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Real-time robust assessment of angles and positions of nonscaled steel outrigger structure with Maxwell-Mohr method

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HIGHLIGHTS

- Computer-aided automatic decision framework assesses general-purpose prototypes of outrigger.
- Steel material outrigger evaluates interactions between material characteristics and structural system.
- Optimal connectivity of outrigger members under structural safety is evaluated using Maxwell-Mohr method.

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ABSTRACT

In this article, a simple and robust real-time decision framework to determine the optimum angle of the outrigger satisfying structural safety of tall buildings is proposed to evaluate a general-purpose prototype of steel outrigger geometry. The methodology is applied to sets of the ratio of height to width generally describing non-scaled outrigger space. To achieve the general-purpose prototype of outrigger geometry, the optimal angles for three sets of height to width of a given outrigger space are examined with respect to displacement capacities using a typical Maxwell-Mohr method, and in the optimal angle, the least horizontal and vertical displacements occur when the quantity is standardized. When the width and height of the outrigger is confirmed in a given tall building, the shape of outrigger, with its good structural performance, can be reflected in the outrigger member position design for general purposes, allowing pre-calculations of the optimal angle and a reduction in quantity. Numerical examples verify the validity and efficiency of the present assessment method to decide optimal angle and position of outrigger truss members with respect to general-purpose prototype.

1. Introduction

Recently, tall buildings have been rapidly increasing the world over [1–3]. While most representative structural systems for tall buildings have been discussed in other Refs. [4–7] the emphasis in this study is on current trends of outrigger systems. Their use and provision are specific to a particular construction or building structure. Generally structural engineers and designers have to conduct a rigorous analysis with a trial and error approach before a conceptual set of information can be achieved, which enables them to estimate certain primary information required by developers or clients before beginning of a project. Therefore, certain generic rules and principles are needed that can help the structural designer compute the requirements of outriggers based on the definition of slenderness ratio of a building (i.e. width and length). These interns would be significant in the approximate judgment of various quantities and costs of materials, labor, construction period, etc.

Among the residential apartments in Korea, most high-rise apartments with heights ranging from 40 to 70 floors are mixed-use apartments. In multi-story buildings with such height, the outrigger system [8,9] is very frequently applied, which effectively controls the excessive drift to lateral load including wind and earthquake loads [10]. Especially in high-rise buildings with 100 or more stories, the use of an outrigger system is essential and a hybrid system combined with mega columns is also often adopted to resist lateral loading of high-rise buildings. Thus, a construction plan where an outrigger will connect a core and a mega column has a significant effect on the overall construction period [11–13].

The construction capacity for one floor of outrigger plays a crucial role in a critical path because outriggers are formed in at least one story and up to 5 stories and in 2–3 zones in high-rise buildings with 100 stories or more. The shape of an outrigger

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(a) Original plan (b) Modified plan

Fig. 1. Bird's eye view of Lotte world tower.

determines the number of members and joints as the determining factors in the construction period. Therefore, outrigger optimization plays an important role in tall building design and has the

Table 1
Overview of Lotte World Tower.

Items	Description
Location	Sincheon-dong, Songpa-gu, Seoul, Korea
Height	555 m
Number of stories	123 stories above ground and 6 stories underground
Purpose	Hotel, office, officetel, retail, etc.
Structure	Core wall + Mega Column + Outrigger Belt Truss

significant challenges [14]. For finding an optimal location of outrigger in tall building subjected to wind load, the efficient outrigger-braced structures were introduced [15]. They are analyzed by the consideration of several wind load types such as uniform wind load, triangular wind load, etc. Then they are verified through computer models in ETABS. An optimization approach of outrigger is considered for the tall building subjected to earthquake load by evaluating the effect of intermediate stiffening beam at an arbitrary level along the height of the building [16]. This approach is examined to identify the best location of outrigger structure and the effect of outrigger on the structure behaviour. In addition, there is a research that topology optimization is used for the purpose of determination of outrigger placement [17]. Therein, the floor-wise outriggers are assigned as the design variables and parameterized by using the Simple Isotropic Material with Penalization (SIMP) method. Recently, the optimum design

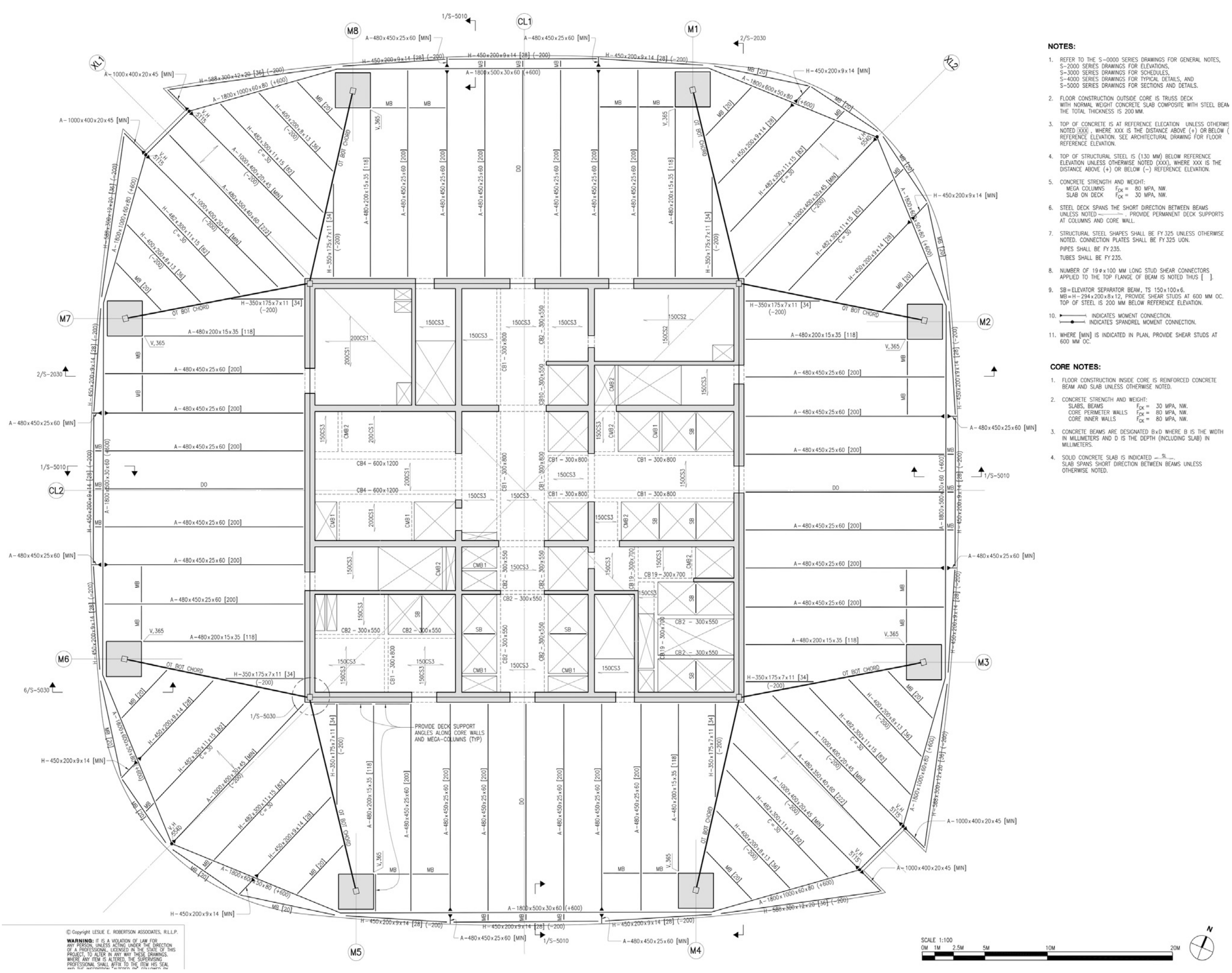

Fig. 2. Structural system and dimension of outrigger + core + mega column in a key plan.