Effect of Seismic Forces on Transmission Line Tower

Prachi Prakashrao Bagmare[1] Dr. N. R. Dhamge[2] Prof. Vinayak D. Vaidya[3]
[1]PG Student [2,3]Professor
[1,2,3]Department of Structural Engineering
[1,2,3]KDK College of Engineering, Nagpur, Maharashtra, India

Abstract— In the present era, Transmission Line Tower plays a great role in human society. 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. In this study, an attempt is made that Transmission Line Tower is modelled using STAAD Pro. The towers are designed in two earthquake zones III & IV with three different soil conditions Hard, Medium & Soft. The towers are modelled using parameters such as constant height, base width, angle sections and variable parameters of bracing system, earthquake zones and soil type. 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. Conclusions were drawn based on the results obtained from the different studies carried out.

Key words: Earthquake Zones, PLS Tower, Soil Conditions, STAAD Pro, Transmission Tower

I. 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 hundredangle 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 advancement in electrical engineering shows need for supporting heavy conductors which led to existence of towers. Towers are tall structures, their height being much more than their lateral dimensions. These are space frames built with steel sections having generally an independent foundation under each leg. The height of tower is fixed by the user and the structural designer has the task of designing the general configuration, member and the joint details. A high voltage transmission line structure is a complex structure in that its design is characterized by the special requirements to be met from both electrical and structural points of view, the former decides the general shape of the tower in respect of its height and the length of its cross arms that carry electrical conductors**.** Hence it has given rise to the relative tall structures such as towers. The purpose of transmission line towers is to support conductors carrying electrical power and one or two ground wires at suitable distance.

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 lowa 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.

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II. 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.

III. STAAD MODEL OF TOWER

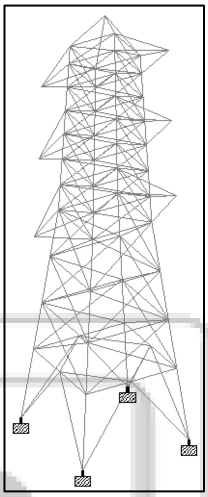

Fig. 1: Cross Braced Tower

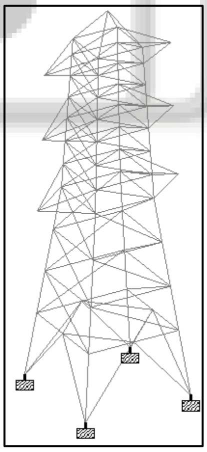

Fig. 2: Diagonally Braced Tower

IV. 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

V. 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 90º Perpendicular)

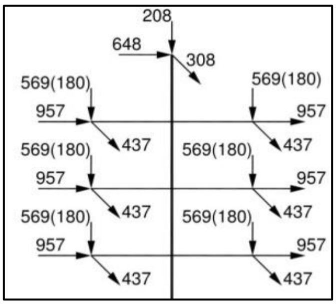

Fig. 3: Cab_Case 1 (Normal Condition Full Wind 90º Perpendicular)

B. Cab_Case 2 (Normal Condition Full Wind 45º Diagonal)

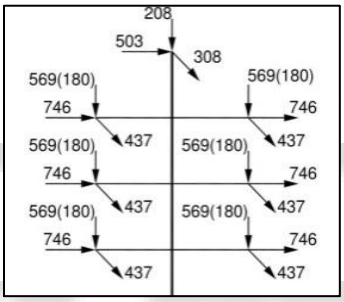

Fig. 4: Cab_Case 2 (Normal Condition Full Wind 45º Diagonal)

C. Cab_Case 3 (Earthwire & Any One Conductor Broken)

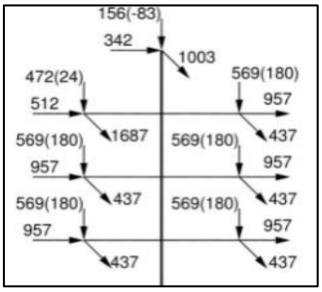

Fig. 5: Cab_Case 3 (Earthwire & Any One Conductor Broken)

D. Cab_Case 4 (Any Two Conductors Broken)

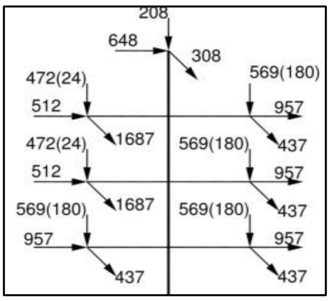

Fig. 6: Cab_Case 4 (Any Two Conductors Broken)

E. Cab_Case 5 (Anticascade Condition)

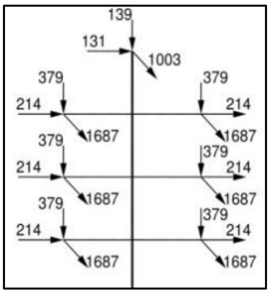

Fig. 7: Cab_Case 5 (Anticascade Condition)

F. Cab_Case 6 (Normal Condition with No Wind Pressure on Tower Body)

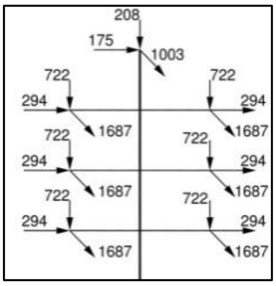

Fig. 8: Cab_Case 6 (Normal Condition with No Wind Pressure on Tower Body)

VI. TOWER ANALYSIS AND RESULTS

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

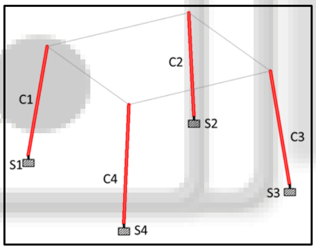

Fig. 9: Analysis results

A. Seismic Analysis

1) Cross Braced Tower in Zone 3

a) Member Forces

Column	L/C	Fx	Fy	Fz	Mx	My	Mz
C1	DL+CAB_CASE6+EQZ-	-143.234	-0.005	-0.087	0	0.173	-0.004
C2	DL+CAB_CASE6+EQZ-	-89.839	-0.011	0.09	0	-0.309	-0.023
C3	DL+CAB_CASE6+EQZ-	183.272	-0.058	0.059	0	-0.223	-0.141
C4	DL+CAB_CASE6+EQZ-	139.728	-0.048	-0.12	0	0.251	-0.118

Table 1: For Hard & Medium soil type

Column	L/C	Fx	Fy	Fz	Mx	My	Mz
C1	DL+CAB_CASE6+EQZ	-108.374	0.004	-0.068	0	0.214	0.011
C2	DL+CAB_CASE6+EQZ	-64.575	-0.005	0.128	0	-0.242	-0.012
C3	DL+CAB_CASE6+EQZ	218.377	-0.049	0.086	0	-0.174	-0.125
C4	DL+CAB_CASE6+EQZ	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	Mx	My	Mz
S1	DL+CAB_CASE6+EQZ-	-19.511	-159.132	-28.794	-0.736	0.067	0.056
S2	DL+CAB_CASE6+EQZ-	6.189	-100.362	-22.42	-0.856	-0.121	0.025
S3	DL+CAB_CASE6+EQZ-	-28.689	200.226	-38.226	-0.196	-0.084	-0.494
S4	DL+CAB_CASE6+EQZ-	15.345	152.362	-31.538	-0.292	0.092	0.573

Table 3: For maximum Reaction Fy

Support	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+CAB_CASE5+EQZ-	-18.813	-157.187	-28.579	-0.747	0.071	0.036
S2	DL+CAB_CASE5+EQZ-	8.046	-112.727	-23.791	-0.842	-0.117	0.002
S3	DL+CAB_CASE5+EQZ-	-26.831	187.861	-36.855	-0.21	-0.089	-0.517
S4	DL+CAB_CASE5+EQZ-	16.043	154.307	-31.753	-0.281	0.088	0.553

Table 4: For maximum Reaction Mx

Support	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+CAB_-CASE1+EQX-	-13.481	-80.283	-11.395	-0.198	-0.015	0.52
S2	DL+CAB_-CASE1+EQX-	-12.	102.25	9.191	-0.	-0.	0.107

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S3	DL+CAB_-CASE1+EQX-	-21.55	178.076	-19.741	0.367	0.044	-0.005
S4	DL+CAB_-CASE1+EQX-	-3.716	6.341	0.802	0.036	0.085	0.663

Table 5: For maximum Reaction Mz

2) CROSS BRACED TOWER IN ZONE IV

a) Member Forces

Column	L/C	Fx	Fy	Fz	Mx	My	Mz
C1	DL+CAB_CASE6+EQZ-	-151.949	-0.007	-0.091	0	0.163	-0.008
C2	DL+CAB_CASE6+EQZ-	-96.155	-0.012	0.08	0	-0.326	-0.025
C3	DL+CAB_CASE6+EQZ-	174.496	-0.06	0.052	0	-0.235	-0.145
C4	DL+CAB_CASE6+EQZ-	133.478	-0.05	-0.128	0	0.236	-0.121

Table 6: For Hard & Medium soil type

Column	L/C	Fx	Fy	Fz	Mx	My	Mz
C1	DL+CAB_CASE6+EQZ	-99.66	0.006	-0.064	0	0.224	0.015
C2	DL+CAB_CASE6+EQZ	-58.259	-0.004	0.138	0.001	-0.226	-0.009
C3	DL+CAB_CASE6+EQZ	227.153	-0.047	0.093	0	-0.162	-0.122
C4	DL+CAB_CASE6+EQZ	170.982	-0.041	-0.08	0	0.325	-0.105

Table 7: For Soft soil type

b) Support Reactions

Support	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+CAB_CASE6+EQZ	-13.391	-110.998	-20.747	-0.62	0.087	0.113
S2	DL+CAB_CASE6+EQZ	9.636	-65.524	-15.499	-0.675	-0.083	0.163
S3	DL+CAB_CASE6+EQZ	-22.837	248.693	-29.793	-0.049	-0.057	-0.407
S4	DL+CAB_CASE6+EQZ	19.115	186.866	-25.018	-0.139	0.124	0.688

Table 8: For maximum Reaction Fy

Support	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+CAB_CASE6+EQZ-	-20.735	-168.758	-30.403	-0.759	0.063	0.045
S2	DL+CAB_CASE6+EQZ-	5.499	-107.33	-23.804	-0.892	-0.129	-0.002
S3	DL+CAB_CASE6+EQZ-	-29.859	190.532	-39.913	-0.225	-0.09	-0.512
S4	DL+CAB_CASE6+EQZ-	14.591	145.462	-32.842	-0.323	0.085	0.55

Table 9: For maximum Reaction Mx

Support	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+CAB_CASE3+EQX	-12.077	-92.591	-15.559	-0.376	0.038	0.355
S2	DL+CAB_CASE3+EQX	-2.795	63.163	5.838	-0.354	-0.025	-0.037
S3	DL+CAB_CASE3+EQX	-24.049	206.209	-20.582	0.543	0.086	0.185
S4	DL+CAB_CASE3+EQX	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	Mx	My	Mz
C1	DL+CAB_CASE6+EQZ-	-144.581	-0.032	0.01	0	0.156	-0.011
C2	DL+CAB_CASE6+EQZ-	-92.073	-0.033	-0.068	0.001	-0.439	-0.01
C3	DL+CAB_CASE6+EQZ-	181.561	-0.003	-0.123	0	-0.315	-0.154
C4	DL+CAB_CASE6+EQZ-	137.367	-0.002	-0.031	0	0.267	-0.157

Table 11: For Hard & Medium soil type

Column	L/C	Fx	Fy	Fz	Mx	My	Mz

C1	DL+CAB_CASE6+EQZ	-110.225	-0.029	0.026	0	0.205	0.005
C2	DL+CAB_CASE6+EQZ	-66.466	-0.029	-0.061	0.001	-0.356	0.007
C3	DL+CAB_CASE6+EQZ	216.051	0.001	-0.11	0	-0.252	-0.139
C4	DL+CAB_CASE6+EQZ	-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	Mx	My	Mz
S1	DL+CAB_CASE6+EQZ-	-19.533	-160.015	-28.745	-0.503	0.032	0.274
S2	DL+CAB_CASE6+EQZ-	6.315	-102.262	-22.546	-0.583	-0.062	-0.248
S3	DL+CAB_CASE6+EQZ-	-28.602	199.399	-38.15	0.331	-0.009	-0.301
S4	DL+CAB_CASE6+EQZ-	15.309	150.682	-31.522	0.006	0.076	0.592

Table 13: For maximum Reaction Fy

Support	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+CAB_CASE5+EQX-	-19.1	-153.437	-26.971	-0.511	0.031	0.248
S2	DL+CAB_CASE5+EQX-	6.436	-119.318	-23.461	-0.555	-0.056	-0.239
S3	DL+CAB_CASE5+EQX-	-27.339	191.957	-34.814	0.312	-0.017	-0.34
S4	DL+CAB_CASE5+EQX-	14.274	148.124	-31.256	0.023	0.075	0.582

Table 14: For maximum Reaction Mx

Support	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+CAB_CASE1+EQX-	-13.54	-81.255	-11.393	-0.321	-0.006	0.446
S2	DL+CAB_CASE1+EQX-	-12.067	100.311	9.062	-0.371	-0.016	-0.296
S3	DL+CAB_CASE1+EQX-	-21.502	177.028	-19.733	0.521	0.053	-0.12
S4	DL+CAB_CASE1+EQX-	-3.791	4.461	0.736	0.215	0.054	0.538

Table 15: For maximum Reaction Mz

4) *Diagonally Braced Tower in Zone 4*

a) Member Forces

Column	L/C	Fx	Fy	Fz	Mx	My	Mz
C1	DL+CAB_CASE6+EQZ-	-153.17	-0.033	0.006	0	0.144	-0.014
C2	DL+CAB_CASE6+EQZ-	-98.474	-0.034	-0.07	0.001	-0.459	-0.014
C3	DL+CAB_CASE6+EQZ-	172.939	-0.003	-0.126	0	-0.331	-0.158
C4	DL+CAB_CASE6+EQZ-	131.004	-0.003	-0.033	0	0.25	-0.161

Table 16: For Hard & Medium soil type

Column	L/C	Fx	Fy	Fz	Mx	My	Mz
C1	DL+CAB_CASE6+EQZ	-101.636	-0.028	0.03	0	0.217	0.009
C2	DL+CAB_CASE6+EQZ	-60.065	-0.028	-0.06	0.001	-0.336	0.012
C3	DL+CAB_CASE6+EQZ	224.673	0.001	-0.106	0	-0.236	-0.136
C4	DL+CAB_CASE6+EQZ	169.18	0.003	-0.022	0	0.353	-0.136

Table 17: For Soft soil type

b) Support Reactions

Support	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+CAB_CASE6+EQZ	-13.631	-112.691	-20.857	-0.466	0.04	0.299
S2	DL+CAB_CASE6+EQZ	9.806	-66.772	-15.487	-0.49	-0.039	-0.181
S3	DL+CAB_CASE6+EQZ	-23.107	246.882	-29.8	0.383	0.004	-0.266
S4	DL+CAB_CASE6+EQZ	19.222	185.986	-24.	0.078	0.093	0.638

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Table 18: For maximum Reaction Fy

Support	L/C	Fx	Fy	Fz	Mx	My	Mz
S1	DL+CAB_CASE3+EQX	-12.148	-93.661	-15.522	-0.39	0.021	0.375
S2	DL+CAB_CASE3+EQX	-2.844	61.238	5.654	-0.284	0.004	-0.35
S3	DL+CAB_CASE3+EQX	-23.976	205.036	-20.559	0.633	0.081	0.002
S4	DL+CAB_CASE3+EQX	1.473	60.009	-6.096	0.122	0.083	0.651

Table 19: For maximum Reaction Mx & Mz

VII. GRAPHICAL COMPARISON

A. Axial force in Hard & Medium Soil

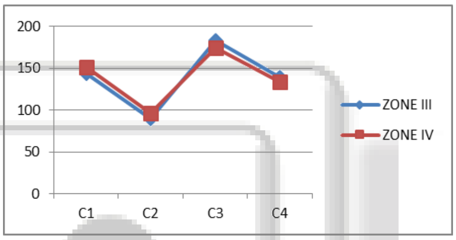

Fig. 10: Cross Braced Tower

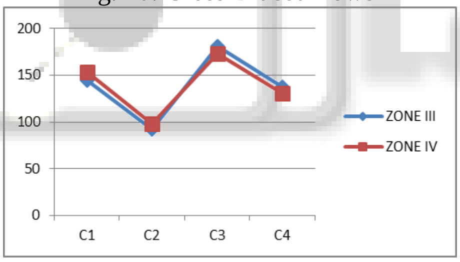

Fig. 11: Diagonally Braced Tower

B. Axial force in Soft Soil

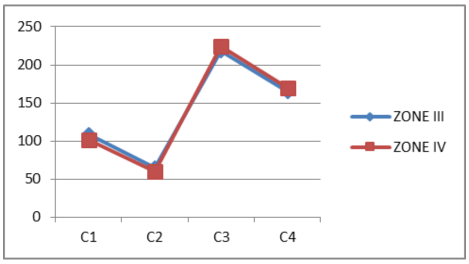

Fig. 12: Cross Braced Tower

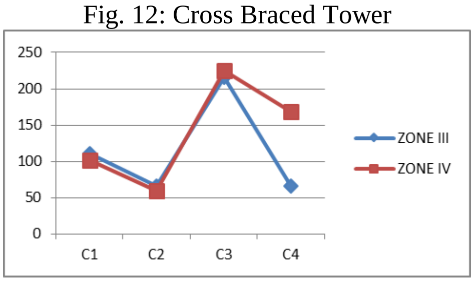

Fig. 13: Diagonally Braced Tower

C. For Reaction Fy

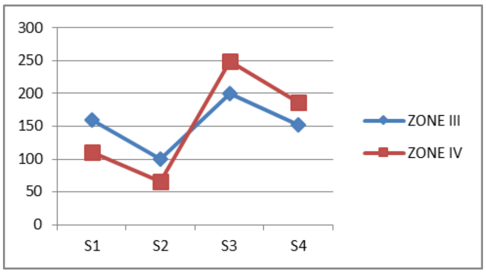

Fig. 14: Cross Braced Tower

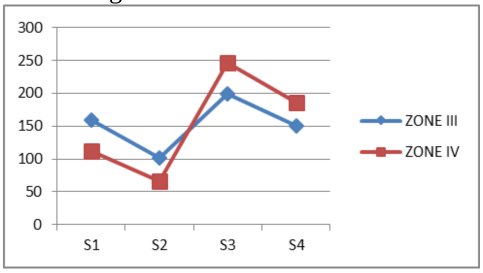

Fig. 15: Diagonally Braced Tower

D. For Moment Mx

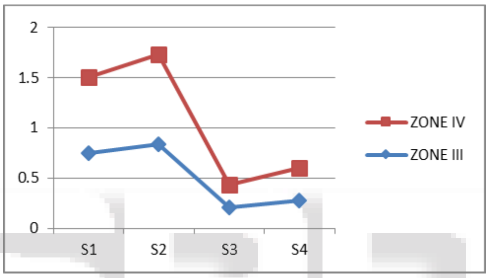

Fig. 16: Cross Braced Tower

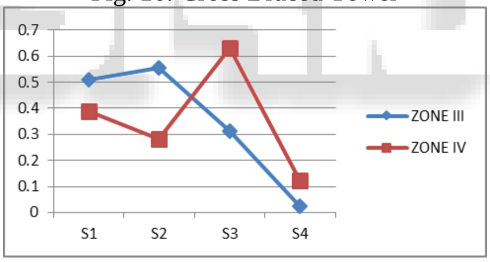

Fig. 17: Diagonally Braced Tower

E. For Moment Mz

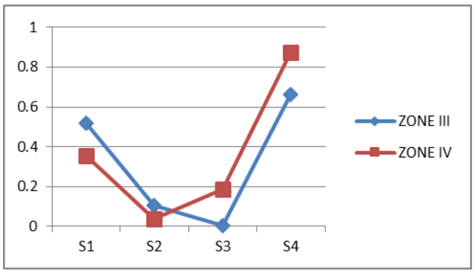

Fig. 18: Cross Braced Tower

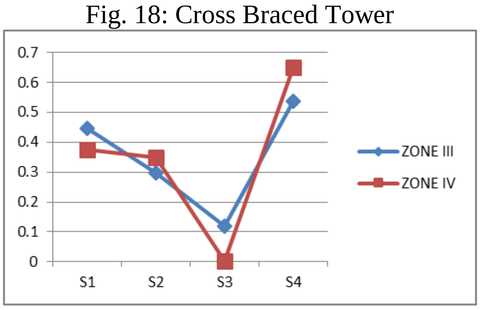

Fig. 19: Diagonally Braced Tower

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VIII. Conclusion

- 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.

References

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