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DESIGN, CONSTRUCTION AND HEALTH MONITORING FOR A LARGE SPAN PEDESTRIAN BRIDGE

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Summary

This paper focuses on design, construction and health monitoring for a floating pedestrian bridge cross two cliffs. The substructure of the bridge is located near cliffs. The superstructure of the bridge is a curved box girder supported by a tilting cable-arch system. A parabolic steel arch spans about 100 m between two cliffs and rises 25 m above cliff levels.

The key design issues on the substructure and superstructure are included as follows: 1) 3D laser scanning techniques for modeling of rock mass structures and numerical analysis evaluations for the substructure; 2) performance investigations for the superstructure, such as form-finding for the cable-arch-girder structure, overall stability for the curved girder and human-induced vibration control with different crowd density. Rotation construction process is introduced to complete the bridge at the severe mountain site. Joint details at the bases are designed and numerical analysis for the whole construction is performed to verify the feasibility of the construction. Health monitoring considerations for cable forces and girder vibrations under working states are suggested at last.

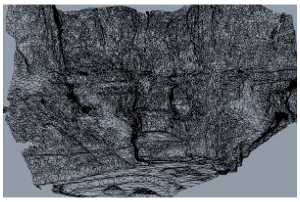
Keywords: 3D laser scanning; rock mass analysis; formfinding; overall stability; human induced vibration; cable-arch structure; rotation construction; health monitoring

As shown in Fig. 1, here in the Tanxi Mountain tourist area, which is located in Zibo, Shandong Province, China, a tilting pedestrian bridge was constructed cross two cliffs, in which a inclined tube arch supports a plane curved girder through 13 cables. The span of the bridge is 103m and the length of the curved girder is about 125m, the inclined arch is a parabolic arch with the height of 25m, the angle between the arch and the girder is 60 degrees, the width of the bridge deck 1.8m.

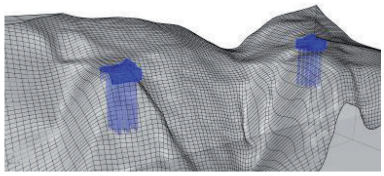
Fig. 1. Pedestrian Bridge, Zibo, China, 2016, a) Sketch view, b) Photo by Haizhou Chen

4 issues are discussed here: the stability of the rock mass structures, how to design a flexible superstructure, how to satisfy the requirement of human induced vibration, how to construct the bridge with severe onsite conditions. Here in the paper, a brief story is told on solving a flexible titling pedestrian on a mountain.

As shown in Fig.2, a rock mass model is built using 3D laser scanning techniques and bridge bases are integrated into the model. It is shown that the unstable area would be strengthened and strengthened measurements are suggested after the evaluation.



a) rock mass model



b) interaction model for rock mass and bases

Fig. 2. Rock mass model for stability analysis

The overall stability of the pedestrian is investigated with two software, the national 3D3S and the general FEM package ANSYS. Two combinations considered wind loads in different directions are included. The difference with or without defects are also considered in the analysis. The maximum defects is 1/300*L* and the results is shown in Table 3. Through buckling analysis, it is found that the buckling coefficient is over 9. In the elastic limit analysis, the limit coefficient is almost 7, and the results are almost the same with or without defects. In the elasto-plastic analysis, it is found in all cases the limit coefficient are over 2.5. It can be concluded that the structure is not a defect-sensitive structure and it satisfies the requirement of integral stability.

The vertical fundamental frequency of the bridge is 2.05Hz, and the total mass of the structure is about 414t. The mass ratio of TMDs is 2.5% located in the 1/4 and 3/4 span of the bridge. For the installation of the mass ratio of 2.5% TMD pedestrian bridge, the vertical acceleration time history curve of the investigation node is shown in Fig. 3 and the damping effect is shown in Fig. 4. The figures show that the vibration reduction effect of TMD is obvious, and the maximum vertical acceleration can be limited to 0.462m/s^2. The peak value at the investigated node is reduced from 2.683m/s^2 to 0.462m/s^2, and the vibration reduction rate reaches to 83%.

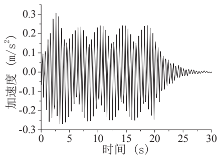


Fig. 3. Vertical acceleration time history curve under given load pattern (with TMD)

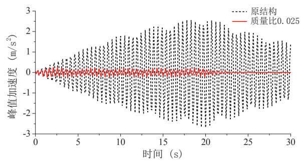


Fig. 4. The vibration control efficiency of mass ratio 2.5% TMD

Because of poor construction onsite conditions, two stage rotation construction process is carried out. First, the arch and the curved girder were all placed plane in assembly area. Then, the two parts translated to rotation position. In the first rotation stage, the main operation is to rotate the curved girder. Two jacks pushed the arch upward along the climbing pole, the climbing pole was hinged at the base and the pole rotated with the movement of the arch. After the first rotation, the arch and the curved girder were welded at the supports to make them become a whole. Then cable were tensioned to the given values obtain in initial state analysis. When finishing these operation, the second rotation operation started to make the bridge rotate in a whole to the design position. When the rotation completed, the supports were weld to the bases.

In this paper, numerical simulations for some design key issues for a tilting pedestrian supported by cable-arch system are carried out and the main conclusions are as follows:

1) 3D laser scanning and stability analysis of rock mass structures to ensure the stability of the substructure;
2) The analysis of the initial state, working state and overall stability of the bridge prove that the superstructure satisfies the requirements well;
3) Arranging TMDs on the bridge can significantly reduce the vibration acceleration of the structure under the pedestrian load. The TMD parameters are suggested in this paper.
4) Put forward a rotation construction method. The numerical simulation of the construction process is carried out to verify the feasibility of the construction process and the reliability and safety of the climbing device and the rotating joints.