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Analysis on Optimal Design of Telecommunication Towers of Different Bracing System using Staad Pro Software

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Abstract: Lattice steel communication tower is a framework construction made of galvanized steel or aluminum section with a typical height from 50m to 100m above the ground level and many type of the bracing system have been design such as XB, X, Y, YD, K and KD bracing system. This study is focused on analysis an optimal design of the tower to reduce the cost of telecommunication lattice steel tower construction by comparing the well-practiced tower bracing type and two others bracing type which is Y-bracing and X-B bracing and the tower was subjected to the basic wind load and the self-weight of the tower. The displacement and the stress towards toward the tower was determined by using the STAAD.Pro V8i. Due to this study is focusing on the comparison of the bracing type, the properties of all 3 model were same which is by using the open section angle steel 200 x 200 x 20 for the bottom section of the tower and 150 x 150x 12 for the upper section of the tower. The MS1553:2002 was used to refer the basic wind speed and the wind load force acting towards the tower have been computed in the STAAD pro software by using the ASCE-7. As a result, The XB bracing type give a bad result for all the measurement that been compare while the K bracing type seems to be the most optimal design among the other 2 bracing type.

Keywords: Analysis Tower, Telecommunication, Lattice Tower, Wind Force

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1. Introduction

Lattice steel communication tower is a framework construction made of galvanized steel or aluminum section with a typical height from 50m to 100m above the ground level. This structure was constructed purposely for the telecommunication provider such as Celcom and Maxis for placing signal antenna. There are few designs for the telecommunication tower that are practiced in Malaysia such as the monopole tree where the structure was constructed on a straight tree. In the urban area, the antennas were placed on a high-rise building structure. The structure that been constructed on those day was a wooden pole with zinc iron barbed. In the book of Design of Electrical Transmission Lines: Structures and Foundations by Sriram Kalaga and Prasad Yenumula, the first lattice tower have been constructed on 1829 that made by steel structure and the design look similar with the most popular steel structure constructed in Paris, Eiffel Tower.

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 in the field of telecommunication and power line system. Because one latticed tower design may be used for hundreds of towers on a power transmission and communication purposes, 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 [1].

In this study, the design of self-supporting steel lattice tower is analyzed for the same zone of basic wind speeds and aiming at comparing 4-legged communication towers with different selection of bracing systems which is K-bracing, Y-bracing and X-B-bracing. The towers will be designed using STAAD.Pro according to Eurocodes and the wind forces towards the tower was calculated based on reliable Malaysian standards.The main focus is to ensure that the common practice design for telecommunication lattice steel tower in malaysia is not a over-designed tower due to the wind load case in Malaysia. A drawing of well practised design have been used as a refference for the comparison of the lateral load act on the tower with difference bracing type. The more complex type of bracing tends to reduce the value of lateral load on the tower but will increase the usage of steel in the tower.

The objectives of this study are as follows; (1) to analyze 3 steel telecommunication tower with difference bracing type using STAAD Pro. (2) to conducts a comparative study for similar heights of towers using different bracing patterns for Wind load.

1.1 Bracing system

The bracing members are arranged in many forms which bear tension alone, or tension and compression as an alternative and the diagonal braces are efficient elements for developing stiffness and resistance to wind loads [2]. In his study, X-B, single diagonal, X-X, K and Y bracings were modeled in his study which give a result X-B bracing system have the lowest value of joint displacement among the others bracing system, but the weight of the tower is to be high due to the use of this system. For the conclusion for this study, the Y bracing system was the most efficient bracing system because it has a low value of joint displacement, but the weight is the lightest among the other bracing system.

[3] had conducted a research regarding the lateral load behavior of towers with various types of bracings which is X-bracings, XB- bracings, K- bracings and Y- bracings. The wind load was referring the IS 1893-2002 and the K style bracing tends to be the optimized bracing for lateral loads on steel towers. The above findings showed that the overall weight or the lateral force for K-type bracing is lower compared to other types of bracing because the arrangement of the bracing might help to distribute the force among the members. The highest value of force was determined in the compression members.

1.2 Loads

Load such as dead load, self-weight, wind load and snow load are one of the factors that can influence the action toward the structure. A group of researchers have done a research on the response of steel lattice telecommunication masts under environmental actions and seismic loading. Based on their observation, the slender and flexible steel lattice telecommunication masts are primarily subject to the environmental actions of wind and ice [4]

The load generated by the self-weight of the structure affects the structure without significant adjustments over its lifetime. This load is an intrinsic property of the load carrying device and should, thus, not be removed without altering the structure's load carrying properties.

By referring the BS EN 1993-3-1:2006 on clause 2.3.6, an imposed load have been discussed on that part. The national annex may give information of imposed load on platform and railing. The following characteristic imposed load are recommended:

- Imposed load on platform :2.0kN/m^2
- Imposed load on railing :0.5kN/m^2

So, the total of live load act to the tower due to the weight of the workman for the maintenance work was state as 2.5kN/m^2.

2. Methods

The analysis and design of the tower structures were performed using STAAD Pro software. To performed the model few consideration was taken into account.

2.1 Desription of structures

There were 3 difference model of tower with different type of bracing have been modeled by using the STAAD.Pro software. The first model was reffered by the well-practised design where the design have been obtained from a company in Johor Bahru. As the design of the well-practised lattice tower is using the K-bracing type, the first model for this study have been done with using the K-bracing type and followed by the other two bracing type which is Y-bracing and XB-bracing as shown in figure 1. The Y and XB bracing type was selected based on the past study result and being used in this study to compare the outcomes.

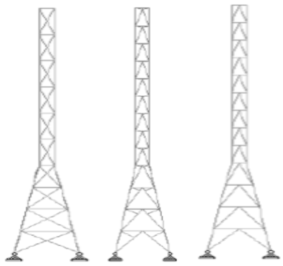

Figure 1: XB, Y and K bracing type.

Since the focused of this study is to make a comparison of the internal forces on the structure members thus all types oThe towers were split into two section ; upper section and bottom section for the structure configuration. Two types of sizes were choosen ; 200 x 200 for the member at the bottom section and 150x150 for the members at upper section.

In this study tower is modeled as a 3D space by considering tower as a truss.

2.2 Material

Using STAAD , analysis of transmission towers has been carried out as a 3-D structure. The tower members are designed as angle section. The angle section of hot rolled members are used with mild steel of grade 275 N/mm^2.

Table 1: General Information of tower

Item	Description
Height of tower	60m
Width of tower	8 m
Steel type	Open section angle leg
Steel dimension	Bottom section: 200 x 200 x 20 Below Section: 150 x 150 x 12
Support type	Fixed Support

2.3 Loading

The following loads were considered in the transmission tower analysis

1.Self Weight

2.Wind load and

3. Antenna Load

The self weight of the tower can be precisely estimate by the software based on the selected sizes applied in the modelling and acting in downward direction. The typical density of steel is 7850 kg/m^3 .Wind load acting horizontally on the exposed surfaces of the structures. The wind speeds reported in MS 1553:2002 were extracted from the Gringorten System Study for the 50-year return period, which takes into account the two major zones. Zone I is Peninsular Malaysia's inland region with a wind speed of Vb = 33.5 m/s. The design wind speed is obtained by multiplying the basic wind speed (Vb) by the factors such as the terrain, and topography factor. The analysis of te basic wind speed was used to calculate the force act to the member of tower by using the ASCE-7. Wind load considered is acting in X and Z directions. Figure 2 shows the design value of the wind pressure due to height result.

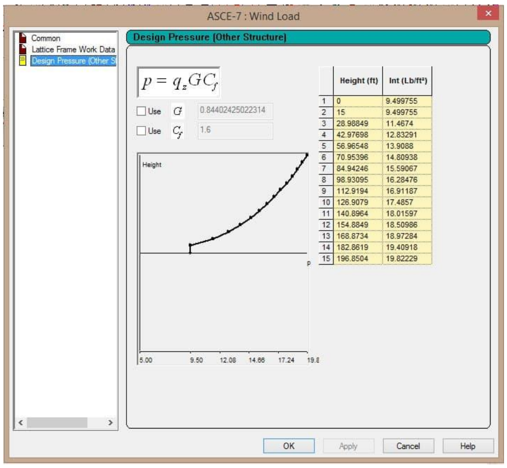

Figure 2: Design value of wind pressure.

These are the standard antennas that usually being attached at the top of the communication tower. Therefore, some of these antennas will be used as sample design in designing both tower.

Antenna Type of TX 3.6 386 10.18 with weight of 386kg is the example of standard antennas that usually being attached at the top of the communication tower. Specific load from the antenna, the numbers of antenna and the exact location should be considered in the analysis of the communication tower. In practise, designer should have the specification and the information on the arrangement for mounting up the antenna at specific height from the tower base.

3. Results and Discussion

This part will shows and discusses about the outcomes of the analysis results for the 3 difference design of telecommunication lattice steel tower that been model using the STAAD.Pro V8i software. The model of the tower were simulated with the wind action that been auto generated by using the ASCE 7-10 based on the basic wind force in Malaysia. The focus of this analysis have compare the maximum force and the node displacement for all of the tower model. Next, the weight of the steel used for the tower model have been compared.

3.1 Unity check

The result of the unity check was based on the design code of EN1553-1-1:2005 that been set up and assigned to the model during the design process in the Staad Pro.The result showed that all of the unity check result for all 3 model constructed that been evaluated by using the EN 1553-1-1:2005 design code have a value below than 1. From this checking, all of the model is pass in term of the selection of the properties which is using the 200 x 200 and 150 x 150 open angle steel. As shown in figure 3, the maximum member located at the leg part of the tower.

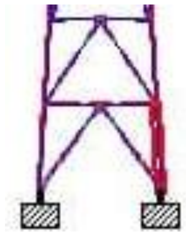

Figure 3: Location of the maximum force member.

3.2 Result of the analysis due to the wind load pressure and self-weight of tower.

In this part of result analysis, force on the members in X and Y direction, the maximum stress in member and the node displacement data have been execute from the Staad Pro output. All the data have been tabulated in table 2.

Table 2: Result of data

Type of bracing	Result						
	Max. force in X-direction (kN)	Max. force in y-direction (kN)	Max. Stress (N/mm^2)	Member length (m)	Displacement (mm)		
					x	y	z
Y-bracing	534.956	10.472	69.906 (C)	5.686	120.163	21.890	3.892
XB-bracing	603.055	9.125	85.294 (C)	5.686	136.037	22.601	10.483
K-bracing	516.430	10.493	69.109 (C)	5.686	122.079	19.893	2.389

From the table 2, the value recorded for maximum force in X-direction is 534.956kN, 603.055kN and 516.43kN for the Y,XB and K bracing type while the maximum force value recorded in the Y-direction is 10.472kN, 9.125kN and 10.493kN respectively. As we can compare the value of force for X-direction and Y-direction, the data show that the value for X-direction is greater than the value for Y-direction due to the dominant force acting to the tower were come from the wind force on the X-direction while the Y-direction force was come from the self-weight of the tower.

The next result that will be discuss is about the maximum stress value on the member for all of the tower model. From the result output, the maximum stress member for all the tower model was identidied to be located on the leg of the tower as shown in figure 3. This arguement have been support by referring to the length of member of the maximum stress for all the tower model tend to have the same value.

The value of maximum stress in member for Y-bracing is 69.906N/mm2, 85.294N/mm^2 for XB- bracing and 69.109N/mm^2 for K- bracing model. All of the maximum stress value recorded was act as compressive force.

Result tabulated in table 2 is about the node displacement. The data of node displacement result will show the impact of force towards the displacement of certain node on the tower. For X bracing type model, maximum value of node displacement recorded for X-direction is 120mm, 136mm for XB bracing type and 122mm for the K bracing type. As the maximum force data, the value for Y and Z direction show a small value because the major force acted on the tower was occur on the X-direction of the tower.

3.3 Weight of steel used for the tower model.

In order to achieve the objective of the study which is to determine which kind of model will use the least amount of steel, an analysis for the steel take off have been used to know the ammount of steel used for each tower model. A bar chart have been attached on figure 4 to show the comparison of weight of steel used in each tower model.

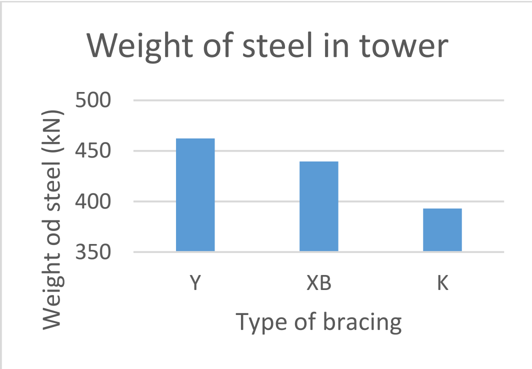

Figure 4: Graph weight of steel used.

As we can see from the graph above, the Y bracing type have the highest amount of steel used with the weight of 462kN while the XB bracing type have a weight of 440kN steel used in the tower model. The K bracing type of tower model recorded the lightest weight among the others model with a weight 393kN of steel used for this model.

4. Conclusion

The main objective of this study have being achieved by managed to do a modelling of 3 difference type of bracing for telecommunication lattice steel tower by using the STAAD Pro V8i software. All of the model have been pass by referring to the unity check result which have the ratio below than 1 for all model.

For the comparison of the forces acted on the members, the result show that the XB-bracing give the largest value of force among the other bracing type and the K bracing type give the least value of force which is the force is 516kN. For the value of maximum stress on members, XB bracing again became the highest value recorded with the value of stress 85N/mm^2 while the Y and K bracing share the same value of stress in member is 70N/mm^2.

In term of node displacement, the Y bracing type showed the lowest value of displacement which is 120mm and followed by the K bracing with the displacement is 122mm and the highest value of displacement among this 3 type of bracing was owned by the XB bracing with the displacement value is 136mm.

It can be concludde, the XB bracing type give the worst result among the other 2 bracing type for this study. All of the criteria that been measured in this study give a bad result for the XB bracing. So, only the K and the Y bracing that suitable for the most efficient design that can be compare for this study. As we have discuss about the force acting on the member, the final judgement that can be conduct in order to determine the most optimal type of bracing for this study is by referring to the analysis of steel used among these 3 difference type of bracing. The K bracing shows to have the least amount of steel used compared to the XB and the Y bracing with only used 393kN of steel. As the past study that being done by [3], he had conclude that the K bracing is the optimal type of bracing can be approve in this study.

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