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Cost Comparison of RCC Framed and Steel Framed Structure for a Five Storied Building

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Abstract: ***Analysis the frame structure is performed by STAAD modeling. The effect of gravity loads and lateral loads are considered in the analysis. The structure is six-storied (Ground floor + Five floors) building with 3.0m as the height of each floor. The overall plan dimension of the building is 17.0 m x 8.0m. The structure is modeled in STAADPRO V8i (series 4). The analysis is carried out on RCC structure and STEEL structure as a three dimensional structure and the members of the steel structure are designed as rolled I-Sections. The reactions at supports are compared and also cost comparison for both Reinforced Cement Concrete structure and Steel Structures.***

Keywords: RCC structure, STEEL structure, *STAAD modeling*

1. Introduction

A building is a man-made structure with a roof and walls standing more or less permanently in one place. Buildings serve several needs of society – primarily as shelter from weather, security, living space, privacy, to store belongings, and to comfortably live and work. A building as a shelter represents a physical division of the human habitat (a place of comfort and safety). Ever since the first cave paintings, buildings have also become objects or canvases of artistic expression. In recent years, interest in sustainable planning and building practices has also become an intentional part of the design process of many new buildings. A slab is a flat two dimensional planar structural element having thickness small compared to its other two dimensions. It provides a working flat surface or a covering shelter in buildings. It primarily transfers the load by bending in one or two directions. Reinforced concrete slabs are used in floors, roofs and as the decks of bridges. The floor system of a structure can take many forms such as in situ solid slab or pre-cast units. Slabs may be supported on monolithic concrete beam, steel beams, walls or directly over the columns. Concrete slab behave primarily as flexural members and the design is similar to that of beams.

The tallness of a building is relative and cannot be defined in absolute terms either in relation to height or the number of stories. But, from a structural engineer's point of view the tall building or multi-storied building can be defined as one that, by virtue of its height, is affected by lateral forces due to wind or earthquake or both to an extent that they play an important role in the structural design. Tall structures have fascinated mankind from the beginning of civilization. The Egyptian Pyramids, one among the seven wonders of world, constructed in 2600 B.C. are among such ancient tall structures. Such structures were constructed for defiance and to show pride of the population in their civilization. The growth in modern multi-storied building construction, which began in late nineteenth century, is intended largely for commercial and residential purposes.

The construction of multi-storied buildings is dependent on available materials, the level of construction technology.

1.1 Behaviour of Structure under Lateral Loads

Recently there has been a considerable increase in the number of tall buildings both residential and commercial and the modern trend is towards taller and slenderer structures. Thus the effects of lateral loads like wind loads, earthquake forces are assigning importance and almost every designer is faced with the problem of providing adequate strength and stability against lateral loads. This is a new development, as the earlier building designers usually designed for the vertical loads, and as an afterthought, checked the final design for lateral loads as well. Generally, those buildings had sufficient strength against lateral loads due to numerous partitions and short span beams and cross beams and no modification in the design was needed.

Now, the situation is quite different and a clear understanding of the effects of lateral loads on a building and the behaviour of various components under these loads is essential. Shear walls are specially designed structural walls incorporated in the plane of the wall due to wind, earthquake and other forces. The term ‘shear wall’ is rather misleading as such walls behave more like flexural members. They are usually provided in tall buildings and have been found immense use to avoid total collapse of buildings under seismic forces. It is always advisable to incorporate them in buildings built in regions likely to experience earthquake of large intensity or high winds. Shear walls for wind are designed as simple concrete walls. The design of these walls for seismic forces requires special considerations as they should be safe under repeated loads. Shear walls are generally made of concrete or masonry. They are usually provided between columns, in stairwells, lift wells, toilets, utility shafts, etc. tall buildings with flat slabs should invariably have shear walls. Such systems are compared to slabs with beams have very little resistance even to moderate lateral loads. Initially shear walls were used in reinforced concrete buildings to resist wind forces. These came into general practice only as late as 1940. With the introduction of shear walls, concrete construction can be used for tall buildings also. However, the most important property of shear walls for seismic design, as different from design for wind is that it should have good ductility under reversible and repeated overloads. In planning shear walls, we should try to reduce the bending tensile stresses due to lateral loads as much as possible by loading them with as much gravity forces as it can safely take. They should be also laid symmetrically to avoid tensional stresses.

In this study a 3-D model in STAAD PRO has been developed to analyze the behavior of reinforced concrete tall building & steel structure building under wind and earthquake loads. This will explain briefly also the effect of wind or earthquake loads on the structures for the comparative study between wind and earthquake effects on RCC framed building & steel framed building. Importance factor of building and their effects on the performance of tall buildings were discussed. Our purpose is to analyze & design both the structure & study the effect on foundation & as well as the effect on costing of material for construction purpose. The model has been designed for G+five storied building.

2. Literature Review

2.1 Consideration of Seismic Design of Multistoried Steel Structure using STAAD-Pro [1]

In this Study, the steel structure is the moment resisting frame with deck system for floors as well as brick work for wall. Study showed that the design of column using different types of Indian steel section such that I-section, double I-section, face to face channels section with IS 800:1984. Using above sections, the seismic design of (G+1), (G+3) & (G+6) steel frame was carried out by STAAD-Pro. Also the present work considered all important design parameter in STAAD-Pro.

2.2 Behavior of multistoried building under the effect of wind load [2]

Wind is a phenomenon of great complexity because of' the many flow situations arising from theinteraction of wind with structures. Wind loads as specified IS: 875 (Part 3) - 1987 are considered in theanalysis. In this project analysis of G + 11 building carried out by using STAAD PRO. Analysis is done forvarious variations such as 1) Terrain with few or no obstructions having heights below 1 .5 m. 2) Terrainwith obstructions having heights between 1.5 to 10m. 3) Terrain with numerous closely spaced obstructions having the size of' building structures up to 10 m in height. 4) Terrain with numerous large high closely spaced obstructions. According to Internal Pressure Coefficients (C_{pi}) provided for that various variations. This analysis is (lone for wind speed 44 m/s, 47 m/s, 50 m/s. Results obtained from STAAD-PRO analysis are used for obtaining significant relations of' moments, forces and displacement with wind speeds. Moments, forces and displacement obtained from all cases are compared with wind speeds, according to their percentage of' opening provided for various variations.

3. Analysis of Structure

It includes plan, different types of load and load combination, how to proceed in Staad pro etc.

3.1 Plan of the Structure

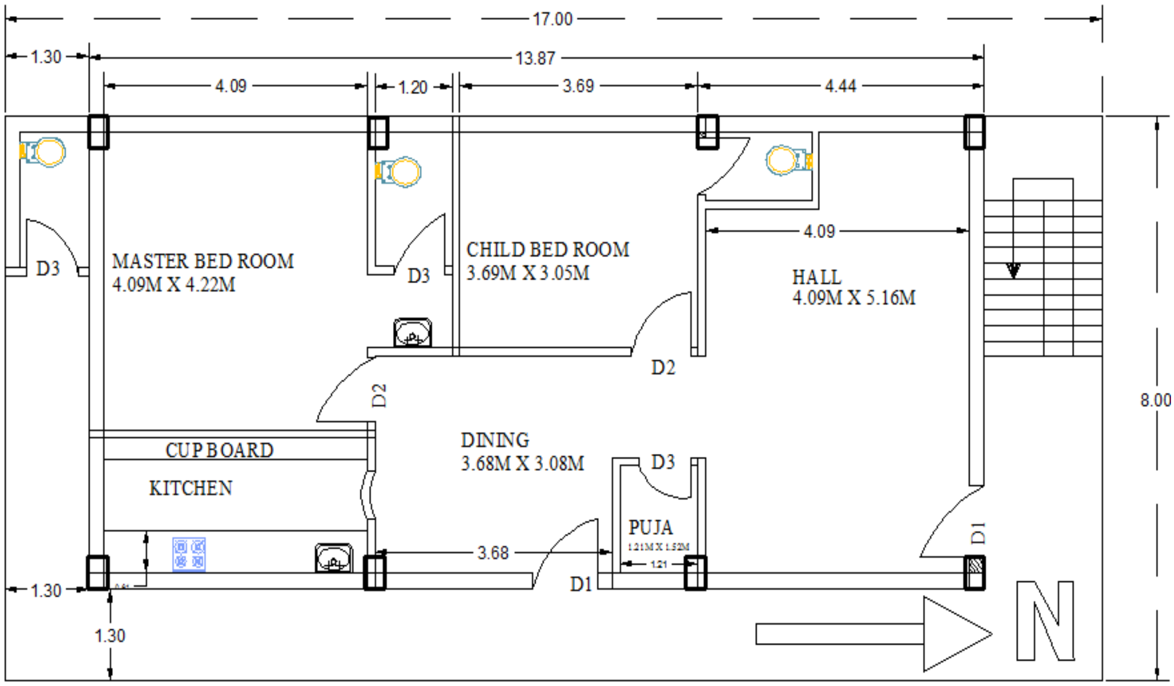

Figure 1: Plan

3.2 Loads of structure

The loadings were calculated partially manually and rest was generated using STAAD PRO load generator. The loading cases were categorized as:

- Self-weight
- Dead load from slab
- Live load
- Wind load
- Seismic load
- Load combinations

3.2.1 Self-Weight

The self-weight of the structure can be generated by STAAD PRO itself with the self-weight command in the load case column.

3.2.2 Dead Load

All permanent constructions of the structure form the dead loads. The dead load comprises of the weights of walls. Partitions floor finishes, false ceilings, false floors and the other permanent constructions in the buildings. The dead load loads may be calculated from the dimensions of various members and their unit weights. The unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24kN/m^3 and 25kN/m^3 respectively.

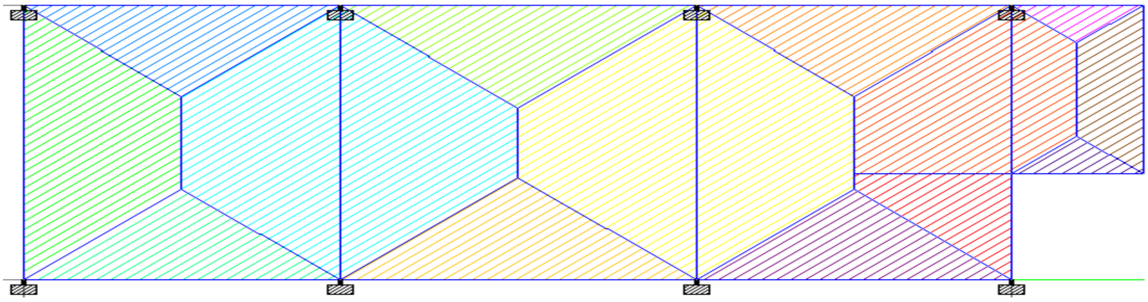

Figure 2: Load distribution by trapezoidal method

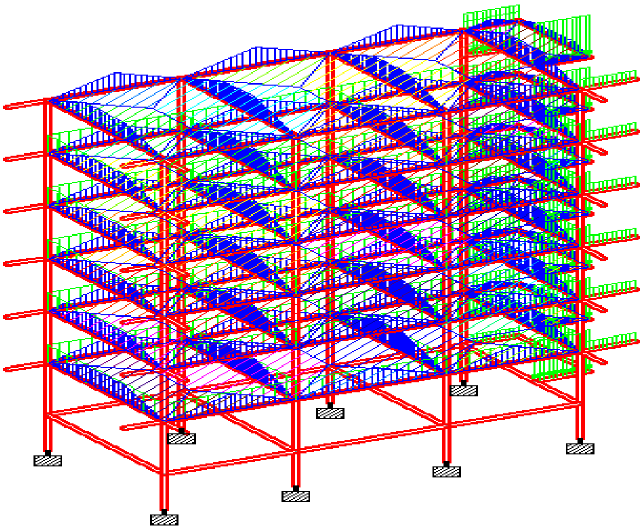

Figure 3: Structure under dead load from slab

3.2.3 Imposed Loads

Imposed load is produced by the intended use or occupancy of a building including the weight of movable partitions, distributed and concentrated loads, load due to impact and vibration and dust loads. Imposed loads do not include loads due to wind, seismic activity, snow loads and loads imposed due to temperature changes to which the structure will be subjected to creep and shrinkage of the structure.

Live load: The live load considered in each floor was 2.0 kN/sq m and for the terrace level it was considered to be 1.5 kN/sq m. The live loads were generated in a similar manner as done in the earlier case for dead load in each floor. This may be done from the member load button from the load case column.

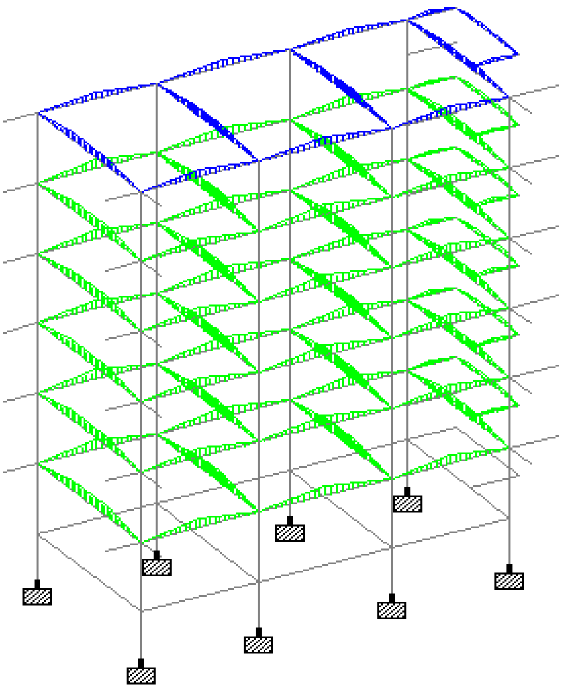

Figure 4: The structure under live load

3.2.4 Wind Load

Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards.

Design Wind Speed (V_z)**:** The basic wind speed (V_b) for any site shall be obtained from and shall be modified to include the following effects to get design wind velocity at any height (h) for the chosen structure:
a) Risk level
b) Terrain roughness, height and size of structure and
c) Local topography

It can be mathematically expressed as follows:

Where,
$V_z= V_b * k_1 * k_2 * k_3$
V_z = design wind speed at any height z in m/s
k_1 = probability factor (risk coefficient)
k_2 = terrain, height and structure size factor and
k_3= topography factor

Wind pressures and forces on buildings/structures:
The wind load on a building shall be calculated for:
a) The building as a whole
b) Individual structural elements as roofs and walls and
c) Individual cladding units including glazing and their fixings.

Pressure Coefficients - The pressure coefficients are always given for a particular surface or part of the surface of a building. The wind load acting normal to a surface is obtained by multiplying the area of that surface or its appropriate portion by the pressure coefficient and the design wind pressure at the height of the surface from the ground. The average values of these pressure coefficients for some building shapes Average values of pressure coefficients are given for critical wind directions in one or more quadrants. In order to determine the maximum wind load on the building, the total load should be calculated for each of the critical directions shown from all quadrants. Where considerable variation of pressure occurs over a surface, it has been subdivided and mean pressure coefficients given for each of its several parts. Then the wind load, F, acting in a direction normal to the individual structural element or Cladding unit is:
$F= (C_{pe} – C_{pi}) A P_d$
Where,
C_{pe}= external pressure coefficient,
C_{pi}= internal pressure- coefficient,
A = surface area of structural or cladding unit, and
P_d = design wind pressure element

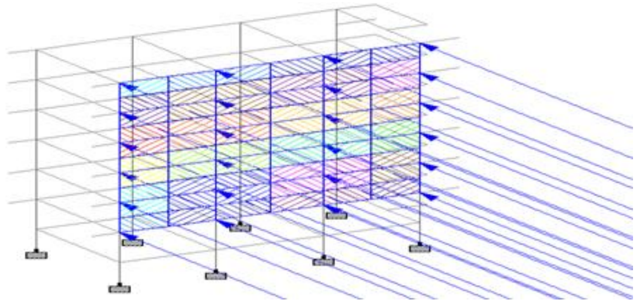

Figure 5: Wind load effect on structure elevation and plan

3.2.5 Seismic Load

Design Lateral Force
The design lateral force shall first be computed for the building as a whole. This design lateral force shall then be distributed to the various floor levels. The overall design seismic force thus obtained at each floor level shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action.

Design Seismic Base Shear
The total design lateral force or design seismic base shear (V_b) along any principal direction shall be determined by the following expression:
$V_b = A_h W$
Where,
A_h = horizontal acceleration spectrum
W = seismic weight of all the floors

Fundamental Natural Period
The approximate fundamental natural period of vibration (T_a), in seconds, of a moment-resisting frame building without brick in the panels may be estimated by the empirical expression:
Ta=0.075 h0.75 for RC frame building
Ta=0.085 h0.75 for steel frame building

This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected. The approximate fundamental natural period of vibration (T,), in seconds, of all other buildings, including moment-resisting frame buildings with brick lintel panels, may be estimated by the empirical Expression:
T=0.09H/√D
Where,
h= Height of building
d= Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

Distribution of Design Force
Vertical Distribution of Base Shear to Different Floor Level. The design base shear (V) shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

Q_i =Design lateral force at floor i,
W_j =Seismic weight of floor i,
h_i =Height of floor i measured from base, and

n=Number of storeys in the building is the number of levels at which the masses are located.

Dynamic Analysis

Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements, for the following Buildings:

a) *Regular buildings* -Those greater than 40 m in height in Zones IV and V and those greater than 90 m in height in Zones II and 111.
b) *Irregular buildings* – All framed buildings higher than 12m in Zones IV and V and those greater than 40m in height in Zones 11 and III.

The analytical model for dynamic analysis of buildings with unusual configuration should be such that it adequately models the types of irregularities present in the building configuration. Buildings with plan irregularities cannot be modeled for dynamic analysis.

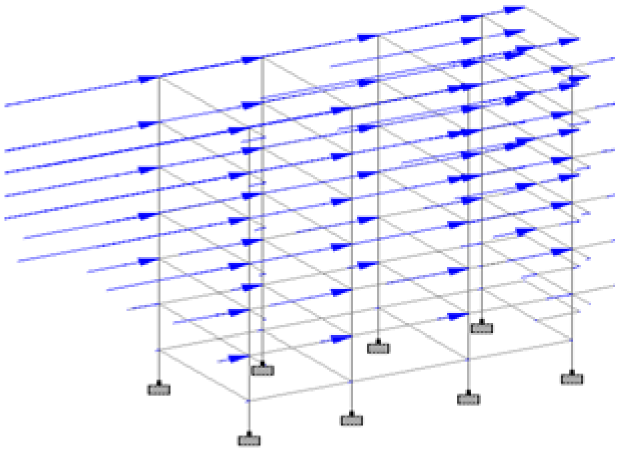

Figure 7: Structure under seismic loading

3.2.6 Load combination

The structure has been analyzed for load combinations considering all the previous loads i**n** proper ratio. In the first case a combination of self-weight, dead load, live load and wind loadwas taken into consideration. In the second combination case instead of wind load seismic load was taken into consideration.

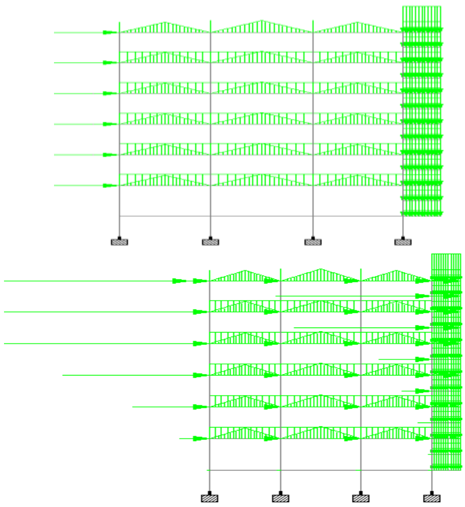

Figure 8: Structure under combination with wind load and seismic load

4. Cost Comparison of Steel and RC Frames

Total weight of steel bars in beams and columns for RCC structure is
=7442.975 + 3023.19
= 10,466.165kg's
= **10.466 Tonnes**

Total volume of concrete in beams and columns for RCC structure is
45.275 + 19.44
= **64.825m^3**

Cost of steel bars/ Tone = Rs. 39,000.

Cost of concrete/cubic meter = Rs. 6,000.

Therefore, total cost of reinforcing bars = 10.466 x 39,000 = Rs.4, 07,940/-
Total cost for volume of concrete = 64.825 x 6,000 =Rs. 3, 88,950/-
Therefore, Total cost of RCC framed structure = **Rs.7, 96,890/-**
Therefore, Total weight of Steel sections for beams = 22.522Tonnes and
Cost of beams = Rs.6,75,245/-
Total weight of Steel sections for columns = 12.1295Tonnes and
Cost for columns = Rs.3, 65,360/-
Therefore, cost of sections for beams and columns = 6, 75,245 + 3, 65,360
= Rs.10,40,605/-

Comparison between RCC framed structure and STEEL framed structure

Sl.no	Description	Concrete structure	Steel structure
1	Quantity of material	Total volume of concrete =64.507m^3 Total reinforced bar =10.46TONNES	Total steel quantity = 34.651 TONNES
2	Cost estimation of structure	Rs.7,96,890/-	Rs.10,40,605/-
3	Durability	More durable than steel structure	Less durable than concrete structure
4	Safety	High endurance in temperature and fire, hence much safer	Protection in temperature and fire is lesser than concrete.
5	Repair	Repair work is easier and cheaper	Repair work is costlier
6	Recycling of material	Recycling of material is not possible, except reinforcing bars	Recycling of most of the material is possible, Hence advantageous

5. Conclusions

1) Dead weight of the steel frame structure is much lesser than RCC framed structure.
2) Bending moment due to seismic force is reduced in Steel structure than RCC framed structure.
3) Overall expense is about 24% higher in steel structure than concrete structure in multistoried building.

4) Concrete structure is durable and safe with respect to steel structure.
5) Steel buildings are having scrap value while in case of RCC buildings scrap value is very less.
6) Steel structure occupies less area than concrete structure so that circulation area will available more in steel structure.

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