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Research Paper

STRUCTURAL BEHAVIOR UNDER LOADING PREDOMINANCE

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In recent years, developments in structural materials, analysis and design methodology in civil engineering has led to the construction of buildings which satisfy static load requirements and also are able to resist the rare dynamic loads like earthquake and wind loads. The structures, which are designed to resist gravity and lateral loads, are subjected to the combination of gravity and lateral loads. In this thesis, the structural response of different types of structural system was assessed for different combinations of gravity and lateral load. Interaction ratio on the column and bracing members under different combination of loads were evaluated for the comparative study on different types of structural system. Based on this, identification of the dominant load carrying members were made and suggestions were given on strengthening/retrofitting. The structural systems considered in this study are analyzed using STAAD.Pro and designed as per relevant Indian standards.

Keywords: Interaction ratio, STAAD.Pro, Structural response, Structural system

INTRODUCTION

Every structural system should be capable to resist gravity and lateral loads. During its life time these structural systems are subjected to different combinations of gravity (Dead, Live and other imposed loads) and lateral loads (Wind, seismic, other lateral loads, etc.). Generally the efficiency of the structure in resisting gravity loads is almost same for different types of structural system. Under lateral loads the efficiency of the structural system depends on the type of structural system adopted.

The function of the structural members in a structural system is to safely transfer the loads coming on the structure to the foundation. The distribution of the forces on the structural member under gravity loads, i.e., dead and other imposed loads is uniform. But in case of lateral loads, i.e., wind and seismic load the distribution of the forces is not uniform and it depends on the geometry, location of the column and other many

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factors. Due to this non uniform distribution of forces the structural system, torsion is induced which leads to damage.

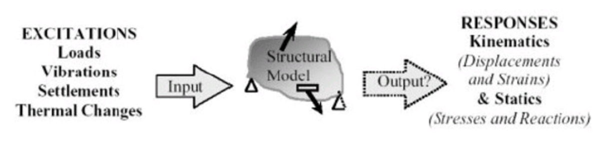
Hence it is necessary to understand the effect of lateral loading on the structural components and also to identify the dominant members for further strengthening/ rehabilitation. Hence, this work is aimed to understand the structural response parameters of different types of structural system under the combination of gravity and lateral loads. The structural systems considered in this study are analyzed using STAAD.Pro and designed as per relevant Indian standards.

The different types of structural systems considered in this study,

- Structural Steel Building
- Structural Steel Latticed Tower
- RCC Building (symmetrical)
- RCC Building (unsymmetrical)

A structure must be idealized by a mathematical model so that its behaviors can be determined by solving a set of mathematical equations.

Figure 1: Definition of a Structural System



LITERATURE REVIEW

The literature review describes about response of the structural system under the application external loads. Some of the literatures emphasized on strengthening of the existing buildings in seismic prone regions.

Maison and Neuss (1985) performed the computer analysis of an existing 44 story steel frame high-rise building to study the influence of various modeling aspects on the predicted dynamic properties and computed seismic response behaviors. The predicted dynamic properties are compared to the building's true properties as previously determined from experimental testing. The seismic response behaviors are computed using the response spectrum (Newmark and ATC spectra) and equivalent static load methods.

Hoxey.(1991) assessed the performance of the building frame under wind by comparing measured mean strains on the centre portal frame with calculated values derived from the external measured pressure distribution together with a suitable internal pressure coefficient and an appropriate structural frame characteristic fixing to the foundation. The dynamic behavior of the frame is examined by power spectral analysis of external and internal pressures and portal frame strains.

Awkar and Lui (1997) studied responses of multi-story flexibly connected frames subjected to earthquake excitations using a computer model. The model incorporates connection flexibility as well as geometrical and material nonlinearities in the analyses and concluded that the study indicates that connection flexibility tends to increase upper stories inter-storey drifts but reduce base shears and base overturning moments for multi-story frames.

Taranpreet Singh (2006) evaluated two types of RC buildings using inelastic method (Pushover Analysis). Firstly, a symmetrical building is analyzed using ANSYS for the procedure development as per ATC-40. Then, Seismic Evaluation is performed on unsymmetrical building (L-shape), which is designed in the first part as without considering seismic effect and in the second part, Analysis is carried out on the same building designed seismically as per IS 1893:2002. The results have been compared for these two analysis cases and strengthening is suggested for the affected members.

Garcia *et al*. (2010) tested a full-scale two-storey RC building with poor detailing in the beam column joints on a shake table as a part of the European research project ECOLEADER. After the initial tests which damaged the structure, the frame was strengthened using Carbon Fibre Reinforced Materials (CFRPs) and re-tested. This paper investigates analytically the efficiency of the strengthening technique at improving the seismic behavior of this frame structure.

Praval Priyaranjan (2011) evaluated an existing building located in Guwahati (seismic zone V) using equivalent static analysis using STAAD.Pro. Seismic force demand for each individual member is calculated for the design base shear as required by IS-1893:2002. Corresponding member capacity is calculated as per Indian Standard IS456:2000. Deficient members are identified through demand-to-capacity ratio. A local retrofitting strategy is adopted to upgrade the capacity of the deficient members.

Misam and M Madhuri (2012) studied the performance of the high rise buildings with soft storey at the lower level subjected to earthquake. Also has been tried to investigate on adding of shear wall in various arrangements to structure in order to reduce soft story effect on seismic response of building.

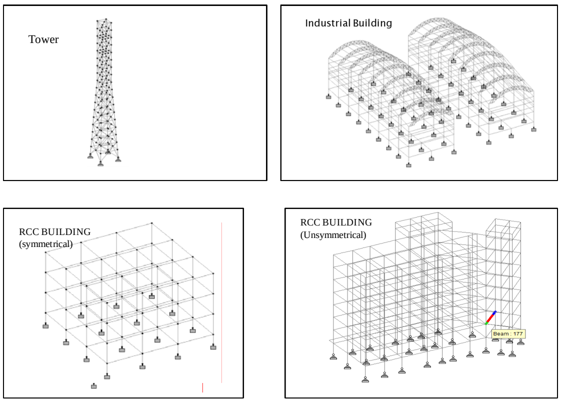
METHODOLOGY

The structural systems considered in this study are modeled using STAAD.Pro. Structural analysis is a process to analyze a structural system to predict its responses and behaviors by using physical laws and mathematical equations. Based on the assumptions, on the geometrical properties of the members, a preliminary analysis was carried out and the structural member geometries were arrived as per relevant Indian standards. After pass with that analysis, a detailed analysis is carried out. Description of four different structural systems considered is (Figure 2).

Structural Steel Latticed Roof Top Tower: The lattice type tower is of 27 m high with square cross section. The tower is constructed as 9 panels each of height 3 m. The top four panels are of size 1.5 m x 1.5 m. For remaining height the width increases to 3 m x 3 m .From 5th to 9th panels top and bottom width varies. For 9th panel top width is 2.7 m x 2.7 m wide and bottom width is 3 m x 3 m. The tower members-legs, bracings, tie bracing and platforms are made up of equal angle sections with minimum yield strength of 250 MPa. All the angle sections confirm to IS: 2062. Bolted connections of 16 mm bolts are used.

Reinforced Concrete Building (Symmetrical): The reinforced concrete building selected for study is of size 15 m x 15 m in plan and 9 m high and the floor level is 0.3 m above normal ground level. Plinth beams are provided at this floor level .Each floor is of height 3 m . Full brick work of 23 cm is provided on all outside beams and half brick of 12 cm is on all inside beams. Columns are of size 30 cm x 30 cm. Beams are of size 30 cm x 23 cm. Slabs of size 12.5 cm are used for design. Grade of concrete considered is M25 and steel is Fe415.

Figure 2: Different Types of Structural System



Structural Steel Industrial Building: The industrial building consists of two units; each unit is of size 40 m x 13 m in plan and is connected by a 10 m x 10 m size building at the middle portion along the longitudinal side. The height of the outer building is 9 m and whereas the connected building is 5 m. The roof of the building is made of curved truss tubular members. This building has a mezzanine floor at 5 m above ground level.

Reinforced concrete Pedestals of size 100 cm x 40 cm are provided for a height of 1.5 m and Steel columns of section ISMB600 for outside columns 9 m height. ISWB300 and ISMB300 are given as inside columns. Base plates are given for column steel connections. For mezzanine floor steel section beams and concrete slabs are used. Brick work is provided for a height of 3 m and top covered with claddings.

Beams of size ISMB450 are provided at 5 m levels and Girts of Z section 200ZS60 x 2 are provided at 1.5 m intervals to support sheetings. Since Roof is curved top level girts will come at different levels.

Roof truss members are made of pipe sections PIP761.OH for verticals and PIP889.OH for diagonals and PIP1270.OH for main members. Purlins are of made with Z sections of size same as that of girts 200Z60 x 2. The structural members are made up of rolled sections with minimum yield strength of 250 MPa.

Reinforced Concrete Building (Unsymmetrical): Building selected is a seven storey commercial building used for hotel purpose. Including lift room total height of building is 25.70 m. Plinth beams are provided at floor level .Cantilevered parapets are provided from first floor onwards .Building has a length of 30.198 m and width of 10.975 m. For a length of 25.70 m its a frame of two spans and rest of the length it is tapered and a single span frame. Two set of staircases, Columns of size 50 cm x 25 cm and beams of size 45 cm x 25cm are provided. Brick works are given according to the plan given. Ground floor is of height 3.25 m, First floor 3.1 m and 2nd to 6th floor 3 m height. Slab is of size 12.5 cm. Water tank and lift rooms are at top level. Grade of concrete considered is M25 and steel is Fe415.

All the above buildings are analyzed using STAAD.Pro Software. Loads Considered are Dead load , Live load , Seismic load and Wind load – Wind load on a structure act.

- Horizontally, transverse to the direction of span

- Horizontally, along the direction of span
- Vertically upwards, causing uplift
- Vertically downwards, causing suction

The reinforced concrete building selected for study is of size 15 m x 15 m in plan and 9 m high and the floor level is 0.3 m above normal ground level. Plinth beams are provided at this floor level. Each floor is of height 3 m . Full brick work of 23 cm is provided on all outside beams and half brick of 12 cm is on all inside beams. Columns are of size 30 cm x 30 cm. Beams are of size 30 cm x 23 cm. Slabs of size 12.5 cm are used for design. Grade of concrete considered is M25 and steel is Fe415.

All combination of loads according to the code is considered and studies are made based on that. For analysis of a structural system the Indian code of practice refers following load combination for Reinforced concrete and structural steel building.

RCC Structural System

- 1.5 DL + 1.5 LL
- 1.5 DL + 1.5 WL
- 1.5 DL + 1.5EQ
- 1.2 DL + 1.2 LL + 1.2 WL
- 1.2 DL + 1.2 LL + 1.2 EQ

Steel Structural System

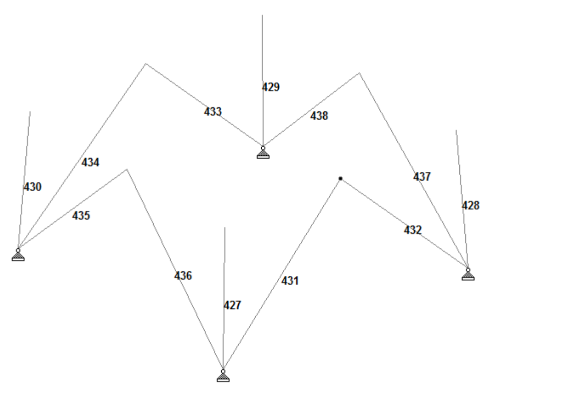
- DL + LL
- DL + LL + WL
- DL + LL + EQ

RESULTS AND DISCUSSION

Three-dimensional analysis of the different types of structural system considered in this study has been carried out using STAAD.Pro. This has been done in order to understand the effect of interaction ratio, i.e., load capacity ratio of the structural members (columns and bracings) under different combinations of load. Four different types of structural system have been considered to compare the effect of each combination of loads. Analysis and design of all the structural system considered in this study are as per the relevant code of practice.

Structural Steel Latticed Roof Top Tower: Loads are calculated as per relevant code of practice and it is applied at each corresponding node. The structure is analyzed with appropriate load combinations and the interaction ratio is evaluated for columns and bracings at the bottom most panel (Figure 3).

Figure 3: Bottom Panel Showing Column and Bracing



The tower is analyzed for three seismic zone areas (Zone – III, IV and V). The interaction ratio evaluated for column and bracing members of the bottom most panel of the tower under different combinations of load and also for different seismic zones is given in Table 1.

From the table, it is observed that,

Table 1: Interaction Ratio of Column and Bracing Members

Beam ID	Load Case	Axial Force kN			Interaction Ratio		
		Zone III	Zone IV	Zone V	Zone III	Zone IV	Zone V
428	DL+WL(N)	205.24	205.24	205.24	0.639	0.639	0.639
428	DL+WL(D)	175.24	175.24	175.24	0.546	0.546	0.546
428	DL+EQ(X)	8.72	9.41	10.40	0.029	0.029	0.032
432	DL+WL(N)	24.23	24.23	24.23	0.646	0.646	0.646
432	DL+WL(D)	20.72	20.72	20.72	0.552	0.552	0.552
432	DL+EQ(X)	1.24	1.34	1.48	0.036	0.036	0.039

Interaction ratio on bracing and column members under Dead load and Seismic combination is very less. This is due to the lesser self-weight of the tower.

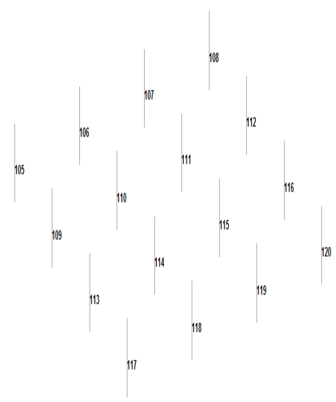
Interaction ratio on bracing and column members under Dead and wind load (Normal) when compared with Dead and wind load (Diagonal) combination is higher. This is due to the lesser lever arm under normal condition.

The axial force on the column and bracing members increases as the seismic zone changes (zone – III to IV and V) this is due to the increase in horizontal co-efficient (Ah).

Reinforced Concrete Building (Symmetrical): This symmetrical reinforced concrete building is of size 15 m x 15 m in plan and 9 m high. It is a three-storey and three bay residential building. The structural members such as columns, beams, slab and foundations are of M25 grade and Fe415 steel. Loads considered in the model are dead load, live load, wind load and seismic load. Loads are calculated as per relevant code of practice and it is applied at each corresponding member and node.

The structure is analyzed with appropriate load combinations and the interaction ratio is evaluated only for columns at the ground floor level (Figure 4).

Figure 4: 3-D view of Ground Floor Column Layout



The reinforced concrete symmetrical building is analysed for three seismic zone areas (Zone – III, IV and V). The interaction ratio evaluated for column members of size 350 mm x 350 mm with 1.97% reinforcement at selected four different locations at the ground floor level of the building under different combinations of load and also for different seismic zones is given in Table 2.

From the table, it is observed that,

Effect of wind loading on the Interaction ratio on column members under Dead load and wind combination is less than the Dead load and seismic combination. This is due to the

Table 2: Interaction Ratio of Column Members

Load Case	Beam ID	Interaction Ratio – III	Interaction Ratio – IV	Interaction Ratio – V
1.5DL+1.5LL	105	0.512	0.464	0.464
1.5DL+1.5EQ(X)	105	0.534	0.738	1.094
1.5DL+1.5EQ(Z)	105	0.552	0.534	0.809
1.5DL+1.5WL(X)	105	0.439	0.287	0.287
1.5DL+1.5WL(Z)	105	0.292	0.269	0.269
1.2DL+1.2LL+1.2WL(X)	105	0.429	0.614	0.898
1.2DL+1.2LL+1.2WL(Z)	105	0.441	0.429	0.648
1.2DL+1.2LL+1.2EQ(X)	105	0.403	0.277	0.277
1.2DL+1.2LL+1.2EQ(Z)	105	0.233	0.279	0.279
1.5DL+1.5LL	106	0.258	0.258	0.258
1.5DL+1.5EQ(X)	106	0.727	1.074	1.632
1.5DL+1.5EQ(Z)	106	0.259	0.469	0.799
1.5DL+1.5WL(X)	106	0.403	0.403	0.403
1.5DL+1.5WL(Z)	106	0.132	0.132	0.132
1.2DL+1.2LL+1.2WL(X)	106	0.621	0.887	1.312
1.2DL+1.2LL+1.2WL(Z)	106	0.162	0.321	0.580
1.2DL+1.2LL+1.2EQ(X)	106	0.371	0.371	0.371
1.2DL+1.2LL+1.2EQ(Z)	106	0.132	0.132	0.132

heavier mass of the building which increases the seismic load on the structure.

Interaction ratio on column members under Dead, live and seismic load is less when compared with Dead and seismic load combination. This is due to the reason that the live load in the structure reduces the moment induced due to seismic load condition.

The interaction ration on the column members increases as the seismic zone changes (Zone – III to IV and V) this is due to the increase in horizontal co-efficient (Ah).

Reinforced Concrete Building (Unsymmetrical): This unsymmetrical reinforced concrete building is of size 30.198 m x 10.975 m in plan and 27 m high. It is a seven-storey commercial building used for hotel purpose. The structural members such as columns, beams, slab and foundations are of M25 grade and Fe415 steel. Loads considered in the model are dead load, live

Figure 5: 3-D View of Ground Floor Column Layout

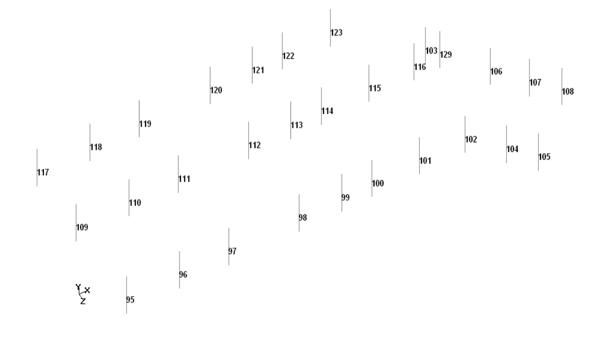
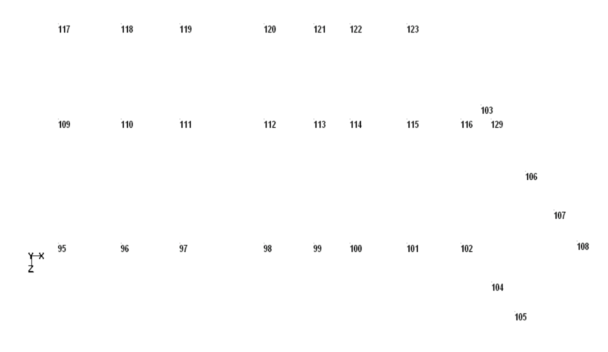


Figure 6: Plan View of Ground Floor Column Layout



load, wind load and seismic load. Loads are calculated as per relevant code of practice and it is applied at each corresponding member and node. The structure is analyzed with appropriate load combinations and the interaction ratio is evaluated only for columns at the ground floor level (Figures 5 and 6).

The unsymmetrical reinforced concrete commercial building is analyzed for dead, live, wind and seismic load (Zone – III). The interaction ratio evaluated for column members of size 550 mm x 550 mm with 2.077% reinforcement at few different selected locations at the ground level of the building under different combinations of load is given in Table 3.

From the table, it is observed that,

Effect of wind loading on the Interaction ratio on column members under any combination of dead, live and wind load is less than any combination of dead, live and seismic load. This is due to the heavier mass of the building which increases the seismic load on the

Table 3: Interaction Ratio of Column Members

Beam ID	Load Case	Axial Force kN	Mux1	Mux1	Muy1	Muy1	Interaction Ratio
95-7	1.5 DL+1.5 LL	3253.5	-11.3	-15.8	21.9	19.3	0.129
95-8	1.5DL+1.5EQ(X)	1797.7	112.2	185.3	14.5	16.1	0.303
95-9	1.5DL+1.5EQ(Z)	2852.1	-14.8	-15.3	203.2	241.5	0.424
95-10	1.5 DL+ 1.5 WL(X)	2248.6	22.2	25.3	20.6	18	0.091
95-11	1.5 DL+ 1.5 WL(Z)	2598.6	-19.3	-27.2	86.7	101.3	0.148
95-12	1.2 DL+1.2 LL+ 1.2 WL(X)	2491.3	18	19.4	18.8	18.7	0.096
95-13	1.2 DL+1.2 LL+ 1.2 WL(Z)	2771.2	-15.2	-22.5	71.7	85.4	0.126
95-14	1.2 DL+1.2 LL+ 1.2 EQ(X)	2130.5	90.1	147.5	14	17.2	0.224
95-15	1.2 DL+1.2 LL+ 1.2 EQ(Z)	2974	-11.6	-13	164.9	197.5	0.333
96-7	1.5 DL+1.5 LL	2467.7	0.2	5.5	29.2	24.9	0.095
96-8	1.5DL+1.5EQ(X)	1892.6	290.8	335.1	23.5	9.5	0.577
96-9	1.5DL+1.5EQ(Z)	2386.2	-3.5	1.3	201.2	233.3	0.378
96-10	1.5 DL+ 1.5 WL(X)	1935.6	70.2	83.9	26	13.9	0.136
96-11	1.5 DL+ 1.5 WL(Z)	2123.5	-19.2	-18.9	95.7	104.5	0.158
96-12	1.2 DL+1.2 LL+ 1.2 WL(X)	1967.3	56.3	69.2	25	21.7	0.115
96-13	1.2 DL+1.2 LL+ 1.2 WL(Z)	2117.6	-15.3	-13	80.7	94.2	0.144
96-14	1.2 DL+1.2 LL+ 1.2 EQ(X)	1932.9	232.7	270.2	23	18.1	0.449
96-15	1.2 DL+1.2 LL+ 1.2 EQ(Z)	2327.8	-2.7	3.1	165.1	197.2	0.307
109-7	1.5 DL+1.5 LL	4404.9	-4.9	-3.4	-11.7	-15.9	0.486
109-8	1.5DL+1.5EQ(X)	2495.4	88.9	168.6	-9.1	-14.9	0.257
109-9	1.5DL+1.5EQ(Z)	3316.8	-11.5	-17.6	385.9	390.4	0.998
109-10	1.5 DL+ 1.5 WL(X)	2931.6	21.9	21.4	-4.5	-8.4	0.11
109-11	1.5 DL+ 1.5 WL(Z)	3147	-8.3	-9.4	141.9	142.6	0.23
109-12	1.2 DL+1.2 LL+ 1.2 WL(X)	3432.8	18	16.1	-4.2	-7.8	0.144
109-13	1.2 DL+1.2 LL+ 1.2 WL(Z)	3605.1	-6.2	-8.5	112.9	112.9	0.21
109-14	1.2 DL+1.2 LL+ 1.2 EQ(X)	3083.8	71.6	133.9	-7.9	-13	0.21
109-15	1.2 DL+1.2 LL+ 1.2 EQ(Z)	3741	-8.7	-15.1	308.1	311.2	0.961

structure.

Interaction ratio on column members under Dead, live and seismic load is less when compared with Dead and seismic load combination. This is due to the reason that the live load in the structure reduces the moment induced due to seismic load condition.

The interaction ratio on the column members under seismic loading combination is always higher than any other combination. This indicates that the seismic loading always governs for the building with heavy mass even though at the higher wind speed locations.

Structural Steel Industrial Building: Loads considered in the model are dead load, live load, wind and seismic load. Loads are calculated as per relevant code of practice and it is applied at each corresponding member and node. The structure is analyzed with appropriate load combinations and the interaction ratio is evaluated only for columns at the ground floor level (Figures 7 and 8).

The structural steel industrial building is analysed for dead, live, wind and seismic load (Zone – III). The interaction ratio evaluated for column members for I section of Indian standard steel ISHB400 at few selected locations of the building under different combinations of load is given in Table 4 .

Figure 7: 3-D View of Column Layout

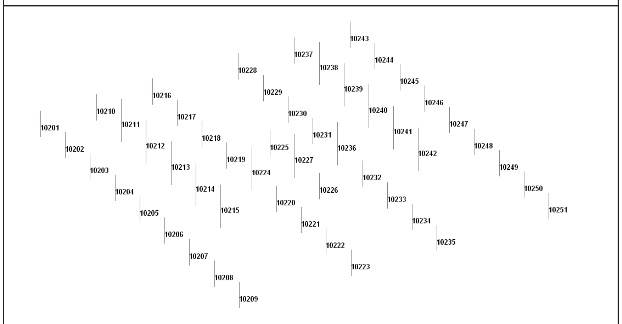


Figure 8: Plan View of Column Layout

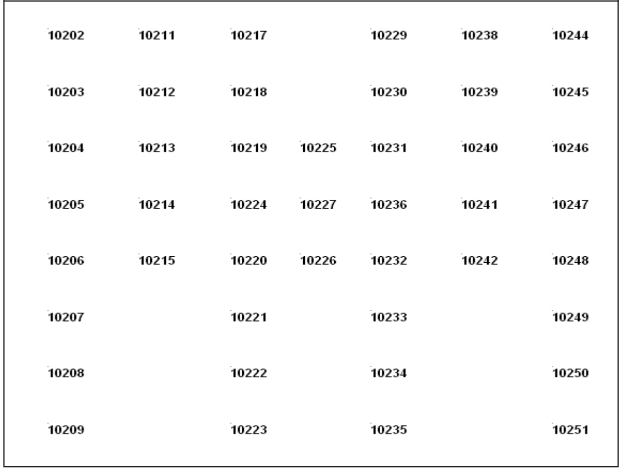


Table 4: Interaction Ratio of Column Members

Beam ID	Load Case	Axial Force	Moment Mxx	Moment Myy	Section	Interaction Ratio
10201	DL+LL	110.3	53.8	0.9	ISHB400	0.467
10201	DL+WL(0)	53.0	18.6	0.2	ISHB400	0.198
10201	DL+WL(90)	52.4	38.8	5.1	ISHB400	0.399
10201	DL+WL(180)	61.8	46.7	0.2	ISHB400	0.387
10201	DL+WL(270)	45.8	41.3	6.8	ISHB400	0.432
10201	DL+EQ(X)	56.2	27.6	0.7	ISHB400	0.267
10201	DL+EQ(Z)	53.3	38.2	11.8	ISHB400	0.500
10201	DL+LL+WL(0)	103.4	34.0	0.1	ISHB400	0.338
10201	DL+LL+WL(90)	102.8	54.2	4.9	ISHB400	0.517
10201	DL+LL+WL(180)	112.2	62.1	0.4	ISHB400	0.506
10201	DL+LL+WL(270)	96.2	56.6	7.0	ISHB400	0.606
10201	DL+LL+EQ(X)	106.6	43.0	0.9	ISHB400	0.403
10201	DL+LL+EQ(Z)	103.7	53.6	11.6	ISHB400	0.614
10202	DL+LL	219.8	65.4	0.3	ISHB400	0.688
10202	DL+WL(0)	91.8	44.6	0.7	ISHB400	0.426
10202	DL+WL(90)	98.3	38.4	5.5	ISHB400	0.471
10202	DL+WL(180)	109.0	74.9	0.4	ISHB400	0.570
10202	DL+WL(270)	87.3	41.7	6.1	ISHB400	0.485
10202	DL+EQ(X)	98.8	2.8	0.2	ISHB400	0.167
10202	DL+EQ(Z)	104.6	36.8	12.8	ISHB400	0.543
10202	DL+LL+WL(0)	207.7	15.9	0.6	ISHB400	0.405
10202	DL+LL+WL(90)	214.2	67.0	5.4	ISHB400	0.775
10202	DL+LL+WL(180)	224.9	103.5	0.3	ISHB400	0.903
10202	DL+LL+WL(270)	203.3	70.3	6.2	ISHB400	0.790
10202	DL+LL+EQ(X)	214.8	31.5	0.3	ISHB400	0.496
10202	DL+LL+EQ(Z)	220.6	65.5	12.7	ISHB400	0.904

From the table, it is observed that,

Effect of wind loading on the Interaction ratio on column members under any combination of dead, live and wind load is less than any combination of dead, live and seismic load. This is due to the heavier mass of the building which increases the seismic load on the structure.

Interaction ratio on column members under dead, live and seismic load is high when compared with dead and seismic load combination. This is due to the reason that the contribution of live load live to the seismic load in the structure is considerably higher when compared to ordinary residential building.

The interaction ratio on the column members under dead and wind or seismic loading combination is always lower than dead and live load combination. This is due to high live load of the industrial building.

CONCLUSION

Based on the study on three-dimensional analysis of different types of structural system using STAAD.Pro for evaluation of interaction ratio of the column and bracing members under different combinations of loading, the conclusions were derived as follows,

Structural Steel Latticed Roof Top Tower: Interaction ratio on bracing and column members under dead load and seismic combination is very less when compared with other combinations of load. This is because dead load (including self-weight and other permanent loads) acting on the steel latticed tower is very less when compared to reinforced concrete building. Seismic load acting on any structure is proportional to the dead load plus a percentage of live load. In case of tower structures the dead load component is very less which leads to lesser seismic force. It is also observed that even at higher seismic zones the effect of seismic load on the tower member is insignificant. Wind load plays a significant role in the design of tower members due to the geometry and the slenderness of the tower.

Reinforced Concrete Building (Symmetrical): Interaction ratio on column members under dead and wind load combination is less than the dead and seismic load combination. This is due to the reason that in case of residential concrete building the dead and live load acting on the building is high, which results in higher seismic load.

Similarly, the effect of interaction ratio on column members under dead and live load is same for different column positions, whereas the interaction ratio of column members under seismic load varies, i.e., for the corner and exterior column, the response under seismic loads will be high and for interior columns it is very less this is due to the lever arm distance of the columns from the centre of gravity of the building.

Reinforced Concrete Building (Unsymmetrical): Interaction ratio on column members under dead and wind load combination is less than the dead and seismic load combination. This is due to the reason that in case of concrete building the dead and live load acting on the building is high, which results in higher seismic load.

In unsymmetrical slender building, the concentration of seismic load is higher as the lumped mass at the higher levels will result in higher moment (force multiplied by height). This always results in higher interaction ratio on the column members under seismic loads.

Structural Steel Industrial Building: Interaction ratio on column members under dead, live and seismic load is high when compared with dead and seismic load combination. This is due to the reason that, generally the behavior of steel structures under seismic load is very insignificant when compared to wind load. This is not true when the magnitude of the live load acting on the structure is high. Due to this the seismic load becomes significant and it plays an important role in the design.

From the above conclusion, it is very well understood that Dead and live load plays a major role in the seismic load calculation. Slender steel structural systems are always governed by the wind load. Whereas, steel structural system with heavier live load, seismic load governs the design. In case of buildings with magnitude of dead load and live load is high, than the interaction ratio on the structural member under seismic load will be always governs and vice versa. Distribution of the seismic force to the structural members will be uniform if the columns are placed symmetrically. Non-uniform distribution of column forces will result in torsion in the structural components and the rate of damage will be very high.

It is also noted that interior columns in the structural system which is designed for seismic zone III is also adequate when it is checked under the seismic zone IV. The exterior columns in the same structural system which is found inadequate should be strengthened by using retrofitting to take care of the additional seismic load. This will avoid further damage to the structure and its components under higher unexpected earthquakes.

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