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Failure mechanism and retrofitting strategy of transmission tower structures under ice load

Qiang Xie [a,b,*], Li Sun [a]

[a] Department of Building Engineering, Tongji Univ., Shanghai 200092, China
[b] State Key Laboratory of Disaster Reduction in Civil Engineering, Tongji Univ., Shanghai 200092, China

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ABSTRACT

An experimental study was conducted on two pairs of subassemblages of a typical 500 kV transmission tower of the same type as those suffered the most severe damage during ice disaster in South China in 2008. The objectives are to study the failure mechanism of transmission towers under extreme load of freezing rain and to investigate the pertinent retrofitting strategy for increasing the load-carrying capacity of towers so as to prevent their collapse. The difference between specimens in each pair is that one had an additional diaphragm as measures of retrofitting while the other did not. The mechanical behavior, failure mode, strain and deformation at critical points, of the specimens were studied. The test results revealed that buckling of the main leg was the predominant failure mode of structures. For the two subassemblages without diaphragm, the out-of-plane deformations in the joints of diagonal bracings were relatively large and the buckled main angle members exhibited apparent torsion, which significantly decreased the load-carrying capacity of specimens. But for the two subassemblages with diaphragms, the out-of-plane deformations of cross-bracings were markedly inhibited by the added diaphragms and the buckling mode of the main member approached flexural buckling without torsion. As a result, the ultimate strength was increased by 18.3% and 17.6% for the single-panel and double-panel tower subassemblages respectively. It shows that the addition of the diaphragm significantly improved the mechanical performance of transmission towers by reducing the torsional effect on main members and inhibiting the out-of-plane deformation of diagonal braces.

1. Introduction

High-voltage transmission towers are one important component of modern electrical power system. But due to the rapidly increased height and span, transmission tower-conductor coupling systems are more susceptible to natural disasters which have been more frequent and severe over the past few years. Taking China as an example, in earlier 2008, the Southern area suffered severe ice disasters. The power systems sustained serious damage due to the catastrophic freezing rain. According to released statistics, the gross number of collapsed and damaged towers with rating above 35 kV of State Grid Corporation of China and local electrical companies reached 7263 [1]. In 1998, one unprecedented ice storm struck the Montréal region of Canada on January 4 and continued until early January 10. Over those 80 h, the maximum thickness of freezing precipitation exceeded 100 mm. And totally, there were about 1000 transmission tower structures that were brought to failure. In addition, as reported by relevant literature, the power systems in many other countries including United States, Germany, United Kingdom, etc. were all subjected to serious ice disasters during past few years.

In order to mitigate the damage caused by natural calamities, study on the failure mechanism and retrofitting of tower structures is of great significance and urgency. In practice, steel angles are commonly used as members of transmission tower. Due to the asymmetry of their cross sections, the stability of these angles would be a complex issue [2]. Over the past several decades, considerable studies have been carried out to capture the mechanical behavior of angles [3,4]. Kemp and Behncke [5] performed a series of 13 tests to investigate the property of cross-bracing systems in tower structure. It could be obtained that the end eccentricities caused by bolting one leg of each bracing to the main legs would significantly influence the displacement within the bracing system. Consequently, the intersection joints of tension and compression bracing system deflected along the out-of-plane direction even at low loads and bending moments were then induced. At global structure level, Albermani and Kitipornchai [6] and Albermani et al. [7] established a finite element model which took the influence of both geometric and material nonlinearities into account. The tower was modeled with beam-column and truss elements. The calculation results were found to agree well the corresponding test results.

Based on the aforementioned findings, some important design codes have been developed [8,9]. But unfortunately, there were some

* Corresponding author at: Department of Building Engineering, Tongji Univ., Shanghai 200092, China.
E-mail address: qxie@tongji.edu.cn (Q. Xie).

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