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COST ANALYSIS OF RCC BUILDING SUBJECTED TO DIFFERENT CROSS-SECTION OF COLUMN IN SEISMIC ZONE IV

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Abstract

This paper presents the cost analysis of low-rise building and medium-rise building havingdifferent cross-sectionof column i.e. rectangle, square & circular. In order to perform this study, different models were prepared (G+3, G+7, G+11 storey buildings)and each model was analyzed and designeddesigning software(Staad.pro)for different variable loads by Response spectrum method(dynamic seismic analysis in zone-IVas per IS: 1893-2016). Cross-sectional area, percentage of steel and total quantities of concrete and steel were recorded from staad.pro and then cost analysis was performed by considering the rates of concrete and steel.The results of the analysis show that the total cost of G+3 building (i.e. total cost of concrete and steel) is minimum for the building having rectangle cross-section and found safe and economical, the total cost of G+7 building (i.e. total cost of concrete and steel) is minimum for the building having square cross-section and found safe and economical and the total cost of G+11 building (i.e. total cost of concrete and steel) is minimum for the building having square cross-section and found safe and economical.

Keywords: Seismic Analysis, Cost Analysis, Different Cross-section of Column, Low-Rise Building, Medium-Rise Building,Multi-Storey Structure, Staad.Pro.

1. Introduction

Being a civil engineer, one must know how the buildings are designed as well as constructed and the parameters and components which are to be considered and their behavior. In order to familiarize with these parameters and processes, scrutinized study of various related codes must be done prior to the design. There are mainly three types of structures (material wise) as under:

- RCC Structure
- Steel Structure
- Composite Structure (steel sections encased in Concrete)

All these above-mentioned structures have different purposes and different structural components i.e. slab, beam, column foundation etc, and the loads (normally dead and live load) are to be transferred from these members in same sequence to the soil. The trend of development in India shows that majority of the construction works involves the use of Reinforced Cement Concrete.

Column shouldhave high strength and stability in order toresist forces acting on it. Column, being the vertical member, must carry axial load and bending moment and transmit them to the foundations. The different cross-section, size and reinforcement will have different effects on the behavior of column and resisting action as well. These parameters shall be determined in such a manner that the column will transfer the load to the foundation easily without being damaged.

Cost, being the other important parameter, shall be calculated very carefully, once the designing is done. The cost of concrete and reinforcement contributes 50% to the total cost of any building. But estimating and calculating these costs of building are a scrutinized process. The item rate of concrete and reinforcement may vary with the project type and the location of the project where the building is to be construction. Therefore, different parameters are to be consider which affect the costing of the project.

There is a huge need to know the behaviorof column when the cross-section changes from circular to rectangular to square in low-rise and medium-rise building and to know the most econimical section of the column in a building when analyzed and designed with Response Spectrum Method as per IS: 1893-2016.

In this paper, study was performed in software Staad.Pro software to find out the best suited cross-sectional shape of the column with respect to the area, percentage of steel and cost related to it. Different low-rise and medium-rise buildings were developed and analyzedwith dynamic seismic analysis for seismic zone IV (as per IS: 1893-2016) with different load combinations.

Previously, many experiments were done using Staad.Pro for analyzing different types of building, such as Analyzing The Effect Of Cross-Sectional Change Of Column On Symmetrical R.C.C. Frame Structure, Analyzing The Effect Of Change In Cross-Section Of Column On Unsymmetrical R.C.C. Frame Structure, Earthquake Resistant Design Of Open Ground Storey Framed Building, Seismic Analysis of High Raised Building by Response Spectrum Method had been done, but no research work has been carried outwith respect to the shape and cross-section of the column.

2. Research Program

The orientation for research program mainly focuses on:

- To study the behavior of different cross-sections of column in RCC frame building when designed as per IS: 1893-2016 and its different aspects.
- To perform dynamic seismic analysis (Response spectrum analysis) on RCC frame buildings for seismic zone-4 as per code IS: 1893-2016 in STAAD.Pro
- To calculate the total quantity of concrete and reinforcement of RCC frame building.
- To perform cost analysis on RCC frame building and compare the results between various models.

In order to perform above-mentioned study, following codeshas been used:

- BIS:875-1987 (part-1) for Dead Load
- BIS:875:1987 (part-2) for Live Load
- BIS:1893-2016, for Seismic Loads
- BIS:456-2000, for Reinforced Structures

Models:

Total 9 models as mentioned below were designedusing Staad.Pro:

- G+3 with circular, rectangular and square cross-section of column.
- G+7 with circular, rectangular and square cross-section of column.
- G+11 with circular, rectangular and square cross-section of column.

The height of storeyis taken as 3.25m, with total no of bays as 4 in x-direction and z-direction and the size of one bay (panel size) is6 x 7m.

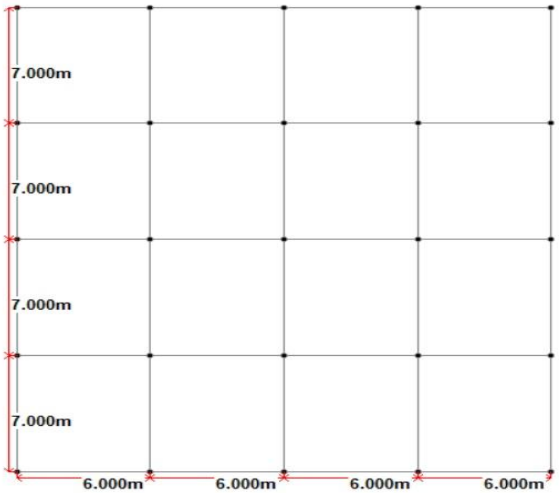

Fig-1: Plan of Building

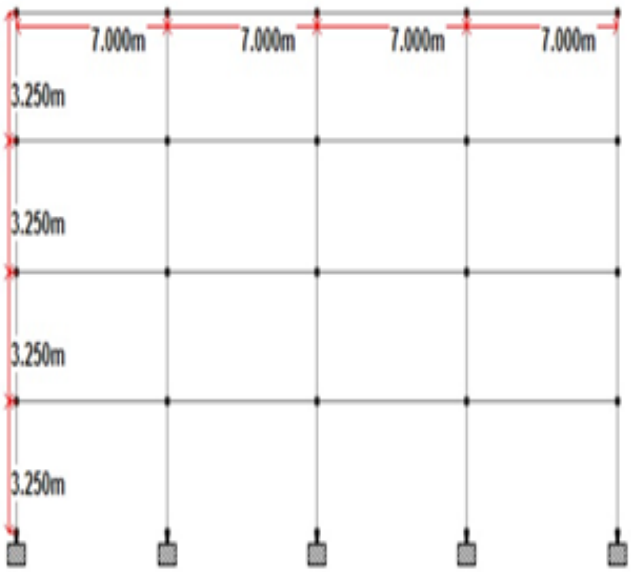

Fig-2: Elevation of G+3 Storey Building.

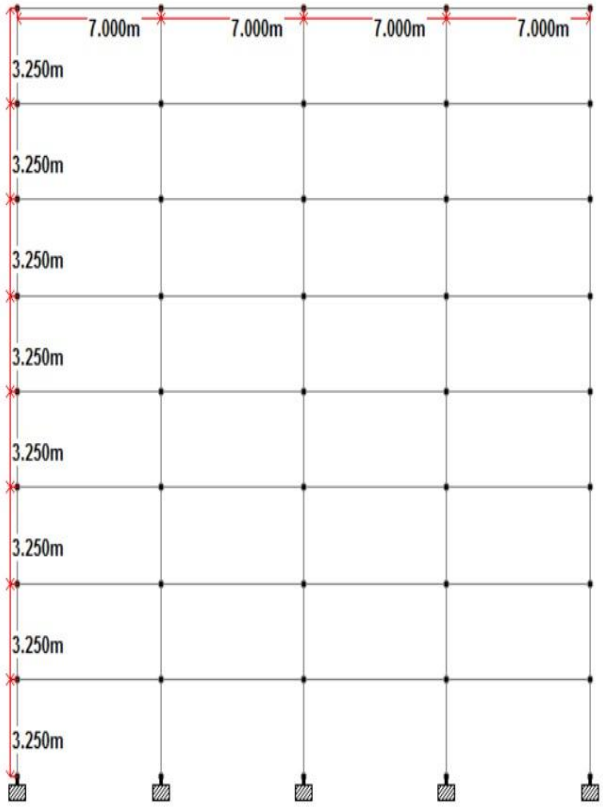

Fig-3: Elevation of G+7 Storey Building.

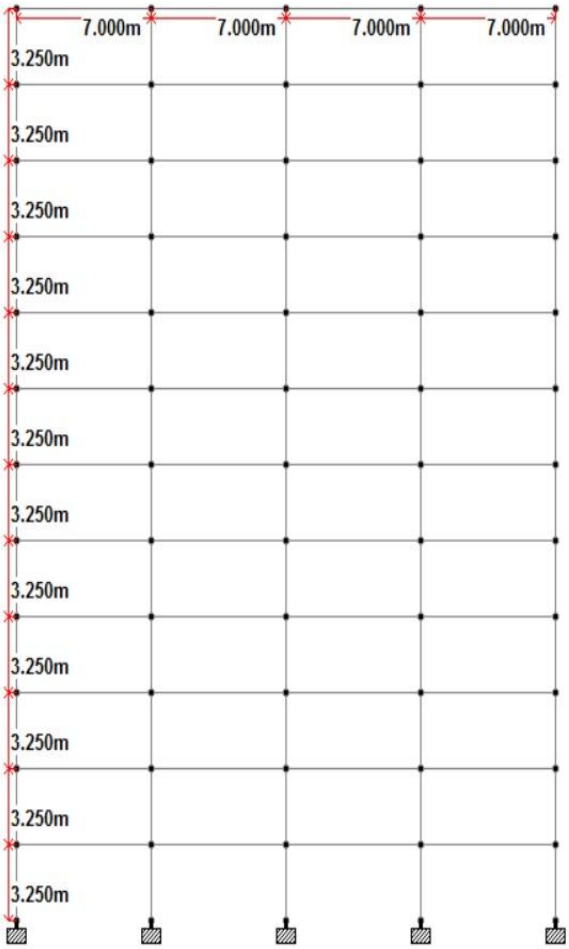

Fig-4: Elevation of G+11 Storey Building.

Input Data for preparingRCC frame structures:

Common data:

a) Grades of Material:

Grade of Concrete is M-25.

Grade of Steel reinforcement is Fe-500.

b)Earthquakeparameters (as per IS: 1893-2016):

Seismic Zone	IV
Response reduction factor	5 (SMRF)
Importance factor	1.2

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

Dead Load :(As per the calculations)

Load on outer walls: 13.8 kN/m

Load on inner walls: 6.9 kN/m

Load on parapet:2.6 kN/m

Load on slab: 6 kN/sqm

Live Load: (As per IS: 875 Part-II)

Load on all floors: 3 kN/sqm

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:

- 1.5(DL+LL)
- 1.2(DL+LL)
- 1.2DL+1.2LL+1.2EQ (x direction)
- 1.2DL+1.2LL+1.2EQ (-x direction)
- 1.2DL+1.2LL+1.2EQ (z direction)
- 1.2DL+1.2LL+1.2EQ (-z direction)
- 1.2DL+1.2LL+1.2EQ (y direction)
- 1.2DL+1.2LL+1.2EQ (-y direction)
- 1.5DL
- 1.5DL+1.5EQ (x direction)
- 1.5DL+1.5EQ (-x direction)
- 1.5DL+1.5EQ (z direction)
- 1.5DL+1.5EQ (-z direction)
- 1.5DL+1.5EQ (y direction)
- 1.5DL+1.5EQ (-y 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)
- 0.9DL+1.5EQ (y direction)
- 0.9DL+1.5EQ (-y direction)

Variable data:

The cross-sectional properties which have been assigned to the structural members of different storey buildings for the design procedure have been mentioned below:

a) Concrete properties for G+3 building:
Beams: 380x300mm

Columns:

Circular	Rectangular	Square
675mm	600x525mm	600x600mm

b) Concrete properties for G+7 building:

Beams:

Upto 4th floor	450x380mm
Beyond 4th floor	380x300mm

Columns:

Circular	**Rectangular**	**Square**
Upto 4th floor		
825mm	750x600mm	675x675mm
Beyond 4th floor		
675mm	600x525mm	525x525mm

c) Concrete properties for G+11 building:

Beams:

Upto 4th floor	450x450mm
5th to 8th floor	450x380mm
Beyond 8th floor	380x300mm

Columns-

Circular	**Rectangular**	**Square**
Upto 4th floor		
900mm	900x675mm	750x750mm
5th to 8th floor		
750mm	750x600mm	600x600mm
Beyond 8th floor		
600mm	600x525mm	525x525mm

3. Results

Total number of models prepared for the study was 9 (3 for G+3, 3 for G+7 and 3 for G+11) and analyzed. Results were obtained from the post-processing of Staad.Pro.The results were represented in tabular manner and comparison was made between similar type of buildings having different cross-section of the column. Cost analysis of all the structures was also done before the comparison.

Threedifferent locations (i.e. A, B, C)of column were considered for obtaining results for each building as shown in Fig-5in order to perform the comparison:

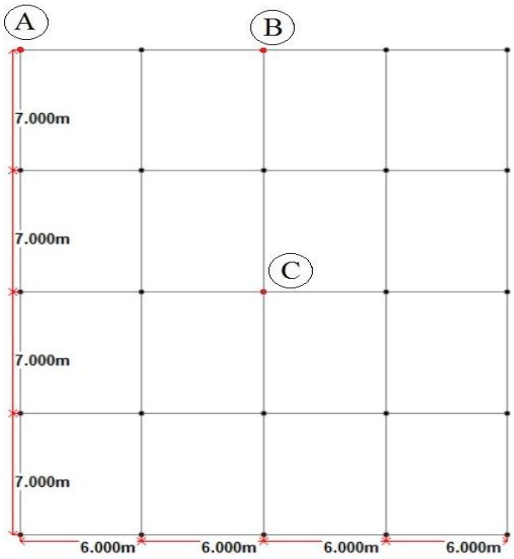

Fig-5: Location of the points A, B, C.

3.1. Results obtained for G+3 Building:

Table: 1 Cross-Sectional Area Of Column.

Shape of Column	Cross-sectional Area
Circular	0.36 m^2
Rectangular	0.32 m^2
Square	0.36 m^2

Table: 2 Perctantage Of Reinforcement Provided.

Shape of Column	% of Steel Provided		
	A	B	C
Ground Floor			
Circular	1.74	1.74	1.84
Rectangular	1.99	1.99	2.29
Square	1.63	1.56	1.63
4^{th} floor			
Circular	0.82	0.94	0.82
Rectangular	0.86	1.14	0.86
Square	0.88	0.88	0.88

Table: 3Total Quantities Of Concrete And Steel.

Building type	Concrete (m^3)	Steel (tonne)
Building Having Circular Column	266.6	38.1
Building Having Rectangular Column	220.9	38.8
Building Having Square Column	235.6	37.9

Table: 1 and Table: 2 represents the cross-sectional area of column and percentage of reinforcement provided in different G+3 buildings.

Table: 4Total Cost Of Concrete And Steel.

Building type	Concrete (lakhs)	Steel (lakhs)
Building Having Circular Column	12	15.24
Building Having Rectangular Column	9.95	15.52
Building Having Square Column	10.6	15.16

Note: Following are the rates of concrete and steel taken for the purpose of cost analysis:

- Cost of concrete per cumec = Rs4500/-
- Cost of steel per kg = Rs40/-

Table: 5 Total Cost Of G+3 Building.

Building type	Total Cost Of G+3 Building in lakhs
Building Having Circular Column	27.24
Building Having Rectangular Column	25.46
Building Having Square Column	25.76

After cost analysis, the results were represented in table: 5 which was performed on different G+3 storey building and it was concluded that the total cost of G+3 building is minimum for the building having rectangle cross-section and found economical.

3.2. Results obtained for G+7 Building:

Table: 6Cross-Sectional Area Of Column.

Shape of Column	Cross-sectional Area
Upto 4^{th} floor	
Circular	0.54 m^2
Rectangular	0.45 m^2
Square	0.46 m^2
from 5^{th} to 8^{th} floor	
Circular	0.36 m^2
Rectangular	0.32 m^2
Square	0.28 m^2

Table: 7 Perctantage Of Reinforcement Provided.

Shape of Column	% of Steel Provided		
	A	B	C
Ground floor			
Circular	1.42	1.50	1.91
Rectangular	1.6	1.95	2.51
Square	1.58	1.72	2.47
5^{th} floor			
Circular	0.91	0.95	0.94
Rectangular	1.14	1.14	1.24
Square	1.36	1.45	1.75
8^{th} floor			
Circular	0.82	1.01	0.82
Rectangular	1	1.19	0.86
Square	1.14	1.45	0.82

Table: 6 and Table: 7 represents the cross-sectional area of column and percentage of reinforcement provided in different G+7 buildings.

Table: 8 Total Quantities Of Concrete And Steel.

Building type	Concrete (m^3)	Steel (tonne)
Building Having Circular Column	665.7	96.6
Building Having Rectangular Column	545	96.5
Building Having Square Column	534.1	96.6

Table: 9 Total Cost Of Concrete And Steel.

Building type	Concrete (lakhs)	Steel (lakhs)
Building Having Circular Column	30	38.64
Building Having Rectangular Column	24.5	38.6
Building Having Square Column	24	38.64

Note: Following are the rates of concrete and steel taken for the purpose of cost analysis:

- Cost of concrete per cumec = Rs4500/-
- Cost of steel per kg = Rs40/-

Table: 10 Total Cost Of G+7 Building.

Building type	Total Cost Of G+7 Building in lakhs
Building Having Circular Column	68.64
Building Having Rectangular Column	63.1
Building Having Square Column	62.64

After cost analysis, the results were represented in table: 10 which was performed on different G+7 storey building and it was concluded that the total cost of G+7 building is minimum for the building having square cross-section and found economical.

3.3. Results obtained for G+11 building:

Table: 11 Cross-Sectional Area Of Column.

Shape of Column	Cross-sectional Area
Upto 4^{th} floor	
Circular	0.64 m^2
Rectangular	0.60 m^2
Square	0.56 m^2
from 5^{th} to 8^{th} floor	
Circular	0.44 m^2
Rectangular	0.45 m^2
Square	0.36 m^2
Beyond 8^{th} floor	
Circular	0.28 m^2
Rectangular	0.32 m^2
Square	0.28 m^2

Table: 12 Perctantage Of Reinforcement Provided.

Shape of Column	% of Steel Provided		
	A	B	C
Ground floor			
Circular	1.26	1.54	2.16
Rectangular	1.19	1.61	2.26
Square	1.39	1.85	2.68
5^{th} floor			
Circular	0.81	0.81	1.54
Rectangular	0.80	0.80	1.39
Square	0.88	1.25	2.68
9^{th} floor			
Circular	1.24	1.42	1.49
Rectangular	1	1	1
Square	1.16	1.36	1.42
12^{th} floor			
Circular	1.08	1.42	0.84
Rectangular	1	1.14	0.86
Square	1.14	1.42	0.82

Table: 11 and Table: 12 represents the cross-sectional area of column and percentage of reinforcement provided in different G+11 buildings.

Table: 13 Total Quantities Of Concrete And Steel.

Building type	Concrete (m^3)	Steel (tonne)
Building Having Circular Column	1070.1	157.5
Building Having Rectangular Column	951.1	156.6
Building Having Square Column	896.4	158

Table: 14 Total Cost Of Concrete And Steel.

Building type	Concrete (lakhs)	Steel (lakhs)
Building Having Circular Column	48.15	63.0
Building Having Rectangular Column	42.8	62.64
Building Having Square Column	40.4	63.2

Note: Following are the rates of concrete and steel taken for the purpose of cost analysis:

- Cost of concrete per cumec = Rs4500/-
- Cost of steel per kg = Rs40/-

Table: 15 Total Cost Of G+11 Building.

Building type	Total Cost Of G+11 Building in lakhs
Building Having Circular Column	111.15
Building Having Rectangular Column	105.44
Building Having Square Column	103.6

After cost analysis, the results were represented in table: 15 which was performed on different G+11 storey building and it was concluded that the total cost of G+11 building is minimum for the building having squarecross-section and found economical.

4. Conclusion

Different buildingshaving different cross-sections of column (i.e. rectangular, square and circular)were analyzed in Staad.Pro software. Following conclusionshave been made from the post-processing results in terms of Cost (i.e. total cost of concrete and steel) of building:

- The total cost of G+3 building (i.e. total cost of concrete and steel) is minimum for the building having rectangle cross-section and found safe and economical.
- The total cost of G+7 building (i.e. total cost of concrete and steel) is minimum for the building having square cross-section and found safe and economical.
- The total cost of G+11 building (i.e. total cost of concrete and steel) is minimum for the building having square cross-section and found safe and economical.

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