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Design, Analysis and Seismic Performance Evaluation of Industrial Junction Tower

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ABSTRACT: Junction towers are necessary to change the conveyor direction or the direction of material transportation in an industry. These tower are generally accommodated by the mechanical components like pulley, drive pulley, driving motors, belt conveyors etc. The height of this tower mainly depends upon the height of conveyor placed to carry the materials and also on the number of platforms. Junction Tower mainly consist of steel beams, columns and bracing system. Generally these transfer towers are designed to handle a variety of loads such as dead load, live load, wind load, earthquake load and load due to equipment and conveyor belt tension. Junction tower being a supporting structure need to be analyzed and designed with great importance. Therefore in this present study, a transfer tower of height 33 m with two platforms is designed and analyzed as per IS codal provision under gravity and lateral loads using STAAD Pro V8i SS5. Comparison is then made between working stress method and limit state method. The results so obtained through this study is further investigated to draw suitable conclusion.

KEYWORDS: Junction tower, Conveyor belt, Equipment loads, Bracings, Wind load, Working stress method, Limit state method, Seismic zones.

I. INTRODUCTION

Junction tower is a steel framed structure which is used in belt conveyor system i.e., in small and large scale industries, coal handling plants, iron ore transportation etc. In the junction tower the material flow from the main conveyor belt to another conveyor belt which helps in transfer of the material from one location to another location. Since it is used as a junction point to transfer the material from one conveyor belt to another conveyor belt in the system, therefore it is known as Transfer Tower. The junction towers also helps in transferring the materials from one belt conveyor to other belt conveyor going in two or more direction. The change of direction is achieved by dropping the material from upper level to lower level of conveyor running in different direction.

Basically the junction tower and its components are idealized as spaced frames composed of frame elements such as beams, columns and bracings. The floors of the junction tower is generally covered by chequered plates. This Structures is braced in all directions to transfer lateral loads to foundation and to reduce the moments and to control the deflection. The main loads acting on the structure like dead load, live load, conveyor with coal or ore loads are the transverse load which is transferred through beams and columns to the large area of footing and the bracings between the two columns helps to resist the seismic force and wind force.

II. MODEL DESCRIPTION

The dimensions of the junction tower that we are designing have the plan dimension of 6m×7.7m and a height of 33m. It is having double platform with the mono rail of capacity of 5000kg and contains a conveyor BC-10 having a belt tension of 3000kg. The first platform is at the elevation of 28.125m and second platform is at elevation 24.195m. The openings are provided for conveyor belt, Mono rail, and chute. The cladding is provided from 24.35m till the roof so the equipment's placed on the platform is covered. The roof is provided with the slope of 1 in 5 on either side. The dead load, live load, wind load acting on the junction tower is calculated as per the codes IS: 875 part1, part2, part3 respectively. The equipment loads and other few loads are considered as given by the company's recommendations.

Figure 1 to 5 shows the plan and elevation of the developed junction tower model.

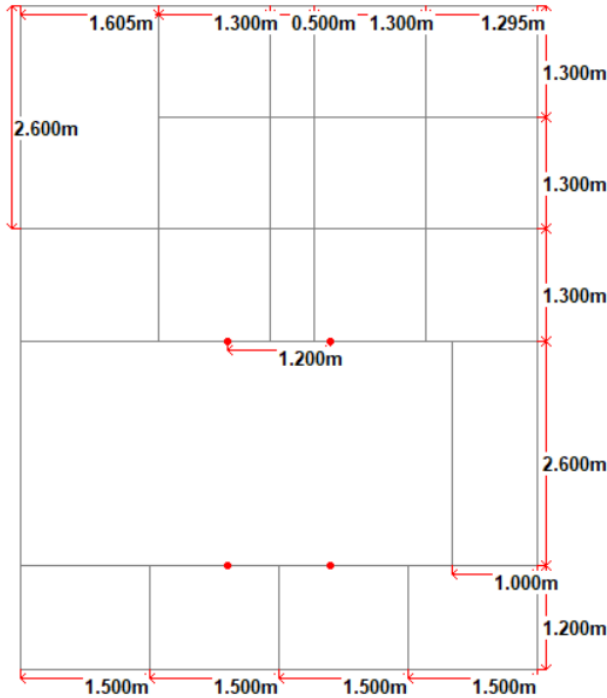


Fig. 1 Plan of Platform - 1

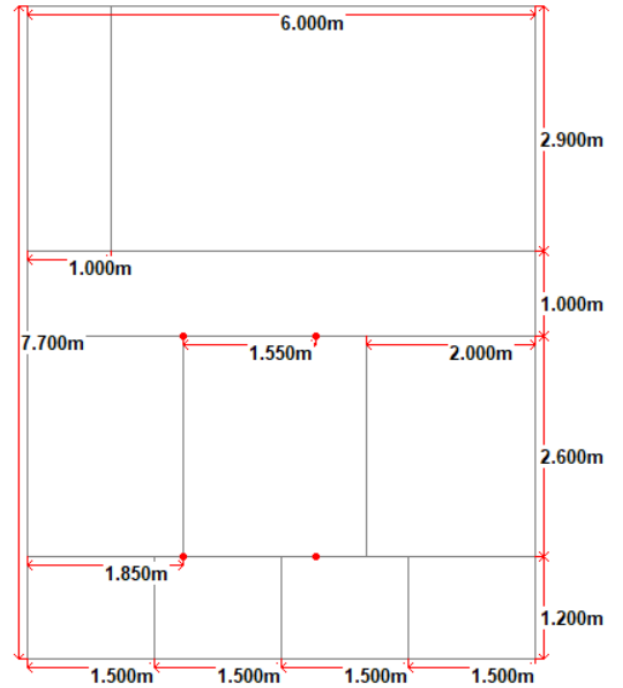


Fig. 2 Plan of Platform - 2

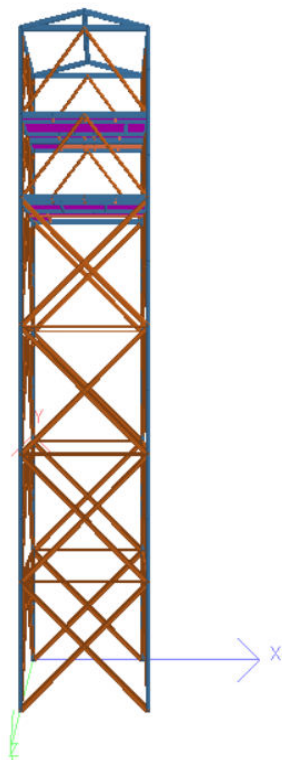


Fig. 3 Elevation along X-direction

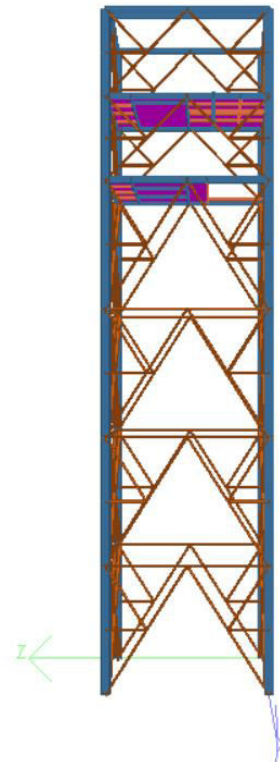


Fig. 4 Elevation along Z-direction

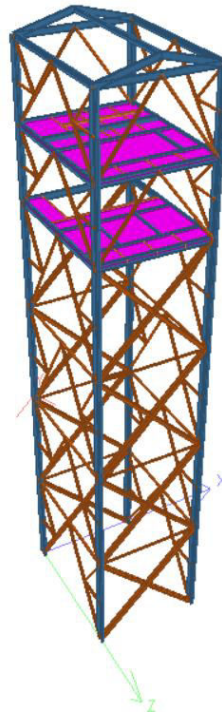


Fig. 5 3D model of the Transfer Tower

III. CALCULATION OF LOADS AND SEISMIC ANALYSIS

By considering the following data, the loads on beams, columns and bracings are calculated and designed in both working stress method and limit state method and they are compared.

Loads on Platform

DL includes beams on the floor and chequered plates with stiffeners which is taken as 100 kg/m².

LL on the platform is taken as 500 kg/m² (as per clause 3.2.1.1 of IS 875 (Part 2)-1981).

Loads on Roof

Dead Load involves

Self-weight of the sheet = 8 kg/m²

Self-weight of the rafter = 15 kg/m²

Self-weight of the purlins = 15 kg/m²

Self-weight of the bracings = 5 kg/m²

Total DL on the roof = 43 kg/m²

Live Load involves

LL considered on the roof for 1:5 slope = 75 kg/m²

Dust load = 50 kg/m²

Total LL on the roof = 125 kg/m²

Side Sheetting Load

Load due to side sheetting = 15 kg/m²

Hand Railing Load

Load due to hand railing loads = 15 kg/m²

Staircase Load

Load due to staircase of width 1m = 200 kg/m²

Wind Load

Wind load is calculated as follows,

Design wind speed $V_z = V_b k_1 k_2 k_3$ (Clause 6.3 of IS 875 (Part 3): 2015)

Where, V_z = design wind speed at height z, in m/s.

V_b = basic wind speed, m/s

k_1 = probability factor



k_2 = terrain roughness and height factor

k_3 = topography factor

Wind pressure is given by, $P_z = 0.6 V_z^2$ (from Clause 7.2)

Table. 1 Design wind pressure P_z at various height

Height (in m)	k_2	V_z (in m/s)	P_z (N/m ²)	P_z (kg/m ²)	P_z (kN/m ²)
10	1.00	34.65	720.37	73.48	0.720
15	1.05	36.38	794.10	81.00	0.794
20	1.07	37.08	824.96	84.15	0.824
30	1.12	38.81	903.73	92.18	0.903
50	1.17	40.54	986.10	100.58	0.986

Table. 2 Total load on each column (in kg)

Column	DL	LL	Belt tension in X-direction		Wind in X-direction		Wind in Z-direction	
			P	Qx	P	Qx	P	Qz
1	10470	29688	8268	684	29310	5031	20395	4336
2								
3								
4								

Table. 3 Total load on each column (in kN)

Column	DL	LL	Belt tension in X-direction		Wind in X-direction		Wind in Z-direction	
			P	Qx	P	Qx	P	Qz
1	103	292	81	7	288	50	200	43
2								
3								
4								

Table. 4 Comparison of column sections

Columns	Condition	Column section in WSM	Column section in LSM
1, 2, 3 and 4	With lateral bracings	ISMB 500	ISMB 400
1, 2, 3 and 4	Without lateral bracings	ISMB 600	ISMB 550

Table. 5 Comparison of Platform-1 beams between WSM and LSM (With lateral bracings)

Details of Platform Beams		
Beam No	Section of WSD	Section of LSD
1	ISMB 350	ISMB 300
2	ISMB 300	ISMB 250
3	ISMB 300	ISMB 250
4	ISMB 500	ISMB 400
5	ISMC 300	ISMC 300
6	ISMB 350	ISMB 300
7	ISMB 350	ISMB 300
8	ISMB 300	ISMB 250
9	ISMC 200	ISMC 150
10	ISMC 200	ISMC 150
11	ISMC 200	ISMC 150
12	ISMC 200	ISMC 150



13	ISMC 200	ISMC 150
14	ISMB 350	ISMB 300

Table. 6 Comparison of Platform-1 beams between WSM and LSM (Without lateral bracings)

Details of Platform Beams		
Beam No	Section of WSD	Section of LSD
1	ISMB 350	ISMB 250
2	ISMB 300	ISMB 250
3	ISMB 300	ISMB 250
4	ISMB 300	ISMB 250
5	ISMC 400	ISMC 300
6	ISMB 350	ISMB 250
7	ISMB 350	ISMB 250
8	ISMB 300	ISMB 250
9	ISMC 175	ISMC 150
10	ISMC 175	ISMC 150
11	ISMC 175	ISMC 150
12	ISMC 175	ISMC 150
13	ISMC 175	ISMC 150
14	ISMB 350	ISMB 250

Table. 7 Comparison of Platform-2 beams between WSM and LSM (With lateral bracings)

Platform Beams Detailing		
Beam No	Section of WSD	Section of LSD
1	ISMB 350	ISMB 250
2	ISMB 300	ISMB 200
3	ISMB 300	ISMB 200
4	ISMC 350	ISMC 300
5	ISMB 350	ISMB 250
6	ISMB 350	ISMB 250
7	ISMC 200	ISMC 150
8	ISMB 300	ISMB 200
9	ISMB 300	ISMB 200
10	ISMC 200	ISMC 150
11	ISMB 350	ISMB 250

Table. 8 Comparison of Platform-2 beams between WSM and LSM (Without lateral bracings)

Platform Beams Detailing		
Beam No	Section of WSD	Section of LSD
1	ISMB 350	ISMB 300
2	ISMB 300	ISMB 250
3	ISMB 300	ISMB 250
4	ISMC 400	ISMC 300
5	ISMB 350	ISMB 300
6	ISMB 350	ISMB 300
7	ISMC 175	ISMC150
8	ISMB 300	ISMB 250
9	ISMB 300	ISMB 250
10	ISMC 175	ISMC 150
11	ISMB 350	ISMC 300



Table. 9 Comparison of bracings in X-direction between WSM and LSM (With lateral bracing)

At level	Bracing	Section in WSM	Section in LSM
6.045 m	Horizontal	70 x 70 x 10 (SD)	65 x 65 x 6 (SD)
	Diagonal	200 x 200 x 16 (SD)	200 x 200 x 16 (SD)
24.195 m	Diagonal	100 x 100 x 10 (SD)	100 x 100 x 10 (SD)

Table. 10 Comparison of bracings in Z-direction between WSM and LSM (With lateral bracing)

At level	Bracing	Section in WSM	Section in LSM
6.045 m	Horizontal	70 x 70 x 10 (SD)	65 x 65 x 6 (SD)
	Diagonal	110 x 110 x 10	110 x 110 x 10
24.195 m	Diagonal	110 x 110 x 10	110 x 110 x 10

Table. 11 Comparison of bracings in X-direction between WSM and LSM (Without lateral bracing)

At level	Bracing	Section in WSM	Section in LSM
6.045 m	Horizontal	100 x 100 x 10 (SD)	100 x 100 x 8 (SD)
	Diagonal	200 x 200 x 16 (SD)	200 x 200 x 16 (SD)
24.195 m	Diagonal	100 x 100 x 10 (SD)	100 x 100 x 8 (SD)

Table. 12 Comparison of bracings in Z-direction between WSM and LSM (Without lateral bracing)

At level	Bracing	Section in WSM	Section in LSM
6.045 m	Horizontal	100 x 100 x 10 (SD)	100 x 100 x 8 (SD)
	Diagonal	200 x 200 x 12	200 x 200 x 12
24.195 m	Diagonal	200 x 200 x 12	200 x 200 x 12

Under the seismic analysis, the behavior of the junction tower subjected to the action of the earthquake loads located in different zones i.e. in Zone II, Zone III, Zone IV and Zone V are examined.

The following elements were taken into consideration while performing the analysis.

Importance factor, I = 1.5

Response reduction factor, R = 5

Soil type = Type II (medium soil)

Damping = 5%

Load combination is considered as per IS 800: 2007 and IS 1893 (Part I): 2016

IV. RESULTS AND DISCUSSION

Graph Fig. 6 to Fig. 9 represents the variation of the section depth in Platform-1 and Platform-2 between WSD and LSD with and without lateral bracings. Table 13 represents the comparison made between the steel take off in working stress method and limit state method. Fig. 10 shows the average displacement in junction tower. Fig. 11 shows the storey drift in junction tower.

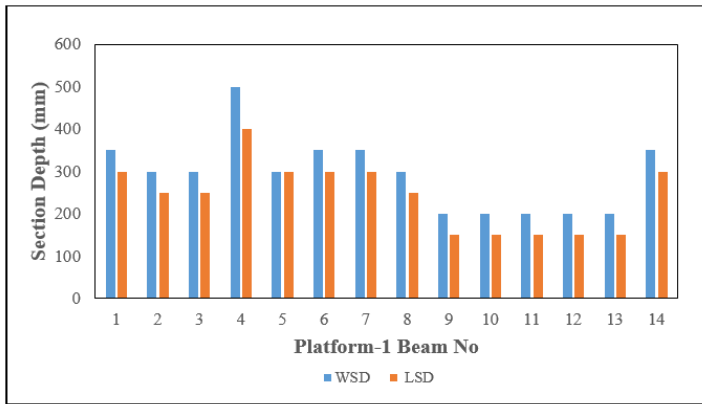


Fig. 6 Variation of section depth in Platform-1 between WSD and LSD (With lateral bracings)

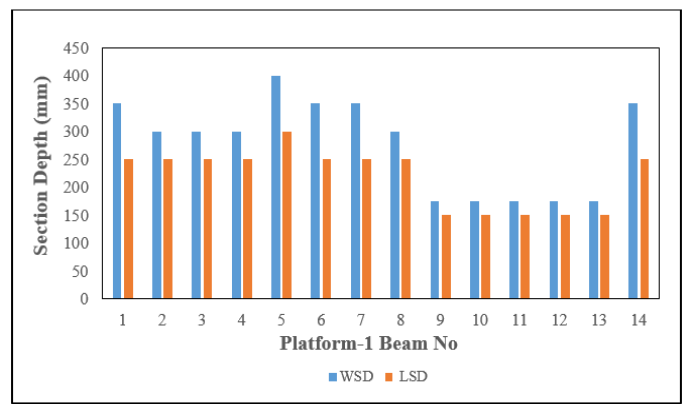


Fig. 7 Variation of section depth in Platform-1 between WSD and LSD (Without lateral bracings)

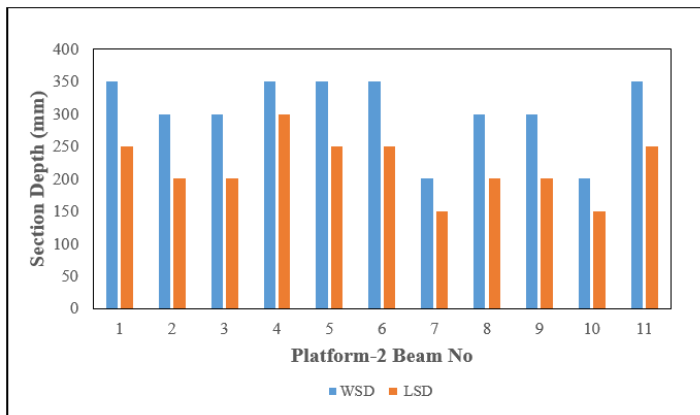


Fig. 8 Variation of section depth in Platform-2 between WSD and LSD (With lateral bracings)

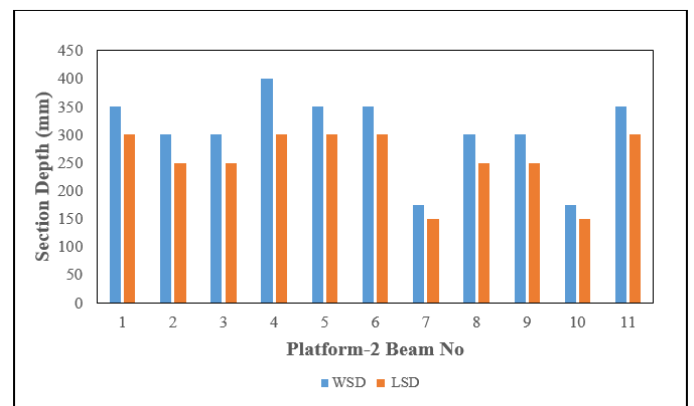


Fig. 9 Variation of section depth in Platform-2 between WSD and LSD (Without lateral bracings)

Table. 13 Comparison of Steel Take off

Conditions	Steel Take off in WSM		Steel Take off in LSM	
	In kN	In Tonnes	In kN	In Tonnes
With lateral bracings	391.962	40.00	325.812	33.23
Without lateral bracings	451.028	46.00	428.427	43.70

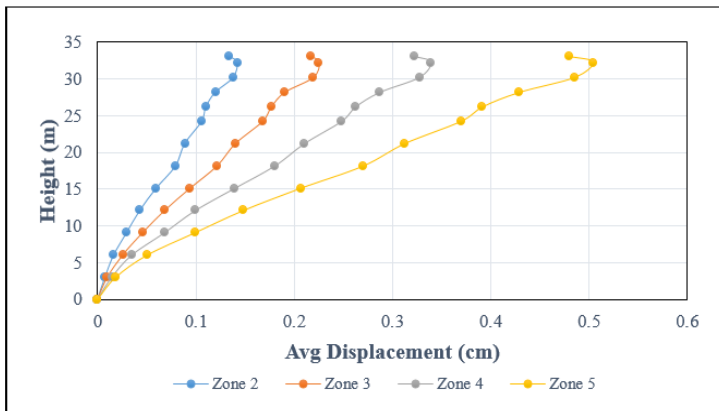


Fig. 10 Average Displacement in Junction Tower

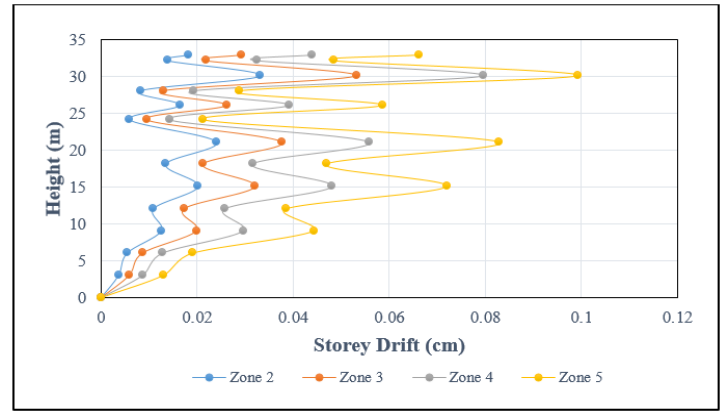


Fig. 11 Storey Drift in Junction Tower

The following are significant findings from the above investigations:

- Since the limit state designs are produced by multiplying the loads by a factor of 1.5, they will withstand a greater load than the working stress design section.
- From Fig. 6, when the limit state method is used in place of the working stress method to design Platform-1 beams which built with lateral bracing, the section depth is lowered by 18.01%.
- From Fig. 7, the section depth of Platform-1 beams that are developed without lateral bracings is typically reduced by 19.81% when designed using limit state method rather than working stress method.
- From Fig. 8, when the limit state design is used to design Platform-2 beams rather than the working stress method, the section depth of the beams that are built with lateral bracings is typically lowered by 28.35%
- From Fig. 9, there is an average decrease of 16.13% in the section depth of the Platform-2 beams that are developed without lateral bracing, when designed in the limit state method compared to the working state method.
- Even for the column sections, the sectional depth are reduced by 20% and 8.33% for with and without lateral bracings respectively, when designed by limit state method.
- We can infer from the above information that the working stress method design will result in heavier section than the limit state design. As a result, the limit state sections consume less material and are therefore more efficient for the specified load conditions.
- From Fig. 10, Zone II, III, IV and V, experiences the maximum displacement of 0.1423 cm, 0.2249 cm, 0.3389 cm and 0.5042 cm respectively. As a result, the maximum displacement rises with increasing seismic zones.
- And also in the average displacement rises as the junction tower’s height increases up to 32.3m, after which it slides down.
- From Fig. 11, following the same pattern of increasing values for higher seismic zones, a larger value of storey drift is observed at a height of 30.17 m from the base of the junction tower.

V. CONCLUSIONS

In the current study, analysis and design of the junction tower is carried out by using the STAAD Pro software. Comparison between the sections designed by working stress method and limit state method is executed. And the following conclusions are drawn:

- The working stress method design will result in a heavier section than the limit state design. As a result, the limit state sections consume less material and are therefore more efficient for the specified load conditions.
- The limit state method is more cost-effective than the working stress method.
- The lightweight sections produced by the limit state approach are ideal for improving a structure’s performance during earthquake.
- With an increase in earthquake zones, the junction tower gradually experiences more disturbance.
- In comparison to higher seismic zones, zone II will experience less displacement and drift due to lower seismic force value

- The structure may need to adopt adequate earthquake resistant measures (such as damping) for a better performance to overcome the increased displacements in higher seismic zones.

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