On The Reliability of Flat Space Structures with Initial Imperfections

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ABSTRACT

The existence of initial imperfections in manufacturing or assemblage of real structures is inevitable. Many of these imperfections in double-layer space structures, such as the curvature and length imperfections, are random in nature. In this paper, the effect of initial curvature imperfection in the load carrying capacity of double-layer space structures is investigated. For this purpose, three different types of supports are considered. The curvature imperfection is considered as a random number by gamma distribution. The probabilistic model is used to distribute the random imperfections among all members of the structure. The collapse behavior and the ultimate capacity of the considered structures are determined using nonlinear analysis and this procedure is repeated by Monte Carlo simulation method. Finally, the reliability of structures is determined. The results show that the collapse behavior of double-layer grid space structures are highly sensitive to the random distribution of initial imperfections.

Keywords: space structures, random variable, gamma distribution, initial imperfections, reliability, Monte Carlo simulation method.

1. INTRODUCTION

Double-layer space trusses are one of the frequently used structures in large open areas because of their major advantages like high stiffness, relatively light weight, easy to erect and ability to cover open areas [1]. Although, space structures are highly safe, their collapse is not common, e.g. collapse of double-layer roof of the Hartford coliseum [2].

In general, space truss structures were the subject of many researchers. Schmidt et al. studied different types of trusses and showed that yielding of tension members not affects its load bearing capacity whereas buckling of compression members is critical [3, 4]. Because, after buckling, a member loses its strength and conveys the exerted force to neighboring members which cause them to buckle and finally would result in progressive collapse of structure. Earlier works by Affan [5] and Affan and Calladine [6] showed that the number of redundant bars, which could be removed without affecting the stability of structure, is about 15 to 25 percent of the total number of truss members.

Space structures have the high degree of indeterminacy and typically contain hundreds of members which they inevitably incorporate with different kind of imperfections. Initial curvature of truss members is one of the most common forms of geometric imperfections in space structures. Hence, in order to estimate the safety and reliability of these structures, it is necessary to consider the effects of such uncertainties. In this regard, several investigations have been conducted by researchers that most of which including one or more random variables. Wada and Wang studied the influence of random variation of member strength and construction errors on the mechanical behavior of double-layer space structures [7]. They showed that construction errors, like assembly errors, have considerable influence on the load carrying capacity of these structures. El-Sheikh worked on the sensitivity of the overall strength of double as well as triple-layer space structures to geometrical imperfections together with the critical locations at which imperfect members should not be included [8-11].

Moreover, in recent years, many researches are conducted on the influence of geometrical imperfections on structural behavior. Kala analyzed the effects of random distribution of imperfections on the lateral-torsional buckling of I shaped rolled beams with simple supports [12]. Vryzidis et al. investigated the effect of random initial imperfection in buckling capacity of steel pipes. Numerical analyses and experimental results shown that not only initial imperfection has noticeable effects on the system's buckling capacity, but also it affects the failure mode of the pipes as well [13]. Zhao et al. used the Monte Carlo simulation method to investigate the effects of random geometrical imperfections on concentrically braced frames and showed that these imperfections have a substantial effect on design forces [14].

This paper is focused on the influence of initial curvature imperfections in the load bearing capacity of double-layer space structures. Initial curvature imperfection is assigned to structural members using Monte Carlo simulation method and the reliability of the considered structures is calculated for different types support condition. All of the analyses have been carried out using the OpenSees finite element software [15].