Behaviour of Symmetrical RCC and Steel Framed Structures Under Seismic and Wind Loading

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Abstract **-Buildings are nowadays built as high rise that has multiple floors above ground aiming to increase floor area. The common practice of high rise building construction is a framed structure i.e., building of reinforced cement concrete with beams and columns, with slab resting on beams. Also nowadays, new types of construction techniques are introduced which include steel structures, in which beams and columns are made of pre-fabricated steel sections. The changes in the method adopted for construction influences various parameters of the building. These changing aspects can be studied by modelling the multi-storied building under the effect of seismic and wind forces respectively and comparing various parameters like the displacements in the building, column forces and moments generated in the building. This paper tries to find out the changes in the various structural parameters of these different types of construction techniques on symmetrical G+10, G+15 and G+20 multi-storied buildings under the effect of seismic and wind forces respectively. It discusses the analysis & design procedure adopted for the evaluation of symmetrical high rise multi-storied buildings G+10, G+15 and G+20 under effect of Wind and Earthquake forces. In these buildings, R.C.C. and Steel are considered to resist lateral forces resisting system. This study examines G+10, G+15 and G+20 storied buildings using STAAD.ProV8i. Total 12 numbers of various models are analysed& designed & it proves thatsteel building is better option. Analytical results are compared to achieve the most suitable resisting system.**

Keywords: **Seismic Force, Wind Force, Symmetrical, RCC, Steel, Displacement, STAAD.ProV8i**

I. INTRODUCTION

In India mostly RCC structural member are used and for low rise building they seems to be the most convenient and economic construction. But use of reinforced concrete in case of high rise building is not suitable because of the increased dead load; span restrictions, cost of construction and even the time required is more. To overcome this, structural engineers nowadays are using different materials for construction of high rise building. Steel is being used as an alternative construction material especially when we are dealing with the earthquake and wind forces.

This study involves comparison between wind and seismic loads on symmetrical building structures G + 10, G+15, and G+20 using RCC and Steel on design software STAAD.ProV8i.

II. METHODOLOGY

In this paper, a computational study was carried out and a 3-D model is developed on STAAD.ProV8i to analyse the behaviour of steel building and reinforced concrete building under wind and earthquake loading. A structure can be defined as assemblage of elements STAAD.ProV8i is capable of analysing and designing structure.

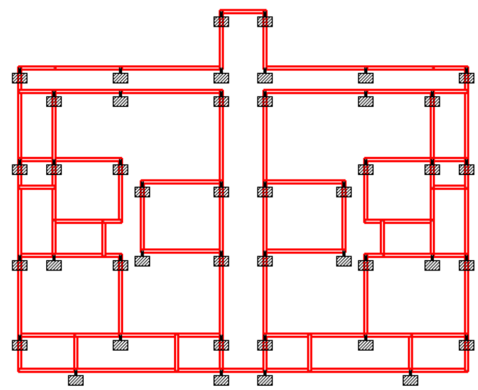


Fig. 1 Base Model of Symmetrical Building

In this report 2 cases are taken into consideration:

CASE 1: Wind Load Analysis

CASE 2: Seismic Load Analysis

Under each case there are 3 buildings with varying floors above ground floor:

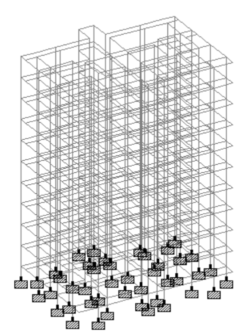


Fig. 2 Model of Symmetrical Building

BLDG 1: G+10

BLDG 2: G+15

BLDG 3: G+20

2 models for each building are constructed using 2 different materials:

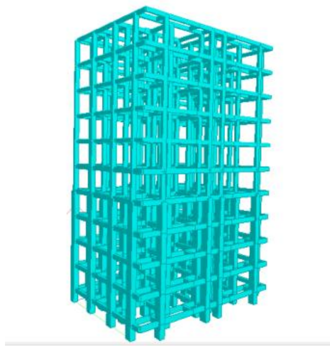


Fig. 3 Rendered Model of RCC Symmetrical Building

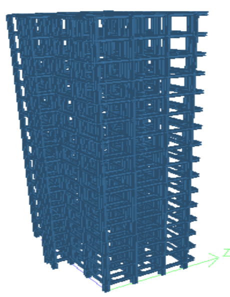


Fig. 4 Rendered Model of STEEL Symmetrical Building

MODEL 1: RCC framed

MODEL 2: STEEL framed

Thus, under wind load analysis for symmetrical structure there will be 6 models. Similarly, under seismic load analysis for symmetrical structure there will be 6 models which are to designed and analysed on STAAD. In all 12 models are formed on STAAD.

III. PHYSICAL PARAMETERS OF THE BUILDING

Sizes of Different Elements

RCC: In RCC model,columns and beams are rectangular in shape.

Table 1

Building Type	Column	SIZE (B x D) mm	BEAM	SIZE (B x D) mm
G+10	Up to G+3	600 × 800	Up to G+5	300 × 500
	Above G+3	300 × 500	Above G+5	200 × 400
G+15	Up to G+7	600 × 800	Up to G+7	300 × 500
	Above G+7	300 × 500	Above G+7	200 × 400
G+20	Up to G+10	600 × 800	Up to G+10	300 × 500
	Above G+10	300 × 500	Above G+10	200 × 400
All the cantilever beams are taken as 300mm × 550mm				

Steel: In steel model, columns and beams are of medium and wide flanges, some with and some without top and bottom cover plate. The dimension of cover plate is in meter.

Table 2

Building Type	Beam	Size
G+10	Up to G+7	ISWB 500
	Above G+7	ISWB 400 TB Cover plate 0.4 × 0.02
G+15	Up to G+7	ISWB 500
	Above G+7	ISWB 400 TB Cover plate 0.5 × 0.02
G+20	Up to G+10	ISWB 550
	Above G+10	ISWB 400 TB Cover plate 0.5 × 0.02
In wind load analysis of G+20 Symmetrical building above G+10 Cover plate is of size 0.5 × 0.03mt		

Table 3

Building Type	Column	Size
G+10	Up to G+3	ISMB 500 TB Cover plate 0.5 × 0.02
	Above G+3	ISMB 400 TB Cover plate 0.4 × 0.02
G+15	Up to G+7	ISMB 500 TB Cover plate 0.6 × 0.02
	Above G+7	ISMB 450 TB Cover plate 0.5 × 0.02
G+20	Up to G+10	ISWB 600 TB Cover plate 0.7 × 0.02/0.03
	Above G+10	ISMB 450 TB Cover plate 0.5 × 0.02/0.03
In wind load analysis of G+15 Symmetrical building above G+7 Cover plate is of size 0.7 × 0.03mt		

Material Properties

Unit weight of brick masonry: 19.20 kN/m3

Unit weight of R.C.C: 25 kN/m3

Unit weight of steel: 78.50 kN/m^3

Grade of concrete: M25 for R.C.C.

Grade of steel: HYSD bars for reinforcement, Fe 415

IV. LOAD CONSIDERATIONS

Gravity loads: Dead load and Live load

Dead Load: The dead load is calculated on the basis of unit weights of materials given in IS 875(Part -1) - 1987. It includes Floor load, Wall load, Parapet load as per IS 875(Part1) and self-weight were considered in software.

a) Floor load = (thickness × unit weight of concrete)100 mm floor thickness = (100×10^{-3}) m × 25 kN/m^3 = 2.5 kN/m^2
50 mm flooring = (50×10^{-3}) m × 24 kN/m^3 = 1.2 kN/m^2
12 mm ceiling plaster = (12×10^{-3}) m × 21 kN/m^3 = 0.252 kN/m^2
Total floor load = 3.952 kN/m^2

b) Wall load = wall thickness × unit weight of brick masonry× effective wall height= 0.230m × 19.2 kN/m^3 × effective wall height
Effective wall height = (Wall height – depth of beam)

c) Wall load (due to Parapet wall at top floor) = (unit weight of brick masonry × parapet wall thickness × wall height) = 19.2 kN/m^3 × 0.115m × 1.0m = 2.2 kN/m

Live Load: Imposed loads shall be assumed in accordance with **IS 875(Part -2) - 1987.** For residential building:

Floor load: 2 $kN/m^2$and Roof load: 1.5 kN/m^2

Seismic Load: The seismic forces shall be calculated in accordance with **IS 1893(Part-1) - 2002.** The effect of seismicforces on the building can be analysed by two methods: Equivalent Static Analysis and Dynamic Analysis.

Seismic load depends upon the following criteria:

a) Design horizontal acceleration co-efficient (A_h): It is a horizontal acceleration co-efficient that was used for design of structures.

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times S_a/g$$

Where, Z is Zone factor; I is Importance factor; R is Response reduction factor and S_a/g is Avg. response acceleration co-efficient

b) Design Seismic Base Shear: The total design lateral force or design seismic base shear, V_b along is determined by the following expression:

$$V_b = A_h \times W$$

Where, A_h = horizontal acceleration spectrum and W = seismic weight of all the floors.

c) Fundamental natural period, T_a: It is the first longest model time period of vibration.

The problem in this paper is analysed as per the code by Response Spectrum Method which is defined as the representation of the maximum response of idealized single degree freedom systems having certain period and damping during earthquake ground motion.

Response Spectrum Method by using STAAD.ProV8i

Response Spectrum Method is elastic dynamic analysis method that relies on the assumption that dynamic response of the structure may be found by considering the independent response of each natural mode of vibration and then combining the response of each in the same way.

For the purpose of seismic analysis, the design spectrum given on Page 16 figure 2 of IS: 1893 (Part 1): 2002 was used. This spectrum is based on strong motion records of eight Indian earthquakes.

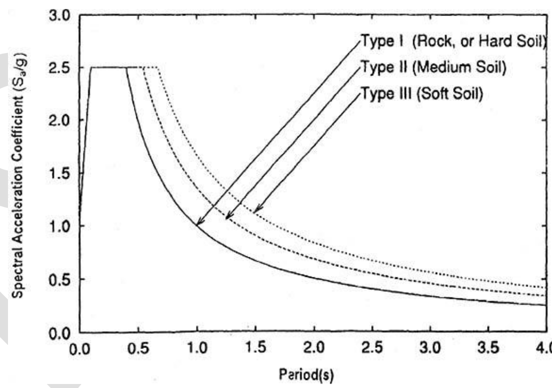


Fig. 5

The design lateral force at each floor in each mode is computed by STAAD.ProV8i in accordance with IS: 1893 (Part 1)-2002. The design lateral force at each floor in each mode is computed by STAAD in accordance with the IS: 1893 (Part 1) -2002 by following equation.

$$Q_{ik} = A_k \times \Phi_{ik} \times P_k \times W_i$$

Where, $A_k$is design horizontal acceleration spectrum value as per design horizontal seismic coefficient using the natural period of vibration T_k of mode k; Φ_{ik} is mode shape coefficient.; P_k is modal participation factor of mode k; W_i is seismic weight of floor i.

STAAD utilizes the following procedure to generate the lateral seismic loads.

1. User provides the value for $\frac{Z}{2} \times \frac{I}{R}$ as factors for input spectrum.
2. Program calculates time periods for first six modes or as specified by the user.
3. Program calculates S_a/g for each mode utilizing time period and damping for each mode.
4. The program calculates design horizontal acceleration spectrum $A_k$for different modes.
5. The program then calculates mode participation factor for different modes.

6. The peak lateral seismic force at each floor in each mode is calculated.
7. All response quantities for each mode are calculated.
8. The peak response quantities are then combined as per method (CQC or SRSS or ABS or TEN or CSM) as defined by the user to get the final results.

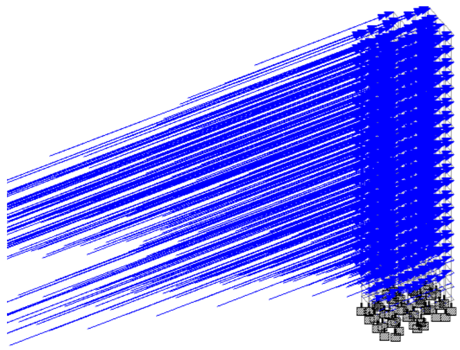


Fig 6

As per IS 1893(Part-1) - 2002

a) Zone factor for Zone - III: Z = 0.16
b) Response reduction factor: R.F = 5 for SMRF (RCC) & 3 for OMRF (Steel)
c) Importance factor: I = 1
d) Rock & soil site factor: SS = 2
e) Type of structure: ST = 1 for RCC & 2 for Steel
f) Damping ratio: DM = 0.05
g) Period in X direction: PX = 0.2
h) Period in Z direction: PZ = 0.2

Wind Load:IS: 875 (Part 3) – 1987 deals with wind loads to be considered when designing building, structures and components thereof. Wind load depends upon wind speed and pressure –

a) Basic wind speed, V_b: IS: 875 (Part 3) - 1987, Fig-1, Page 16 gives basic wind speed map of India, as applicable to 10m height above mean ground level for different zones of the country. Basic wind speed for some important cities/towns is also given in Appendix A.

b) Design Wind Speed, V_z: The basic wind speed V_b for any site is obtained from code and shall be modified to include the following effects of design wind velocity at any height for the chosen structure. It can be mathematically expressed as follows:

$$V_z = V_b \times K_1 \times K_2 \times K_3$$

V_b is design wind speed at any height z in m/s; K_1 is probability factor (risk coefficient); K_2 is terrain, height and structure size factor and K_3 is topography factor. Asper code design wind speed up to 10 m height from mean ground level is considered constant.

c) Design Wind Pressure: The design wind pressure at any height above mean ground level shall be obtained by the fallowing relationship between wind pressure and wind velocity :

$$P_z = 0.6\ V_z^2$$

Where, P_z is Design wind pressure in N/m² at height z and V_z is design wind speed at any height z in m/s.
Basic wind speed for Bhopal: V_z= 39 m/s
Risk Coefficient: K_1 = 1
Topography factor, K_3 = 1

As per IS 875(Part-3) - 1987

Terrain, height and structure size factor, K_2 is calculated by considering the following: Class: B for G+10 and G+15; Class: C for G+20 and Terrain: Category 3

The values of design wind pressure is inserted in wind load definition while modelling the structure for wind load on STAAD.ProV8i

Table 4

Height , m	For Category - 3, K_2		$V_z = V_b \times K_1 \times K_2 \times K_3$	$P_z = 0.6\ V_z^2$ kN/m²	
	Class – B	Class - C		Class - B	Class – C
Up to 10	0.88	0.82	39 K_2^2	0.707	0.613
15	0.94	0.87	39 K_2^2	0.806	0.690
20	0.98	0.91	39 K_2^2	0.876	0.755
25	1.005	0.935	39 K_2^2	0.921	0.789
30	1.03	0.96	39 K_2^2	0.968	0.841
35	1.045	0.963	39 K_2^2	0.996	0.846
40	1.06	0.966	39 K_2^2	1.025	0.851
45	1.075	0.964	39 K_2^2	1.054	0.848
50	1.09	1.02	39 K_2^2	1.084	0.949
55	…	1.028	39 K_2^2	…	0.964
60	…	1.036	39 K_2^2	…	0.979
65	…	1.044	39 K_2^2	…	0.994
100	…	1.10	39 K_2^2	…	…

V. LOAD COMBINATIONS

The gravity loads, wind loads and earthquake loads will be taken for analysis.

For Seismic Load Analysis:

DL is Dead Load; LL is Live Load; EQX is earthquake in X direction and EQZ earthquake in Z direction. All these are included in the design of structure.

Table 5

		Load Combinations
Seismic Load	**For RCC**	1.5(DL + LL)
		1.2(DL + LL ± EQX)
		1.2(DL + LL ± EQZ)
		1.5(DL ± EQX)
		1.5(DL ± EQZ)
		0.9 DL ± 1.5 EQX
		0.9 DL ± 1.5 EQZ
	For STEEL	1.7(DL + LL)
		1.3(DL + LL ± EQX)
		1.3(DL + LL ± EQZ)
		1.7(DL ± EQX)
		1.7(DL ± EQZ)
		1.3(DL + LL)

For Wind Load Analysis:

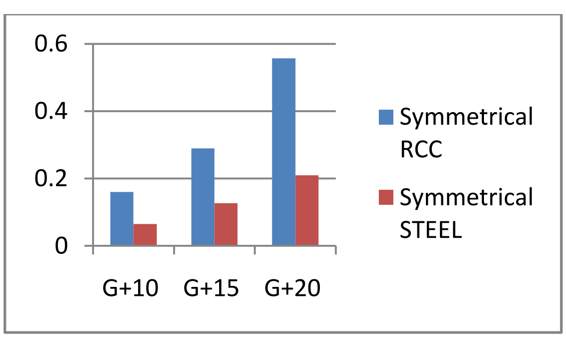
WWX is Wind blowing in +X direction (Windward side); WLX is Wind blowing in -X direction (Leeward side); WWZ is Wind blowing in +Z direction (Windward side) and WLZ is Wind blowing in -Z direction (Leeward side)

Table 6

		Load Combinations
Wind Load	**For RCC**	1.5(DL + LL)
		1.2(DL + LL ± WWX)
		1.2(DL + LL ± WLX)
		1.2(DL + LL ± WWZ)
		1.2(DL + LL ± WLZ)
		1.5(DL ± WWX)
		1.5(DL ± WLX)
		1.5(DL ± WWZ)
		1.5(DL ± WLZ)
	For STEEL	1.7(DL + LL)
		1.3(DL + LL)
		1.7(DL ± WWX)
		1.7(DL ± WLX)
		1.7(DL ± WWZ)
		1.7(DL ± WLZ)
		1.3(DL + LL ± WWX)
		1.3(DL + LL ± WLX)
		1.3(DL + LL ± WWZ)
		1.3(DL + LL ± WLZ)

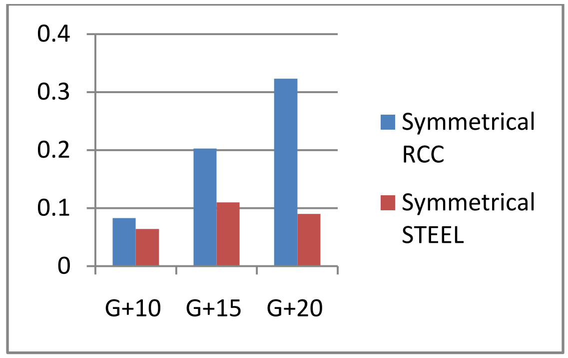
VI. RESULTS

Node Displacement of Symmetrical Building Due To Seismic Load



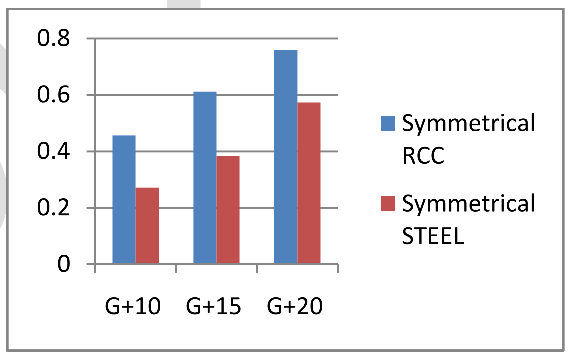
The chart shows that node displacement in steel structure is less than that in structure which is constructed using reinforced concrete when seismic load is applied.

Node Displacement of Symmetrical Building Due To Wind Load



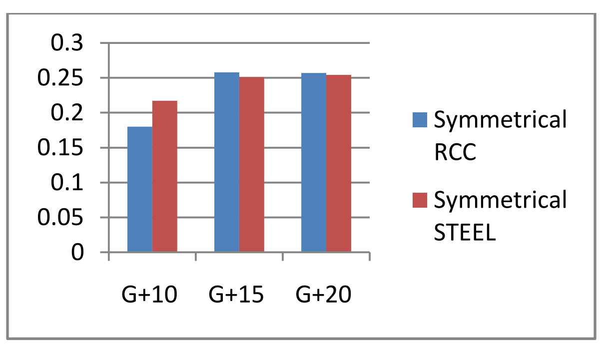
The chart shows that node displacement in steel structure is less than that in structure which is constructed using reinforced concrete when wind load is applied.

Column Forces of Symmetrical RCC & Steel Building Due To Seismic Load



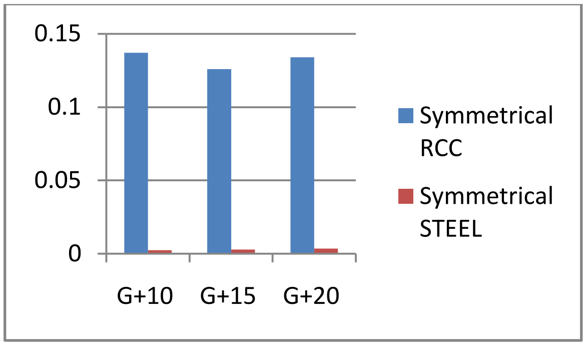
The chart shows that column forces in steel structure is less than that in structure which is constructed using reinforced concrete when seismic load is applied.

Column Forces of Symmetrical RCC & Steel Building Due To Wind Load



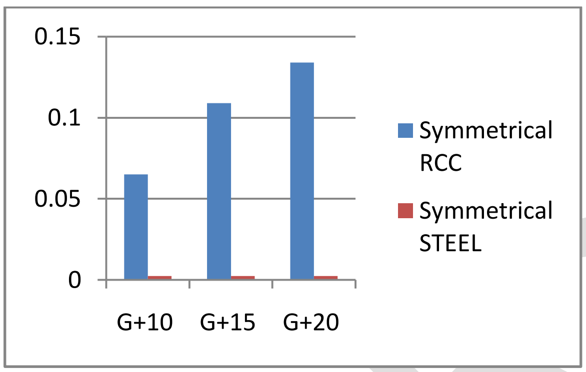
The chart shows that column forces G+15 and G+ 20 steel structures is less than that in structure which is constructed using reinforced concrete when wind load is applied. But in G+10 RCC building has less column forces than that in steel.

Moment of Symmetrical RCC & Steel Building Due To Seismic Load



The chart shows that moment in the RCC buildings are maximum and minimum in STEEL building.

Moment of Symmetrical RCC & Steel Building Due To Wind Load



The chart shows that moment in the RCC buildings are maximum and minimum in STEEL building.

VI. CONCLUSIONS

An analysis and design result of G+10, G+15, G+20 storied R.C.C and Steel buildings is done. The comparison of results shows that:

a) The node displacement in Steel structures is less than that in RCC structure in both the loading cases- wind load and seismic load.
b) Column forces in R.C.C. structure is on higher side than that of Steel structure in case of seismic loading.
c) Column forces in G+15 and G+ 20 RCC and Steel structures are almost same under the effect of wind load but G+10 RCC building has less column forces than that in steel because of the ductile behaviour of the steel which resist the wind force better than that in concrete.
d) Moment in RCC structure compared to Steel is very highboth in seismic and wind load. Steel structures have very low bending moment.

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