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Analyzing the Effect of Change in Cross-Section of Column on Unsymmetrical R.C.C. Frame Structure

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***Abstract*— This paper presents the effect of cross-sectional change of column (i.e. rectangular, square & circular shape) on unsymmetrical R.C.C. frame structure. G+3, G+7, G+11 storey buildings were designed for this study with different cross-section of column and then it was analyzed by using the software Staad.pro for gravity loads as well as seismic forces with the codal provisions provided in IS-456:2000 and IS-1893:2002. The objective of this paper mainly focuses on finding out the optimum cross-section for the column involving minimum cost of the building under same loading conditions and other parameters. After optimizing the structure in software, results were recorded and have been presented in this paper. The results of the analysis show that square is the optimum shape of column for G+3, G+7, G+11 storey buildings as the total cost of the building involving the cost of concrete and steel is minimum as compared to other two cross-sections (i.e. rectangular and circular).**

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

I. INTRODUCTION

While designing any structural building, the only concern of the designer is the stability of the structure and its behavior under internal and external forces. These forces mainly comprise of dead load of the building, superimposed load, snow load, or some other loads due to excitation such as earthquake, wind etc.

More forces will be generated in taller building. Therefore, for resisting higher forces, high strength components of the building are required.

Column, being the vertical member, is the most critical member in a structure as it transfers the whole load from all the other structural members to the foundations. For this purpose, column should be highly stiff. Its shape, cross-section and the area of reinforcement will change with the total load (vertical and horizontal) acting on the building.

Shape of column can vary for any building according to its purpose. After calculating the total load acting on it, its size and area of reinforcement shall be calculated. Different shapes behave differently under same loading conditions and other same structural parameters, therefore, shape of a column should be chosen wisely.

Previously, different researchers performed different research work for analyzing different types of structures using Staad.Pro software. Various research papers include Analysis and Design of 3 storey building subjected to seismic load using Staad.Pro, Analysis of Multi-storey building subjected to gravity and seismic loads with varying Inertia, Comparison of percentage steel and concrete quantities of a R.C.C building in different seismic zones, Seismic Analysis of a R.C.C building by response spectrum method, however, no one had carried out their research work related to the varying cross-section of the column (i.e. rectangular, square and circular) with variable height of the building.

Conventional thinking is being carried with the structural design that circular column is only best for giving architectural appearances, but it's not always true. Therefore, there is a need for finding out which shape of the column can be used economically for different storied buildings under same loading conditions and same parameters.

Therefore, different models (G+3, G+7, G+11) were developed and analyzed in Staad.Pro software for this study. For this paper, unsymmetrical R.C.C frame structure with varying height is chosen and results for its percentage steel, concrete quantities and their costs are recorded and compared with each other.

II. RESEARCH PROGRAM

The orientation for this research program are mainly categoried as:

- To study the effect of cross-sectional change (i.e. rectangle, square, circle) on the column after optimising the buildings and compare the results with each other
- To calculate the percentage steel and area of the column for different cross-section with Staad.Pro at 3 different locations i.e. A, B, C and compare the results.
- To calculate and compare the total quantities of Steel and Concrete from the post-processing results of Staad.Pro.
- To calculate and compare the total cost of the building in terms of Steel and Concrete for all the 3 different cross-sectional buildings.

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- To study the recorded results of all the structures and compare them for obtaining the best optimum cross-section for different storey building.

Following codes are used for this research program:

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

Models:

Total 9 models as described below were developed in Staad.Pro:

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

The height of each floor has been taken as 3.25m with total no of bays as 4 in both direction and the size of panel as 7 x 6m as shown below:

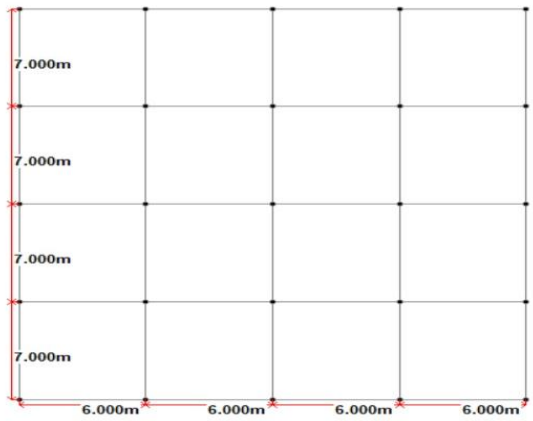

Fig. 1. Plan of the Building.

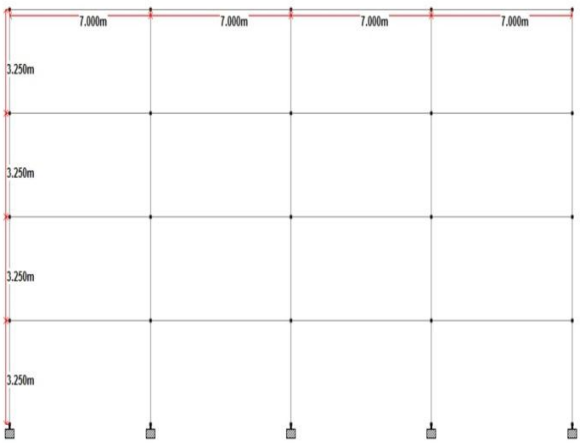

Fig. 2. Elevation of G+3 Storey Building.

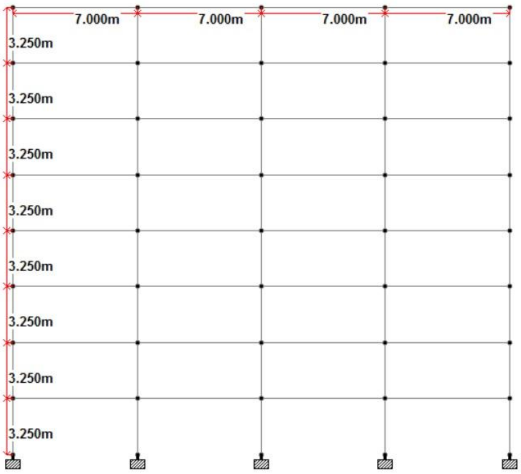

Fig. 3. Elevation of G+7 Storey Building.

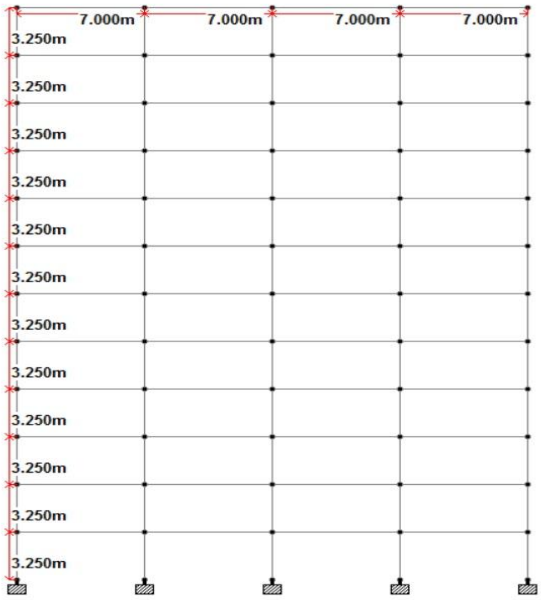

Fig. 4. Elevation of G+11 Storey Building.

Input Data for modeling Structures:

A. Common data**:**

a) Design Parameters:

- Concrete used in the building is of grade M-25.
- Steel Reinforcement is of grade Fe-500.
- Maximum proportion of steel in column is taken as 4%.

b) Seismic Parameters:

- Seismic Zone (Z): 4.
- Response reduction factor (R): 5 for Special Moment Resisting Frame (SMRF).
- Importance factor (I): 1.5 for Important Buildings.

c) Following variable loads have been taken into consideration for the purpose of analyzing the structure:

- Dead Load:(As per actuals froms calculations)
  - i. Dead load on outer walls: 13.8 kN/m.
  - ii. Dead load on inner walls: 6.9 kN/m.
  - iii. Dead load on parapet: 4.6 kN/m.

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iv. Dead load on slab: 6 kN/sqm.

- Live Load:(As per Codal Provisions)
  i. Live load on all floors: 3kN/sqm.
  ii. Live load on Roof: 1.5kN/sqm.

d) Load Combinations:
As per the codal requirements, different economical load combinations were applied in the purposed structures 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)

B. Variable data:
The prismatic sections assigned to the building for the design procedure have been highlighted below:

a) Concrete properties for G+3 building:

- Beams: 450x230mm
- Columns:
  i. Rectangular columns: 600x525mm
  ii. Square columns: 525x525mm
  iii. Circular columns: dia-600m

b) Concrete properties for G+7 building:

- Beams: 450x300mm
- Columns:
  i. Rectangular columns: 825x525mm upto 4th floor and 600x525mm 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 upto 11th floor and 380x230mm beyond 11th floor.
- Columns:
  i. Rectangular columns: 90x525mm upto 4th floor, 750x525mm from 5th to 8th floor and 600x525mm beyond 8th floor.
  ii. Square columns: 675x675mm upto 4th floor, 600x600mm from 5th to 8th floor and 450x450mm beyond 8th floor.
  iii. Circular columns: dia of 750mm 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 developed, analyzed and results were obtained from the post-processing data of the software Staad.Pro. The comparisons of these results 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.

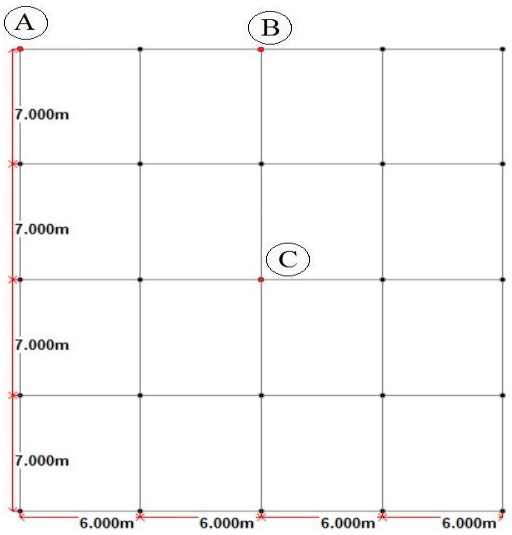

Fig. 5. Location of the points A, B, C.

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

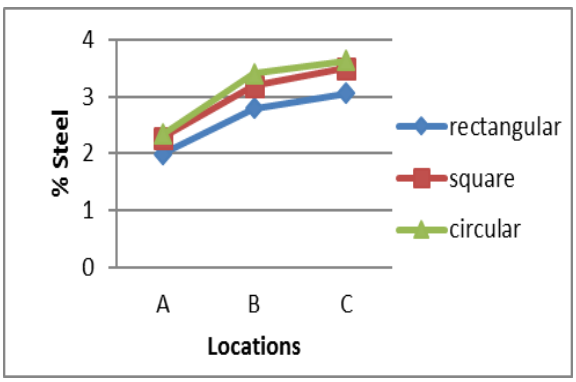

Fig. 6. % of steel for different cross-section.

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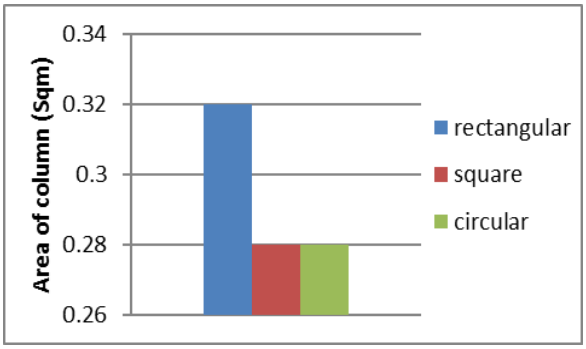

Fig. 7. Area of different column section.

Total quantity of concrete and steel as recorded from the post-processing results of Staad.Pro and analysis of cost for each item is presented below:

TABLE-1: TOTAL QUANTITY OF CONCRETE AND STEEL USED IN G+3 BUILDING.

Total Concrete And Steel Takeoff			
	Rectangular column	Square column	Circular column
Concrete (m^3)	210	197.2	224.6
Steel (tonne)	35.6	36.6	37.3

For the purpose of comparison between the cost of different buildings, cost of concrete and steel is taken as:

- Cost of concrete is Rs4500/- per cumec.
- Cost of steel is Rs40/- per kg.

Cost of concrete and steel have been calculated from the above data and represented in graphical form as under:

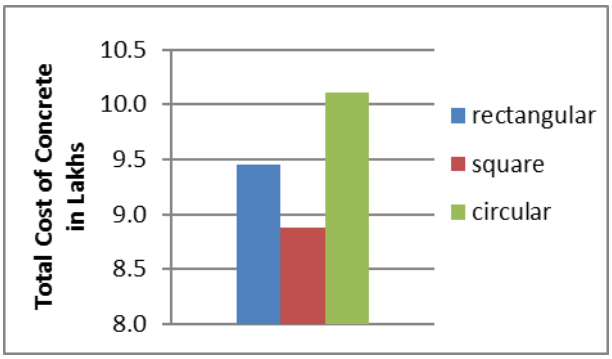

Fig. 8. Total Cost of Concrete

From Fig. 10, it is clearly stated that for the building upto the height of 13m, square is the most economical section for all the three sections as it involves minimum cost of the building.

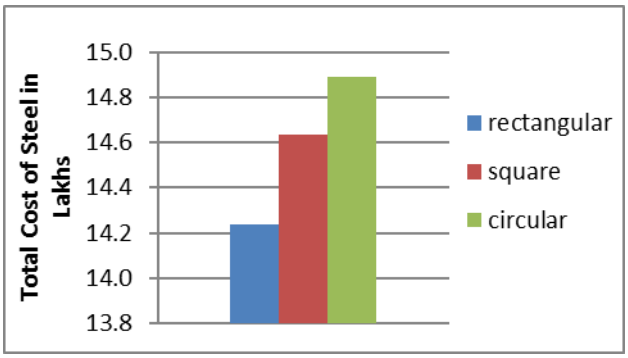

Fig. 9. Total Cost of Steel.

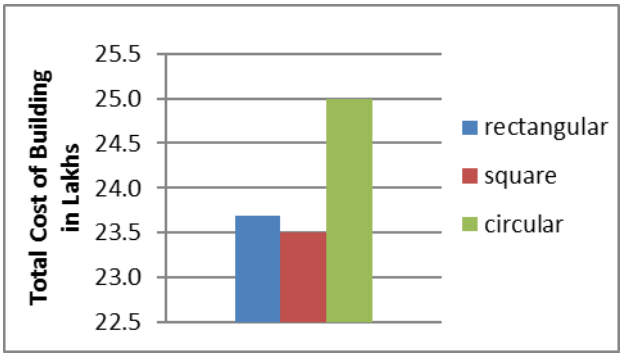

Fig. 10. Total Cost of G+3 Storey Building.

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

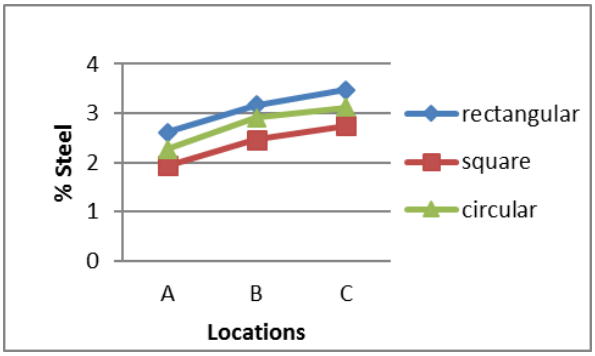

Fig. 11. % of steel at ground floor.

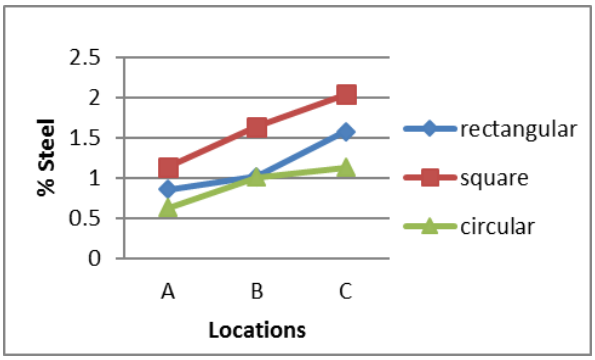

Fig. 12. % of steel at 5th floor.

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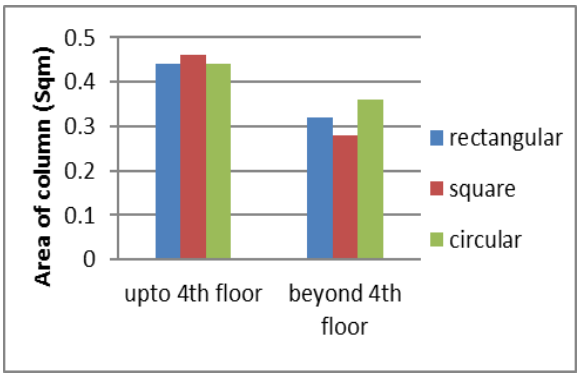

Fig. 13. Area of different column section.

Total quantity of concrete and steel as recorded from the post-processing results of Staad.Pro and analysis of cost for each item is presented below:

TABLE-2: TOTAL QUANTITY OF CONCRETE AND STEEL USED IN G+7 BUILDING.

Total Concrete And Steel Takeoff			
	Rectangular column	*Square column*	*Circular column*
Concrete (m^3)	524	518.5	611.6
Steel (tonne)	85.4	82.3	82.8

For the purpose of comparison between the cost of different buildings, cost of concrete and steel is taken as:

- Cost of concrete is Rs4500/- per cumec.
- Cost of steel is Rs40/- per kg.

Cost of concrete and steel have been calculated from the above data and represented in graphical form as under:

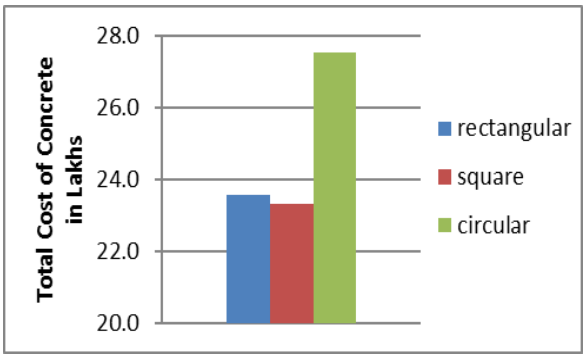

Fig. 14. Total Cost of Concrete.

From Fig. 16, it is clearly stated that for the building upto the height of 26m, square is the most economical section for all the three sections as it involves minimum cost of the building.

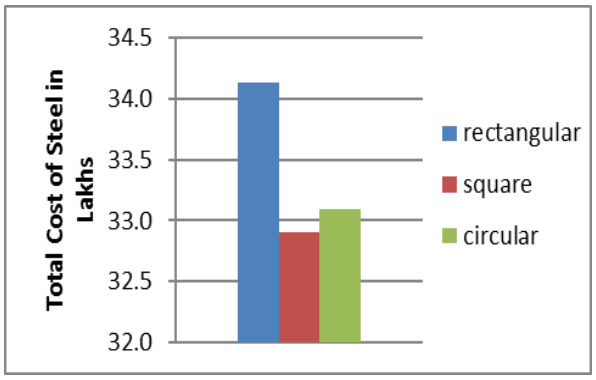

Fig. 15. Total Cost of Steel.

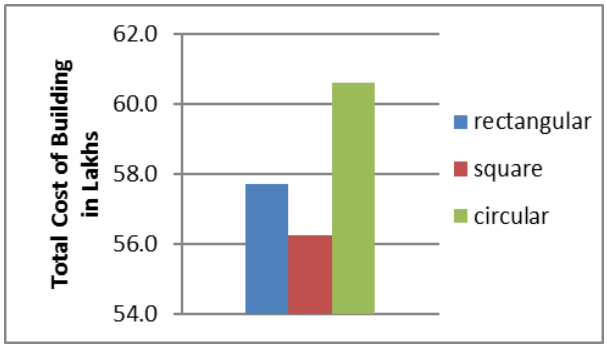

Fig. 16. Total Cost of G+7 Storey building.

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

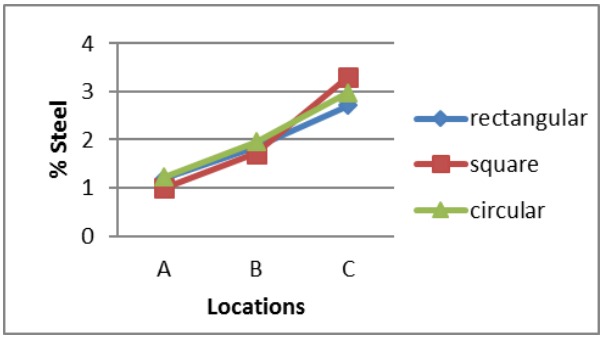

Fig. 17. % of steel at ground floor.

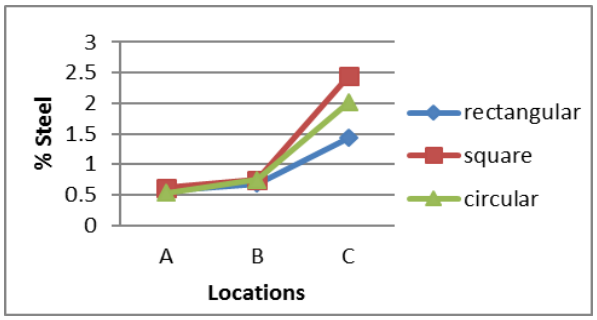

Fig. 18. % of steel at 5th floor.

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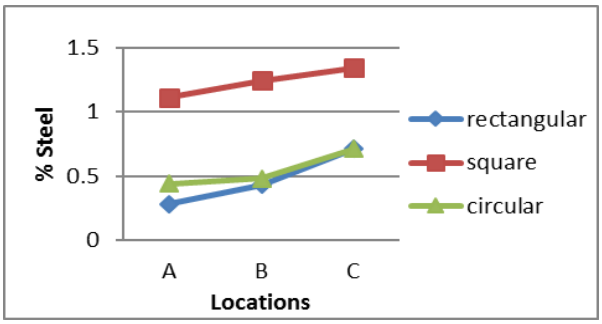

Fig. 19. % of steel at 11th floor.

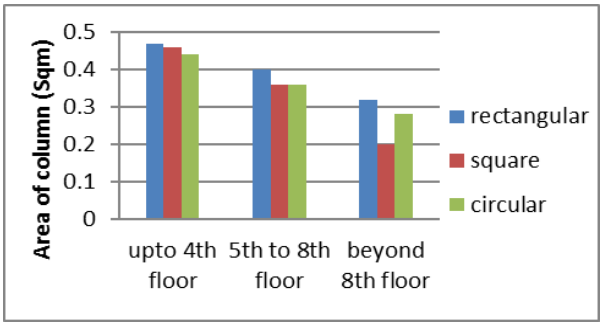

Fig. 20. Area of different column section.

Total quantity of concrete and steel as recorded from the post-processing results of Staad.Pro and analysis of cost for each item is presented below:

TABLE-3: TOTAL QUANTITY OF CONCRETE AND STEEL USED IN G+11 BUILDING.

Total Concrete And Steel Takeoff			
	Rectangular column	Square column	Circular column
Concrete (m^3)	702.7	649.7	766.8
Steel (tonne)	90.7	91.1	91.7

For the purpose of comparison between the cost of different buildings, cost of concrete and steel is taken as:

- Cost of concrete is Rs4500/- per cumec.
- Cost of steel is Rs40/- per kg.

Cost of concrete and steel have been calculated from the above data and represented in graphical form as under:

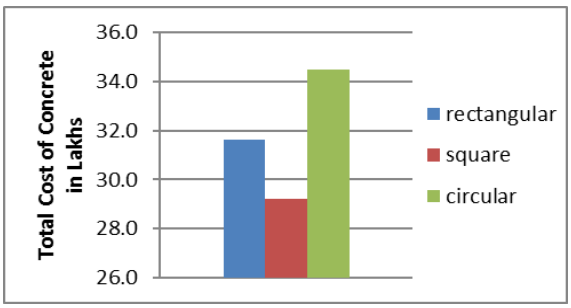

Fig. 21. Total Cost of Concrete.

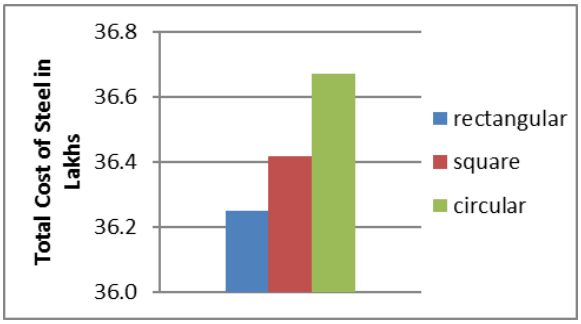

Fig. 22. Total Cost of Steel.

From Fig. 23, it is clearly stated that for the building upto the height of 39m, square is the most economical section for all the three sections as it involves minimum cost of the building.

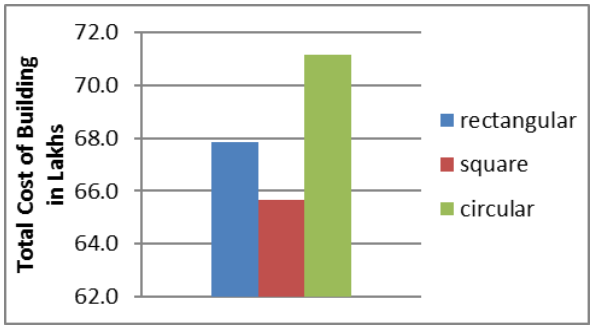

Fig. 23. Total Cost of G+11 Storey Building.

IV. CONCLUSION

During this study, building with variable storeys were analyzed using different cross-sections of column (i.e. rectangular, square and circular) through Staad.Pro. and inferences have been made from the post-processing results including the total cost of concrete and steel. Inferences drawn are as under:

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

It is further observed that:

a) The total quantity of concrete is minimum in case of square cross-section for G+3, G+7 & G+11 storey buildings.
b) The total quantity of steel is minimum for rectangular section for G+3 & G+11 storey building but for G+7 storey building, square section involves minimum quantity of steel.

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