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Experimental and numerical study on lateral stability of temporary structures

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ABSTRACT

This paper investigates the lateral performance of temporary structures, which consist of slender members and corresponding joints, under both vertical and horizontal loads. The ultimate bearing capacity, failure modes and the strain distribution of members are illustrated. Experimental results indicate that the lateral stability of the temporary structures is weaker than the vertical stability. Diagonal bracings are the main load-bearing members which resist horizontal loads while the horizontal bars are used to keep stress low. Based on the joint mechanical parameters and the probabilistic models of initial geometric imperfection, the stochastic finite element models (SFEMs) using the Monte Carlo method have been established. The models can consider the semi-rigid performances of joints and initial geometric imperfection. The numerical results demonstrate consistency with structural tests data. Moreover, the influences of structural layers and spans are analysed based on the SFEM. Multiple factors, including spans, layers and upper vertical loads, should be considered when the lateral capacity of temporary structures is calculated. A rapid prediction formula of the lateral stability of temporary structure has been obtained.

1. Introduction

Temporary structures in this paper are those composed of slender members and corresponding connections, which are lightweight, rapidly assembled, readily dismantled and reusable. These properties make it suitable in viewing facilities (including grandstands), platforms and media facilities, as shown in Fig. 1.

The loads and dimensions of temporary structures are important considerations, given the temporary property of the installations [1]. A number of accidents of temporary structures have occurred [2]. The causes stem from unexpected loads, supports and bracings, among others [3]. Temporary structures, as applied to various structural types, may withstand substantial horizontal, vertical and dynamic loadings from crowds [4] and the wind loads. A temporary grandstand, for example, needs to support crowd-induced

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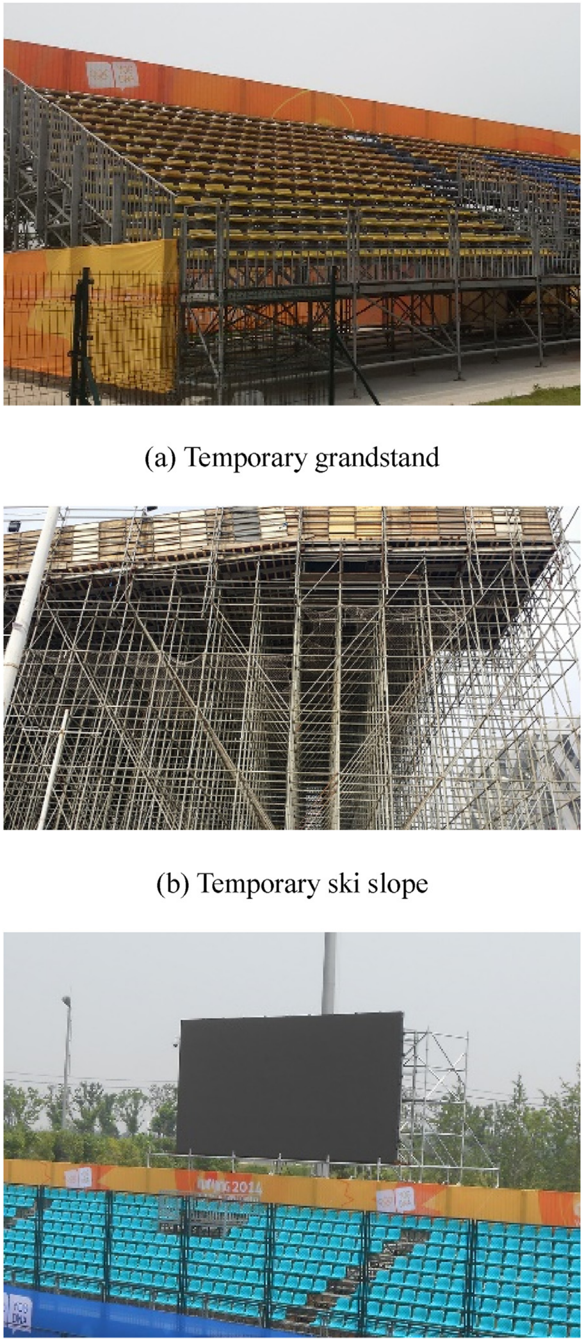

(a) Temporary grandstand

(b) Temporary ski slope

(c) Vision screen

Fig. 1 – Application of temporary structures.

lateral loads [5], as well as wind loads [6], considering that advertising blocks are placed around the stands. The impact of wind loads will become more serious when they are applied in the supports of television screens (Fig. 1(c)). Hence, the temporary structure should have certain vertical support capacity, and sufficient lateral stiffness to resist horizontal loads. Even only under vertical loads, the horizontal movements of temporary structure can be induced, which may be a significant design consideration [7]. Although relative measures have been proposed from the perspective of conceptual design [8], the lateral performance of temporary structure requires further research to provide guidance for design.

Previous research on the temporary structure mostly focused on the fields of scaffolding and formwork [9–11]. The members usually consist of steel tubes, and the connections can be a variety of types, such as couple [12], disc-type [13], plug-pin and cuplock joints [14]. Based on the scaffold system using disc-type joints, Peng et al. [15] investigated the vertical load capacity and failure modes of scaffold structures of various setups during construction. For studying the scaffold system, three-dimensional advanced analysis models, considering the material nonlinearity and geometric imperfection, were developed [16]. Zhang et al. [17] introduced a design method with advanced analysis method to the numerical study of steel scaffold structures, and the reliability and probabilistic analysis for typical steel scaffold shoring structures has been conducted [18,19]. For this type of structure used in engineering construction, the vertical load was the main load. Correspondingly the vertical load was set as the main load form for most researches of scaffolding and formwork. And the research about the lateral capacity of this structure is seldom, which is the main research direction of this paper.

Initial geometric imperfections have significant influence on the behaviour of steel structures, especially for thin-walled and shell structures [20–22]. There are two types of geometrical imperfection considered in advanced analysis of steel framed systems: the initial out-of-straightness of members and the initial out-of-plumb of the story frame. The temporality and reusability of temporary structure require structural members to be used repeatedly, which gradually contributes to initial member out-of-straightness. Furthermore, the joint gap and assembly quality also result in temporary structure initial story out-of-plumb being more significant than other steel structures [23]. An advanced analysis of steel structural systems has been studied [24] and there are three methods of modelling imperfection [25], including scaling of the eigenvalue buckling model (EBM), application of notional horizontal forces and random imperfection method. EBM is widely used for the structure, which involves scaling one or more critical elastic buckling modes and adding the scaled displacements to the perfect geometry. While the number of buckling modes and the corresponding scaling factors were uncertain [26–28]. The random imperfection method recognizes that the initial geometric imperfection is uncertain by its nature, which is more accordance with the actual conditions. This paper adopted the random imperfection method using Monte Carlo method [29] based on the actual data of geometric imperfections.

The variety of applications for the temporary structure increases to the complexity of work statement. This paper focuses on the lateral stability of the temporary structure and investigates the ultimate bearing capacity and failure modes of the structure under both vertical and horizontal loads. The strain distribution in member and the effect of diagonal bracing are discussed. The SFEMs are established using the Monte Carlo method. Furthermore, the influences of the number of spans and layers on the lateral stability of the temporary structure are investigated, and the quantitative prediction method is presented.