parameters:

- Concrete used is of grade M-25.
- Steel reinforcement is of grade Fe-500.
- Maximum proportion of steel in column is 4%.

b. Seismic loading parameters:

- Seismic Zone(Z) of building is 4.

- Response reduction factor is 5 for Special Moment Resisting Frame (SMRF).
- Importance factor (I) of building is 1.5.

c. For the purpose of analysing the structure, following variable loads have been taken into consideration:

- Dead Load: (As per actuals from calculations)
  i. load on outer walls: 13.8 kN/m.
  ii. load on inner walls: 6.9 kN/m.
  iii. load on parapet : 4.6 kN/m.
  iv. load on slab: 6 kN/sqm.
- Live Load: (As per codal provisions)
  i. load on all floors : 3 kN/sqm.
  ii. load on Roof: 1.5 kN/sqm.

d. Load Combinations:

As per the codal requirements, different load combinations applied for determining the loads and forces in the purposed structures are given as under:

- DL+LL = for foundation design
- 1.5(DL+LL) = for all beams and columns of top floor
- 1.5DL+1.35LL(10% Reduction)
- 1.5DL+1.2LL(20% Reduction)
- 1.5DL+1.05LL(30% Reduction)
- 1.5DL+0.9 LL(40% Reduction)
- 1.5DL+0.75LL(50% Reduction)
- 1.2DL+0.3LL+1.2EQ (x direction)
- 1.2DL+0.3LL+1.2EQ (-x direction)
- 1.2DL+0.3LL+1.2EQ (z direction)
- 1.2DL+0.3LL+1.2EQ (-z direction)
- 1.5DL+1.5EQ (x direction)
- 1.5DL+1.5EQ (-x direction)
- 1.5DL+1.5EQ (z direction)
- 1.5DL+1.5EQ (-z direction)
- 0.9DL+1.5EQ (x direction)
- 0.9DL+1.5EQ (-x direction)
- 0.9DL+1.5EQ (z direction)
- 0.9DL+1.5EQ (-z direction)

II. VARIABLE DATA:

The prismatic sections assigned for the design procedure have been highlighted in the subsequent paras as:

a. Concrete properties for G+3 building:
- Beams: 450x230mm
- Columns-
  i. Rectangular columns: 600x525mm
  ii. Square columns: 600x600mm
  iii. Circular columns: Dia-675mm

b. Concrete properties for G+7 building:
- Beams: 450x300mm
- Columns-
  i. Rectangular columns: 975x525mm upto 4th floor and 675x525mm beyond 4th floor.
  ii. Square columns: 675x675mm upto 4th floor and 525x525mm beyond 4th floor.
  iii. Circular columns: Dia of 750mm upto 4th floor and 675mm beyond 4th floor.

c. Concrete properties for G+11 building:
- Beams: 450x230mm
- Columns-
  i. Rectangular columns: 975x525mm upto 4th floor, 750x525mm from 5th to 8th floor and 600x525mm beyond 8th floor.
  ii. Square columns: 750x750mm upto 4th floor, 600x600mm from 5th to 8th floor and 450x450mm beyond 8th floor.
  iii. Circular columns: Dia of 825mm upto 4th floor, 675mm from 5th to 8th floor and 600mm beyond 8th floor.

III. RESULT

Total 9 numbers of models (3 models for G+3, 3 models for G+7 and 3 models for G+11) were designed, analyzed and results were obtained from the post-processing window of software Staad.Pro. The comparisons of results so obtained were done with same type of building having different cross-section of the column.
In every building, three locations were taken for comparison i.e. A, B, C as shown in Fig. 5.
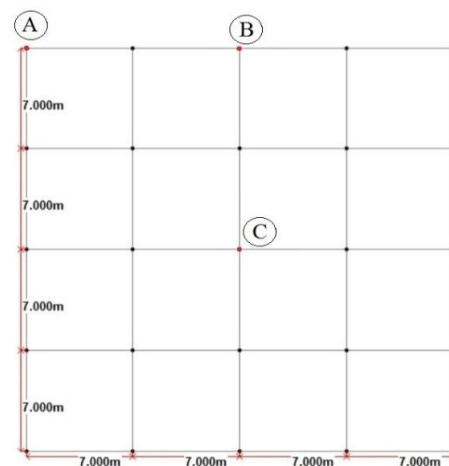

Fig. 5.   Location of the points A, B, C.

3.1. Results obtained for G+3 Building have been represented in the graphical form as under:
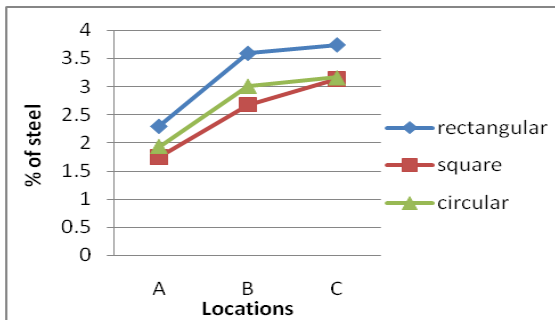

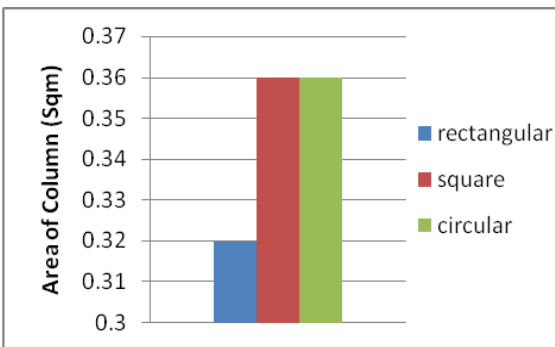Fig. 6.   % of steel for different cross-sections.

Fig. 7.   Area of different column section.

Total quantity of concrete and steel as calculated with the help of Staad.Pro including analysis of cost for each item is presented below:

TABLE I: TOTAL QUANTITY OF CONCRETE AND STEEL USED IN G+3 BUILDING IS SHOWN AS UNDER:

Total Concrete And Steel Takeoff			
	Rectangular column	Square column	Circular column
Concrete (m^3)	218.3	232.9	264
Steel (tonnes)	45.94	44.01	45.06
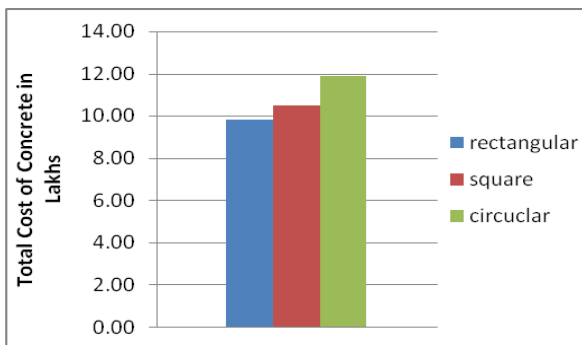
Fig. 8.   Total Cost of Concrete.

Note: Cost of concrete per cumec has been taken as Rs4500/- and cost of steel as Rs40/- per kg for the purpose of comparison.

Total cost of concrete and steel for different cross-section are shown in Fig. 8. and Fig. 9. respectively.
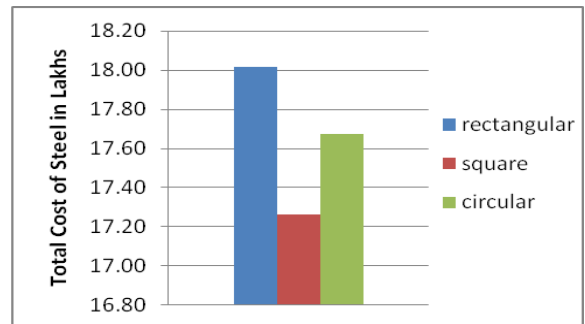
Fig. 9.   Total Cost of Steel

It can be clearly seen from Fig. 10. that the total cost of building is minimum for square section and it can be used economically upto the height of 13m.
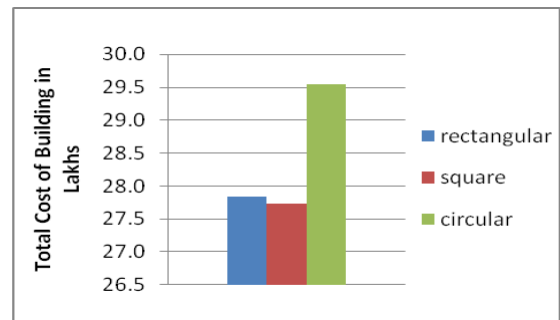

Fig. 10.   Total Cost of G+3 Storey Building.

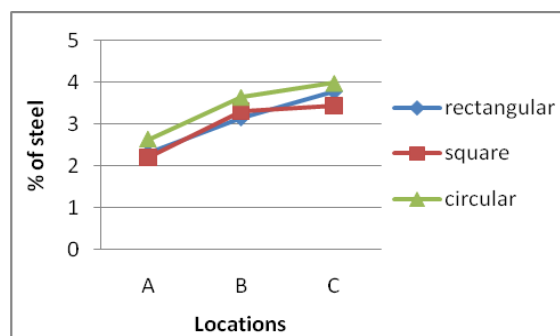3.2. Results obtained for G+7 Building have been represented in the graphical form as under:

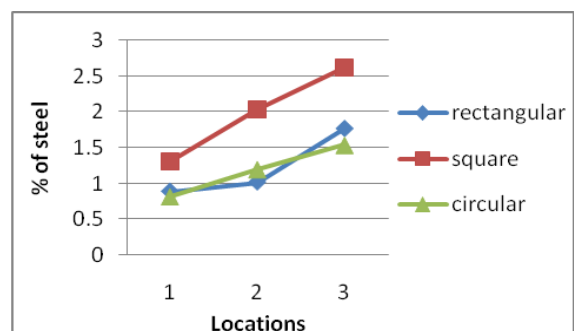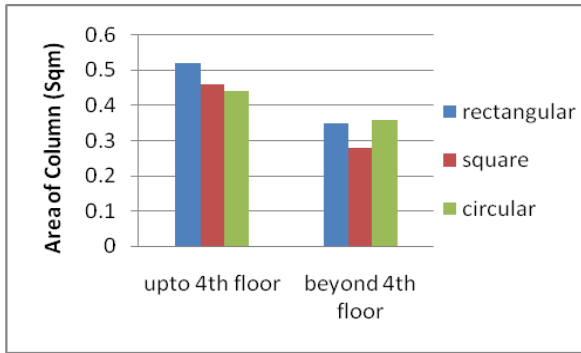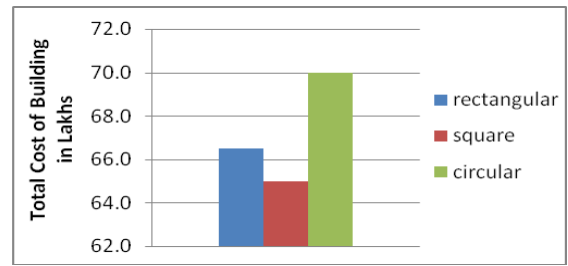Fig. 11.   % of steel at ground floor.

Fig. 12.   % of steel at 5th floor.

Fig. 13.   Area of different column section.

Total quantity of concrete and steel as calculated with the help of Staad.Pro including analysis of cost for each item is presented below:

TABLE II: TOTAL QUANTITY OF CONCRETE AND STEEL USED IN G+7 BUILDING IS SHOWN AS UNDER:

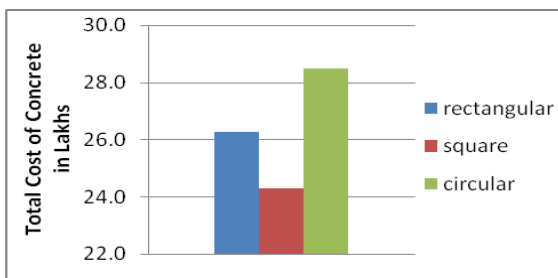| Total Concrete And Steel Takeoff			
	Rectangular column	*Square column*	*Circular column*
Concrete (m³)	584	540.1	633.2
Steel (tonnes)	102.5	103.71	105.79

Fig. 14.   Total Cost of Conctrete.

Note: Cost of concrete per cumec has been taken as Rs4500/- and cost of steel as Rs40/- per kg for the purpose of comparison.

Total cost of concrete and steel for different cross-section are shown in Fig-14 and Fig-15 respectively.
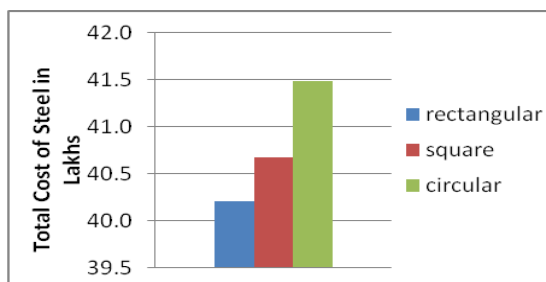

Fig. 15.   Total Cost of Steel.

It can be clearly seen from Fig. 16. that the total cost of building is minimum for square section and it can be used economically upto the height of 26m.

Fig. 16.   Total Cost of G+7 Storey Building.

3.3. Results obtained for G+11 Building have been represented in the graphical form as under:
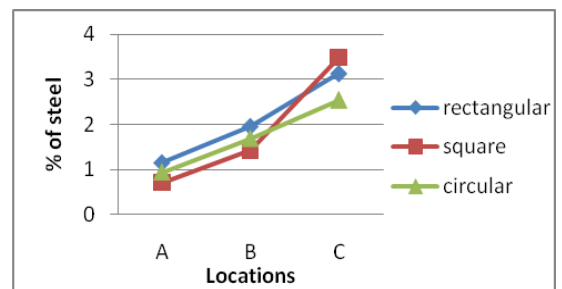

Fig. 17.   % of steel at ground floor.
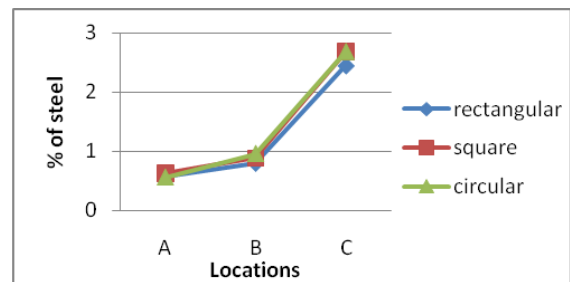

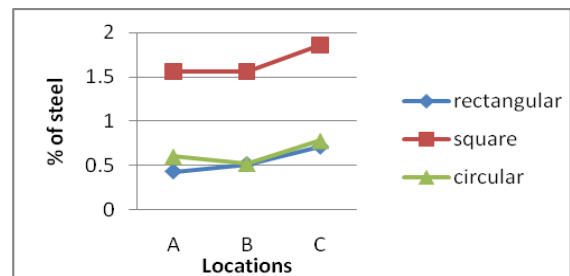
Fig. 18.   % of steel at 5th floor.
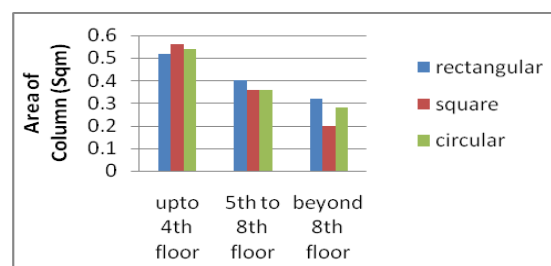

Fig. 19.   % of steel at 11th floor.

Fig. 20.   Area of different column section.

Total quantity of concrete and steel as calculated with the help of Staad.Pro including analysis of cost for each item is presented below:

TABLE III: TOTAL QUANTITY OF CONCRETE AND STEEL USED IN G+11 BUILDING IS SHOWN AS UNDER:

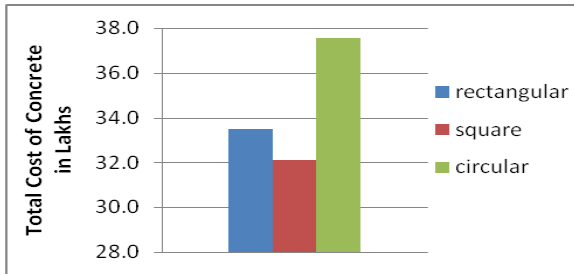| Total Concrete And Steel Takeoff			
	Rectangular column	*Square column*	*Circular column*
Concrete (m³)	744.6	713.5	834.2
Steel (tonnes)	109.9	106.5	108.5

Fig. 21.   Total Cost of Concrete.

Note: Cost of concrete per cumec has been taken as Rs4500/- and cost of steel as Rs40/- per kg for the purpose of comparison.

Total cost of concrete and steel for different cross-section are shown in Fig. 21. and Fig.22. respectively.
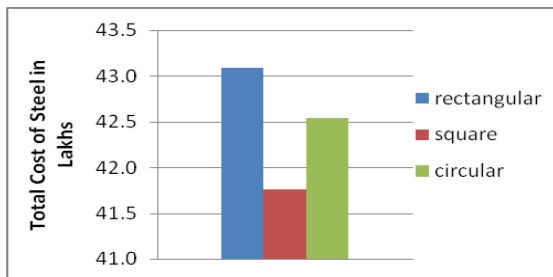

Fig. 22.   Total Cost of Steel.

It can be clearly seen from Fig.23. that the total cost of building is minimum for square section and it can be used economically upto the height of 39m.
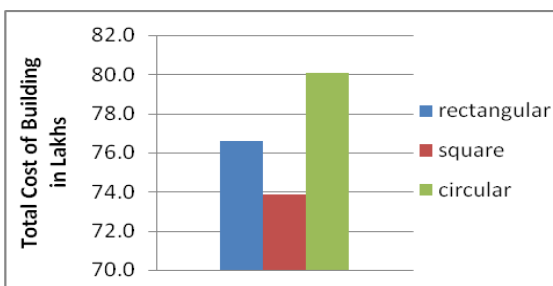

Fig. 23.   Total Cost of G+11 Storey Building.

IV. CONCLUSION

Buildings with total height of 13m, 26m and 39m were analyzed using three different cross-sections of column (i.e. rectangular, square and circular) through Staad.Pro software. Following interferences have been made from the post-processing results with respect to the total cost of building:

    a.   Total cost of the building (i.e. cost of concrete and steel) for G+3, G+7 & G+11 storey buildings is minimum for square cross-section.

It is further observed that:

    a.   The total quantity of concrete is minimum for rectangular section for G+3 storey building but for G+7 & G+11 storey building, square section involves minimum quantity of concrete.

    b.   The total quantity of steel is minimum for square section for G+3 & G+11 storey building but for G+7 storey building, rectangular section involves minimum quantity of steel.

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