

## SEISMIC FORCES ON TRANSMISSION LINE TOWER

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**Abstract** - In the present era, the telecommunication industry plays a great role in human societies and thus much more attention is now being paid to telecommunication towers than it was in the past. Many towers were failed for seismic load. Due to earthquake the transmission line may collapse, and it will cause economic loss as well as the secondary disasters such as fire. Therefore it becomes very to analyse the tower for seismic forces Once happens the earthquake, the transmission line may collapse, it will cause economic loss, fire and whole society paralyze. In this work, the transmission tower with different bracings (K, cross and diagonal) will be analyzed under seismic loading for two zones viz. zone III and zone IV and three soil conditions Hard, Medium and Loose using STAAD PRO software. . The cable loads are calculated using PLS Tower software. After completing the analysis, the comparative study is done with respect to axial force, reactions & moments for all different towers.

**Key Words:** Earthquake Zones, PLS Tower, Soil Conditions, STAAD Pro, Transmission Tower, Bracings.

### 1. INTRODUCTION

India has a large population residing all over the country and the electricity supply need of this population creates requirement of a large transmission and distribution system. Also, the disposition of the primary resources for electrical power generation viz., coal, hydro potential is quite uneven, thus again adding to the transmission requirements. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure. Mechanical supports of transmission line represent a significant portion of the cost of the line and they play an important role in the reliable power transmission. They are designed and constructed in wide variety of shapes, types, sizes, configurations and materials.

Electric Power is today playing an increasingly important role in the life of the community. In the electric power system the production and transmission of power are two predominant factors. For the purpose of transmission of electricity towers are the main medium with some wires at required distances and altitudes. The remote hydroelectric power plants have given rise to the need for extra high voltage. Thus the study of designing and erection of steel towers has become a challenging task.

Transmission line tower normally comprise of several hundred angle members eccentrically connected. Structural analysis of this type of structure requires extensive data generation. Conventional process of data generation in describing the topology, geometry, load and support conditions are very tedious, time consuming and susceptible to error. In general, most towers may be idealized as statically determinate and analyzed for forces.

The study of seismic design is now a major national concern, and as the research continues the level of seismic design practice becomes more sophisticated. This has the effect of raising the level of professional responsibility and expanding the knowledge of which the professional is expected to be cognizant. With this change in the range of knowledge has come a revised conception of professional responsibility and liability that is affecting all design areas. As design and construction become increasingly institutionalized, the used demands protection from random hazards of life safely or even discomfort over which he or she has no control. That control rests with the institutions, and the professionals and the courts are increasingly reinforcing this view of responsibility.

Strong earthquake has serious impact on the safety and reliability of the operation to transmission tower-line system. Once happens the earthquake, the power system will be suffered serious damage, not only cause huge economic loss directly or indirectly, but also can cause secondary disasters, such as fire. That's why it necessitates to design the structures subjected to all seismic forces and to apply such a major, so that minimum losses will take place.

*A. Software used: Staad.Pro*

STAAD is a structural analysis and design computer program. An older version called STAAD-III for windows is used by Iowa state university for educational purpose for civil and structural engineers. The commercial version STAAD. Pro is one of the most widely used structural analysis and design software. It supports several steel, concrete and timber design codes. STAAD.Pro allows structural engineer to analyse and design virtually any type of structure through its flexible modeling environment, advance features and fluent data collaborations.

A Transmission Tower of 35m height with square base constructed on Hard, Medium and Soft soil subjected to

earthquake loadings in Zone III and Zone IV has been considered and modelled using STAAD.Pro V8i software.

### 2. Scope and Objectives

The present work is based on the study of effect of earthquake on Transmission Line Tower. The analysis is based on the two zones III & IV & and three soil conditions Hard, Medium & Loose. The entire modeling, analysis and design is carried out by using STAAD V8.0 version software. The overall specific objectives of this study are:-

- To analyse the Cross braced Transmission Line Tower located in two earthquake zones built on hard, medium and soft soils.
- To analyse the diagonal braced Transmission Line Tower located in two earthquake zones built on hard, medium and soft soils.

### 3. Staad Model of Tower

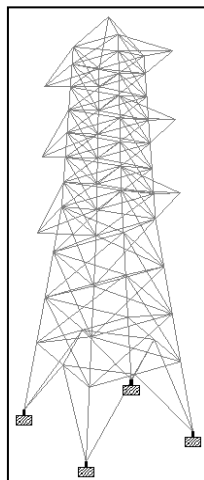


Fig. 1: Cross Braced Tower

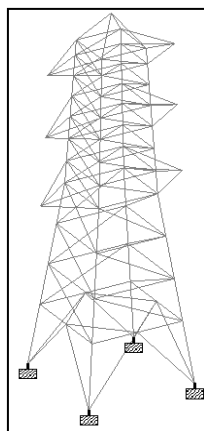


Fig. 2: Diagonally Braced Tower

### 4. Tower Details

- 1) Height of tower: 35m
- 2) Base Width: 9m (Square Base)
- 3) Type of Tower: Suspension Straight Tower
- 4) Transmission line voltage: 220 kv
- 5) Angle of line Deviation: 0 to 2 degree
- 6) Terrain Type: Plain
- 7) Cross arm: Pointed
- 8) Member Properties:
  - Columns – ISA 180x180x15
  - Cross Arms – ISA 100x100x6
  - Bracings – ISA 90x90x6

### 5. Loads Considered In Staad Analysis

- Dead Load (DL)
- EQX (Earthquake Load in X direction)
- EQZ (Earthquake Load in Z direction)
- WLX (Wind Load in positive X direction)
- WLX- (Wind Load in negative X direction)
- WLZ (Wind Load in positive Z direction)
- WLZ- (Wind Load in negative Z direction)

#### A. Cab\_Case 1 (Normal Condition Full Wind 90° Perpendicular)

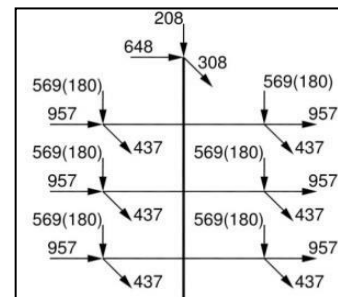


Fig. 3: Cab\_Case 1 (Normal Condition Full Wind 90° Perpendicular)

#### B. Cab\_Case 2 (Normal Condition Full Wind 45° Diagonal)

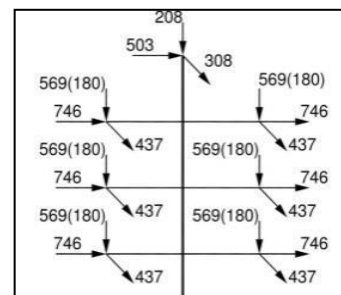


Fig. 4: Cab\_Case 2 (Normal Condition Full Wind 45° Diagonal)

C. Cab\_Case 3 (Earthwire & Any One Conductor Broken)

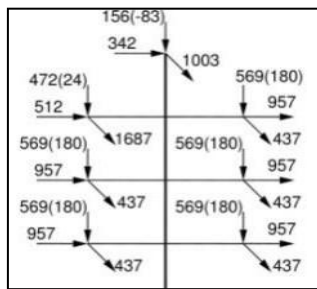


Fig. 5: Cab\_Case 3 (Earthwire & Any One Conductor Broken)

D. Cab\_Case 4 (Any Two Conductors Broken)

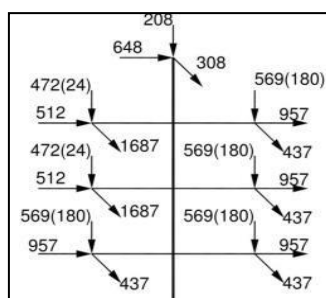


Fig. 6: Cab\_Case 4 (Any Two Conductors Broken)

E. Cab\_Case 5 (Anticascade Condition)

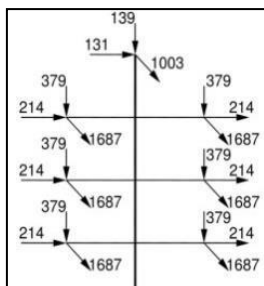


Fig. 7: Cab\_Case 5 (Anticascade Condition)

F. Cab\_Case 6 (Normal Condition with No Wind Pressure on Tower Body)

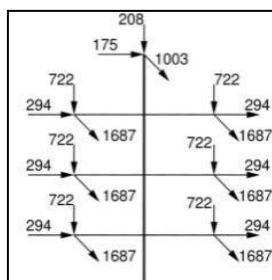


Fig. 8: Cab\_Case 6 (Normal Condition with No Wind Pressure on Tower Body)

6. Tower Analysis and Results

The analysis results are studied and compared for the following four base columns.

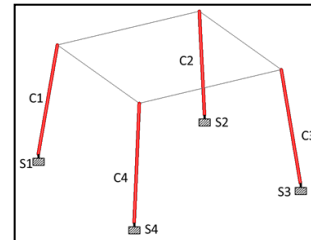


Fig. 9: Analysis results

A. Seismic Analysis

1) Cross Braced Tower in Zone 3

a) Member Forces

Column	L/C	F <sub>x</sub>	F <sub>y</sub>	F <sub>z</sub>	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
C1	DL+CAB_CASE6+EQ Z-	-143.234	00.05	-0.087	0	0.173	-0.004
C2	DL+CAB_CASE6+EQ Z-	-89.839	-0.011	0.09	0	-0.309	-0.023
C3	DL+CAB_CASE6+EQ Z-	183.272	-0.058	0.059	0	-0.223	-0.141
C4	DL+CAB_CASE6+EQ Z-	139.728	-0.048	-0.12	0	0.251	-0.118

Table 1: For Hard & Medium soil type

Column	L/C	F <sub>x</sub>	F <sub>y</sub>	F <sub>z</sub>	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
C1	DL+CAB_CASE6+E QZ	108.374	0.004	-0.068	0	0.214	0.011
C2	DL+CAB_CASE6+E QZ	-64.575	-0.005	0.128	0	-0.242	-0.012
C3	DL+CAB_CASE6+E QZ	218.377	-0.049	0.086	0	-0.174	-0.125
C4	DL+CAB_CASE6+E QZ	164.731	-0.043	-0.088	0	0.31	-0.108

Table 2: For Soft soil type

b) Support Reactions

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE6+E QZ-	19.511	159.132	28.794	-0.736	0.067	0.056
S2	DL+CAB_ CASE6+E QZ-	6.189	100.362	-22.42	-0.856	-0.121	0.025
S3	DL+CAB_ CASE6+E QZ-	28.689	200.226	38.226	-0.196	-0.084	-0.494
S4	DL+CAB_ CASE6+E QZ-	15.345	152.362	31.538	-0.292	0.092	0.573

Table 3: For maximum Reaction Fy

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE5+E QZ-	18.813	157.187	28.579	-0.747	0.071	0.036
S2	DL+CAB_ CASE5+E QZ-	8.046	112.727	23.791	-0.842	-0.117	0.002
S3	DL+CAB_ CASE5+E QZ-	26.831	187.861	36.855	-0.21	-0.089	-0.517
S4	DL+CAB_ CASE5+E QZ-	16.043	154.307	31.753	-0.281	0.088	0.553

Table 4: For maximum Reaction Mx

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE5+E QZ-	18.813	157.187	28.579	-0.747	0.071	0.036
S2	DL+CAB_ CASE5+E QZ-	8.046	112.727	23.791	-0.842	-0.117	0.002
S3	DL+CAB_ CASE5+E QZ-	26.831	187.861	36.855	-0.21	-0.089	-0.517
S4	DL+CAB_ CASE5+E QZ-	16.043	154.307	31.753	-0.281	0.088	0.553

S1	DL+CAB_ CASE1+EQX	-13.481	-80.283	-10.198	-0.015	0.52
S2	DL+CAB_ CASE1+EQX	-12.066	102.25	9.191	-0.523	0.107
S3	DL+CAB_ CASE1+EQX	-21.55	178.076	-19.741	0.367	-0.005
S4	DL+CAB_ CASE1+EQX	-3.716	6.341	0.802	0.036	0.663

Table 5: For maximum Reaction Mz

2) CROSS BRACED TOWER IN ZONE IV

a) Member Forces

Column	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
C1	DL+CAB_ CASE6+E QZ-	151.949	-0.007	-0.091	0	0.163	-0.008
C2	DL+CAB_ CASE6+E QZ-	-96.155	-0.012	0.008	0	-0.326	-0.025
C3	DL+CAB_ CASE6+E QZ-	174.496	-0.06	0.052	0	-0.235	-0.145
C4	DL+CAB_ CASE6+E QZ-	133.478	-0.05	-0.128	0	0.236	-0.121

Table 6: For Hard & Medium soil type

Column	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
C1	DL+CAB_ CASE6+E QZ	99.66	0.06	-0.04	0	0.224	0.015
C2	DL+CAB_ CASE6+E QZ	58.259	-0.04	0.138	0.001	-0.226	-0.009

C3	DL+CAB_ CASE6+E QZ	227 .153	-0. 047	0. 093	0	-0. 162	-0. 122
C4	DL+CAB_ CASE6+E QZ	170 .982	-0. 041	-0. 080	0	0. 325	-0. 105

Table 7: For Soft soil type

b) Support Reactions

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE6+E QZ	-13.391	-110.998	20.747	-0.62	0.087	0.113
S2	DL+CAB_ CASE6+E QZ	9.636	-65.524	15.499	-0.675	-0.083	0.163
S3	DL+CAB_ CASE6+E QZ	-22.837	248.693	29.793	-0.049	-0.057	-0.407

Table 8: For maximum Reaction Fy

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE6+E QZ-	-20.735	16.8758	30.403	-0.759	0.063	0.045
S2	DL+CAB_ CASE6+E QZ-	5.499	10.733	23.804	-0.892	-0.129	-0.002
S3	DL+CAB_ CASE6+E QZ-	-29.859	190.532	39.913	-0.225	-0.095	-0.512
S4	DL+CAB_ CASE6+E QZ-	14.591	145.462	32.842	-0.323	0.085	0.555

Table 9: For maximum Reaction Mx

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE3+EQ X	12.077	92.591	15.559	-0.376	0.038	0.355

S2	DL+CAB_ CASE3+EQ X	-2.795	63.163	5.838	-0.354	-0.025	-0.037
S3	DL+CAB_ CASE3+EQ X	-24.049	6.209	20.582	0.543	0.086	0.185
S4	DL+CAB_ CASE3+E QX	1.557	61.889	-5.942	-0.135	0.134	0.874

Table 10: For maximum Reaction Mz

3) Diagonally Braced Tower in Zone 3

a) Member Forces

Column	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
C1	DL+CAB_ CASE6+E QZ-	-14.4581	-0.032	0.01	0	0.156	-0.011
C2	DL+CAB_ CASE6+E QZ-	-92.073	-0.033	-0.068	0.001	-0.439	-0.01
C3	DL+CAB_ CASE6+E QZ-	181.561	-0.003	-0.123	0	-0.315	-0.154
C4	DL+CAB_ CASE6+E QZ-	137.367	-0.002	-0.031	0	0.267	-0.157

Table 11: For Hard & Medium soil type

Column	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
C1	DL+CAB_ CASE6+E QZ	-110.225	-0.029	0.026	0	0.205	0.005
C2	DL+CAB_ CASE6+E QZ	-66.466	-0.029	-0.061	0.001	-0.356	0.007
C3	DL+CAB_ CASE6+E QZ	216.051	0.001	-0.111	0	-0.252	-0.139
C4	DL+CAB_ CASE6+E QZ	-66.466	-0.029	-0.061	0.001	-0.356	0.007

Table 12: For Soft soil type

b) Support Reactions

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE3+EQ X	12.077	92.591	15.559	-0.376	0.038	0.355

S1	DL+CAB_ CASE6+E QZ-	- 19. 53 3	- 16 0 01 5	- 28. 74 5	-0. 50 3	0. 03 2	0. 27 4
S2	DL+CAB_ CASE6+E QZ-	6. 31 5	- 10 2 26 2	- 22. 54 6	-0. 58 3	-0. 06 2	-0. 24 8
S3	DL+CAB_ CASE6+E QZ-	- 28. 60 2	199 . 39 9	- 38. 15	0. 33 1	-0. 00 9	-0. 30 1
S4	DL+CAB_ CASE6+E QZ-	15. 30 9	150 . 68 2	- 31. 52 2	0. 00 6	0. 07 6	0. 59 2

Table 13: For maximum Reaction Fy

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE5+EQ X-	- 19. 1	- 15 3 43 7	- 26. 97 1	-0. 51 1	0. 03 1	0. 24 8
S2	DL+CAB_ CASE5+EQ X-	6. 43 6	- 11 9 31 8	- 23. 46 1	-0. 55 5	-0. 05 6	-0. 23 9
S3	DL+CAB_ CASE5+EQ X-	- 27. 33 9	191 . 95 7	- 34. 81 4	0. 31 2	-0. 01 7	-0. 34
S4	DL+CAB_ CASE5+EQ X-	14. 27 4	148 . 12 4	- 31. 25 6	0. 02 3	0. 07 5	0. 58 2

Table 14: For maximum Reaction Mx

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE1+EQ X-	- 13. 54	- 81. 25 5	- 11. 39 3	-0. 32 1	-0. 00 6	0. 44 6
S2	DL+CAB_ CASE1+EQ X-	- 12.	10 0.	9. 06 2	-0. 37 1	-0. 01 6	-0. 29 6

		06 7	31 1				
S3	DL+CAB_ CASE1+EQ X-	- 21. 50 2	17 7. 02 8	- 19. 73 3	0. 52 1	0. 05 3	-0. 12
S4	DL+CAB_ CASE1+EQ X-	-3. 79 1	4. 46 1	0. 73 6	0. 21 5	0. 05 4	0. 53 8

Table 15: For maximum Reaction Mz

4) Diagonally Braced Tower in Zone 4

a) Member Forces

Column	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
C1	DL+CAB_ CASE6+E QZ-	- 15 3 1 7	-0. 03 3	0. 00 6	0	0. 14 4	-0. 01 4
C2	DL+CAB_ CASE6+E QZ-	-98. 474	-0. 03 4	-0. 07	0. 00 1	-0. 45 9	-0. 01 4
C3	DL+CAB_ CASE6+E QZ-	172 . 93 9	-0. 00 3	-0. 12 6	0	-0. 33 1	-0. 15 8
C4	DL+CAB_ CASE6+E QZ-	131 . 00 4	-0. 00 3	-0. 03 3	0	0. 25	-0. 16 1

Table 16: For Hard & Medium soil type

Column	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
C1	DL+CAB_ CASE6+E QZ	- 101 636	-0. 02 8	0. 03	0	0. 21 7	0. 00 9
C2	DL+CAB_ CASE6+E QZ	-60. 065	-0. 02 8	-0. 06	0. 00 1	-0. 33 6	0. 01 2
C3	DL+CAB_ CASE6+E QZ	224. 673	0. 00 1	-0. 10 6	0	-0. 23 6	-0. 13 6
C4	DL+CAB_ CASE6+E QZ	169. 18	0. 00 3	-0. 02 2	0	0. 35 3	-0. 13 6

Table 17: For Soft soil type

b) Support Reactions

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE6+E QZ	- 13. 63 1	- 112 . 691	- 20. 85 7	-0. 46 6	0. 04	0. 29 9

S2	DL+CAB_ CASE6+E QZ	9. 80 6	-66. 772	- 15. 48 7	-0. 49	-0. 03 9	-0. 18 1
S3	DL+CAB_ CASE6+E QZ	- 23. 10 7	246. 882	- 29. 8	0. 38 3	0. 00 4	-0. 26 6
S4	DL+CAB_ CASE6+E QZ	19. 22 2	185. 986	- 24. 93 6	0. 07 8	0. 09 3	0. 63 8

Table 18: For maximum Reaction Fy

Support	L/C	Fx	Fy	Fz	M <sub>x</sub>	M <sub>y</sub>	M <sub>z</sub>
S1	DL+CAB_ CASE3+E QX	- 12. 14 8	- 93. 661	- 15. 52 2	-0. 39	0. 02 1	0. 37 5
S2	DL+CAB_ CASE3+E QX	-2. 84 4	61. 238	5. 65 4	-0. 28 4	0. 00 4	-0. 35
S3	DL+CAB_ CASE3+E QX	- 23. 97 6	205. 036	- 20. 55 9	0. 63 3	0. 08 1	0. 00 2
S4	DL+CAB_ CASE3+E QX	1. 47 3	60. 009	-6. 09 6	0. 12 2	0. 08 3	0. 65 1

Table 19: For maximum Reaction Mx & Mz

## 7. Graphical Comparison

### A. Axial force in Hard & Medium Soil

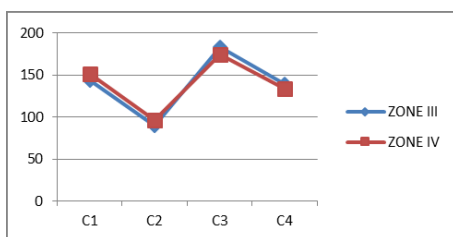


Fig. 10: Cross Braced Tower

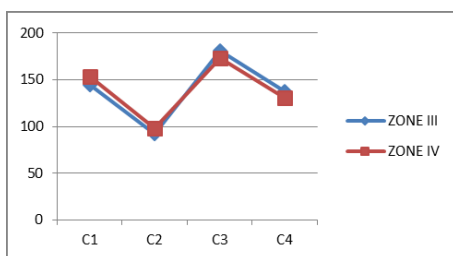


Fig. 11: Diagonally Braced Tower

### A. Axial force in Soft Soil

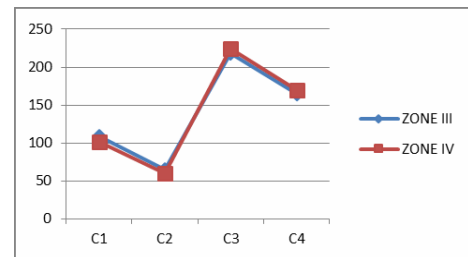


Fig. 12: Cross Braced Tower

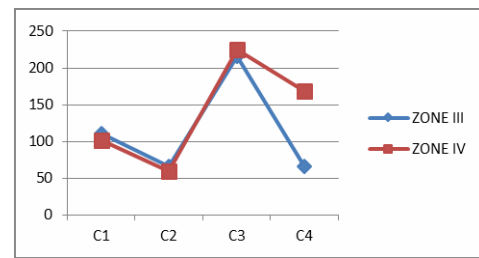


Fig. 13: Diagonally Braced Tower

### A. For Reaction Fy

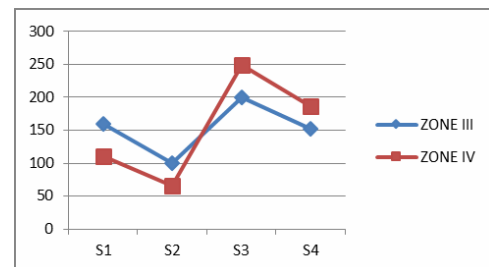


Fig. 14: Cross Braced Tower

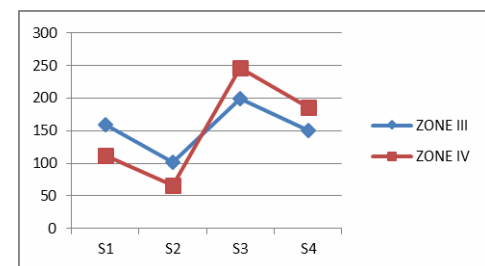


Fig. 15: Diagonally Braced Tower

### B. For Moment Mx

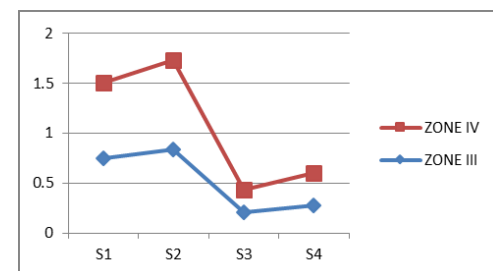


Fig. 16: Cross Braced Tower

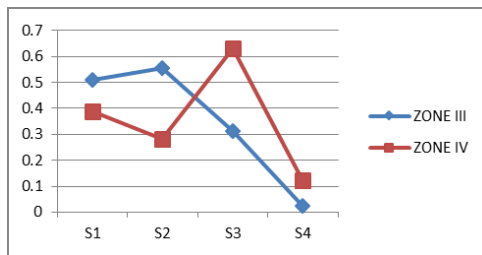


Fig. 17: Diagonally Braced Tower

C. For Moment  $M_z$

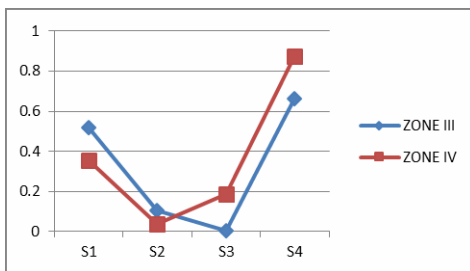


Fig. 18: Cross Braced Tower

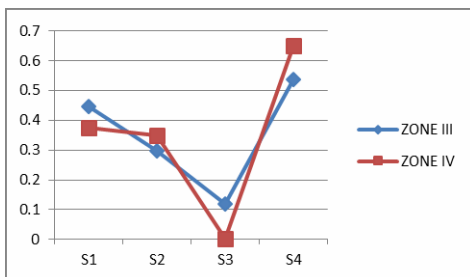


Fig. 19: Diagonally Braced Tower

8. Conclusions

- The results for axial force is same in Hard soil & Medium soil.
- Axial force increases in soft soil by 16% approx.
- Axial force in zone III is less than that in zone IV.
- Axial force increases by 4% approx. in zone IV.
- The values of support reactions are found to be maximum in zone IV.
- Support Reactions increases in zone IV by 18% approx.

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