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Stability of reticulated shells considering member buckling

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ABSTRACT

In order to understand the influence of member buckling on the stability of reticulated shells, a key problem of how to distinguish the member buckling for reticulated shell structures was pointed out, and judgment methods of member buckling were obtained. Using a Kiewitt-8 dome as an example, the buckling characteristic and propagation rule of member buckling were studied. Meanwhile, a reticulated dome model tested was analyzed and compared by using the finite element software ANSYS. Judgment results of member buckling and the influence of member buckling on the structure were obtained. The judgment results accorded well with the test. Then taking the member buckling into consideration, the effect of material nonlinearity, initial geometrical imperfections, and member size on the stability of the members and the reticulated shell structures were investigated. The results show that the methods adopted can judge the member buckling for reticulated shell structures effectively; the member buckling and its propagation can affect the stability of the structure directly.

1. Introduction

Stability analysis is a principal problem for the design of the single-layer reticulated shell structures. Since 1960s, the research on the stability of reticulated shell structures has been a hot issue which has been attracting research communities' attention [1]. The theories, known as the continuum shell analogy and the finite element method, have had many successful applications for reticulated shell structures [2]. In the long period of time, the continuum shell analogy method performs well on estimating the buckling load of several particular reticulated shell structures [3].

Up to 1970s, with the rapid development of computer technology and the availability of advanced finite element software, substantial progress has been made in the researches on the stability of the reticulated shell structures. The elastic stability and elasto-plastic stability of reticulated shells have been well investigated by adopting the geometrically nonlinear elastic analysis (GNA) and the geometrically and materially nonlinear analysis (GMNA), and these research works last up to the present day [4–9].

The current theoretical research concentrates on the global buckling of the reticulated shell structures. However, the interaction of member buckling and global buckling of the structure is not a negligible problem. This problem has not been systematically explored, not yet available results for engineering application. For investigating the interaction of member buckling and global buckling, the judgment method of member buckling in the nonlinear analysis of the structure is a primary issue.

Moreover, the current finite element method analyzes the stability of the reticulated shell structure, only through judging whether the total stiffness matrix is singular to get the global stability of the structure, and the member buckling cannot be distinguished. On the other hand, due to the influence of geometrical nonlinearity of the structure, second-order effect causes the increase of the internal force of members. Therefore, before the structure achieves the critical state of the global buckling, the member buckling has the possibility to take place.

In 1961, the Bucharest dome in Romania (a single-layer reticulated dome, span is 93.5 m, rise is 19.107 m), the local snow load caused the buckling of members in the dome, then the instability area expanded continuously, at last the dome collapsed suddenly [10]. Fig. 1 is the exterior view of the Bucharest dome and the black dots represent the positions of member buckling. Meanwhile, the research indicated that the buckling of compression members caused the collapse of the grid structure of Hartford gymnasium in the USA in 1978 [11]. The engineering accidents above show that for the stability analysis of the reticulated shell structure, taking the stability of members into account and studying the interaction of member buckling and global buckling is of great importance.

Reference [10] proposes a middle plastic hinge model of the member, assuming that before the buckling of the member, the member is in the completely elastic deformation condition, and when the internal force achieves ultimate bearing capacity of the member, this member is supposed to appear a plastic hinge in the middle of the member. This model can reflect the post-buckling behaviour of the compression member. Reference [12] puts forward the geometrical nonlinear Euler theory, which defines the ultimate bearing capacity of each member in advance, then remove the member that achieves its ultimate bearing capacity in the GNA.

In this paper, based on the finite element package ANSYS, the judgment methods of member buckling in the nonlinear analysis of the reticulated shell structure were obtained. And the methods were

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