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Experimental study on the stability of the transmission tower with hybrid slab foundation

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ABSTRACT

In this paper, a 1:5 scaled tower model for a typical 220 kV single-circuit power transmission tower with hybrid slab foundation has been designed and tested. The scaled tower model was tested under the movement of horizontal ground surface stretching with normal working loading conditions. One of the main objectives of this research is to investigate the stability of the power transmission tower subjected to horizontal ground movement by using hybrid slab foundation. The deformations of the tested tower model and stresses and strains within the different structural members of the tower and the reinforced concrete slab of the foundation have been fully measured. A large mount comprehensive test data has been generated. The research clearly indicated that compared to the isolated tower leg's foundation the proposed hybrid slab foundation has very good resistance, in terms of truss members' deformations and stresses, to the ground movement.

1. Introduction

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 and environmental conditions is an important research area which attracts many researchers [1–6]. In some countries, such as China, many transmission towers have to pass across coal mining areas, where ground surface cracking, subsidence, non-uniform settlement, etc. have caused partial or overall damage of many transmission towers [7–9]. The construction of ultra-high-voltage transmission systems requires even higher reliability of transmission towers.

Bruhn et al. [10] have studied the structural behaviour of lattice steel transmission tower under the ground surface's motion in the mining areas. Sun [11] proposed a composite reinforced concrete slab foundation to enhance the resistance of the transmission towers on the ground deformations. Li et al. [12] have analysed the structural responses of transmission towers under coupled actions between the tower and the transmission wires using FE method. Based on FE analysis, Yang et al. [13] suggested that the resistance of transmission towers on ground deformation could be increased considerably by using large scale flat-slab foundation. Shu et al. [14] have proposed a method for determining the thickness of the slab foundation based on a series of FE analyses. Yuan et al. [15] conducted an experimental test on a 500 kV self-supporting transmission tower to study the structural behaviour of the tower subjected to the stretching and compressing of the tower's supports. Moon et al. [16] conducted an experiment on a half-scaled sub-structure of transmission tower to investigate the failure mode of the tower under wind load. Prasad Rao et al. [17–18] have carried out a series of full-scale tests on the transmission towers to study the early failure modes of the towers and the causes of failure. Also they have conducted a series of numerical analyses on the transmission towers using software NE-Nastran. The numerical results have been compared with the calculations from different design codes.

As mentioned above, the majority of the studies conducted on the behaviour of transmission tower subjected to ground deformations were mainly focused on FE numerical analysis. Very limited researches have been done to experimentally investigate the impact of ground surface deformations on the structural stability of transmission towers. Therefore, the main objectives of this research are:

- Conduct a large-scale test on a 1:5 scaled sub-structure tower model for a typical 220 kV transmission tower with hybrid slab foundation for the first time. The test simulates the horizontal motion of ground surface.
- Investigate the stability of the 220 kV power transmission tower subjected to horizontal ground surface motion by adopting the newly proposed hybrid slab foundation. The test generates a series

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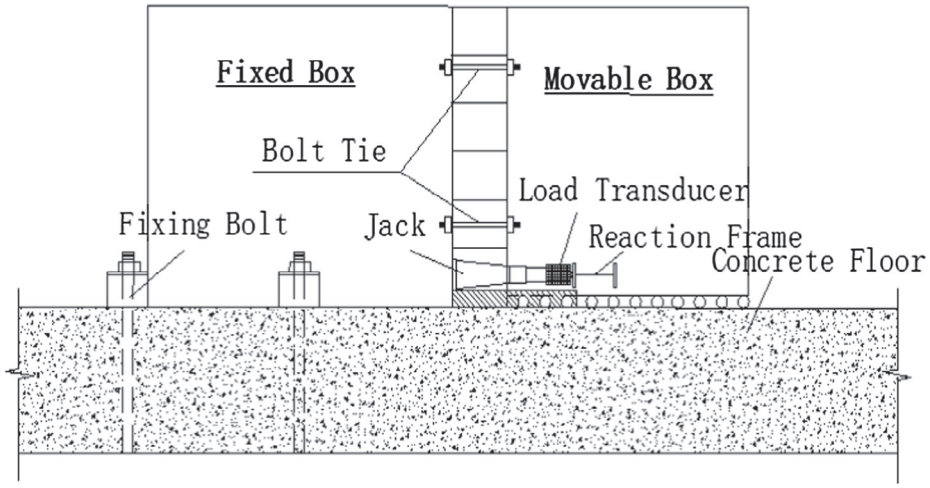
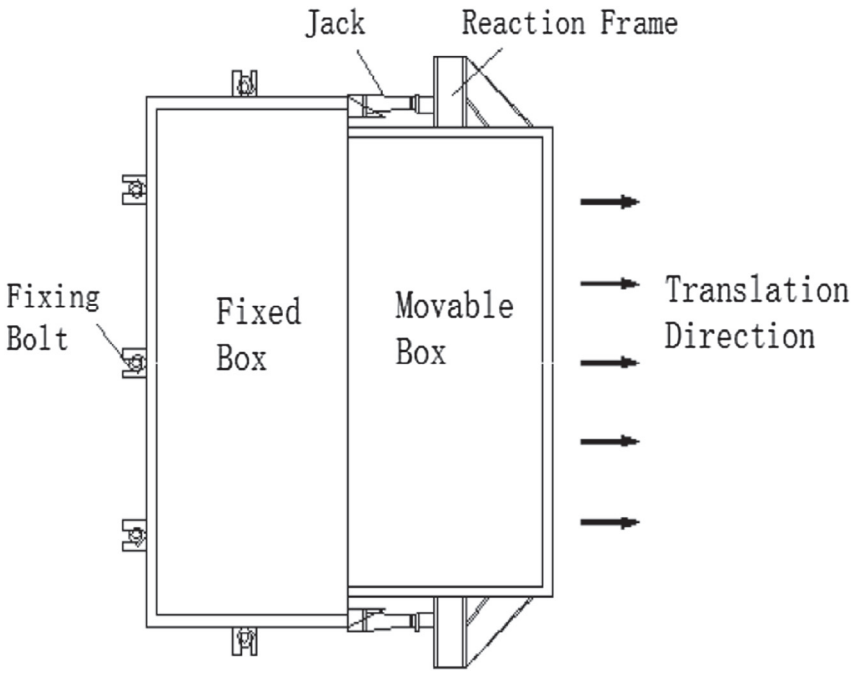


(a) Elevation of the test setup



(b) Plan view of the test setup

Fig. 1. Test rig for simulating horizontal ground movements.

of valuable data on the behaviour of the tower, stress and strain states within the structural members and foundation of the tower. The test data can be used to validate numerical models developed by the follow research in the field.

- Compare the behaviour of the scaled tower model with different type foundations of the transmission tower, and assess the tower's resistance to the ground movements by employing hybrid slab foundation.

2. Design of experiment

The influences of the ground surface deformations, such as the ground surface level movement, horizontal tensile and compression deformations, and the tilting, etc., on the behaviour of the transmission tower in mining area are very complex. To design a large-scale test on the transmission tower which can consider the influence of tensile force of the conductors and ground-wire subjected to ground motion is very complicate and difficult. Due to the limitation of current structural lab's conditions in this research only self-weights of the tower and conductors and ground-wire were considered. Therefore the shift in tower center of gravity due to horizontal ground movement was negligible under only vertical loading conditions. This has been proved by previous test [19]. The more feasible way to investigate the behaviour of transmission tower under real loading conditions is to use FE analysis which needs to be validated under more simple loading conditions by using available test data.