Study of Transmission Towers And Proper Selection In Terms Of Its Effectiveness, Behavior, Deflection And Economic Evaluations

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ABSTRACT

A tower or mast is a tall skeleton structure with a relatively small cross-section, which has a large ratio between height and maximum width. A tower is freely standing self-supporting structure fixed to the base or foundation while a mast is tall structure, pinned to the base. Self-supporting latticed structures are used in a wide variety of civil engineering applications, most commonly to support transmission lines that transmit and distribute electricity. The towers are with various heights e.g. the height of television towers may vary from 100m to 300m, while those for radio transmission and communication networks the height may vary from 50 to 200m etc. In this research the height of tower is 100m. Depending upon the size and type of loading, towers are grouped into tower with large vertical loads and towers with mainly horizontal wind loads. The gravity loads are almost fixed, since these are dependent on the structural design. Seismic load is also not critical as mass of the structure is not very heavy and it is more near the ground. However, the maximum wind pressure is the chief criterion for the design of lattice towers. We also consider only wind load analysis, since the tower is dominated by wind load. Today most of structural engineers face a problem with selecting a bracing system to overcome the wind load applied on the tower. As result in order to reduce the problem of selecting appropriate bracing system as per functional requirement different transmission tower analyzed and tried to compare the bracing system, that is, Single diagonal bracing, X- bracing, XB bracing, X-B-X Bracing and K-bracing with respect to wind load resisting system and economy.

Keywords: Tower, Latticed Structure, Wind Load, Bracing System, Types of Bracing, Transmission Line.

Abbreviation: D-BS = Diagonal bracing system, X-BS = X-bracing system, XB-BS = XB-bracing system, K-BS = K-bracing system, XBX-BS = XBX-bracing system, MT= Metric Tone

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1. INTRODUCTION

Latticed structures are used in a wide variety of Civil Engineering applications. A latticed structure is a system of members (elements) and connections (nodes) which act together to resist an applied load. Typical latticed structures include grids, roofing structures, domes, and transmission towers. Latticed structures are ideally suited for situations requiring a high load carrying capacity, a low self-weight, an economic use of materials, and fast fabrication and construction. For these reasons self-supporting latticed towers are most commonly used to transmit and distribute electricity.

The design of transmission tower may either too stringent or too complicate. Designer has difficulties to comprehend the required qualities of transmission tower project and which bracing system of the transmission tower is suitable for the needed location. Different designer or engineers have different ideas and different result outcome from analysis. When certain requirements are not meet, problems occurred. It is time to resolve these issues. We need to have a solution that able to a good alternative for desired problem. The solution also should able to provide a guideline to designer to produce an optimum design that fulfill the problem and requirements as well as able to yield the priority of project element to be considered during design stage. One of tools we use to get this is by designing and analyzing different bracing system of transmission tower to select the suitable bracing system of transmission tower for the location desired depending on the basis of economical evaluation and topography of the location.

Transmission line or tower projects are specialize engineering projects which comprise of designs of the transmission line route, tower designs, foundation design, construction of foundation, erection of tower, stringing or dismantling conductor and commissioning of the transmission line. These tasks involved many subtasks and each of these subtasks requires different aspect of engineering field and demands from each project stakeholders.

In Ethiopia the transmission tower is mostly used in hydro power and telecommunication. For example Gilgel Gibe I, II, III, Tana, Malka Wakana, Awash Electric Power Station and other that require huge number of self-supported transmission tower. Because one latticed tower design may be used for hundreds of towers on a transmission line, it is very important to find an economic and highly efficient design.

The arrangement of the tower members should keep the tower geometry simple by using as few members as possible and they should be fully stressed under more than one loading condition. The goal is to produce an economical structure that is well proportioned and attractive (ASCE**,** 1988). Typical towers have a square body configuration with identical bracing in al1 faces. The bracing system modeled and analyzed in transmission tower are diagonal bracing, k-bracing, x-bracing, XB-bracing, and XBX-bracing. Most transmission towers are constructed with asymmetric thin-walled angle sections that are eccentrically connected, are sensitive to material and geometric nonlinearities, and exhibit slippage or semi rigidity at the joints, making the transmission tower one of the most difficult forms of latticed structures to analyze (Kitipomchai, 1992**;** Al-Bermani, 1 WZA)**.** As a result, most computer programs that design and analyze transmission towers make many assumptions to simplify the computations, and ignore any nonlinear effects. This study presents a review of the literature pertaining to computer-aided structural analysis of transmission towers.

2. OBJECTIVES

The objective of this research is to investigate different cases of towers (about five) behavior in terms of displacement due to wind load and their material coast comparison. The specific objective of this study is:

- Comparison of the tower-story displacement due to wind load and tower overall displacement
- To identify which cases of the tower is more preferable in terms of displacement and coast of the material require

3. METHODOLOGY

3.1. General data for analysis and design of tower

The general data for analysis and design of the tower are:

3.1.1 Specimens

This research is studied using five property sections for assigning member truss

- Angle section
- Channel section
- Tube section
- Pipe section

3.1.2 General Data

The general data used for modeling of towers is as below.

- Tower function: lattice tower for telecommunication
- Total height of the tower: 100 m
- Bottom plan dimension: 12.5 × 12.5 m
- Top plan dimension: 3 × 3 m
- Type of slab: solid slab
- Structural system: structural steel- combined truss and bending
- Structural analysis: STAAD Pro.V8i software
- Structural design: STAAD Pro.V8i software
- Load combinations: dead & wind load
- No. of stages: 3
- First stage height of the panel: 5 m
- Second stage height of the panel: 4 m

- Third stage height of the panel: 3 m
- Yield strength of the steel: 250 N/mm^2
- Ultimate strength of the steel: 400 N/mm^2
- Structural Steel: Rolled Sections - Angle, Double angle, Channel & I sections
- References

  EBCS1-Basis of Design and Actions on Structures

  EBCS 3-Design of Steel Structures

3.1.3 Material Property

Reinforcement steel

$$f_{yk} = 250MPa$$
$$f_{ys} = 1.15MPa$$
$$f_{ctd} = \frac{f_{yk}}{f_{ys}} = \frac{250}{1.15} = 217.39MPa$$

3.1.4 Dimensional Rendered View of 100m Lattice Towers [Diagonal, X, K, XB, and XBX bracing]

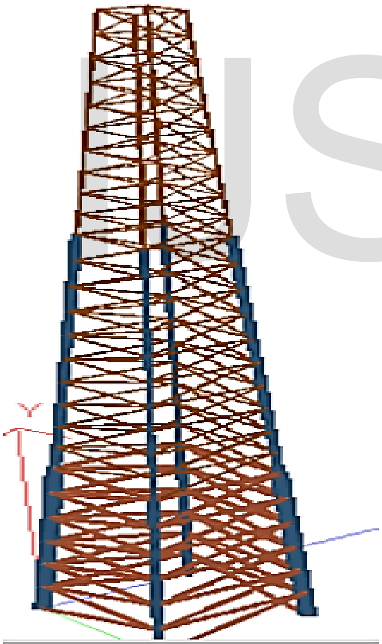

Figure 1. Case-1 Lattice Tower with Diagonal Bracing System Subjected to Wind Load

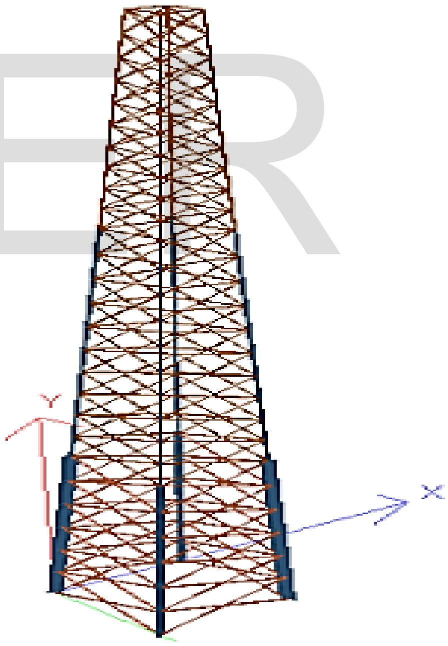

Figure 2. Case-2 Lattice Tower with X- Bracing System Subjected to Wind Load

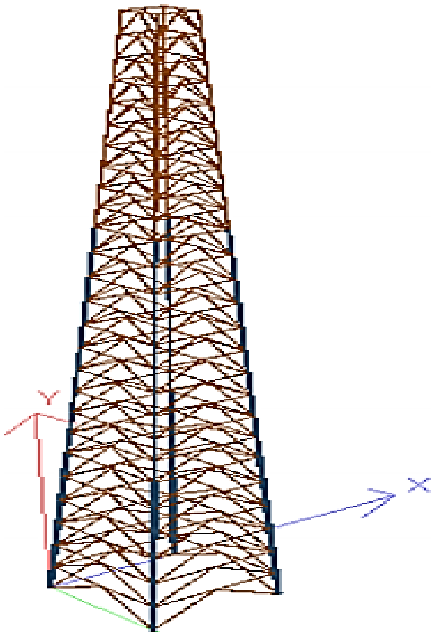

Figure 3. Case-3 Lattice Tower with K- Bracing System Subjected Wind Load

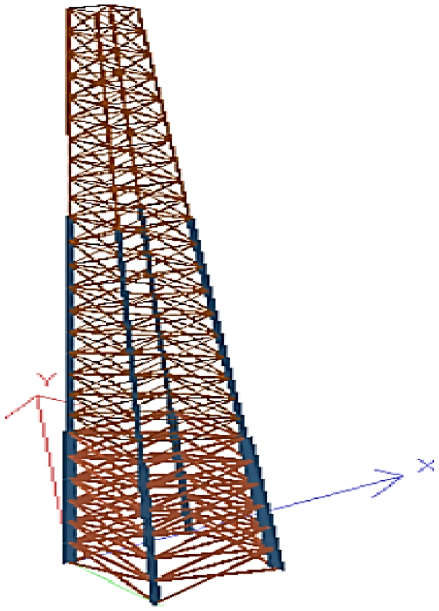

Figure 4. Case-4 Lattice Tower with XB- Bracing System Subjected to Wind Load

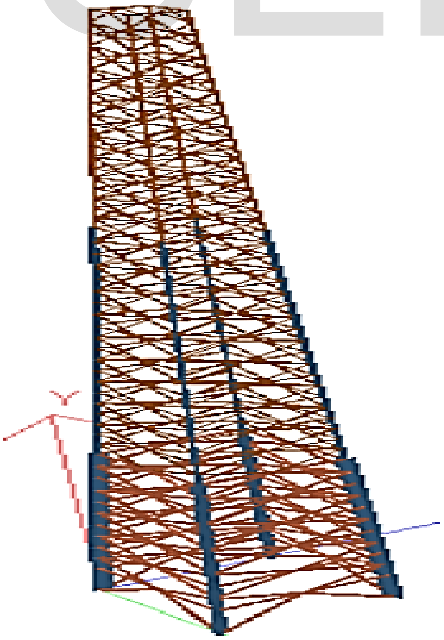

Figure 5. Case-5 Lattice Tower with XBX- Bracing System Subjected to Wind Load

4. RESULT AND DISCUSSION

In this part of the study the percentage of the steel quantity required and the overall displacement of the tower due to wind load in five cases is presented in graph.

4.1. Steel Quantity Comparison of Different Lattice Towers

Table 1. Steel Quantity Comparison of Different Lattice Towers

Cases/Quantity	Structural Steel Quantity[Metric Ton]	
	Quantity(Mt)	Percentage Variation Of Structural Steel With respect to Case 1
Case:1-[D-BS]	178.2	0
Case:2-[X-BS]	55.6	69
Case:3-[K-BS]	98.1	45
Case:4-[XB-BS]	75.6	58
Case:5-[XBX-BS]	87.2	51

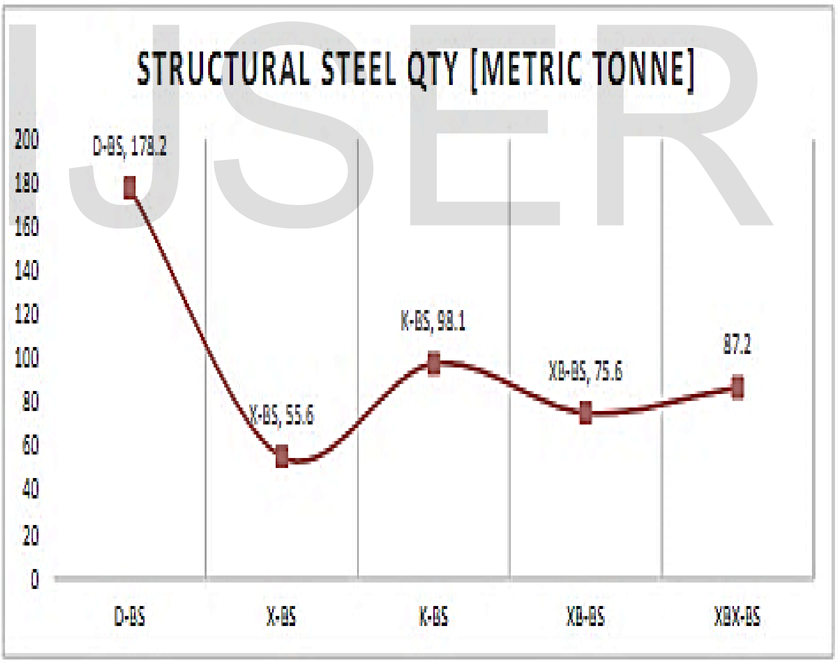

Figure 6. Steel Quantity Comparison of Different Lattice Towers

From the above graph which represents the results of the amount of steel required in MT. The graph shows that the diagonal bracing system requires much amount of steel compared to the other bracing systems. This indicates that when the member's number of the system is decreased the member's size (kg) should be increased in order to resist the displacement of the tower.

4.2. Tower-Story Displacement due to Dead Load and Wind Load

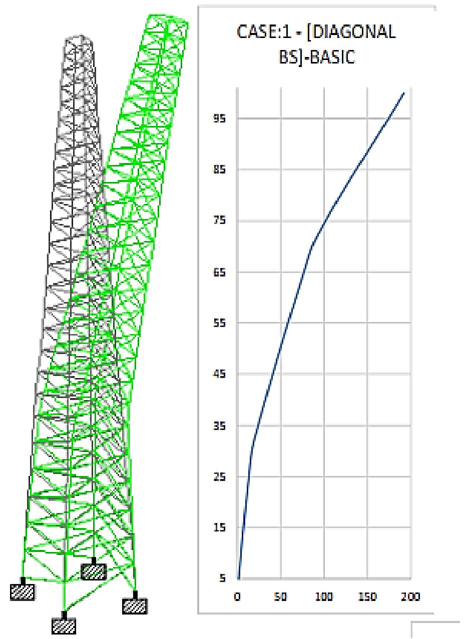

Figure 7. Case-1 Lattice Tower with Diagonal Bracing System Subjected to Wind Load

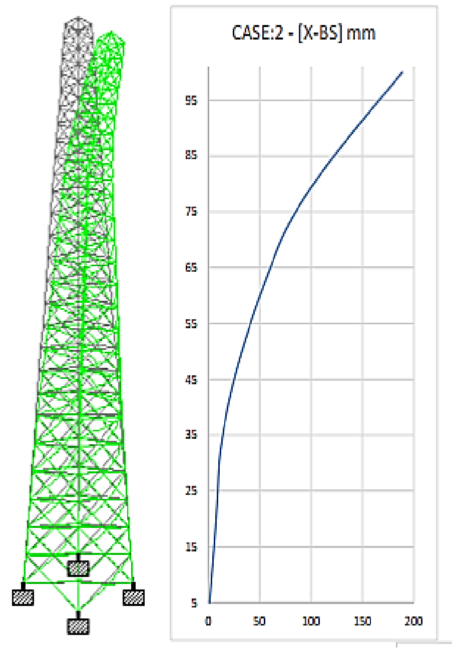

Figure 8. Case-2 Lattice Tower with X-BS Bracing System Subjected to Wind Load

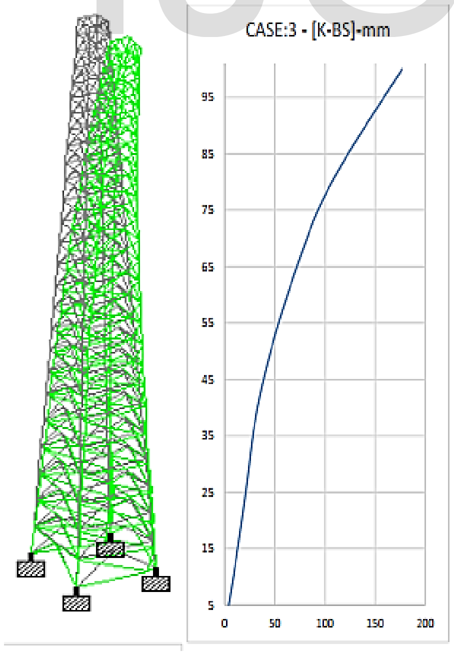

Figure 9. Case-3 Lattice Tower with K-BS Bracing System Subjected to Wind Load

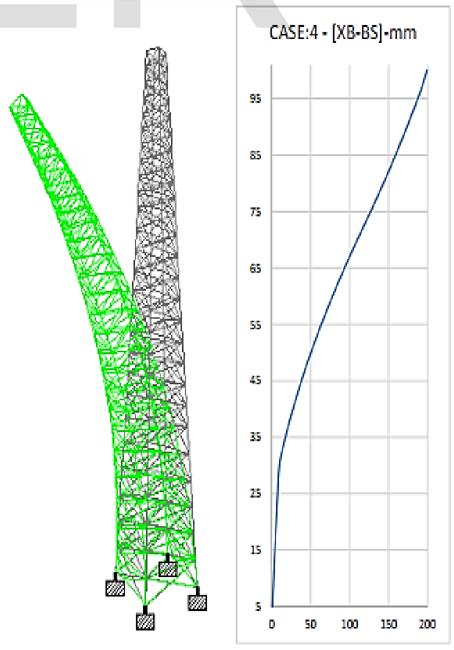

Figure 10. Case-4 Lattice Tower with XB- Bracing System Subjected to Wind Load

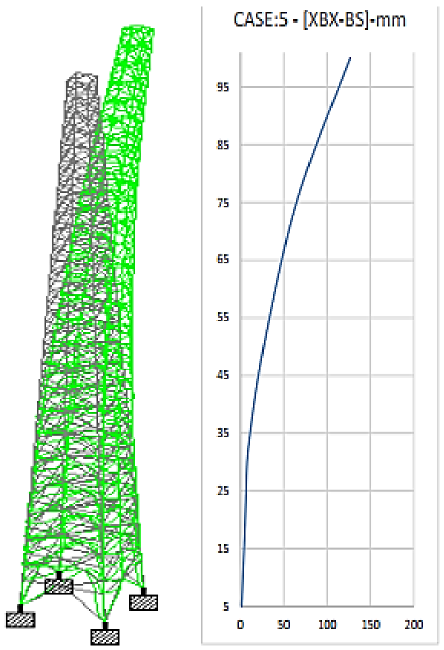

Figure 11. Case-5 Lattice Tower with XBX Bracing System Subjected to Wind Load

From the above graph which represents the results of story displacement at different height of tower in millimeter. The maximum displacement of tower from all cases is 199.2mm at maximum height of tower at 100m.

$$Allowable\ Deflection\ (mm) = \frac{H}{500}$$

$$= \frac{100000}{500} = 200$$

$$[EBCS - 3, 1995]$$

$$Permissible\ Deflection\ (mm) = \frac{H}{300}$$

$$[EBCS - 3, 1995]$$

$$Story\ Displacement\ (mm)$$
$$= 1.895\ \ [From\ STAAD.Provi8\ software$$

Hence all tower cases are safe since all deflection of tower less than allowable deflection

4.3. Overload Displacement of Towers Comparison

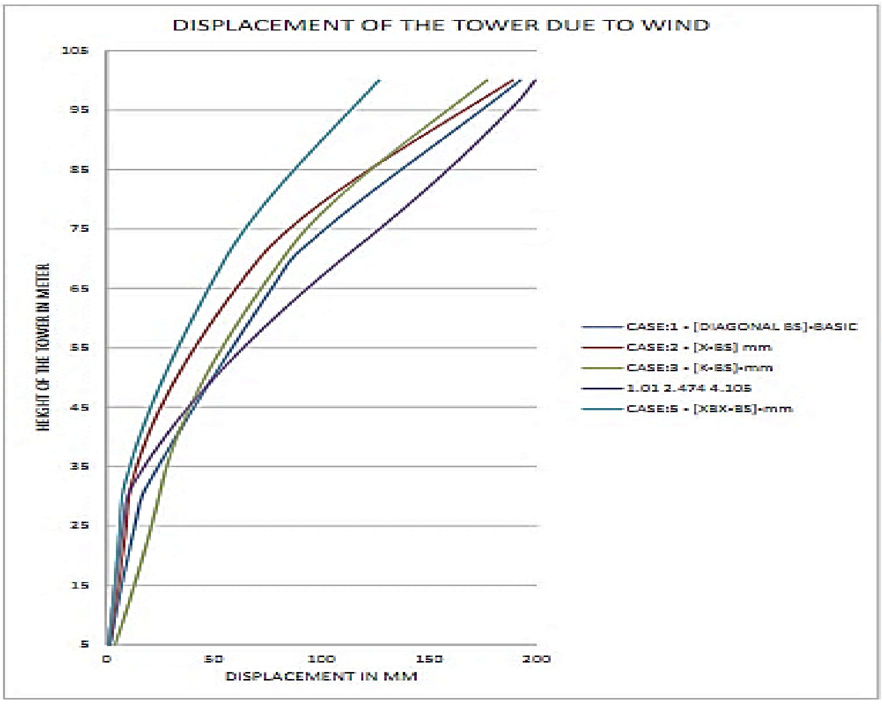

Figure 12. Overall displacement of towers at different height levels

Table 2 Overall displacement of towers at different height levels [STAAD.Provi8 software]

Height of The Tower in Meter	Case:1-[D-BS] mm	Case:2-[X-BS] mm	Case:3-[K-BS] mm	Case:4-[XB-BS] mm	Case:5-[XBX-BS] mm
5	1.895	1.422	3.963	1.01	0.963
10	4.388	3.482	8.616	2.474	2.423
15	7.118	5.647	12.962	4.103	3.826
20	10.064	7.559	17.086	5.865	5.104
25	13.206	9.197	20.947	7.758	6.255
30	16.57	10.479	24.49	9.797	7.317
34	22.523	13.18	27.184	15.824	10.132
38	29.017	16.917	30.728	23.282	13.523
42	35.677	21.33	35.057	31.501	17.438
46	42.517	26.686	40.112	40.534	21.83
50	49.512	32.652	45.829	50.351	26.648
54	56.65	39.307	52.142	60.918	31.847
58	63.913	46.512	58.985	72.197	37.352
62	71.283	54.27	66.286	84.14	43.12
66	78.739	62.443	73.977	96.691	49.122
70	86.257	71.038	81.969	109.861	55.299
73	95.374	78.934	88.207	120.194	60.596
76	105..082	88.303	95.588	130.297	66.556
79	115.363	98.713	103.954	140.128	73.078
82	126.084	110.203	113.389	149.668	80.071
85	137.108	122.388	123.015	158.893	87.44
88	148..3	135.245	133.399	167.792	95.09
91	159.533	148.44	144.109	176.374	102.925
94	170.684	161.909	155.019	184.665	110.855
97	181.65	175.397	165.976	192.696	118.799
100	192.357	188.831	176.861	199.2	126.692

The displacements of transmission tower with different bracing systems at different heights of towers are determined. From graph or table above, the maximum displacement is occurred in case 4 (XB-BS). This is because the structural steel we use in XB-BS is lower sections and, we observed that from the above total material requirement comparison graph XB-BS is the second least amount of material requires (75.6 MT) and as result the maximum tower displacement occur by XB-BS tower bracing system.

5. CONCLUSION

The whole study is concentrated on comparison of lattice tower with different type of bracing which mean Diagonal bracing, X-bracing, K-bracing, XB-bracing &XBX-bracing system. Then, the analysis is carried out using wind load and self-weights of different types of bracing system. Sequentially, the structural steel required for different type of bracing system and there deflection behavior both for story deflection and over all deflection is studied. After overall analysis, design and study, the following points are drawn.

- The quantity of steel required for X-bracing system is 69% less than that required for Diagonal bracing systems. As a result, the transmission tower constructed from X-bracing requires less steel quantity than the other bracing systems.
- Both overall and story deflection is best controlled when use XBX-bracing system configuration than X-racing, K-bracing, XB-bracing and Diagonal bracing system. Thus for effective controlling of overall deflection at top it is better to use XBX –bracing system than the other system.

After all analysis and design of transmission towers with different bracing system we conclude that the X-bracing system of transmission tower is economic since the quantity of steel required for X-bracing system is less than that required for others bracing systems while XBX-bracing system is more effective in controlling story displacement and deflection control of transmission towers.

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