EFFECT OF PULL-OUT FORCES ON TRANSMISSION TOWER RESTING ON PILE FOUNDATION

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Abstract: This study has been carried out to determine capacity of piles as a foundation for transmission tower. The transmission tower structures are subjected to various forces such as lateral forces , uplift forces and moments during its service period. These forces are transferred to foundation and subsequently to the sub soil. Thus the foundations are subjected to large uplift and moments due to wind load and conductor tensile forces. Thus it is important to determine foundation capacity of transmission towers to ensure safe and economic design .In this study the model transmission tower was fabricated and rested on bored cast in- situ concrete piles of slenderness ratio of 4,6 and 8.The field load tests were carried out on the tower foundation system to determine its maximum load carrying capacity. The effect of slenderness ratio on the load carrying capacity was evaluated. The load vs displacement and load vs settlement curves were obtained using test data. It was observed that the capacity of piles in tension is less than the capacity of piles under compression. Also it was noted that the failure in tension piles occur way before the full capacity of compression piles get mobilized.

***Index Terms* - Uplift capacity, Pile foundation, Transmission tower, Model test**

I. INTRODUCTION

The transmission tower structure is important infrastructure for the electric power supply system, which consists of conductors, overhead power lines, steel-lattice tower and lower foundation parts. In particular, lower foundation parts are key component to guarantee the sustainability and continuous serviceability of the entire transmission system. In recent years, with increasing power demands, the safety of the power transmission line is vital important. Hence, the structural behaviour of transmission towers subjected to different loading conditions is an important research area. Design foundation loads associated with these structures are therefore also increasing, however it is often the capacity to resist wind-induced uplift forces and broken cable conditions that control the foundation design.

Various types of foundations are used for transmission tower structures to support electrical power transmission systems, including overhead power lines and steel tower frames. Different types of transmission tower foundations are available, including inverted-T (footing), pile, mat, and single-pole. They are selectively used depending on the size of the structure, the type of load and the soil conditions When the towers are constructed in steep slopes, hilly areas or soft soils, deep foundations, such as piers or piles, are used, although they are more costly.

The high-rise or long-span steel lattice structures, however, is significantly susceptible to lateral loads such as winds due to its light self-weight, high flexibility, and low damping. And the structural damages and progressive collapses of the power transmission towers have been often reported under extreme wind events.

The transmission tower foundations are subjected to significant uplift loads during its design life due to damage forces, wind forces and conductor tensile forces acting on the super structure. Very few papers are available to model and predict the behaviour of piles under uplift loads (Vesic 1970; Meyerhof 1973; Das et al. 1977; Das 1983; Rao and Venkatesh 1985; Chattopadhyay and Pise 1986; Alawneh et al. 1999). Few theories have been developed based on the limit equilibrium method to find the net uplift capacity of the pile (Meyerhof 1973; Das 1983; Chattopadhyay and Pise 1986) and validated through experimental measurements. Indian standard code also gives the guidelines to carry out uplift test on piles under 0% compressive loads (IS-2911_4).Which suggested that the safe uplift capacity of piles can be taken at Two-third of the load at which the total displacement is 12 mm or half of the load at which the load-displacement curve shows a clear break (downward trend).Research work done by Doohyun et al.(2015) suggested design criterion for transmission tower foundations can be given by the 0.1 D(10% of pile diameter) condition for uplift displacement.

All of these have showed that capacity of piles is less under tension in comparison to compressive forces. Also for the tall structures like transmission tower which is subjected to large uplift forces and moments, it is desirable to predict the behaviour of piles under such loads and to determine the resistance offered by same for safe and economic design.

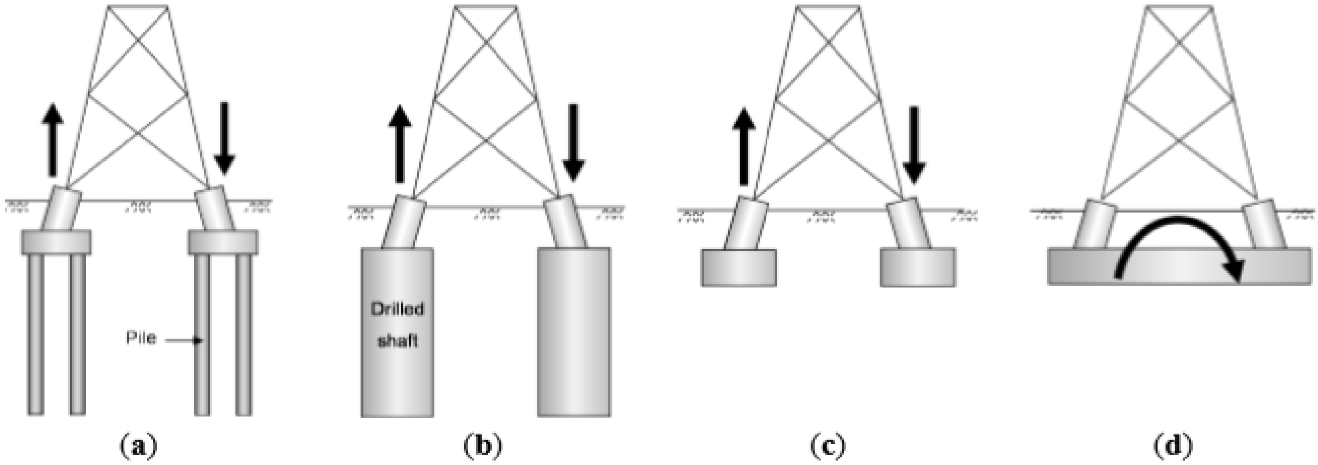

Fig.1 Different types of foundation of transmission tower (a)Pile foundation (b) Pier foundation (c) Inverted T foundation (d) Mat foundation

II. EXPERIMENTAL STUDY

2.1 Material collection and properties

Soil samples were taken by hand auguring up to 1m from the college campus of LDCE, Ahmedabad, India, where model tests were done. The various laboratory tests were carried out on obtained soil samples to find out index properties of soil. Undisturbed soil samples were taken using core cutter method to determine engineering properties of soil. The obtained results of index and engineering properties are showed here in table1 and table 2 respectively.

Table 1 Index properties of Soil

Properties	**Quantity**
Specific gravity	2.67
Optimum moisture content(OMC)	11%
Maximum dry density (MDD)	18.6 KN/m^3
Bulk density	15.8 KN/m^3
Dry density	15.1 KN/m^3
Moisture content	4.22%
Bulk unit weight at 34 % water content	16.46 KN/m^3
Soil classification (IS Classification)	SP-SM

Table 2 Engineering properties of Soil

Properties	**Quantity**
Angle of internal fraction(Φ)	28^0
Cohesion	0.32 kg/cm^2
Permeability (k)	4.53x10^{-4} cm/s

The soil was classified as SP-SM soil having angle of internal friction 28 degree and cohesion of 0.32 kg/cm^2. The tests for engineering properties were carried out on the undisturbed samples to obtain the accurate results.

2.2 Experimental setup

Fig. 2 shows the schematic diagram of model test setup. The welded hook on the top of the tower is pulled with help of steel rope having high capacity(7-8 tons). For the loading the rope goes over the pulley ,at the end of there is arrangement to put weights which will apply load on the tower. Which will create uplift in the one side of the legs(tension) and on the other side the legs will be subjected to compression , which will generate overturning moment. Thus piles will be subjected to tension ,compression and moments. The displacement and settlements of foundation were measured using dial gauges having sensitivity of 0.01mm

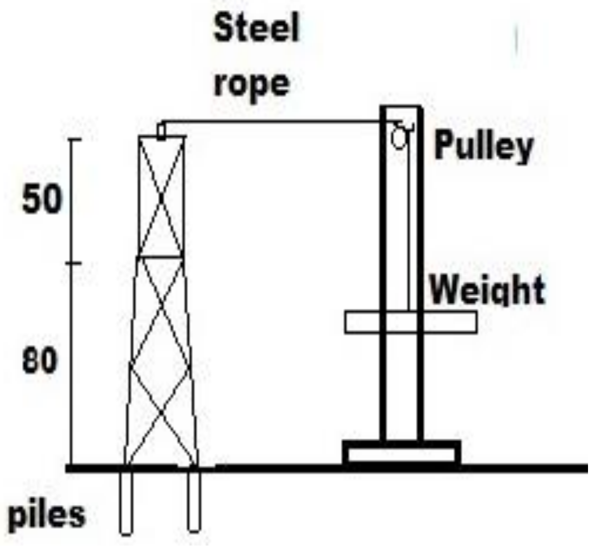

Fig. 2 Schematic diagram of the test setup(All dimensions in cm)

2.3 Casting of piles

Concrete Cast- In-situ piles of L/D ratio 4,6 and 8 is casted on which the tower will be rested(connected using plate and bolting) and will be tested. M-25 grade of concrete (1:1.5:3) is used and 6 bars of 3mm diameter were used as reinforcement .Diameter of pile was chosen as 5cm and length of piles were 20 cm, 30 cm and 40 cm.

2.4 Fabrication of model tower

Model tower made up of Mild steel IS angles of following specification. Main leg angle were made using IS 35X35X5mm angles, the bracings were made using IS 25X25X25mm angles. The height of tower was 1.3 metre and base width and top width of tower were 40X40 cm and 20X20 cm respectively.

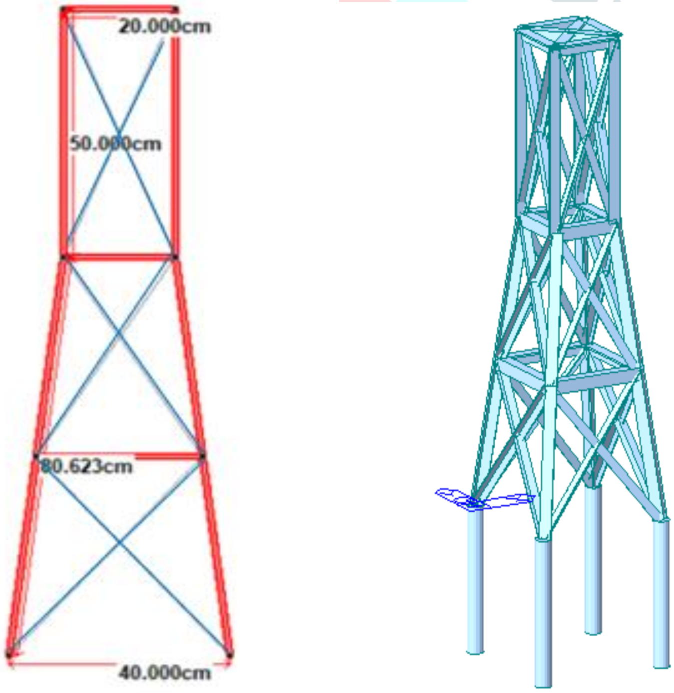

Fig. 3 Dimensions of model transmission tower

III. RESULT AND DISCUSSION

In the present study the load tests were carried out on the model tower foundation system. From the test data the Load vs displacement graphs were obtained for the piles having slenderness ratio of 4,6 and 8. The failure of piles in uplift was considered at the displacement of 0.1d(10% of pile diameter) which was at 5mm displacement. The results obtained for uplift displacements are shown in fig.4. The load vs settlement for different slenderness ratio is shown in fig.5. The horizontal displacement of tower was also measured by dial-gauge located at the top of the tower, the load vs horizontal displacement curves are shown in fig.6. Comparative ultimate load carrying capacity of piles having slenderness ratio 4,6 and 8 is shown in fig.7.

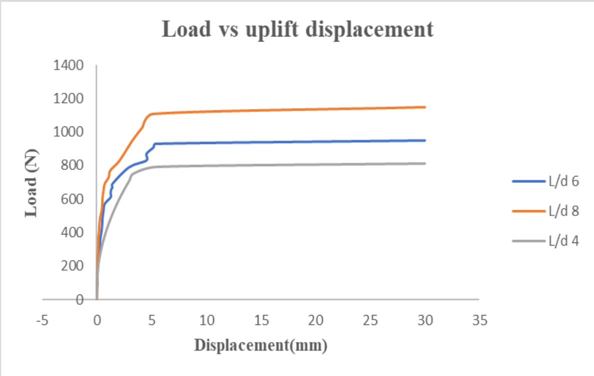

Fig. 4 Load v/s uplift displacement

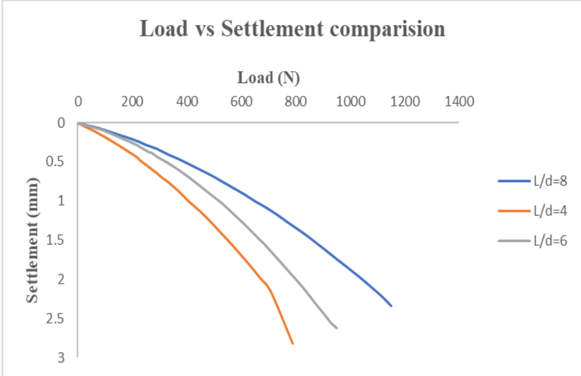

Fig. 5 Load v/s Settlement

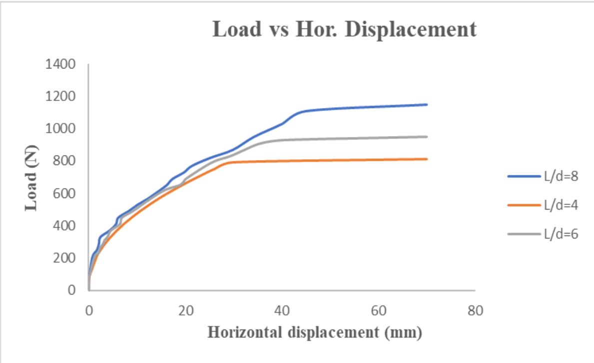

Fig. 6 Load vs Horizontal displacement

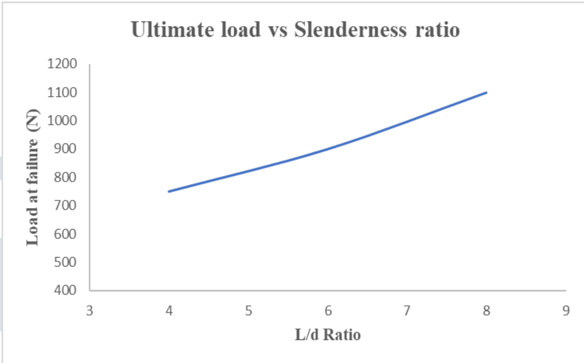

Fig.7 Ultimate Load v/s L/d ratio

IV. CONCLUSION

The following conclusions were drawn from the experimental test results.

- The load carrying capacity of piles having slenderness ratio 6 is 20% more than the piles having slenderness ratio 4. For piles having slenderness ratio 8 it is 47% more.
- The Settlement reduces with the increase in slenderness ratio.
- The failure displacement(0.1d) is observed in tension piles way before then the settlement criteria(0.1d) in compression piles. Such that at the failure load the settlements were only 48%, 46% and 44% of 0.1d criteria for slenderness ratio of 4,6 and 8 respectively.

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