Journal of Constructional Steel Research 72 (2012) 219–226

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Influence of geometrical and structural parameters on the behaviour of squared plan-form single-layer structures

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ARTICLE INFO

Article history:
Received 6 September 2011
Accepted 20 December 2011
Available online 28 January 2012

Keywords:
Geometrically nonlinear analysis
Single-layer structures
Reticulated shell
Joint-rigidity
Rise-span ratio
Wind loads

ABSTRACT

Although there is a great deal of papers on single-layer latticed structures, practically the totality of them is devoted to domes. Therefore, the authors have chosen to analyse squared plan-form single-layer structures studying the influence of joint-rigidity, mesh-density, rise-to-span ratio and load combination in their behaviour, through a Design of Experiments analysis. After identifying the most influential parameters, more FEM analyses were run resulting in interesting conclusions which included economic considerations. The influence of initial imperfections was also investigated.

1. Introduction

Latticed space structures are a good structural solution to the problem of spanning large uninterrupted distances, and providing at the same time the opportunity to produce an immense variety of design shapes. Bradshaw et al. [1] offered a historical perspective on how spatial structures have evolved. Makowski [2] and IASS WG8 [3] analysed the causes of this development and presented a complete summary of their advantages, from both a structural and an architectural point of view.

In the last years, the interest in single-layer reticulated shells has grown significantly. The main aspect of these structures is that their behaviour is highly nonlinear and is affected by diverse factors, such as mesh-density, rise-to-span ratio and joint rigidity. Having known this point, this paper is focused on the influence of these factors in single-layer squared plan-form structures. Some authors have developed similar studies before. Park et al. [4] and Ogawa et al. [5] presented parametric studies on the buckling loads of single-layer domes. Their papers only dealt with vertical loading. Kato et al. [6] and Ma et al. [7] performed parametric studies with uniform and non-uniform loading. However, all these works were always focused on circular plan-form domes. Kato et al. [8] discussed the effect of joint rigidity on the reduction of failure loads in spherical domes. Sohn et al. [9] numerically analysed the influence of joint rigidity and geometric parameters on the buckling load of a single-layer structure with only one free node. Nevertheless, the most useful study was that carried out by Gioncu [10] who presented a comprehensive review on the collapse of single-layer latticed domes. Also, the articles by Gioncu and Balut [11] and Gantes [12] drew the attention of designers to the relevant factors in the instability of single-layer reticulated shells. Some other authors like Erbatur [13], Saka [14] and Hearn [15] studied different ways to get the optimum shape of the structure considering some of those factors.

In this paper, the authors have chosen to analyse single-layer square plan-form structures and have performed an extensive study of the influence of joint-stiffness, mesh-density, rise-span ratio and load case on their behaviour. Firstly, a Design of Experiment (DoE) methodology was used to identify the most influential factors. After the DoE analysis, a total of 24 different structures have been studied through geometrically non-linear analyses with FEM based software. The analysed structures were always composed of more than 200 joints and 500 members. The structures were loaded under different combinations of actions taking into account self-weight, imposed loads and wind and snow loading in order to check the resistance to ultimate limit states.

2. Influential parameters

The parameters involved in the definition of a single-layer structure are: the joint-rigidity, the mesh-density, the rise-to-span ratio, the load case and member cross-section.

A DoE analysis was developed in order to evaluate the influence of each parameter. This DoE analysis required the selection of two relevant values for each variable.

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doi:10.1016/j.jcsr.2011.12.007