Seismic Assessment of Junction Tower Using Response Spectrum Method

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Abstract- *The good performance of Nonlinear Static Procedures on the seismic assessment of bridges and frames structures is nowadays generally recognized. However, the usage of such methods in the case of junction towers has until now been considered by a limited number of authors. This fact limits the application of Dynamic analysis to junction tower. In order to obtain suitable elements of comparison between different methods, the performance of dynamic analysis is estimated. To plan a Junction tower and a Response Spectrum analysis are proposed. The design involves load calculations manually and evaluating the whole structure by STAAD Pro. The design methods used in STAAD-Pro analysis are Limit State Design meeting the requirements to Indian Standard Code of Practice. The structure was subjected to self-weight, dead load, live load, wind load and seismic loads under the load case details of STAAD.Pro. Seismic load calculations were done following IS 1893-2007. The codes of practice to be followed were also specified for design purpose with other significant information. The critical members are found out using the utility check. From the analysis it found that the structural displacements in both X and Z direction is within the limit.*

Keywords- Base Shear, Natural Frequency, Mass participation Factor, Peak Storey Shear, Response Spectrum method.

I. INTRODUCTION

An earthquake is the vibrating of the surface of the earth, resultant after the unexpected discharge of energy in the Earth's lithosphere, which will produces seismic waves. Underground eruptions are calculated using the instrument seismometers. In the ground's surface., volcanic activity apparent themselves by vibrating & some dislocation of the ground & its most overall wisdom, the word earthquake is used to define any seismic occurrence, whether it is natural or it is affected by persons which creates seismic waves. The comportment of a building throughout underground eruption, be subject to analytically on its complete shape, size and geometry, in addition to, how the earthquake forces are carried to the ground. Hereafter, at the forecasting stages itself, architects & structural engineers must work together to confirm that the disapproving structures are evaded & a virtuous erection outline is taken.

Dynamic analysis would be incorporated in a routine built Seismic Design philosophy. It is generally recognized that, structural design within these deformation-based criteria, using performance-based design procedures, are more likely to behave reasonably in seismic scenarios than the structural design allowing to the classic force-based philosophy. It is also widely accepted that performance criteria can be better controlled by evaluating the deformations in the structure, both at global and component levels. Static Procedures are supposed to be actual practical, tools to consider the seismic routine of structures. On the further side, dynamic response spectrum analysis is done, which is an applicable drawback in design offices, where the deadlines are preventive.

Several scientific studies were developed representative the good performance of some dynamic procedure on the seismic assessment of relatively simple, structures such as regular buildings capable of being analyzed by planar frames and bridges. Though, certain issues silent need to be simplified concerning the layout with which the dynamic analysis has to be executed, thus lacking extra research and development. The positive outcome from recent research seems to indicate that it is certainly useful to continue to pursue the further development and verification of dynamic procedures taking a further step with the response spectrum analysis, with the objective of arriving at an ultimate introduction in seismic design codes and regulations of improved procedures capable of distributing with plan, irregular structures. A tower is a tall structure, taller than it is wide. The good routine of dynamic procedures on the earthquake valuation of bridges and frames structures is nowadays generally familiar. However, the usage of such approaches in the case of junction towers has studied by a limited number of authors. To overcome this fact, the application of response, spectrum analysis procedure to junction tower had been proposed. In present work, the junction tower is subjected to ground motions. The model is created and the static analysis & a response spectrum analysis are executed using the structural and design software STAAD Pro.

1. RESPONSE SPECTRUM ANALYSIS:

The use of dynamic processes for the earthquake assessment of planar frames & bridges has become very popular amongst the structural, engineering community. The reason for their success lies in the possibility of gaining a significant awareness into the dynamic earthquake behavior of structures in a simple and practical way. This methodology documents the multi- modes of response of an erection to be taken into reflection. This is essential in many structure codes, for all except for very minor or complex, structures. The structural response can be conveyed as a combination of modes. STAAD.Pro analysis can be used to initiate these ways for a structure. Succeeding are the categories of combination

- Absolute **-** peak values
- Square root of the sum of the squares (SRSS)
- Complete quadratic combination (CQC) **-** a system i.e., an expansion on SRSS for closely spaced modes

The end results of a response, spectrum method exploration; powdered motion is normally dissimilar after that which would be planned conventional from a linear active study using that earth motion, because information of the period is lost in the route of creating the response spectrum.

2. SCOPE OF PROJECT

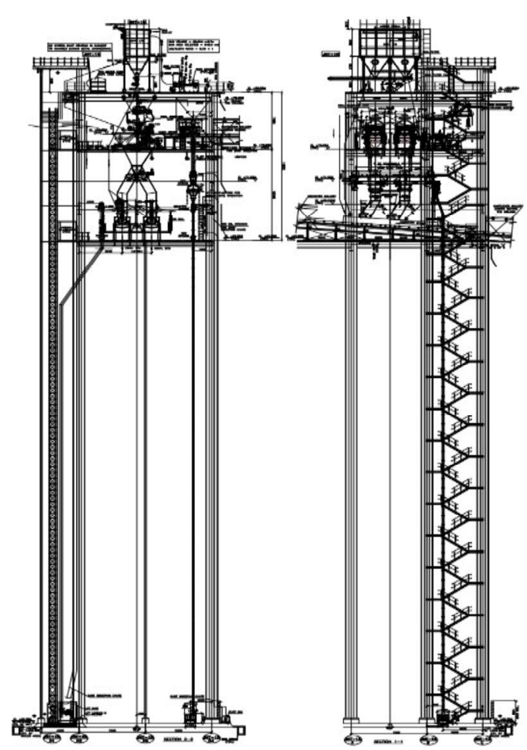
The work of dynamic procedure in the seismic valuation & design of structures had been increased substantial approval in recent years, assisted by a great number of wide verification studies, that have established their relatively better precision in assessing the seismic response of regular structures. However, the extension of such use to the case of junction tower has been the object of only restricted analysis, which effectively ends up by limiting significantly employment of dynamic procedure to assess tower structures. With these few studies were typically concentrated on the application and verification of a single dynamic procedure only, rather than providing a virtual appraisal of the altered available methodologies describing their relative accuracy and limitations. In order to obtain beneficial features with comparison between different methodologies, the performance of commonly employed dynamic procedures is evaluated in this work.

Following are the objectives of carrying out analysis and design of junction tower:-

- Static analysis for junction tower according to IS codes.
- Dynamic analysis (Response Spectrum analysis) for tall structure likewise junction tower according to IS codes.
- Design for dynamic loads, seismic loads and also for dynamic effect of wind loads.
- The peak factor percentage & base shear are calculated and compared with each other.

II. SYSTEM DESCRIPTION

The structure which is considered in this research is a Junction tower that is fully built-up by steel structure. The structure consists of steel joints with bracing system. The typical elevation of the structure which has connection with the other structure in the project plant is shown in the figure below. It consist of sweeping chute opening, trump iron opening, opening of reject chute and lift opening. Also conveyor 37A & 37B and screw conveyor are supported. S2 & S3 are the support of the conveyor 37A and 37B. This conveyor helps in processing of transmission of coal from one conveyor to other conveyor. Also some floors have portion is given for landing to maintenance purposes. This conveyor plays vital role for the process of collecting coal from conveyor 37A &37B which will give another output to the next equipment. These materials are sent through the screw conveyors. Here tramp iron chute opening is provided which helps in supporting the conveyor. There are two coal sampling units in the structure.



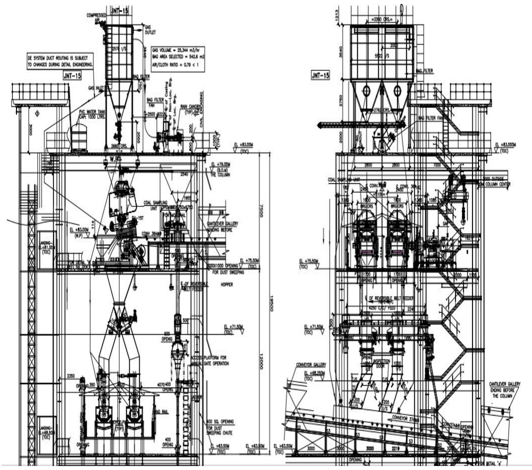


Figure 1. Elevation of Junction Tower

1. METHODOLOGY

1. The structure is completely is built by steel structure. The steel columns and beams are connected with the help of welding connections. Most of the section that is considered is built-up section.
2. The foundation is connected with the help of base plate and is connected using bolted connection.
3. Model is created in Staad Pro. Software. The loading are applied to it and the model is analyzed.
4. Steel columns & beams were modeled as 2D Stick elements connecting these concrete elements in continuity.
5. Seismic Response Spectrum method was used for generation of seismic loads which were used in the static analysis of Structure.

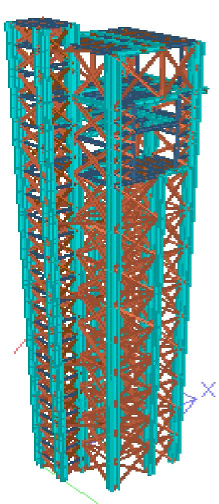


Figure 2. Isomeric View Of Junction Tower

III. ANALYSIS

STATIC ANALYSIS –

The single/integrated model combining the steel columns & beams & bracings &the soil was assessed by using Staad Pro V8i software. Static analysis was performed according to the loadings with dead load, imposed load, wind loads, seismic loads. In addition to the above loads, equipment's loads, temperature loads were also analyzed.

DEAD LOADS:

The unit weights, of plain concrete & reinforced concrete made with sand and gravel or crushed natural stone aggregate could be taken as 24kN/m² and 25kN/m² respectively. Self-weight of structural system and soil mass of height 12.2m is applied on the raft as soil load 244kN/m²

LIVE LOAD/IMPOSED LOAD:

Live load applied upon the structure is floor load of 7kN/m² (This floor load is distributed as one way) on each floor level.

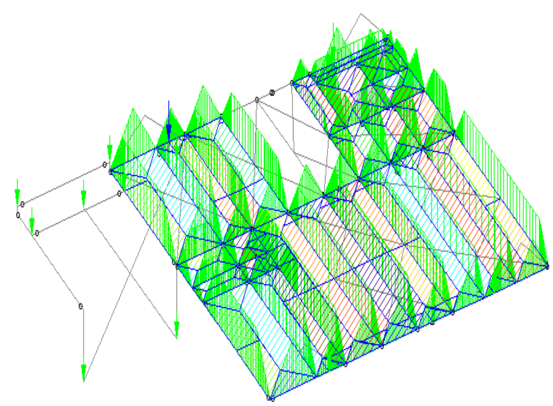


Figure 3. Live Load Application

Seismic loads are applied as full dead load and 50 percent of live load of structure in all three directions.

Load combinations

Load combinations for static & dynamic analysis are according to IS 800-2007 is as shown below.

Table 1. Load Combinations

Load combination	Limit state of collapse							Limit state of serviceability						
	DL	IL	CL	MRL	TL	WL	EL	DL	IL	CL	MRL	TL	WL	EL
DL+IL+CL+ MRL+TL	1.5	2	1	1	1	-	-	1	1	1	-	-	-	-
DL+IL+CL+ MRL+TL+WL	1.2	1	1	1	1	1.2	-	1	1	1	-	-	0.8	-
DL+IL+CL+ MRL+TL+EL	1.2	1	1	1	-	-	1.2	1	1	1	-	-	-	0.8
DL+WL+TL	0.9	-	-	-	1	1.5	-	1	-	-	-	-	0.8	-

Note:

DL= Dead load; IL= Imposed load; CL= component load; TL= Temperature load; WL=Wind load; EL= Earthquake load; MRL=Monorail load;

Static Analysis Results

Table 2. Deflection Check and Story Drift

			Horizontal	Vertical	Horizontal	Resultant
	Node	L/C	X(mm)	Y(mm)	Z(mm)	mm
Max X	542	1935DL+LL	81.925	-19.683	-84.024	118.992
Min X	542	11051 0.85DL	-71.387	12.231	86.900	113.125
Max Y	343	11267 0.85DL	67.151	21.813	-79.809	106.558
Min Y	354	1830DL+LL	-0.436	-74.282	49.772	89.416
Max Z	542	11307 0.85DL	-61.292	-18.928	91.007	111.343
Min Y	544	47 DYN.L	68.560	5.931	-87.359	111.208

IV. RESPONSE SPECTRUM ANALYSIS

1. DYNAMIC ANALYSIS

These discover exposures in a runtime background. It will be achieved, to get the project seismic force & its scattering toward dissimilar stages, laterally with the elevation of the structure & to the numerous lateral load resisting elements for the following structures:

- **Regular structure: -** The structures > 40m, in elevation in zones IV and V and those > 90m in height in zones II and III.
- **Irregular structures: -** Those < 40m in elevation in zones II and III, dynamic analysis even yet not compulsory, is suggested.

The number of modes to be assumed in the analysis should be such that the sum of the overall modal masses of all modes considered is at least 90% of the total seismic mass and the missing mass correction beyond 33%.If modes with natural frequency beyond 33 Hz are to be considered, modal combination shall be taken out only for modes up to 33 Hz.

The response spectrum provided a convenient and practical way to sum up the frequency content of a given acceleration, velocity or displacement. It provides a practical manner to apply the understanding of structural dynamics to design of structures and improvement of lateral force requirements in building codes as per IS standard.

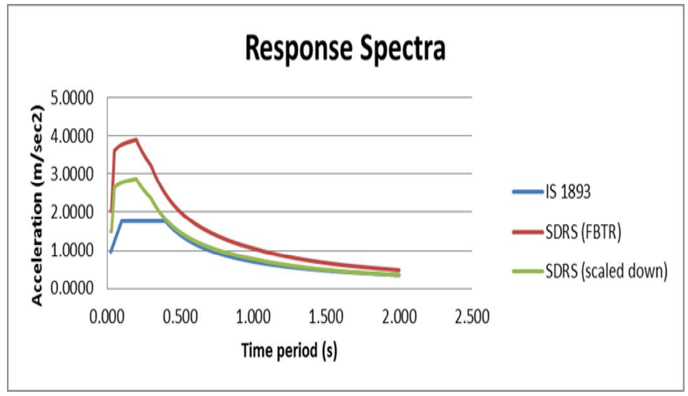


Figure 4. ACCELERATION VS TIME PERIOD

The strength design is carried out according to IS 800-2007. In this technique of design the structure, is to design with stand safely for all loads likely to act on it through itself. The suitable boundary, for security and serviceability supplies already miscarriage happens is called a limit state. The main aim of design is, to succeed adequate chances that the structure will not become unsuited for the practice for which it is proposed, i.e., it will not reach a limit state.

All design parameters are set in the respective analysis models and design checks were did in the Staad Pro software. Following were the out puts of the same. However one beam and one column are checked manually to provide the design satisfaction.

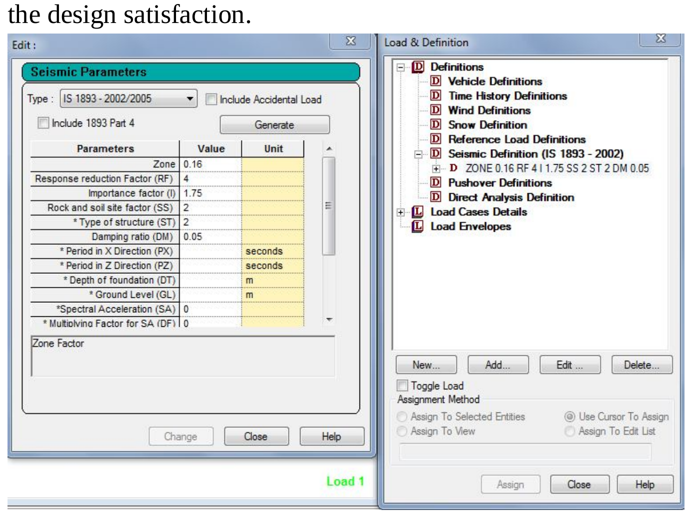


Figure 5. SESIMIC LOADING

Then an extreme value of the scale down ratio was multiplied with time histories corresponding to design of spectrum and a scale down time history which was well-suited with the IS 1893 Design spectrum was used, in the response analysis.

DYNAMIC LOADING:

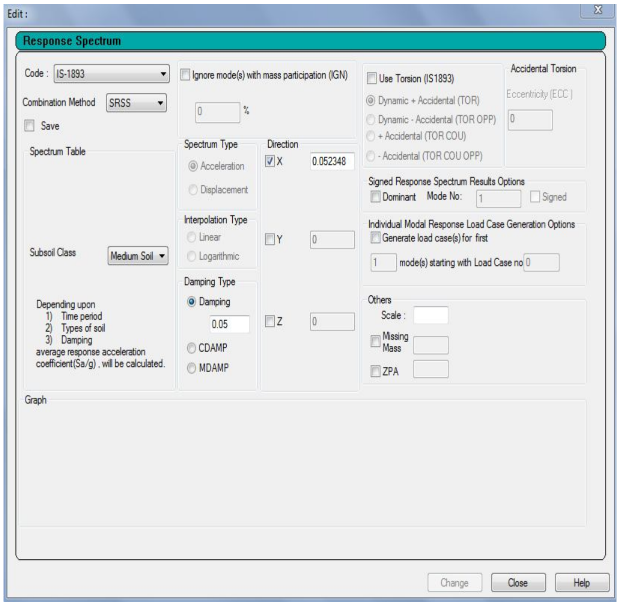


Figure 6. Loading Type of Response Spectrum

- Seismic load will applied on all 3 directions and as per code IS-1893 by combined method of SRSS method. By considering the medium soil.
- ZPA- Zero period acceleration and missing mass in structure will generate in response analysis.

V. OUTPUT FROM RESPONSE SPECTRUM ANALYSIS

1. NATURAL FREQUENCY

Table 3. NATURAL FREQUENCY IN X DIRECTION

MODE	FREQUENCY	PERIOD (seconds)
1	1.348	0.74168
2	1.543	0.64828
3	2.057	0.48606
4	2.301	0.43453
5	2.382	0.41987
6	2.498	0.40035
7	2.526	0.39590
8	2.537	0.39422
9	3.469	0.28824
10	4.001	0.24992
11	4.022	0.24861
12	4.023	0.24859
13	4.023	0.24858
14	4.023	0.24858
15	4.564	0.21912
16	5.254	0.19033
17	5.406	0.18498
18	5.646	0.17712
19	5.703	0.17536
20	5.892	0.16971
21	7.059	0.14165
22	7.269	0.13756
23	7.344	0.13617
24	7.405	0.13505
25	7.473	0.13382

Table 4. Natural frequency in Z direction

A. *MODE*	***B.*** *FREQUENCY*	***C.*** *PERIOD (seconds)*
1	1.101	0.90836
2	1.259	0.79398
3	1.680	0.59529
4	1.879	0.53218
5	1.945	0.51423
6	2.039	0.49033
7	2.062	0.48488
8	2.071	0.48281
9	2.833	0.35302
10	3.267	0.30608
11	3.284	0.30448
12	3.285	0.30446
13	3.285	0.30445
14	3.285	0.30445
15	3.726	0.26836
16	4.290	0.23311
17	4.414	0.22656
18	4.610	0.21693
19	4.656	0.21477
20	4.811	0.20785
21	5.764	0.17349
22	5.935	0.16848
23	5.996	0.16678
24	6.046	0.16540
25	6.102	0.16389

2. MASS PARTICIPATIONS

Mass Participation Factors and Missing Mass Mode

Missing masses in several residual modes were included in the Staad Response Spectrum analysis. It was distinguished that the relative importance of every mode at resonance to the numerous misplaced mass was not greater than 1 and hence it was noted that the frequency of various modes, didn't increase when it reverberates with these missing mass modes. Which additional shows that these missing mass in the corresponding modes does not cause any dynamic extension and the response of the structure under these rigid modes would be similar as ground motion responses or simply the structure experience same displacements as the ground motion displacements.

Table 5. Mass Participation Factor in X-Direction

MODE SHAPE	X	Y	Z	SUM - X	SUM - Y	SUM - Z
481	0	0	0	99.634	96.383	99.330
482	0	0	0	99.634	96.385	99.330
483	0	0.01	0	99.635	96.391	99.331
484	0	0.01	0	99.636	96.400	99.332
485	0.01	0.01	0	99.646	96.412	99.333
486	0	0.02	0	99.647	96.428	99.333
487	0	0	0	99.647	96.429	99.333
488	0	0.02	0	99.647	96.446	99.334
489	0	0	0	99.647	96.448	99.334
490	0	0	0	99.647	96.449	99.334
491	0	0	0	99.647	96.449	99.335
492	0	0	0	99.647	96.453	99.335
493	0	0.01	0	99.647	96.459	99.335
494	0	0.01	0	99.648	96.472	99.338
495	0	0	0	99.648	96.475	99.338
496	0	0	0	99.648	96.476	99.340
497	0	0	0	99.648	96.477	99.341
498	0	0.02	0	99.648	96.496	99.342
499	0	0.02	0.01	99.649	96.517	99.350
500	0	0.01	0	99.650	96.527	99.350
ZPA	0.35	0	0	100	0	0

Table 6. Mass Participation Factor in Z-Direction

MODE SHAPE	X	Y	Z	SUM - X	SUM - Y	SUM - Z
481	0	0	0	99.634	96.383	99.330
482	0	0	0	99.634	96.385	99.330
483	0	0.01	0	99.635	96.391	99.331
484	0	0.01	0	99.636	96.400	99.332
485	0.01	0.01	0	99.646	96.412	99.333
486	0	0.02	0	99.647	96.428	99.333
487	0	0	0	99.647	96.429	99.333
488	0	0.02	0	99.647	96.446	99.334
489	0	0	0	99.647	96.448	99.334
490	0	0	0	99.647	96.449	99.334
491	0	0	0	99.647	96.449	99.335
492	0	0	0	99.647	96.453	99.335
493	0	0.01	0	99.647	96.459	99.335
494	0	0.01	0	99.648	96.472	99.338
495	0	0	0	99.648	96.475	99.338
496	0	0	0	99.648	96.476	99.340
497	0	0	0	99.648	96.477	99.341
498	0	0.02	0	99.648	96.496	99.342
499	0	0.02	0.01	99.649	96.517	99.350
500	0	0.01	0	99.650	96.527	99.350
ZPA	0.35	0	0	100	0	0

3. PEAK STOREY SHEAR

Table 7. Peak Storey shear in X-Direction

STOREY	LEVEL IN METER	PEAK STOREY SHEAR IN kN	
		X	Z
15	86.00	14.73	0.00
14	83.00	90.68	0.00
13	75.50	206.50	0.00
12	71.25	267.65	0.00
11	69.50	274.89	0.00
10	68.25	300.45	0.00
9	63.50	363.06	0.00
8	56.00	417.07	0.00
7	49.00	465.59	0.00
6	42.00	508.76	0.00
5	35.00	545.34	0.00
4	28.00	580.86	0.00
3	21.00	608.96	0.00
2	14.00	630.52	0.00
1	7.00	641.41	0.00
Base	0.00	642.13	0.00

Table 8. Peak Storey shear in Z-Direction

STOREY	LEVEL IN METER	PEAK STOREY SHEAR IN kN	
		X	Z
15	86.00	0.00	18.37
14	83.00	0.00	122.74
13	75.50	0.00	240.49
12	71.25	0.00	300.48
11	69.50	0.00	308.59

10	68.25	0.00	335.68
9	63.50	0.00	402.86
8	56.00	0.00	457.32
7	49.00	0.00	506.64
6	42.00	0.00	553.54
5	35.00	0.00	596.86
4	28.00	0.00	642.82
3	21.00	0.00	681.42
2	14.00	0.00	711.89
1	7.00	0.00	727.83
Base	0.00	0.00	728.90

4. BASE SHEAR OUTPUTS

a) Base Shear for the Junction tower case for seismic mass in X direction from response spectrum

TOTAL SRSS BASE SHEAR = 642.13kN
TOTAL 10PCT BASE SHEAR= 644.48 kN
TOTAL ABS BASE SHEAR= 1172.84 kN
TOTAL CSM BASE SHEAR = 666.86 kN

b) Base Shear for the Junction tower case for seismic mass in X direction from Empirical formula:

Time Period for X-Direction 1893 Loading = 2.40045 Sec
Sa/g as per 1893 = 0.567, Load Factor= 1.000
Factor 'V' as per 1893= 0.0198 x 30118.91

c) Base Shear for the Junction tower case for seismic mass in Z direction from response spectrum

TOTAL SRSS BASE SHEAR =728.90 kN
TOTAL 10PCT BASE SHEAR= 740.66 kN
TOTAL ABS BASE SHEAR= 1511.26 kN
TOTAL CSM BASE SHEAR= 903.01 kN

d) Base Shear for the Junction tower case for seismic mass in Z direction from Empirical formula:

Time Period for Z -Direction 1893 Loading = 2.40045 Sec
Sa/g as per 1893= 0.567, Load Factor= 1.000
Factor 'V' as per 1893= 0.0198 x 30118.91
Time Period Multiplying Factor (Vb/VB) IS 1.0000

5. TIME V/S ACCELERATION GRAPH

Consider maximum Acceleration response spectrum, a slight change in time period can lead to large variation in maximum acceleration.

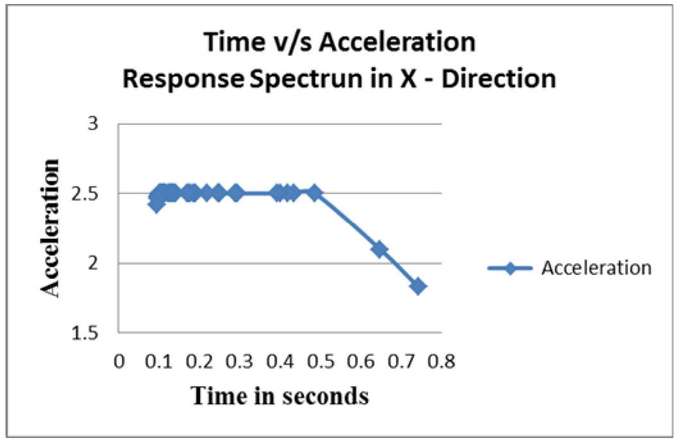


Figure 7. Time v/s Acceleration graph in X-Direction

Peak acceleration in X-Direction is 2.500, when time is 0.48606 Seconds. Maximum variation in acceleration is when time period changes to 0.10 to 0.65 Seconds.

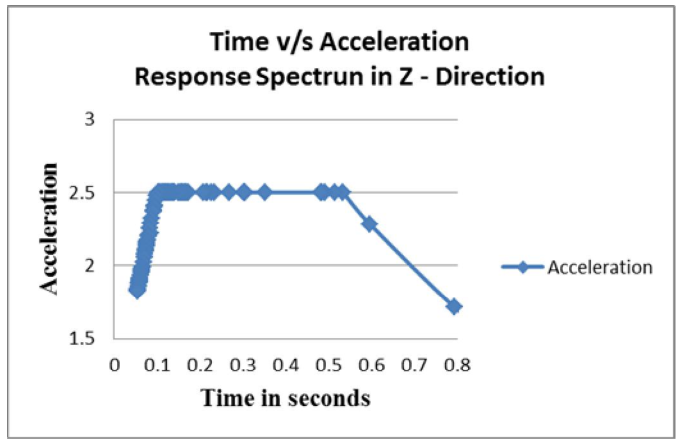


Figure 8. Time v/s Acceleration graph in Z-Direction

Peak acceleration in Z-Direction is 2.500, when time is 0.53218 Seconds. Maximum variation in acceleration is when time period changes to 0.10 to 0.60 Seconds.

6. FREQUENCY V/S ACCELERATION GRAPH

Consider maximum Acceleration response spectrum, a slight change in natural frequency can lead to large variation in maximum acceleration.

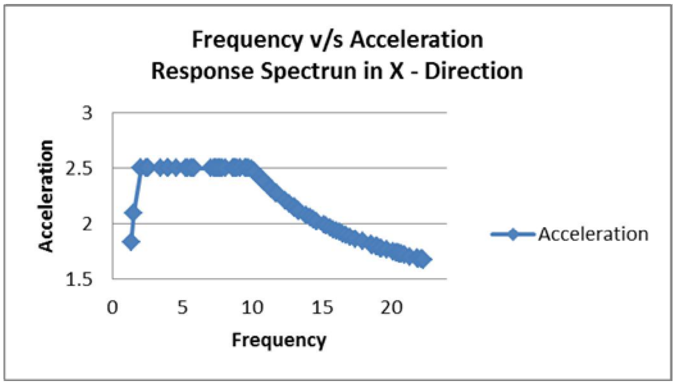


Figure 9. Frequency v/s Acceleration graph in X- direction

Peak acceleration in X-Direction is 2.50, when frequency is 9.789. Maximum variation in acceleration is when frequency changes to 1.543 to 10.154

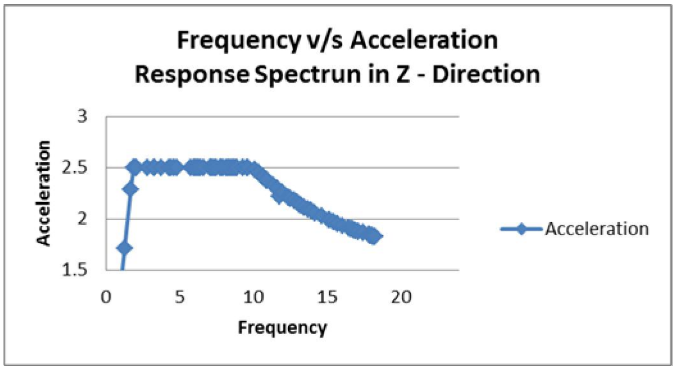


Figure 10. Frequency v/s Acceleration graph in Z- direction

Peak acceleration in X-Direction is 2.50, when frequency is 9.633. Maximum variation in acceleration is when frequency changes to 1.680 to 10.372

VI. CONCLUSIONS

1. Max Base Shears from Response spectrum analysis: X-Direction: 1172.84 kN
   Z-Direction: 1511.26 kN
2. Mode shape is 500 with a Storey Drift of 0.5 and Missing Mass correction factor is applied to achieve greater than 90% of Mass participation in response spectrum analysis.
3. High rise buildings have small natural frequency, hereafter their structural response was established to be maximum in a low frequency earthquake.
4. According to above analysis of Response Spectrum Analysis, it was achieved that mass irregular building frames practice high base shear compare to similar regular building frames.
5. The base shear (Vb) from RS is less than the base shear (VB) calculated using experimental formula for fundamental multiplication factors of 0.052348 was used to scale down response spectrum to IS1893.
6. ZPA-Zero period acceleration suggests extreme acceleration capable by a structure having zero natural frequency (T=0)
7. Modal Combination Rules - The commonly used method for obtaining the peak response quantity from all the modes of interest for a MDOF system is the Square root of the sum of the squares (SRSS) method. SRSS is regarded as the most viable option for any structure.

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