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RESEARCH ARTICLE

WIND ANALYSIS OF STEEL TRANSMISSION TOWER USING DIFFERENT BRACING SYSTEMS

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Wind, bracing systems, transmission tower, displacement, steel take off.

Abstract

The design and analysis of transmission towers, which are essential components in electrical power distribution networks. As the demand for electricity continues to rise, optimizing tower design for efficiency, safety, and cost-effectiveness is the crucial requirement. A transmission tower 5 m high subjected to wind load as per Delhi and Bhopal regions are analyzed. The towers are also analyzed for different bracing systems X, inverted-V and W bracings, in order to check the effective bracing system in reducing the wind responses. The bending moment, shear force, displacement and steel take off were evaluated. It was observed that using W bracing reduces the wind responses more effectively reduced as compared to the X and inverted-V bracing systems. This study contributes to the ongoing efforts to improve transmission infrastructure, providing a framework for future developments in tower design.

Introduction:-

As the backbone of the electrical power distribution network, transmission towers are essential components that carry electricity from power production facilities to final consumers [1]. Overhead power lines, which carry high-voltage energy over great distances, are supported by these towers. The need for effective and dependable power transmission systems has grown more critical as the world's energy consumption rises due to factors including population expansion, industrialization, and the spread of electronic gadgets.

Transmission tower design is a complicated procedure that takes into account a number of variables, such as load-bearing capacity, resistance to wind, ice, and seismic loads and adherence to codal standards. The risk of structural failure is reduced when towers are designed to handle operational loads, severe weather, and other external factors. The transmission towers are classified structurally as lattice, monopole and guyed towers and as per voltage level as high, medium and low voltage towers. Mostly transmission towers are made up of steel structures, due to its strength, durability and also ability to resist the severs environmental condition throughout its life span.

Related Work:-

The design and analysis of transmission tower have evolved significantly over the years. Numerous studies have contributed to our understanding of structural behavior, materials and optimization techniques. Below are some key findings from previous research:
Albermani et al. [1] studied tower sub-structure assembly reinforced with various diaphragm bracings was used in experimental investigations under two different loading scenarios. The findings supported the analytical forecasts and made suggestions for the best kinds of diaphragm bracing. An existing 105 m tall TV tower was successfully upgraded using the most effective diaphragm bracing style. Ghugal and Salunkhe [2] compared the analysed and

designed of 400 kV steel transmission line towers viz having three-legged and four-legged models. The slenderness effect, critical sections, forces and deflections of both three legged and four legged towers were compared. It was observed from the result that up to 21.2% steel and 3.05 % area was saved by three-legged tower as compared to four-legged tower. Patil et al. [3] analysed 220 kV double circuit self- supporting transmission towers with square base for wind load for zones-II, III, IV. Finally, the optimal design of transmission tower using hot-rolled steel was compared for different wind speeds.

Arya and Sindhu [4] analysed transmission tower with an isolated footing subjected to dead load, live load, wind load and seismic loading. STAAD Pro V8i yielded a maximum load of 648 kN under each tower leg. It was discovered that every single tower member was secure and stable. Shrivastava and Khan [5] analysed and designed transmission tower for different type of pylon for seismic zone III. The three different models of tower were considered for study. The tower with angle section and pylons showed greater reduction in weight after optimization. Jadhav et al. [6] analysed 220 kV single circuit transmission line towers situated in wind zone II with different types of cross section like angle, channel, square hollow section, circular hollow section, tube sections. It was observed that transmission tower modelled with tube section was the optimum structural configuration with minimum displacement, axial force and weight. Dhoke [7] studied self-supporting transmission line tower with different types of bracings using hot-rolled steel sections It was observed that single web diagonal pattern bracing system performs better. Sahu and Saxena [8] discussed the detailed literature review of past researchers in the field of transmission tower. The discussed the analysis and software's used for analysis of towers. Modani and Warade [9], Sakhale et al. [10] analysed and designed transmission line tower.

Singh and Tiwary [11] studied the most cost-effective and efficient bracing system for four-legged self-standing electricity towers having square bottom sizes as 8 m, 6.5 m and 5 m. Kim et al. [12] studied to minimize the geometric footprint of the tower by lowering the inclination angle of the main pillars. In order to further simplify tower design, it also investigates the viability of eliminating members such as horizontal and auxiliary components.
The objectives of the present work are to carry out analysis of steel transmission tower of 35 m high subjected to wind loading. The effect of different basic wind speed as per IS 875 (part 3) [13] in the tower are compared. The effect of X, inverted-V and W bracing systems on the bending moment, shear force, displacement and steel take off developed in the tower are compared. All the analysis of steel transmission towers are carried out using Staad. Pro software.

Methodology:-
A steel transmission tower [14, 15] of capacity 11 kV of height 35 m, and arm length of 6.10 m is considered. The footing base is considered square of size 1.6 × 1.6 m. as shown in Figure 1.

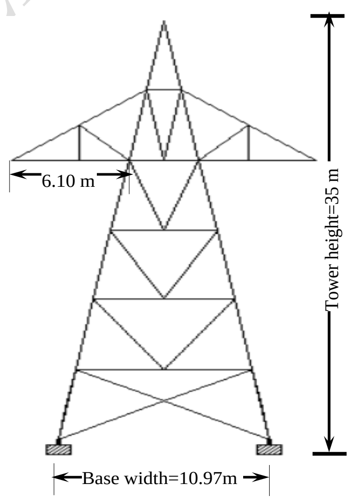

Figure 1 Transmission tower

As per IS 875 (part III) [13] the Case I basic wind speed 47 m/sec for Delhi and Case II basic wind speed 39 m/sec Bhopal is considered. For the effect of varying staging height on the bending moment and shear developed in the tower components for basic wind speed 39 m/sec the different bracing systems as X, Y and W [16, 17] are considered as shown in Figure 2.

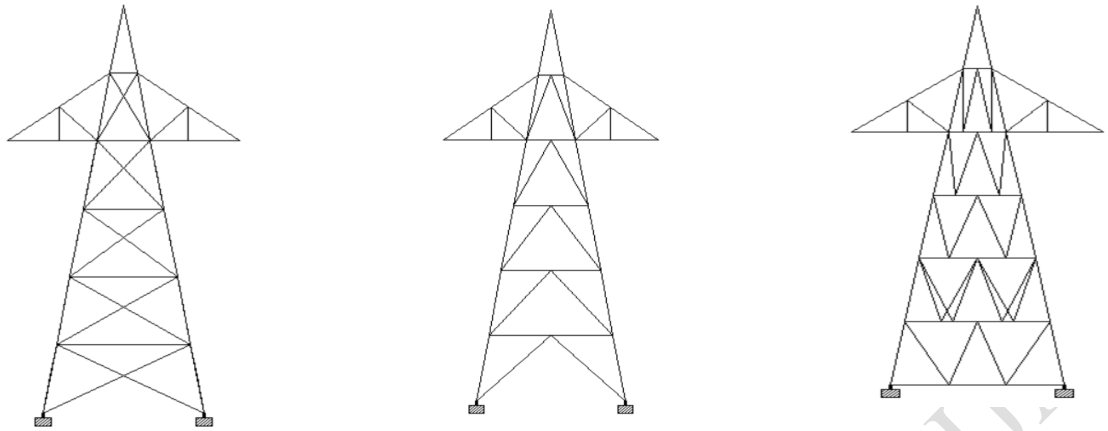

Figure 2 Tower with different bracing systems

Results and Discussions:-

The analysis of steel transmission tower subjected to wind loading is investigated. using Staad. Pro software. The effect of different basic wind speed as per IS 875 (part III) [13] in the tower are compared. The effect of X, inverted-V and W bracing systems on the bending moment, shear force, displacement at varying height of tower and steel take off developed in the tower are evaluated and compared., in order to check the performance of bracing systems to wind responses.

Effect of different wind speed

Figures 3, 4 and 5 shows the effect of different basic wind speed on force and bending moment in X and Z direction, as considered for Case I and Case II on tower.

It can be observed that the basic wind speed for Case I was more thus the forces and bending moment values in X and Z direction are also greater as compared to Case II. Further, the forces and bending moment are more in Y-direction as compared to X and Z directions. Thus, it can be observed that as the basic wind speed increase the wind resposne quantitite also increase.

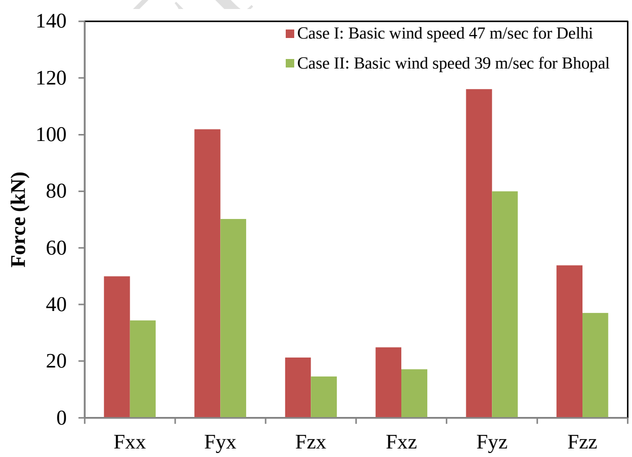

Figure 3 Forces acting on tower in X and Z directions

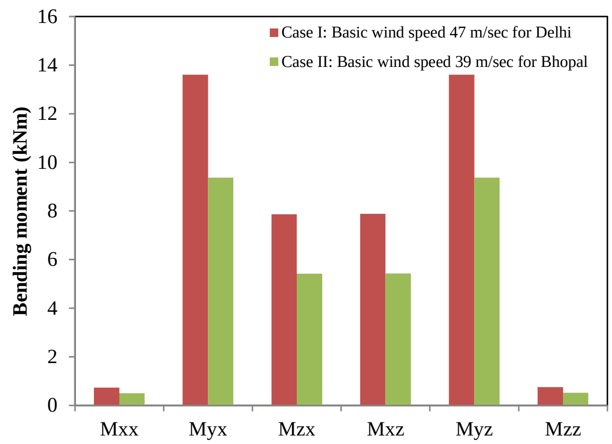

Figure 4 Bending moment acting on tower in X and Z directions

Effect of different bracing systems

For the effect of different bracing systems as X, inverted-V and W was considered on the shear force, bending moment and displacement developed in the tower components for Case II basic wind speed 39 m/sec at varying height of tower are evaluated.

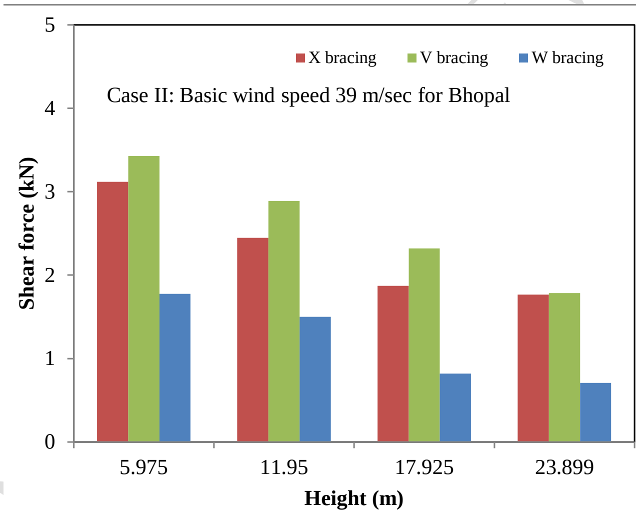

Figure 5 Shear force for different bracing systems

Figure 5 shows the shear force for different bracing systems at varying height of tower at 5.975m, 11.95 m, 17.925 n and 23.899 m. It can be observed that shear force is developed maximum at height 5.975 m from base and decreases at the larger height from the base. The shear force is developed maximum in case of inverted-V bracing system as compared to X and W bracing systems. The minimum shear force is developed in the tower components by using W bracing. By using W bracing systems the shear force is reduced by 43.13% at 5.9775 m height as compared to X bracing and 48.17% as compared to inverted-V bracing.

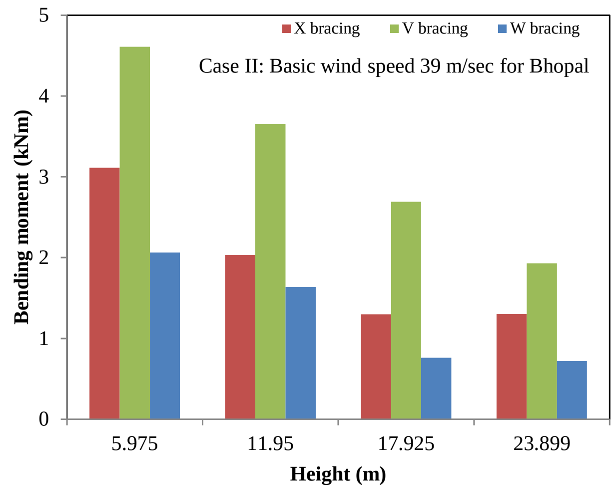

Figure 6 Bending moment for different bracing systems

Figure 6 shows the bending moment for different bracing systems at varying height of tower at 5.975m, 11.95 m, 17.925 n and 23.899 m. It can be observed that bending moment is developed larger at height 5.975 m from base is 3.113 kNm in X bracing, 4.610 kNm in inverted-V bracing and 2.062 kNm in W bracing and decreases towards the larger height of tower from the base. The bending moment is developed maximum in case of inverted-V bracing system as compared to X and W bracing systems. The minimum bending moment is developed in the tower components by using W bracing. By using W bracing systems the bending moment is decreased by 33.76% at 5.9775 m height as compared to X bracing and 55.27% as compared to inverted-V bracing at 5.9775 m height.

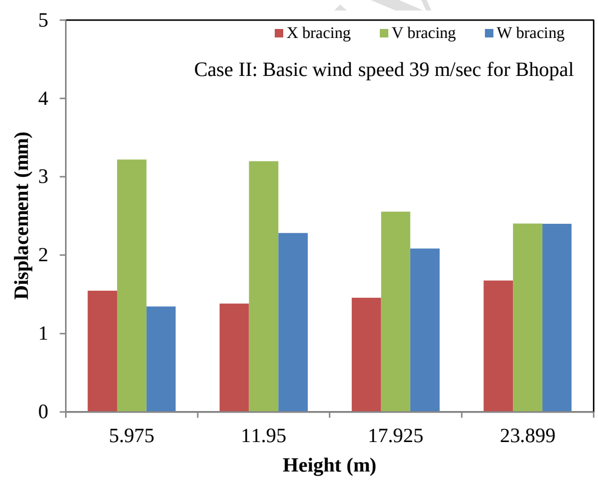

Figure 7 Displacement for different bracing systems

Figure 7 shows the displacement for different bracing systems at varying height of tower at 5.975m, 11.95 m, 17.925 n and 23.899 m. It can be observed that displacement is developed larger at height 5.975 m from base and decreases towards the larger height from the base. The displacement is developed maximum in case of inverted-V bracing system as compared to X and W bracing systems. The minimum bending moment is developed in the tower components by using X bracing.

Steel take-off quantity

Figure 8 shows the steel take-off quantity for steel transmission tower for three different bracing systems under consideration. The steel take-off quantity for W bracing is 100 kN which is less as required by X and inverted-V bracing systems. The quantity is reduced by 16.67 % as compared to X bracing and 6.54 % for inverted-V bracings.

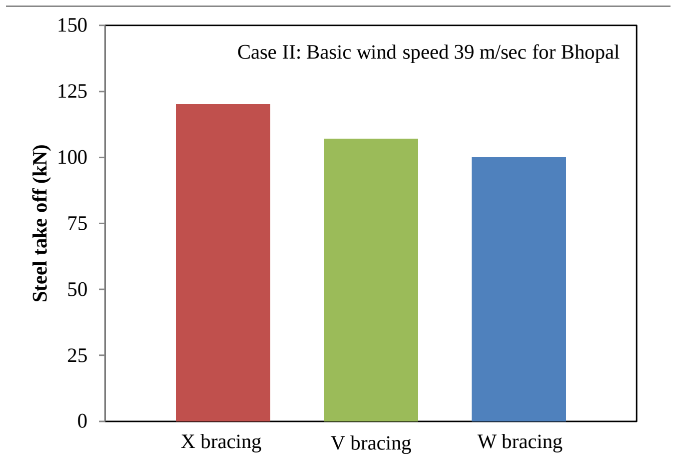

Figure 8 Steel take-off quantities for different bracing systems

Conclusions and Future Scopes:-

The analysis of steel transmission tower subjected to wind loading is investigated. The effect of different basic wind speed as per IS 875 (part III) 2015 in the tower are compared. The effect of X, inverted-V and W bracing systems on the bending moment, shear force, displacement at varying height of tower and steel take off developed in the tower are evaluated and compared., in order to check the performance of bracing systems to wind responses. The following are the conclusions of the present work:

1. It can be observed that the baseic wind speed for Case I was more thus the forces and bending moment values are also greater as compared to Case II. Thus, the basic wind speed increases the wind resposne quantitite also increase.
2. The shear force and bending moment is developed maximum in case of inverted-V bracing system as compared to X and W bracing systems. The minimum shear force and bending is developed in the tower components by using W bracing.
3. The displacement is developed maximum in case of inverted-V bracing system as compared to X and W bracing systems. The minimum bending moment is developed in the tower components by using X bracing.
4. The steel take-off quantity for W bracing is less as required by X and inverted-V bracing systems. Thus, from the present work it shows the efficiency of W bracing system to be used in transmission towers which will reduce the steel section requirement for the design.

Looking ahead, more research can improve the accuracy and usability of predictions. Expanding existing datasets to include a wider variety of concrete mixes and different environmental conditions can help these models work better. Hybrid models or deep learning can also be helpful in determining the parameters and how much feature importance of each parameter carry which affect the compressive strength of concrete.

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