# Comparative Study of Structural Analysis between Reinforced Cement Concrete Structure and Steel Framed Structure

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**Abstract -** *The development of infrastructure sector is taking place at an unprecedented rate and it demands suitable materials to have our structure safer, sustainable and economical. Both the reinforced cement concrete structures and steel framed structures are suitable choice of building construction because of their versatility and reliable properties. Our main endeavor is to deal with the comparative study of structural analysis between steel framed structure and reinforced cement concrete structure. Mass material & storey stiffness, base shear, storey drift ratio, centre of mass, centre of rigidity and displacement is determined and compared to delve into a conceptual clarity regarding material choice. Three-dimensional model of RCC and steel structure are analyzed with the help of software ETABS 2016v16.2.1.*

*Key Words*: **Comparative study, base shear, storey drift ratio, storey stiffness, Seismic coefficient, story response**

## 1. INTRODUCTION

Haphazard and non-engineered construction has raised serious concerns towards the sustainability of various structure constructed in Nepal. While world has laddered in advancement of technology Nepal seemed busy struggling to build its basic infrastructure. The diverse material choice in constructing structure forms or system is the phenomenal part of engineering. Both the reinforced cement concrete structures and steel framed structures are suitable choice for the construction of building because of their versatility and reliable properties. Traditional RCC framed structure is generally used for constructing buildings in Nepal resulting higher dead load, restriction to maximum span and hazardous formwork [1]. Although, RCC and steel structures follows a similar load transfer method, they differ with one another in several factors. RCC is the composite material having concrete with steels bar embedded in it. They ensure better compression and tension withstanding capacity and are used in large number for structural construction to satisfy the basic requirements like stability, strength and serviceability [2]. Steel structure is an assemblage of elements rolled to a basic cross-section making desired size and form in the site [3]. On the other hand, due to the large strength to weight ratio, steel structures tend to be more

economical than concrete structures for tall buildings and large span buildings and bridges and an ecofriendly material, which can easily be dismantled and sold as scarp [4]. Several study regarding the comparative analysis of the material used in the structure is done through continuous research. The literature [5]-[7] reports several techniques of comparisons among these materials.

## 2. DESCRIPTION OF STRUCTURAL MODEL

The current study has models of RCC and steel structure. Following basic parameters are used for the design and analysis of structures.

**Table -1:** Description of Structural Model

| 1. Physical Properties: | |
|---|---|
| Total number | 2 |
| Total height | 12m |
| Floor to floor height | 3m |
| Overall length | 12.195 m (40ft) |
| Overall breadth | 12.195 m (40ft) |
| Plinth area | 148.2 m² (1600 sq. ft) |
| Staircase | Open well staircase |
| Earthquake zone | V |
| 2. Structural Properties: | |
| **For RCC Structure** | |
| Total Number of Column | 16 per storey |
| Section of Column | 300 mm X 300 mm |
| Section of Beam | 230 mm X 350 mm |
| Depth of Slab | 125 mm (5 inches) |
| **For Steel Structure** | |
| Total Number of Column | 16 per storey |
| Section of Column | IS MC350(toe-toe) |
| Section of Beam | IS MB225 |
| Section of Secondary Beam | IS LB75 |
| Depth of Slab | 125 mm (5 inches) |
| **Values Adopted as per IS 875:1987 Part II** | |
| Live Load on Staircase | 3 KN/m² |
| Live Load on Floor: | 3 KN/m² |
| Live Load on Roof | 1.5 KN/m² |
| **Values Adopted as per IS 1893:2002** | |

| Seismic Zone Factor (Z) | 0.36 |
|---|---|
| Response Reduction Factor (SMRF), R | 5 |
| Importance Factor(I) | 1 |
| Time period for RCC | 0.235 sec. |
| Time period for Steel Structure | 0.4417 sec. |
| **Standard Values Adopted:** | |
| Bearing Capacity of Soil | 120 KN/m² |
| Unit Weight of Concrete | 25 KN/m² |
| Unit Weight of Masonry | 20 KN/m² |

## 2.1 Models for Analysis:

Model of RCC and steel framed building of similar sized three storey is modeled as a space frame in which ETABS 2016 is used as the basic tool for the execution of analysis. It is based on Finite Element Method.

-MODEL 1: RCC structure

-MODEL 2: Steel framed structure
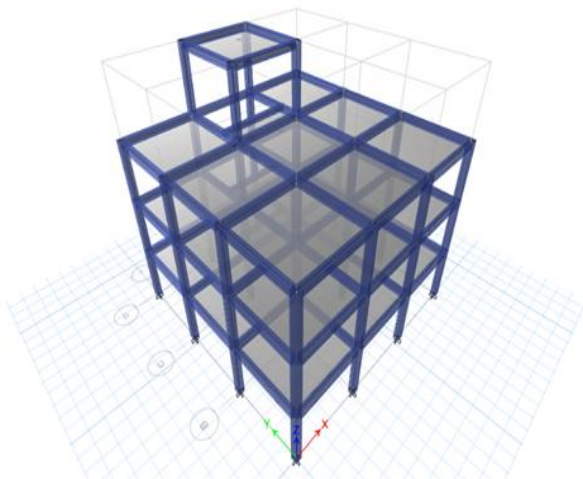


**Model -1**
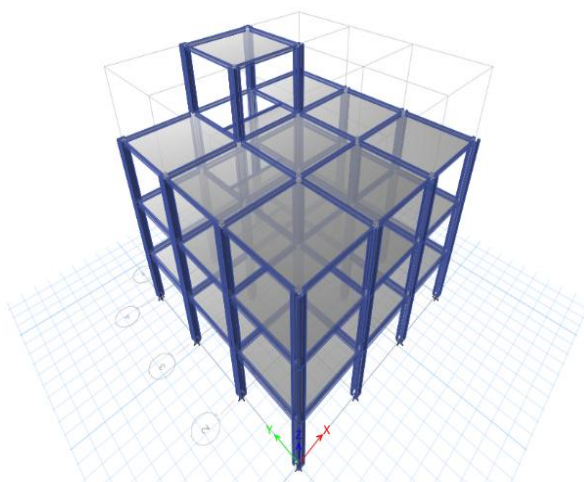


**Model -2**

## 3. RESULT AND DISCUSSION:

Parameters such as mass material, base shear, story drift, storey displacement, story stiffness and fundamental time periods are analyzed and obtained using ETABS2016.

### 3.1. Mass by Material and Storey Stiffness

The material used in the construction of a structure highly changes the characteristics of the whole building. In RCC building, the mass of the building is due to the concrete works but in steel structure, the major load is from the cold rolled steel bars. Comparing stiffness of the material alone, steel has high stiffness compared to the cement and concrete.

The mass of the building in the model with respective of its material and type of element was found as follow.

**Table 2**: Material List by Element Type for RCC and Steel

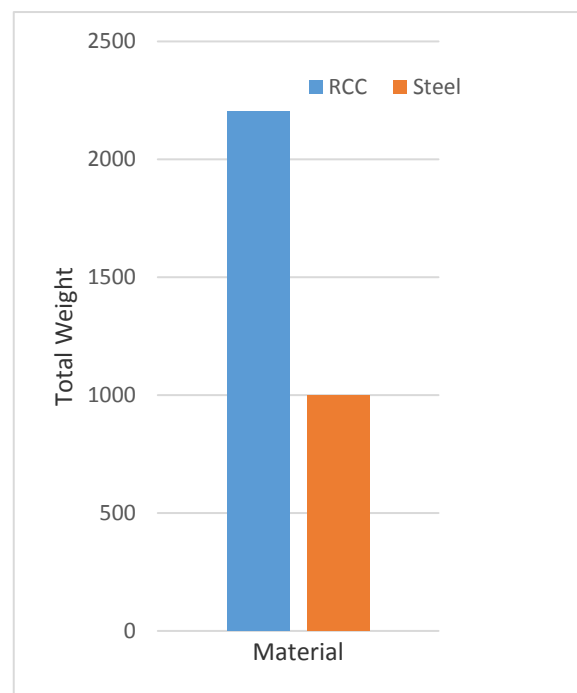| Element | For RCC | | For Steel | |
|---|---|---|---|---|
| | Material | Weight | Material | Weight |
| Column | M25 | 358.796 | Fe250 | 128.430 |
| Beam | M20 | 575.714 | Fe250 | 90.856 |
| Floor | M20 | 1268.695 | M20 | 777.762 |
| Total Weight (KN) | | **2203.205** | | **997.048** |



**CHART 1**: Mass Material of RCC Model versus Steel Model

Maximum storey stiffness for RCC was found 71765.244 KN/m in ground floor towards x-direction and that for steel was 77009.927 KN/m in first floor towards x-direction.
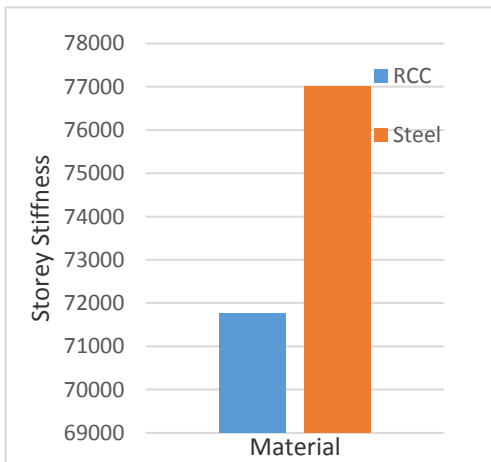
**Chart -2**: Storey Stiffness of RCC Model Versus Steel Model

### 3.2. Base Shear

According to IS 1893 (part I): 2002 Cl. No. 7.6.1, for RCC frame building;

| | | |
|---|---|---|
| Seismic Zone: | = | V |
| Zone factor: | = | 0.36 |
| Response reduction factor= | | 5 |
| Height of the building | = | 9.144m |

(For calculation purpose staircase cover is not adopted here)

For RCC building,

Time period (T)        $= 0.09h/d^{0.5}$     = 0.235

According to IS 1893 (part I): 2002 Cl. No. 6.4.2, the design horizontal seismic coefficient $A_h$ for a structure shall be determined by the following expression.

$A_h = \dfrac{Z I S_a}{2 R g}$

Where,  Z = Zone factor

I= Importance factor

For Normal building;        I=1,

$S_a/g$= Acceleration Spectral coefficient=2.5, for fundamental time period up to 0.1≤T≤0.55. (For medium soil)

R= response reduction factor   = 5

$ZI/2R$        = 0.036

$A_h$        = 0.09

For Steel building,

Time period (T) =        $0.085 h^{0.75}$     = 0.447

According to IS 1893 (part I): 2002 Cl. No. 6.4.2, the design horizontal seismic coefficient $A_h$ for a structure shall be determined by the following expression.

$A_h = \dfrac{Z I S_a}{2 R g}$

Where,        Z = Zone factor

I= Importance factor

For Normal building;        I=1,

$S_a/g$= Acceleration Spectral coefficient=2.5, for fundamental time period up to 0.1≤T≤0.55. (For medium soil)

R= response reduction factor   = 5

$ZI/2R$        = 0.036

$A_h$        = 0.09

Base Shear $(V_b)$=Ah*W

**Table -3:** Base Shear of RCC model

| Load Pattern | Coefficient Used | Weight Used KN | Base Shear KN |
|---|---|---|---|
| $EQ_x$ | 0.09 | 5350.124 | 481.5111 |
| $EQ_y$ | 0.09 | 5350.124 | 481.5111 |

**Table -4:** Base Shear of Steel Model

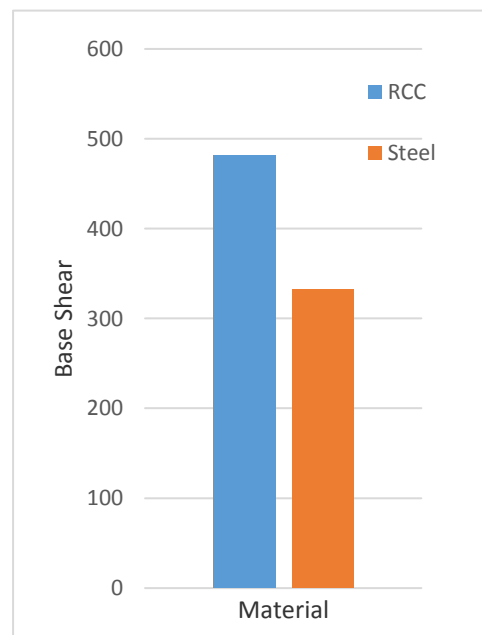| Load Pattern | Coefficient Used | Weight Used KN | Base Shear KN |
|---|---|---|---|
| $EQ_x$ | 0.09 | 3696.261 | 332.6635 |
| $EQ_y$ | 0.09 | 3696.261 | 332.6635 |



**Chart -3**: Base Shear of RCC Model versus Steel Model

### 3.3. Storey Drift

Below table shows maximum drift obtained in X and Y directions which are less than drift limitation of 0.004 in our case which is necessary to avoid discomfort to occupants and to save non-structural elements from damage.

**Table -5:** Storey Drift of RCC Model

| Storey | Output Case | U1(m) | Storey Drift(m) | Drift Ratio |
|--------|-------------|-------|-----------------|-------------|
| RF | $EQ_x$ | 0.00112 | 0.00036 | 0.000121 |
| SF | $EQ_x$ | 0.00309 | 0.00272 | 0.000895 |
| FF | $EQ_x$ | 0.00708 | 0.00398 | 0.001309 |
| GF | $EQ_x$ | 0.01025 | 0.00316 | 0.00104 |
| RF | $EQ_y$ | 0.01078 | 0.00053 | 0.000174 |
| SF | $EQ_y$ | 0.01345 | 0.00266 | 0.000874 |
| FF | $EQ_y$ | 0.01734 | 0.00389 | 0.001279 |
| GF | $EQ_y$ | 0.02043 | 0.00308 | 0.001013 |

**Table -6:** Storey Drift of Steel Model

| Storey | Output Case | U1(m) | Storey Drift(m) | Drift Ratio |
|--------|-------------|-------|-----------------|-------------|
| RF | $EQ_x$ | 0.004209 | 0.00420 | 0.001403 |
| SF | $EQ_x$ | 0.010287 | 0.00607 | 0.002026 |
| FF | $EQ_x$ | 0.017814 | 0.00752 | 0.002509 |
| GF | $EQ_x$ | 0.022518 | 0.00470 | 0.001568 |
| RF | $EQ_y$ | 0.00417 | 0.00417 | 0.00139 |
| SF | $EQ_y$ | 0.010245 | 0.00607 | 0.002025 |
| FF | $EQ_y$ | 0.017835 | 0.00759 | 0.00253 |
| GF | $EQ_y$ | 0.022587 | 0.00475 | 0.001584 |

### 3.4. Story Response - Maximum Story Displacement

Maximum storey displacement for RCC was 0.099mm and that for steel it was 0.086mm.



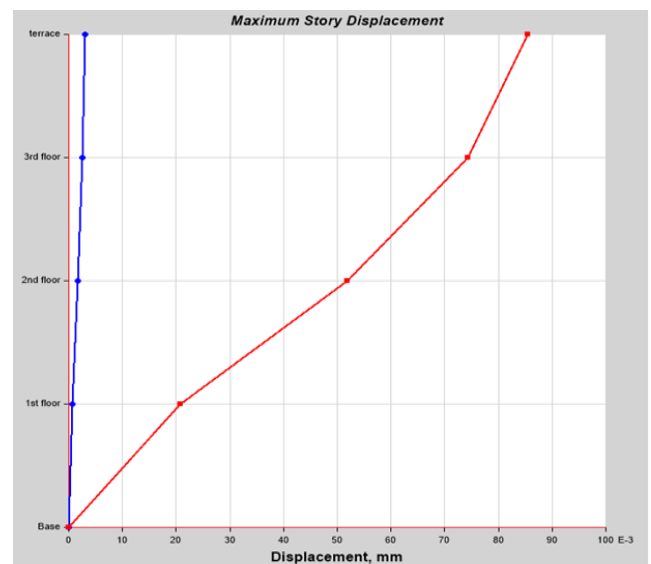**Fig -1**: Story Response- Maximum Story Displacement for RCC Model



**Fig -2**: Story Response- Maximum Story Displacement for Steel Model

### 3.5. Centre of Mass and Rigidity

**Table -7:** Centre of Mass and Centre of Rigidity of RCC Model and Steel Model

| Description | RCC Model | Steel Model |
|-------------|-----------|-------------|
| Centre of Mass (max) | (5.94m,9.9m) | (5.94m,9.9m) |
| Centre of Rigidity(max) | (5.9436m,9.1754m) | (5.94m,8.9174m) |

## 4. CONCLUSIONS

Firstly, the structural analysis of similar building model was done for RCC structure and steel structure. Result from the analysis of two identical models were compare based on their mass by material, storey drifts, base shear, storey displacement and so on. The comparative study of two models resulted to the conclusions are as shown.

- Construction of structure with RCC consumes large amount of raw materials. Hence, the mass material for RCC is greater than for steel frame structure.
- Maximum storey stiffness was greater for steel than concrete.
- Base shear is considerably less for steel structure as compared with RCC, which gives better response during earthquake.
- Story drifts for both models are found within the permissible limit as specified by the code IS 1893(part 1):2002.
- Centre of mass was same for both and centre of rigidity was more for steel.
- Story displacement was more for RCC frame model than steel frame model.

## REFERENCES

[1] Yadav, R. C. (2016). Comparative Analysis of Reinforced Concrete Building and Concrete filled Steel tube Buildings in Nepal. International Conference on Earthquake Engineering and Post Reconstruction Planning . Bhaktapur, Nepal.

[2] S Unnikrishna Pillai, D. M. (2013). Reinforced concrete design. New Delhi: McGraw Hill Education(India) Private Limited.

[3] Duggal, S. (2010). Design of Steel Structures. India: Tata McGraw Hill Education Private limited.

[4] Santha, P. S. Lecture Notes on Steel Structures Design and Drawing. Dandigal, Hyderabad: Institute of Aeronautical Engineering .

[5] Renavikar Aniket, S. Y. (2016). Comparative Study of Analysis and Design of R.C. and Steel Structures. International Journal of Science & Research,Volume 5, Issue 7.

[6] Prof. Prakash Sanghave, M. N. (2015). Comparative Study of Analysis and Design of R.C. and Steel Structures. International Journal of Scientific & Engineering Research, Volume 6, Issue 2.

[7] Bhavani, G. (2016). Comparative Seismic Analysis of RCC, Steel & Steel Concrete. International Journal of Research Sciences.

[8] IS 456:2000 Code of practice for plain and reinforced concrete. New Delhi: Bureau of Indian Standards.

[9] IS 875:1987 Code of Practice for Design Loads for Building and Structure (Part I- Dead Load; Part ii- Imposed Loads). New Delhi: Bureau of Indian Standards.

[10] IS 1893(part I):2002 Criteria for Earthquake Resistant Design of Structures. New Delhi: Bureau of Indian Standards.

[11] IS 13920:1993 Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces. New Delhi: Bureau of Indian Standards.

[12] SP16 Design Aids for Reinforced Concrete to IS 456:1978. New Delhi: Bureau of Indian Standards.