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Experimental study on multi-panel retrofitted steel transmission towers

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ABSTRACT

Due to the increasing demands on power supply and telecommunication services, existing transmission towers are frequently being required to carry extra loads above their initial design limits. A range of methods have therefore been used to increase the capacity of existing towers by retrofitting them in some way. This paper addresses steel lattice transmission towers with main leg members retrofitted by steel angles through bolted double steel angle connectors, a method that is widely used in practice but to date with little experimental research to support it. Three unreinforced tower models and four groups of retrofitted tower models with and without preloading have been tested in the structural laboratories at the University of South Australia. The experimental results verify the effectiveness of the retrofitting method. Load sharing analysis shows that axial loads can be effectively transferred between original tower members and reinforcing members through the bolted-splice system. Preloading reduces the load sharing in reinforcing members in the early loading stage but does not have significant influence on the ultimate strength of the whole structure.

1. Introduction

Steel lattice towers have been used in the electrical industry for more than 100 years. Many of the towers that are currently in service were constructed over 20 years ago, and some can be 50 years old or more. The extent of such transmission lines is vast and the economic and social impacts of the failure of any towers that lead to outages of power are substantial. Due to current increasing demands of power supply and communication services, new conductors and other equipment are often required to be installed on existing towers. When the extra gravity and wind load from the newly installed equipment exceed the initial design capacity, the existing towers need to be upgraded. In some cases this is necessary even without any increased demand on the tower, just because the wind codes to which the towers were originally designed have been upgraded and the tower does not comply with current requirements.

Researchers have proposed quite a few techniques for upgrading existing/damaged steel moment frame structures [1–4]. In general, detailed case-by-case investigation is required for selecting a suitable retrofit method [5,6]. For steel frame structures, improving moment capacity for critical joints and members is usually one of the main tasks in the retrofitted design [7,8]. Upgrade of bracing systems is another economic way to improve the lateral resistance capacity of the whole structure [9–11]. However, much of this work on steel framed buildings has limited application for tower structures, since the focus for towers is primarily on improving the axial load capacity of tower legs.

Unlike steel building frame structures, retrofit studies on tower structures are relatively rare in the existing literature. Albermani et al. [12] and Kitipornchai and Albermani [13] proposed increasing the axial capacity by reducing the slenderness ratio of the main tower legs through adding a series of diaphragm bracing type structures at mid-height points. They developed a non-linear analysis technique that they calibrated against the failure of an existing tower and showed that considerable improvement in the compressive strength could be achieved using this method for towers with slender diagonal members.

For main tower leg members with slenderness ratios lower than 80, the failure is governed more by the squash capacity of the tower legs than the buckling behaviour. Such towers occur very frequently in practice. For these towers, a more effective retrofitting method is to reinforce the legs through attaching additional members, usually called “reinforcing members”, parallel to the existing legs from the base upward. This practice is not currently governed by any design standards and thus the effectiveness of the retrofit method needs to be investigated. In particular the following questions relating to this method need to be answered:

- What is the most effective connection method to use for the connector between the original and reinforcing members in terms of type, location and frequency?
- Is the reinforcing member immediately effective or is it necessary to provide reinforcing beyond the critical point in order to achieve the

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