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Analysis on complex structure stability under different bar angle with BIM technology ☆

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Summary   Sun Valley, the landmark building of World Expo in Shanghai, which has free surface with single-layer reticulated shell structure, is a typical complex structure. CAD/CAM integrated information system to design is used for the complex structure; however, it is a very rigorous process to be used widely. The relevant technology of the Sun Valley is not open to the public at present, so we try to use BIM technology to model the Sun Valley, including architecture modelling and structure analysis. By analysis of the Sun Valley structure using this method, it is proved that the problems in modelling may be solved by writing some script codes in Rhino software and the stability of the model can also be analyzed. The new approach is viable and effective in combination with different softwares such as Rhino, Revit, and Midas in solution of the complex shaped surfaces' structure for modelling and calculation.

Introduction of Project

The Expo Axis and its boulevard is one of the five buildings which remain after the end of the world expo to form the centre of a new urban district of Shanghai. And Sun Valley is the core of the axis. The exterior of Sun Valley is made up of the free curved cylindrical lattice shell structures, which make the building look vivid. Sun Valley integral structure has 10,348 units of nodes interconnected and more than 31,000 root bars connected together with each other. The top diameter of the structure is 97 m; the bottom diameter is 20 m. It has a great number of components with different types of nodes. The angle of the keel is determined by the normal direction of its facet and each keel is not on the same facet. Meanwhile, the structure should achieve the seamless construction; the deviation for each node unit should be less than 0.5 mm, and the deviation angle should be less than 0.25°. The integral structure is precise and artistic.

Sun Valley has a complex and particular structure, with the traditional modelling and structural analysis software such as Auto CAD and PKPM being difficult to establish a

Picture 1-1   Design sketch of Sun Valley.

precise model of the structure. At the same time because of the number of the Sun Valley component, if completely artificial detail is used, not only will there be huge workload but also the efficiency of drawing process will be low (Jia-chun, 2011).

BIM is a 3D-based framework designed to integrate and digitize complete building information so as to express all the building components and their relationships. The goal of BIM has existed for at least 30 years and various standards have been published. Existing literature provide individual aspects of BIM, such as the need for data exchange standards, the future potential and inter-organizational usage of BIM. Usage of BIM technology can turn pure geometry performance to full information model integration; from completing the project individually to completing it collectively; from discrete step-by-step design to whole-process integral design based on the same model. Using this design idea, it can be more efficient to solve the problem and change the problem for single use by targeting the limitations of software development.

Rhinoceros (typically abbreviated Rhino, or Rhino3D) is a commercial 3D computer graphics and computer-aided design (CAD) application software. Rhinoceros geometry is based on the NURBS mathematical model, which focuses on

producing mathematically precise representation of curves and freeform surfaces in computer graphics. By using Rhino, a high precision surface can be established. Then Rhino is used to build the Sun Valley BIM model, combining the BIM model with Midas structure operation function. Therefore, Sun Valley, which is a complex structure and based on BIM technology, can achieve stability analysis. After verifying the feasibility, this method, based on the technology of the BIM, may be applied to do the stability analysis of other complex structures.

Analysis on structure of bar angle

The structural analysis with Sun Valley, firstly the model of Sun Valley BIM, needs to be built through the method of Rhino, then via BIM model to generate a DXF file. In the end, the centreline data, which is located by structural unit DFX file, are imported to the Midas calculation software to process the stability analysis which is positioned as centreline data. Because the cross-section is non-circular tube structure, the imported model through DXF file does not include information about unit cross-sectional direction angle. In this situation, sectional direction parallel to the surface direction cannot be guaranteed. Sun Valley's infrastructure keel is a rectangular unit. In the implementation process, when the model established in Rhino import, DXF files import to the Midas GEN through the directions of the corner, which have all changed into the normal direction of the $X-Y$ plane rather than the double-curved surface normal direction of Sun Valley's structure.

In this case, the designer who is to ensure the reliability of structural calculations often applies the amplification factor of safety to ignore the impact of cross-section corner. This approach is inaccurate and uneconomical, even will be a security risk sometimes (Jia and Cai-qin, 2008).

The same section in different cross-sectionals exists as a major difference between the angles (when the angle
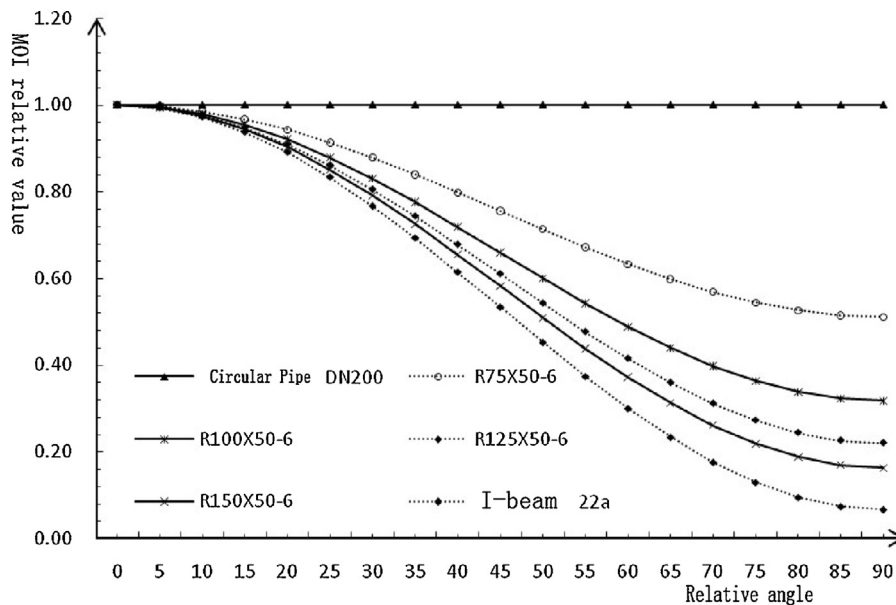
Picture 2-1   Diagram of section angle and bending performance.