Multi-scale analysis of connection joints in an underground spherical shell structure

Yanfeng Zheng*, Chao Yang, Yaozhi Luo, Zhongyi Zhu[a], Yuekun Heng[b]

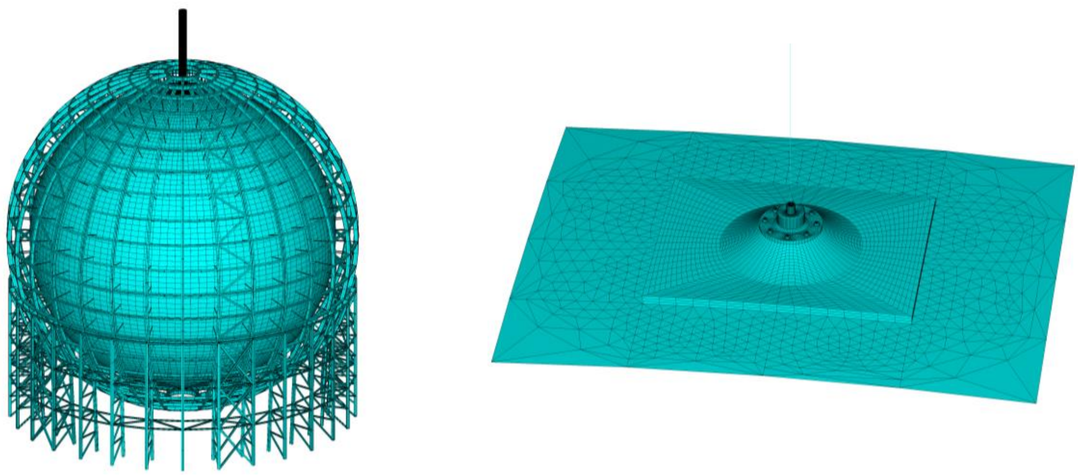
*Space Structure Research Center, Zhejiang University
866 Yuhangtang Road, Hangzhou 310058, China
yanfeng39@zju.edu.cn

[a] Beijing Institute of Architectural Design (Group) Co., Ltd
[b] Institute of High Energy Physics (IHEP) Chinese Academy of Sciences (CAS)

Abstract

The connection joints in a structural model are often modeled using single nodes, from where the loading states of the well-designed joints cannot be obtained. The loads and boundary conditions in isolated joint analysis are overly idealized and different from those of the joints in the actual structure. Modeling the entire structure elaborately with solid elements requires an incredible amount of time and consumes numerous computation resources, although this modeling method can provide the most accurate results. Therefore, an effective and efficient method for analyzing joints in structures is strongly needed.

In this research, a multi-scale modeling method using mixed-dimensional coupling is proposed for the stress analysis of a super-deep underground spherical shell structure (Figure 1a) to balance the accuracy and efficiency. The spherical shell structure consists of an acrylic spherical shell, a stainless steel reticulated shell and 590 rods. There are 590 acrylic connection joints, and the multi-scale model should be fully investigated to obtain the stress distribution of each joint. A multi-scale model consisting of a single refined joint and equipped with simplified joints is proposed (Figure 1b). The simplified joint model is proposed to simulate the joints which are not modeled with solid elements, and the comparison results indicate that the simplified joint model can accurately simulate the stiffness of the joints. A multi-scale model with a cluster of 3×3 refined joints is built to compare the accuracy and efficiency of the proposed multi-scale model. The comparison results reveal that the difference is less than 5%, while the resource consumption is much less.



(a) (b)

Figure 1. Underground spherical shell structure: (a) global FE model; (b) multi-scale model.