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Comparative Study of Structural Behaviour of A, C and D Type Multi Circuit Tower With Maximum Electric Load of 220 KV in Zone III & V[1]

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ABSTRACT

Transmission structures support the phase conductors and shield wires of a transmission line. The structures commonly used on transmission lines are either lattice type or pole type. Lattice structures are usually composed of steel angle sections. Poles can be wood, steel, or concrete. Each structure type can also be self-supporting or guyed. Structures may have one of the three basic configurations: horizontal, vertical, or delta, depending on the arrangement of the phase conductors.

This paper focuses on the design and analysis of transmission tower subjected to the seismic zone three and five. The transmission tower with angle of deviation 0-degree, 30 degree and 60 degrees at the base i.e. type A, C &D towers with multi-circuit is modelled in STAAD pro. The dead load, live load, wind load and seismic loads are applied, further load combination is considered as per IS code 800-2016. The analysis results concluded that the transmission tower with deviation of 0-degree, 30 degree and 60 degrees at the base is economical under zone – III but it becomes highly uneconomical for zone – V. Whereas at the conclusion of this paper it might be suggested to use Type C tower under Zone – III condition.

INTRODUCTION

Transmission towers are required for the distribution of power across the country. As a result, more power stations are being built and placed in strategic locations. System interconnections are also growing in order to increase accuracy and efficiency. Any natural disaster can cause transmission lines to fail if they are not planned appropriately. As a result, it must be stable and well-designed to avoid failure in the event of a natural disaster. It must also meet all applicable national and international regulations. A transmission line's structural and electrical aspects should be considered during planning and design. Insulation and safe clearances of power carrying cables from the ground are the most critical requirements from an electrical perspective.

Transmission line towers account for almost 40% of the total cost of a transmission line. The choice of an optimal form, as well as the appropriate sort of bracing system, goes a long way toward producing a cost-effective transmission line tower design. Electricity is the primary source of power for industry, businesses, and homes. Because of infrastructure development, the demand for energy is increasing due to rapid growth in the industrial region. Electricity is now being used for rail transportation instead of fuel-powered engines due to lower costs. As a result, it is necessary to transfer the high voltage to the area in demand, which necessitates the installation of a transmission line tower to carry Extra High Voltage (EHV).

As for the definition of lattice structures, Gibson and Ashby defined early the structures in which the cell walls have a common generator as two-dimensional cellular structures like honeycombs and defined the structures in which cell walls have random orientations in space as three-dimensional cellular structures like foams . However, there is still no unified concept about the definition of lattice structures, because the topology structures of lattices are not limited to only changing size of struts and connection mode of cells. Many scholars have their own understanding of lattice structures based on Gibson and Ashby's definition of lattice structures. Generally speaking, lattice structures are defined as the three-dimensional structures composed of consecutively and repeatedly arranged interconnected cells, which can also be understood as a porous material structure composed of interconnected struts and nodes in three-dimensional space. Tao et al. defined lattice structure as an architecture formed by an array of spatial periodic unit

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cells with edges and faces. Dong et al. defined lattice structure as the truss-like structure with interconnected struts and nodes in three-dimensional space. Lattice structure as the porous and hollow structure formed by arranging unit cells in three-dimensional space. lattice structure as the space-filling unit cell that is able to be tessellated along any axis with no gaps between the cells. There is a common point in the above definitions of lattice structure, that is, lattice structure is a three-dimensional space structure. For all that, there are still shortcomings in the above definition of lattice structure.

For example, Tao's definition of lattice structure only emphasizes the periodic unit cells arrangement but ignores the aperiodic unit cells. Moreover, the gradient lattice structure appears in the structural design, which cannot be defined by distinguishing periodic and aperiodic unit cells arrangement. From the following definition and classification of lattice structure is a porous three-dimensional spatial structure formed and tessellated by unit cells with different topological geometries, and belongs to cellular structures (including foam structure, honeycomb structure and lattice structure). According to the uniformity of cells distribution, the lattice structures are classified into uniform lattice structures and non-uniform

There are four type of transmission tower according to the angle of deviation at the base as follow

Type of tower	Angle of deviation
A - type	0 deg – 2 deg
B -type	2 deg to 15 deg
C – type	15 deg – 30 deg
D – type	30 deg – 60 deg

Modelling

To explore the objective of the thesis; The transmission tower with X – bracing is considered. In total six models were created in STAAD pro connect edition and analysis is carried out. The description of each models are as follows –

Table 1 Model description

Model	**Description**
Model - 1	The transmission tower at plain ground condition and in zone - III
Model - 2	The transmission tower at 30-degree ground slop condition and in zone - III
Model - 3	The transmission tower at 60-degree ground slop condition and in zone - III
Model - 4	The transmission tower at plain ground condition and in zone - V
Model - 5	The transmission tower at 30-degree ground slop condition and in zone - V
Model - 6	The transmission tower at 60-degree ground slop condition and in zone - V

Design Parameters –

The following design parameters are considered for the analysis and design of transmission structure.

Table 2 Design parameter

Site condition	Flat and sloppy (30 & 60 degree)
Seismic zone	III & V
Frame	SMRF
Importance factor	2
Codes	IS:800 , IS-1893 (Part -1), IS 875 (Part 1 - 4)
Soil condition	Medium
Software used	STAAD pro
Loads	Dead load, Live load, Wind load, Seismic load
Analysis method	Equivalent static method (Eq X & Eq Z)

In the limit state design of steel structures. Auto Load combinations option of STAAD pro is used in this research.

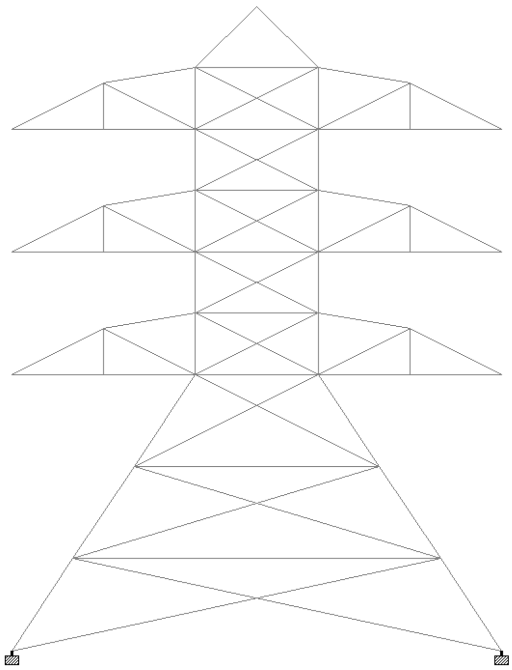

Figure 1 Transmission tower at flat ground

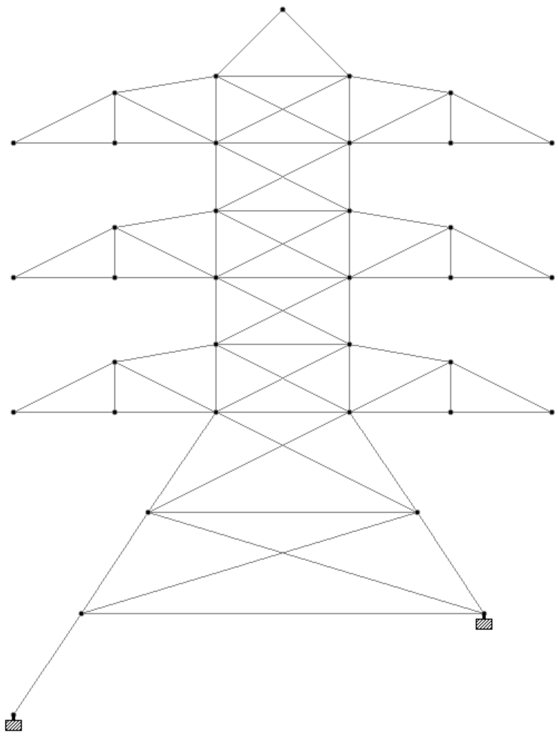

Figure 2 Transmission tower at 30-degree inclined surface

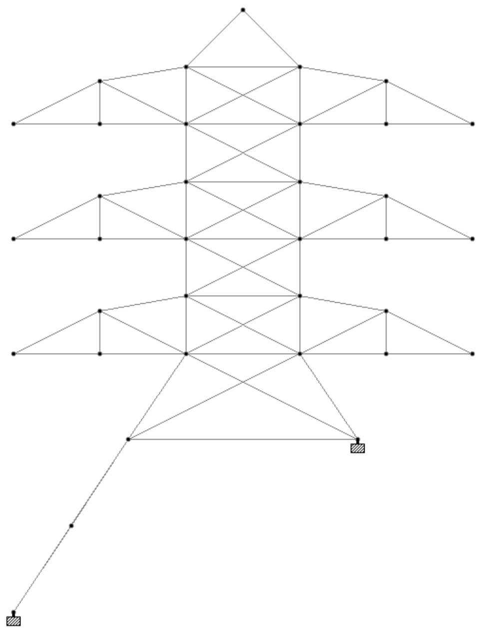

Figure 3 Transmission tower at 60- degree inclined surface

RESULT AND DISCUSSION –

Below are the analysis results of the transmission tower model under Zone – 3.

Axial force –

The maximum axial force in model – 1, model – 2 and model – 3 are as follow.

Table 3 Maximum axial force in M-01 , M-02 & M-03

Model	**Maxi Axial force**
M - 01	557.402 KN
M - 02	534.399 KN
M - 03	517.597 KN

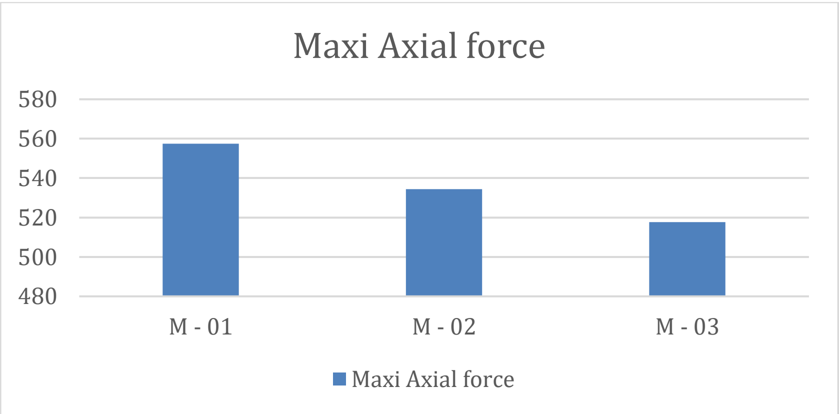

Figure 4 Graphical representation for forces in M01 , M 02 & M03

Comment

As it is clear from the table – 3, there is no significant variation in axial force of model 01, 02 & 03. This may be because of the bracing used in supporting transmission gives more lateral stability to the structure. Which may reduced the axial forces in the members.

Shear force

The maximum shear force in model – 1, model – 2 and model – 3 are as follow.

Table 4 Maximum Shear force in Y & Z direction in model M01, M 02 & M 03

Model	**Maxi Shear force Y**	**Maxi Shear force Z**
M - 01	4.983 KN	1.964 KN
M - 02	4.503 KN	1.939 KN
M - 03	6.412 KN	17.297 KN

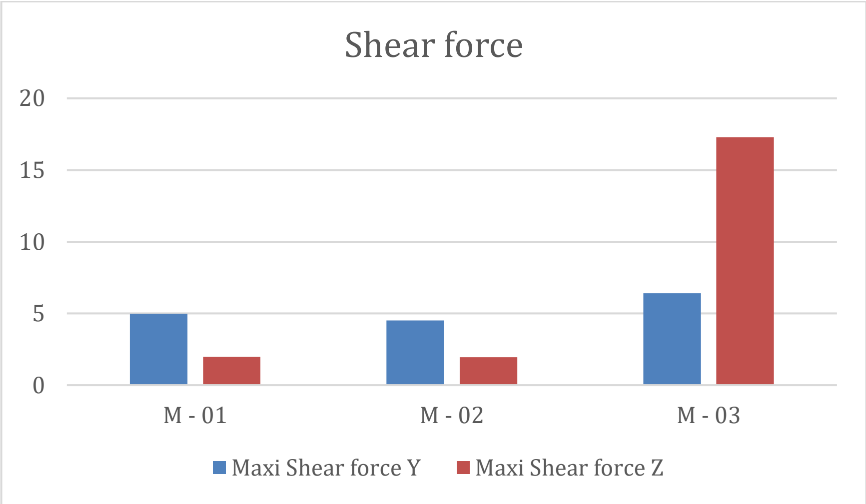

Figure 5 Graphical representation of shear force for model M 01, M-02 & M - 03

Comment

As it is clear from the table – 4, there is no significant variation in shear force of model 01, 02 & 03 in Y - direction. Whereas, there is significate variation in shear force in Z - direction. The members in model – 03 has induced large shear force this may be due to large inclination angle which may give large force in one direction, whereas in other direction i.e. Y direction. This may be because of the bracing used in supporting transmission gives more lateral stability to the structure.

Bending moment

The maximum bending moment in model – 1, model – 2 and model – 3 are as follow.

Table 5 Maximum bending moment in Y & Z direction in model M 01, M 02 & M 03

Model	**Maxi bending Y**	**Maxi Bending Z**
M - 01	3.44 KN-m	10.164
M - 02	4.537 KN-m	10.331
M - 03	181.789 KN-m	38.459

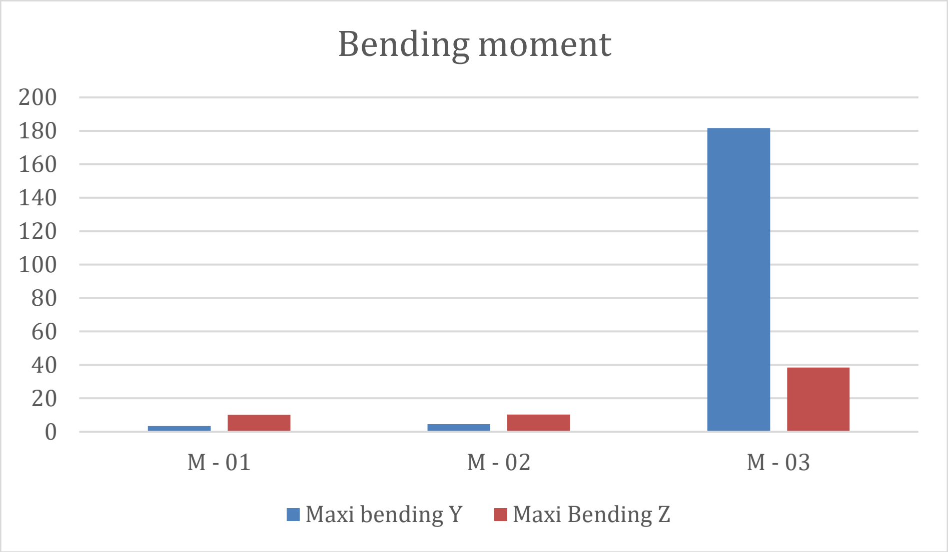

Figure 6 Graphical representation of Maximum Shear force in Y & Z direction in model M01, M 02 & M 03

Comment

As it is clear from the table – 5, there is no significant variation in bending moment of model 01 & 02, whereas in model three the bending moment increases considerably. has induced large shear force this may be due to large inclination angle which may give large force in one direction , whereas in other direction i.e. Y direction. This may be because of the bracing used in supporting transmission gives more lateral stability.

Torsion

The maximum bending moment in model – 1, model – 2 and model – 3 are as follow.

Table 6 Maximum Torsion in model M-01, M-02, M-03

Model	**Maxi bending X (Torsion)**
M - 01	0.006 KN-m
M - 02	0.009 KN-m
M - 03	0.217 KN-m

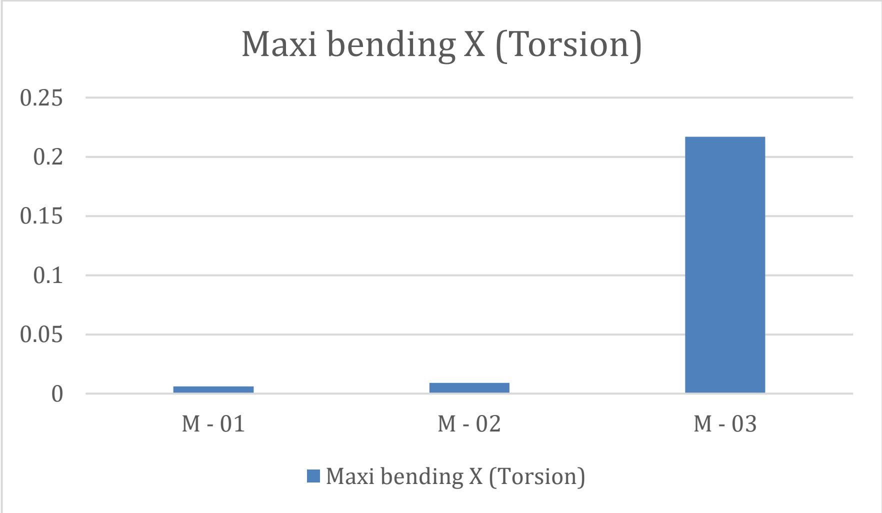

Figure 7 Graphical representation of Maximum Torsion in model M-01, M-02, M-03

Comment

As it is clear from the table – 6, there is no significant variation in axial force of model 01 & 02. This may be because of the bracing used in supporting transmission gives more lateral stability to the structure. whereas in model three the torsion increases considerably. has induced large shear force this may be due to large inclination angle which may give large force in one direction whereas in other direction i.e. Y direction. This may be because of the bracing used in supporting transmission gives more lateral stability.

Displacement –

The maximum bending moment in model – 1, model – 2 and model – 3 are as follow.

Table 7 Displacement table for model M-01, M-02, & M-03

Model	**Displacement**
M - 01	15.528
M - 02	14.284
M - 03	1054.217

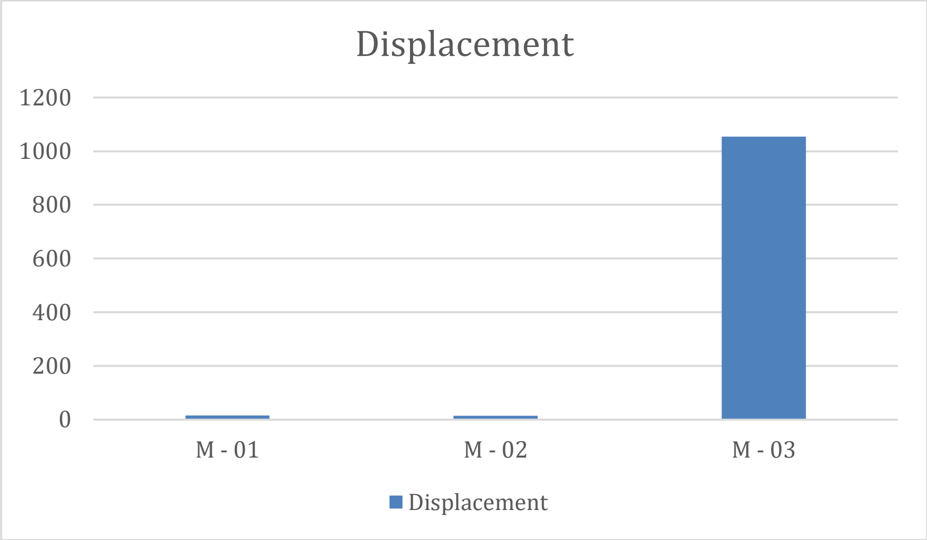

Figure 8 Graphical representation Displacement for model M-01, M-02, & M-03

Comment

As it is clear from the table – 7, there is no significant variation in displacement of model 01 & 02. This may be because of the bracing used in supporting transmission gives more lateral stability to the structure. whereas in model three the displacement increases considerably. has induced large shear force this may be due to large inclination angle which may give large force in one direction.

Base shear

The maximum bending moment in model – 1, model – 2 and model – 3 are as follow.

Table 8 Base shear in model M - 01, M - 02 & M - 03

Model	Base shear in X	Base shear in Z
M – 01	304.712	304.138
M – 02	270.42	288.814
M - 03	295.905	300.309

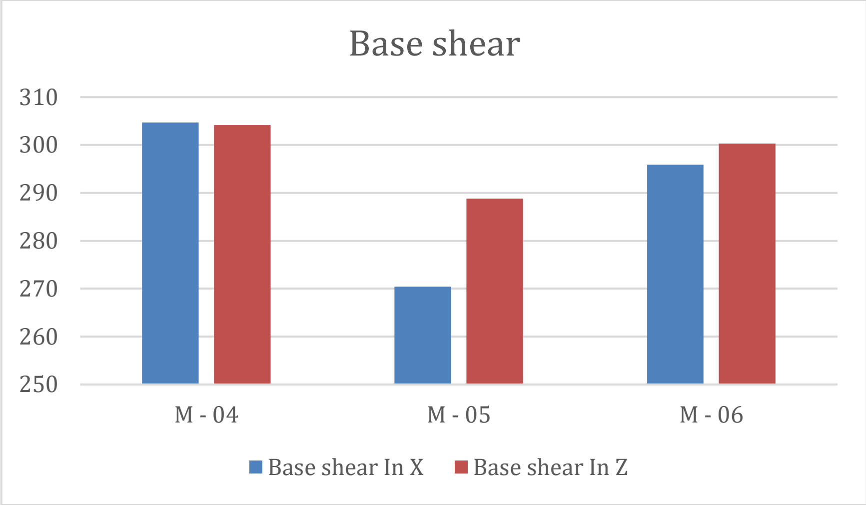

Figure 9 Graphical representation of Base shear in model M - 01 , M - 02 & M - 03

Axial force

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 9 Maximum axial force in M-04 , M-05 & M-06

Model	**Maxi Axial force**
M - 04	625.519
M - 05	581.547
M - 06	557.144

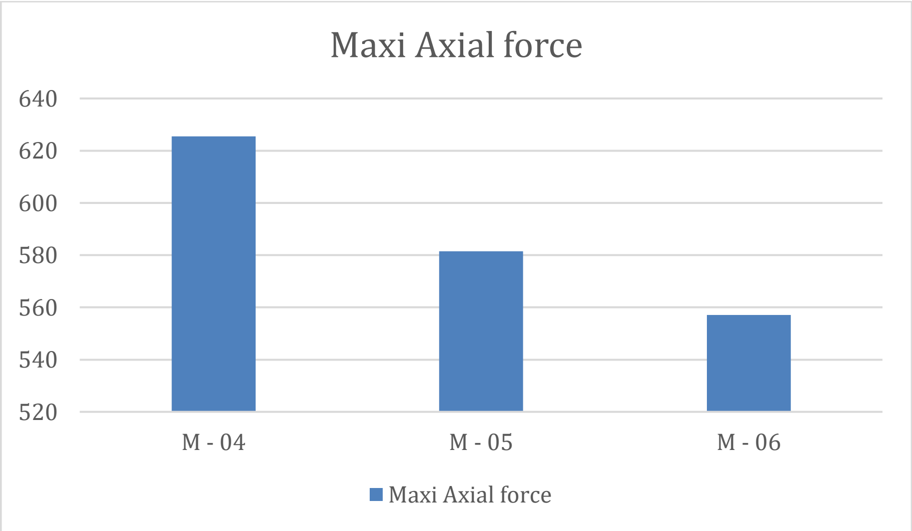

Figure 10 Graphical representation Maximum axial force in M-04 , M-05 & M-06

Comment

As it is clear from the table – 9, there is no significant variation in shear force of model 04, 05 & 06 in Y - direction. Whereas, there is significate variation in shear force in Z - direction. The members in model – 03 has induced large shear force this may be due to large inclination angle which may give large force in one direction, whereas in other direction i.e. Y direction. This may be because of the bracing used in supporting transmission gives more lateral stability to the structure.

Shear force

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 10 Maximum Shear force in Y & Z direction in model M04, M 05 & M 06

Model	Maxi Shear force Y	Maxi Shear force Z
M - 04	4.228	4.575
M - 05	4.508	2.805
M - 06	6.412	16.998

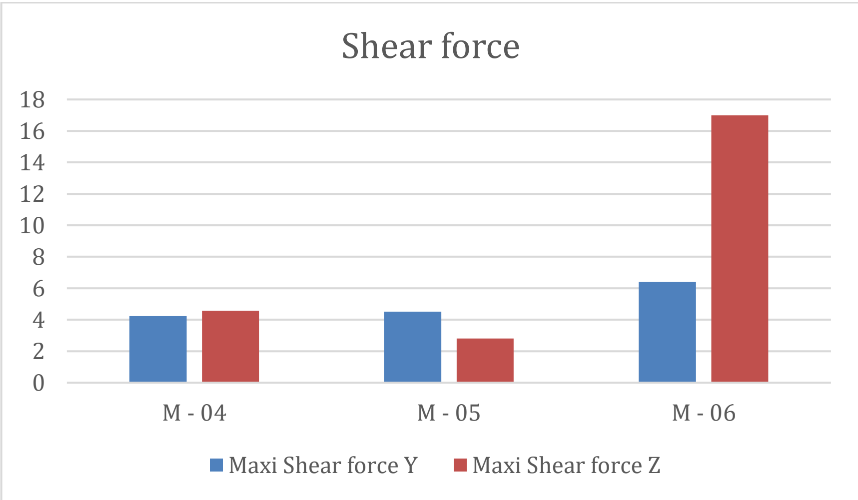

Figure 11 Graphical representation of Maximum Shear force in Y & Z direction in model M04, M 05 & M 06

Comment

As it is clear from the table – 10, there is no significant variation in shear force of model 01, 02 & 03 in Y - direction. Whereas, there is significate variation in shear force in Z - direction. The members in model – 03 has induced large shear force this may be due to large inclination angle which may give large force in one direction, whereas in other direction i.e. Y direction. This may be because of the bracing used in supporting transmission gives more lateral stability to the structure.

Bending moment

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 11 Maximum bending moment in Y & Z direction in model M 04, M 05 & M 06

Model	**Maxi bending Y**	**Maxi Bending Z**
M - 04	9.738 KN-m	10.402 KN-m
M - 05	5.651 KN-m	10.331 KN-m
M - 06	181.789 KN-m	38.459 KN-m

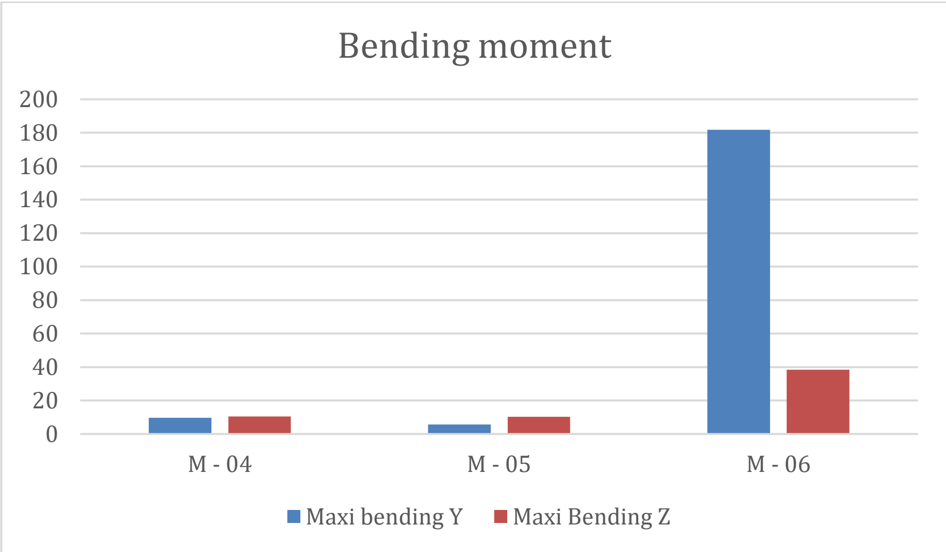

Figure 12 Graphical Representation Maximum bending moment in Y & Z direction in model M 04, M 05 & M 06

Comment

As it is clear from the table – 11, there is no significant variation in axial force of model 01, 02 & 03. This may be because of the bracing used in supporting transmission gives more lateral stability to the structure.

Torsion

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 12 Maximum Torsion in model M-04, M-05, M-06

Model	**Maxi bending X (Torsion)**
M - 04	0.011 KN-m
M - 05	0.009 KN-m
M - 06	0.217 KN-m

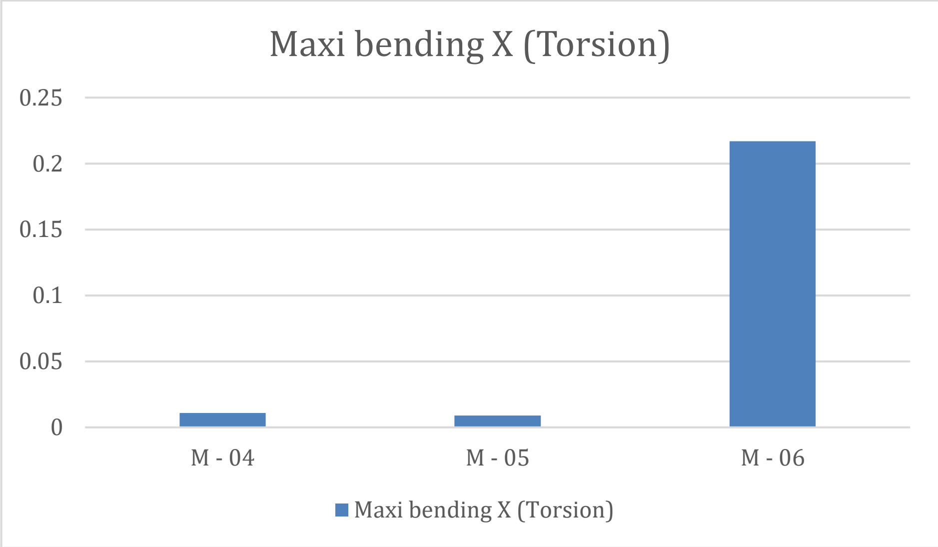

Figure 13 Graphical representation Maximum Torsion in model M-04, M-05, M-06

Comment

As it is clear from the table – 12, there is no significant variation in axial force of model 01, 02 & 03. This may be because of the bracing used in supporting transmission gives more lateral stability to the structure.

Displacement

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 13 Displacement table for model M-04, M-05, & M-06

Model	**Displacement**
M - 04	21.734
M - 05	17.419
M - 06	1054.217

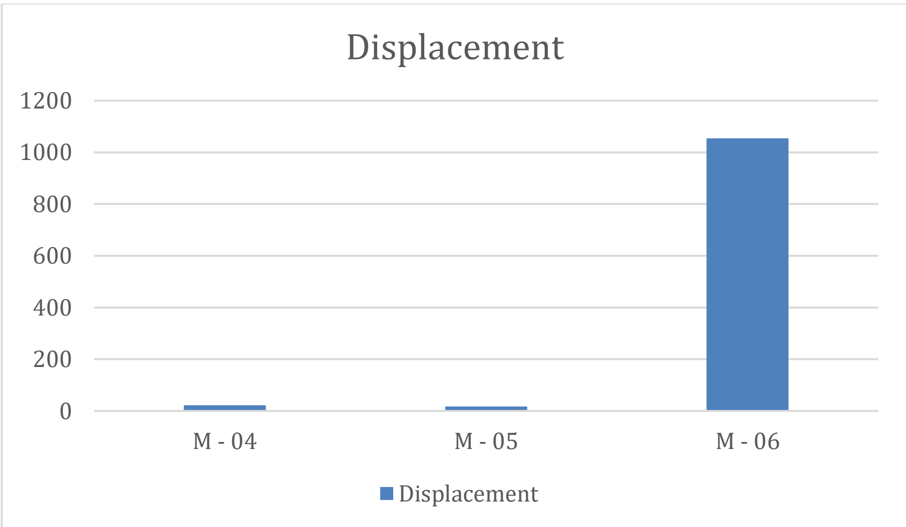

Figure 14 Graphical representation Maximum displacement in model M-04,M-05,M-06

Comment

As it is clear from the table – 13, there is no significant variation in bending moment of model 04 & 05, whereas in model six the bending moment increases considerably. has induced large shear force this may be due to large inclination angle which may give large force in one direction, whereas in other direction i.e. Y direction. This may be because of the bracing used in supporting transmission gives more lateral stability.

Base shear

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 14 Base shear in model M - 04, M - 05 & M - 06

Model	Base shear In X	Base shear In Z
M - 04	331.203	347.131
M - 05	289.265	313.889
M - 06	280.544	327.933

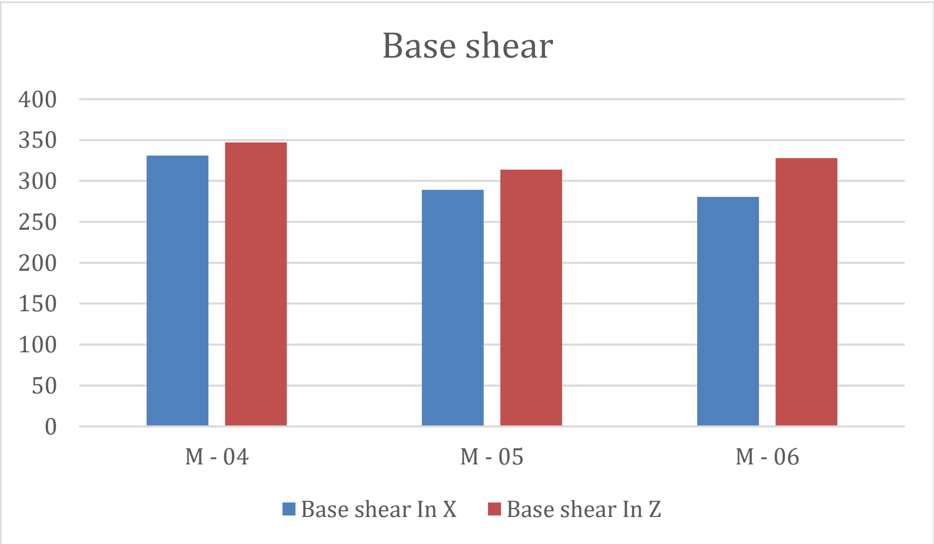

Figure 15 Graphical representation of Base shear in model M - 04 , M - 05 & M - 06

Comment

As it is clear from the table – 3, there is no significant variation in axial force of model 01, 02 & 03. This may be because of the bracing used in supporting transmission gives more lateral stability to the structure.

Comparative results –

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 15 Comparative table for axial force model M - 01, M - 02, M - 03, M - 04 , M - 05 & M - 06

Model	Maxi Axial force	Model	Maxi Axial force
M – 01/04	557.402	M - 04	625.519
M – 02/05	534.399	M - 05	581.547
M – 03/06	517.597	M - 06	557.144

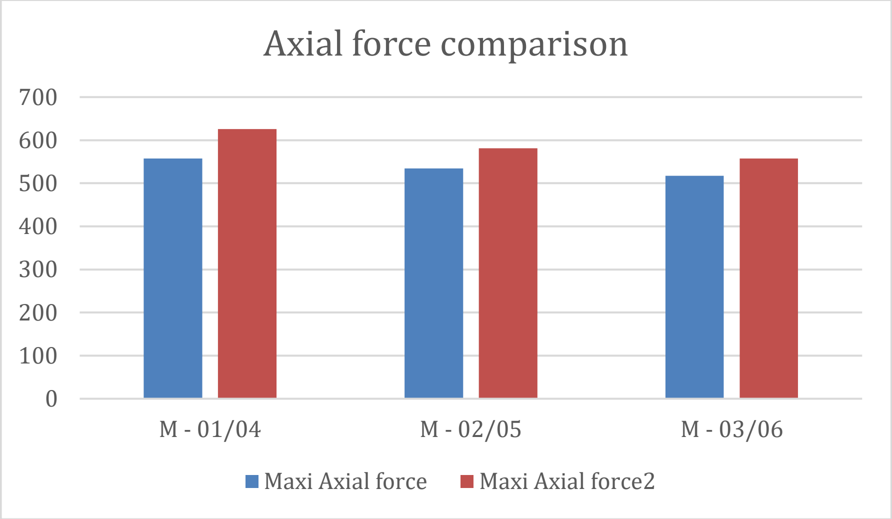

Figure 16 Graphical representation of Comparative forces for model M - 01, M - 02 , M - 03 , M - 04 , M - 05 & M - 06

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 16 Comparative table for Shear force in Y model M - 01, M - 02, M - 03, M - 04 , M - 05 & M - 06

Model	**Maxi Shear force Y**	**Maxi Shear force Y**
M – 01/04	4.983	4.228
M – 02/05	4.503	4.508
M – 03/06	6.412	6.412

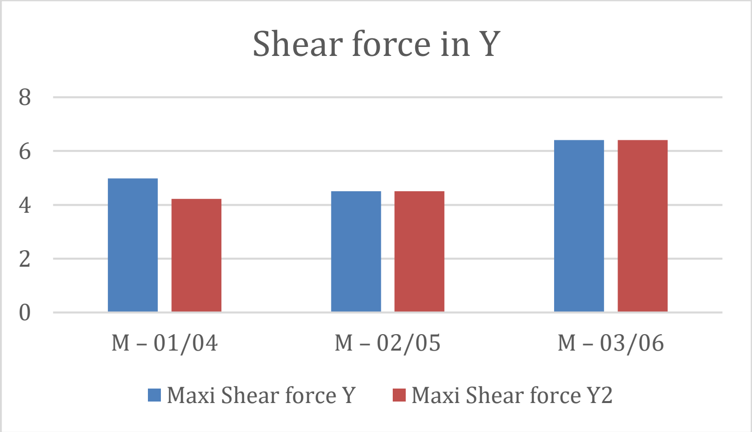

Figure 17 Graphical representation of comparative for Shear force in Y model M - 01, M - 02, M - 03, M - 04 , M - 05 & M - 06G

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 17 Comparative table for Shear force in Z model M - 01, M - 02, M - 03, M - 04 , M - 05 & M - 06

Model	**Maxi Shear force Z**	**Maxi Shear force Z**
M – 01/04	1.964	4.575
M – 02/05	1.939	2.805
M – 03/06	17.297	16.998

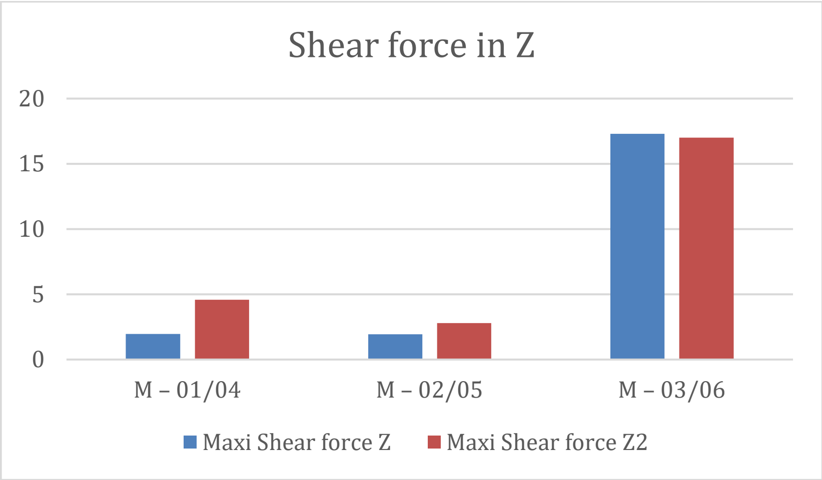

Figure 18 Graphical representation of comparative for Shear force in Z model M - 01, M - 02, M - 03, M - 04 , M - 05 & M - 06

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 18 Comparative table for bending moment in Y model M - 01, M - 02, M - 03, M - 04 , M - 05 & M - 06

Model	**Maxi bending Y**	**Maxi bending Y**
M – 01/04	3.44 KN-m	9.738 KN-m
M – 02/05	4.537 KN-m	5.651 KN-m
M – 03/06	181.789 KN-m	181.789 KN-m

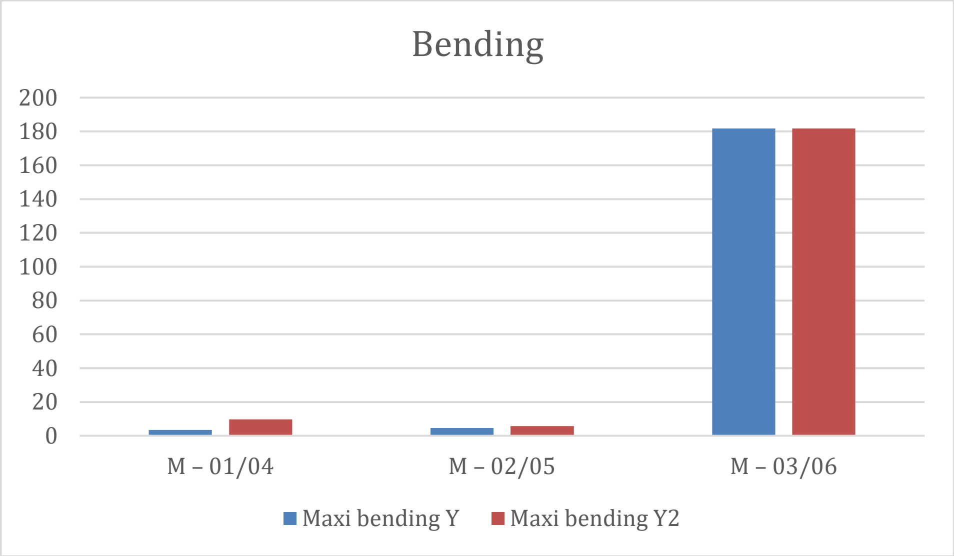

Figure 19 Graphical representation Comparative for bending moment in Z model M - 01, M - 02, M - 03, M - 04 , M - 05 & M – 06

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 19 Comparative table for bending moment in Z model M - 01, M - 02, M - 03, M - 04 , M - 05 & M - 06

Model	**Maxi Bending Z**	**Maxi Bending Z**
M – 01/04	10.164 KN-m	10.402 KN-m
M – 02/05	10.331 KN-m	10.331 KN-m
M – 03/06	38.459 KN-m	38.459 KN-m

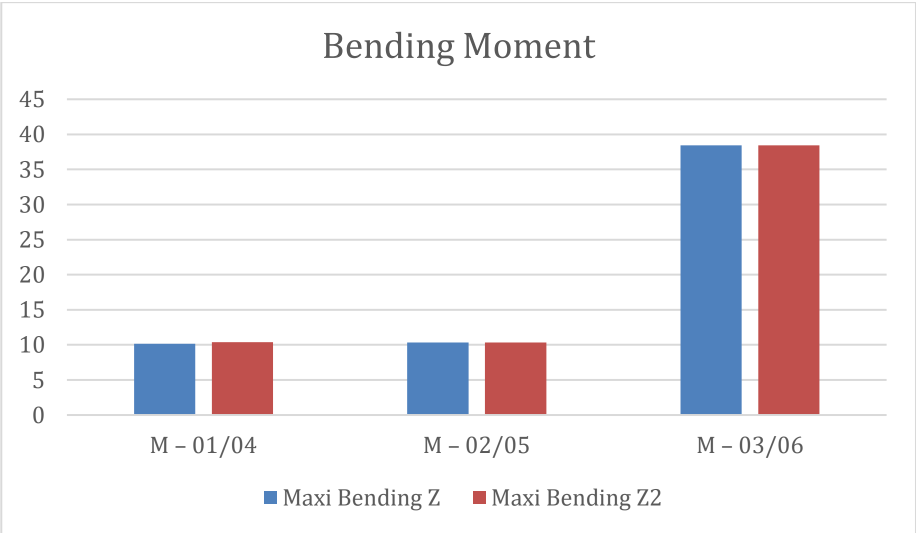

Figure 20 Graphical representation Comparative for bending moment in Z model M - 01, M - 02, M - 03, M - 04 , M - 05 & M – 06

STEEL TAKE OFF

The maximum bending moment in model – 4, model – 5 and model – 6 are as follow.

Table 20 Steel take off for model M - 01, M-02, M-03, M-04, M-05 & M-06

Model	**Steel take off (M01, M02, M03)**	**Steel take off (M04, M05, M06)**
M – 01/04	2501 KN	3071 KN
M – 02/05	3261 KN	4356 KN
M – 03/06	4278 KN	5198 KN

Comment

As it is clear from the table – 20 that the required weight of steel is very large in model six, five, three, two. Whereas the steel take is comparatively very less in model one and four. This may be due to the amount of steel will need more because the section size is more to resist the force in inclined condition required.

CONCLUSION

This paper focuses on the design and analysis of transmission tower subjected to the Zone three and five. The transmission tower resting on the surface of 0-degree, 30 degree and 60 degrees is modelled in STAAD pro. The dead load, live load and seismic loads are applied, further load combination is considered as per IS code. As it is clear from the table – 01 - 20, that the induced large axial, shear force , bending moment displacement etc parameters less in model one and five this may be due to large inclination angle which may give large value of the parameter. This may be because of the bracing used in supporting transmission gives more lateral stability. The analysis results concluded that the transmission tower on the inclined surface of 0-degree, 30 degree and 60 degrees is economical under zone – III but it becomes highly uneconomical for zone – V.

Base shear

1. The Type C tower in zone III gives an average of 36**%** more base shear as compare to Type A tower in zone III and 42.8% more force as compare to type D tower..
2. The Type C tower in zone V gives an average of 68**%** less base shear as compare to Type A tower in zone V and 92.8% more force as compare to type D tower. .

Displacement

1. The Type C tower in zone III gives an average of 19.8% more displacement as compare to Type A tower in zone III .
2. The Type C tower in zone V gives an average of 97.24**%** more displacement as compare to Type C tower in zone V .

Force

1. Force in Type C tower in zone III 35.45% less forces as compare to Type A tower in zone V .
2. Force in Type D tower in zone III 45.5% less forces as compare to Force in Type C

Moment

1. Moment 4.94% less moments as compare Type C tower in zone III with respect to Type D tower in zone III.
2. Moment 64.97 % more moments as compare to Type D tower in zone V with respect to Type C tower in zone V.

Hence Type – C tower is more suitable for Zone III it may give better performance under assumed design conditions.

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