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Decision framework for optimal installation of outriggers in tall buildings

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ABSTRACT

Installation sequence of outrigger system, an important structural component of high-rise buildings, is often determined simply based on engineers' experience, posing a threat to the structural safety and stability. This paper proposes a comprehensive decision framework for developing the optimal installation plan for the outrigger system, in which construction simulation and safety analysis of the overall structural system are well integrated. The proposed framework is applied to a super-tall building with a height of 600 m. First, the finite element method (FEM) model of the skyscraper used for construction simulation is validated by field measurements during Typhoon 'Nida'. Based on the validated FEM model, the lower limits (earliest) for installing the outrigger system are obtained through the outrigger trusses' safety analysis for the service stage of the building, while the upper limits (latest) are determined through the analysis of structural stiffness and global stability for the construction stage. Thereupon, a rational plan is established for installing the outrigger system into the skyscraper, and the viability and efficiency of the proposed decision framework are examined by analyzing the construction simulation models. The outcomes of this study are expected to be of use and interest for structural engineers and researchers involved in construction management of installing outriggers into high-rise buildings, and therefore provide valuable implications for other similar projects.

1. Introduction

The rapid developments of materials, construction technologies, and structural systems have given rise to a significant increase of skyscrapers over the past decades. The reduction of the top drifts and base core overturning moments under lateral loads, such as earthquakes and wind loads, has drawn increasing attention in the structural design of super-tall buildings [1–4]. It is noted that the outrigger system is considered one of the most effective structural systems to improve the structural lateral stiffness and overall stability, which has been widely used in high-rise buildings [5]. The principle of using an outrigger system to enhance the structural lateral stiffness and overall stability is that the core-tube and the external columns are connected by rigid horizontal cantilevers. When a high-rise building is subjected to lateral loads, the rotation of the core-tube is restrained by the columns and the outriggers, and therefore the bending moments carried by the core-tube can be reduced effectively and the overall lateral displacements of the building can be mitigated [6]. Besides, the vertical shear of the core-tube can be partly transferred to the external columns via the outrigger system, and thereby the system forces the external columns to participate in carrying the overturning moment. Previous studies have suggested that an outrigger system could account for approximately 30% of the total lateral stiffness and then reduce the total displacements by about 25% to 32% [7,8]. Given the importance of outrigger systems in tall buildings, the installation sequence of an outrigger system is of great concern in the construction of tall buildings [9], due to its great influence on structural safety at both construction and service stages. In practices, the installation of outrigger systems can be classified into three types, which are introduced briefly below:

(1) Installation of outriggers at an early construction stage

Installing an outrigger system at the early construction stage of a tall building can efficiently enhance the structural performance since the installed outrigger system could improve the structural stiffness and stability from the beginning of the construction. However, the cumulative differential deformation between the external columns and the core-tubes, due to the creep and shrinkage of concrete, could result in increasing additional stress in the outriggers, and thereby deteriorating the safety margin of the outriggers in the long-term service stage [9–11]. Although the adverse effects of differential deformation could be alleviated by the well-designed wall thickness and column size [12], it is inevitable to have the long-term differential shortening due to the creep and shrinkage of concrete, which may cause undue internal stress

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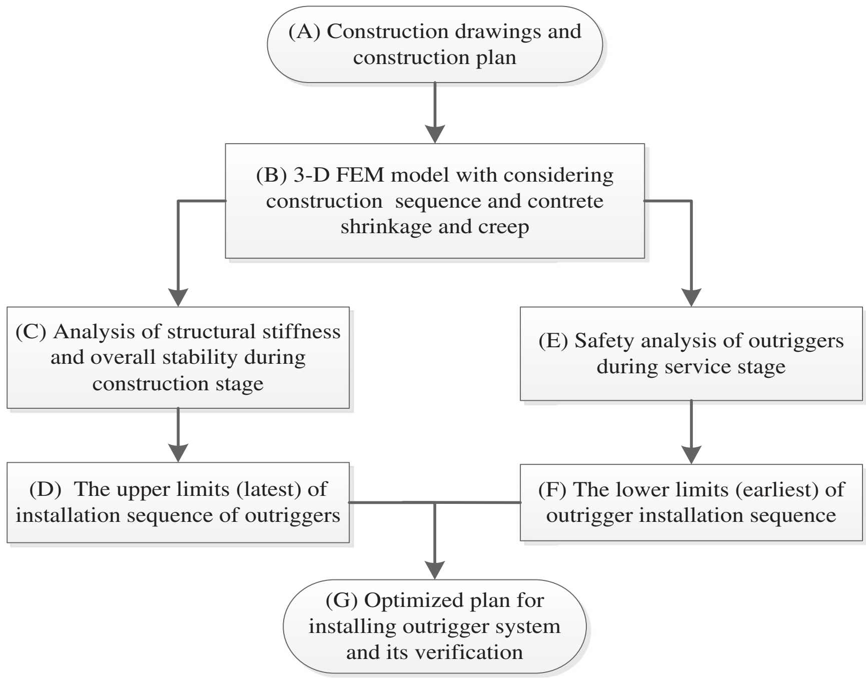

Fig. 1. A flowchart illustrating the methodology for optimized installation of an outrigger system. Section 'C' and 'E' are further specified in Figs. 2 and 3.

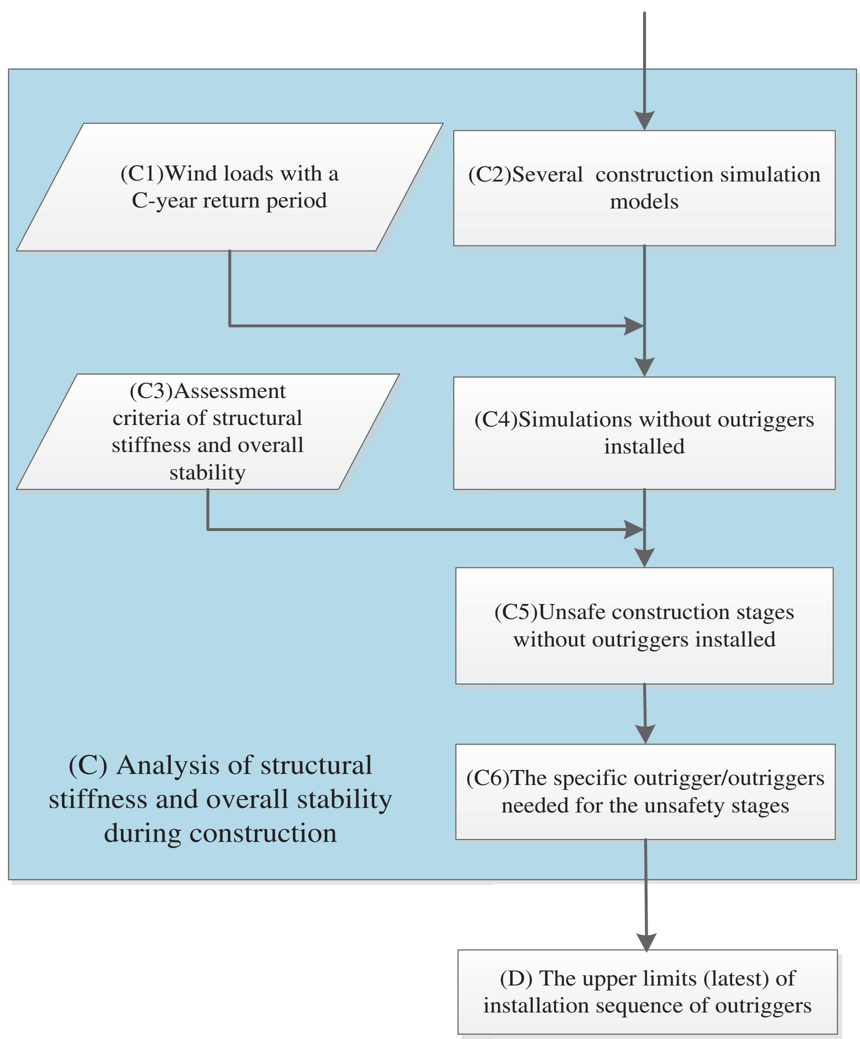

Fig. 2. Sub-flowchart 'C' in Fig. 1. 'C-year' represents the construction duration.