Dynamic characteristic analysis of double-column machine bridge of spillway gate

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Abstract. The machine bridge has problems in many earthquake cases, such as cracking at the end of the column, excessive local displacement, and even severe damage. To improve the seismic property of the machine bridge, a new design method is proposed, namely the double-column machine bridge. The finite element analysis is used to analyze the dynamic time history of the structure, and the stress and displacement of the structure during the earthquake action are studied. In addition, the collision analysis between the machine bridges is carried out, which is based on the results of the three-dimensional finite element calculation. The results show that the double-column machine bridge has better seismic performance. Compared with the ordinary machine bridge, the displacement and stress of the new structure under the large earthquake are obviously reduced. By optimizing the structure, the collision between structures can be effectively avoided.

1. Introduction

The longitudinal length of the machine bridge is very long in a large spillway gate. Therefore, the size of the cross section of the machine bridge must be increased, which increases the difficulty of design and construction. Especially when the earthquake comes, the machine bridge with larger size is extremely vulnerable to damage under severe dynamic loads. To solve this problem and improve the mechanical properties of the machine bridge, a new design method is proposed, as shown in Figure 1. The design of the double column divides the machine bridge into multiple identical components, which not only reduces the construction difficulty, but also improves the overall stability of the machine bridge.

The dynamic time history analysis of the machine bridge is the main work of this research. Unlike the traditional dynamic response spectrum analysis, this method can calculate the stress and displacement of the structure during the whole process of earthquake action. Combined with the subsequent collision analysis, it is possible to grasp the working state of the machine bridge more realistically, get the weak position, and further improve the seismic performance[1]. Therefore, the new design method and the results of three-dimensional finite element analysis are significant for practical engineering application.
2. Calculation principle

2.1. Establishment of finite element model
This study analyzes the two-column and common-type machine bridges separately. The software Ansys was used to construct a three-dimensional finite element model, including the machine bridge, middle pier and corresponding foundation. At the same time, the finite element model corresponding to the form of common machine bridge is established, and the superiority of the double-column machine bridge is reflected by comparing the mechanical properties of these two forms.

In the two types of finite element models, the X direction is perpendicular to the river direction, the Y direction is vertical, and the Z direction is along the river direction. In addition, normal constraints are set on the side of flood control bridge and foundation, and full constraints are set on the bottom of foundation[2].

2.2. Calculating parameters and loading conditions
In the whole gate structure, C30 concrete is used for Pier and bottom slab, C40 concrete is used for machine bridge, flood control work bridge and overhaul bridge, and hollow block filling wall is used for partition wall of control room. The spillway gate is located on the strong weathered mixed granite, and the bearing capacity of the rock foundation is 500KPa.

This paper mainly considers the weight of the gate, the wind load, the live load of the control room roof, and the load of the engine room. According to the seismic code, the additional mass method is used to realize the dynamic effect of the reservoir water on the lock chamber[3], and the earthquake wave at a scale of 8 in Chinese with a duration of 20s is input perpendicular to the river direction.

3. Transient analysis results
In the dynamic time history analysis of the machine bridge, the top and bottom of the machine bridge column are selected as the key locations to study, and the changing law of the first principal stress at the two key locations is obtained during the earthquake. At the same time, this paper carries out dynamic time-history analysis of common machine bridge structure, and compares the analysis results of the two structural forms, as shown in the following figure, to verify the superiority of the design method of double-column machine bridge in hydraulic structure.

As shown in the following figures, when analyzing the position of the top of the machine bridge, if the common machine bridge structure is adopted, the first principal stress of the position is near 7 MPa at most times, and the maximum value reaches 13 MPa; if the double-column machine bridge is used, the position reaches 5.5 MPa at most times, and the maximum value reaches 10 MPa. When analyzing the position of the bottom of the machine bridge column, the first principal stress of the position is near 6 MPa in most cases, and the maximum value reaches 10.5 MPa. If the double-column machine bridge is used, the position reaches 5 MPa in most cases, and the maximum value reaches about 9
In addition, this paper presents the difference time histories of the first principal stress of two types of machine bridges at key positions, as shown in Fig. 3. From this point of view, the use of double-column machine bridge structure can reduce the stress value at important locations to a certain extent, which greatly reduces the possibility of damage of machine bridge under earthquake.

From the results of dynamic time history analysis, it can be seen that the dynamic response of the machine bridge is largest at about 14.50 s during the 20 s earthquake action. Fig. 4(a) and Fig. 4(b) are the first principal stress contours of two types of machine bridge structures at that time. Comparing with the common machine bridge structure, the maximum compressive stress of the double-column machine bridge structure is 6.89 MPa, which meets the requirements. The tensile stress on the surface of spillway gate pier and machine bridge column is relatively large, which may cause local damage,
but not large-scale damage. Based on the high intensity of the seismic wave at a scale of 8, the results of this dynamic time history analysis are acceptable in practical engineering.

4. Collision analysis results

Under the action of earthquake, the possibility of collision between adjacent double-column machine bridge in spillway gate is greater. According to the results of dynamic time history analysis, this paper makes a further collision analysis of the double-column machine bridge. The top of the control room, the top and the bottom of the machine bridge column are considered as the dangerous locations for the collision analysis.

According to the results of seismic time history analysis, the maximum relative displacement of three dangerous locations and their occurrence time are sorted out in this paper, as shown in Table 1. According to Table 1, the relative displacement of the top of the control room and the machine bridge column is about 70 mm in the earthquake, which is relatively large and prone to collision. However, the relative displacements at the bottom of the machine bridge column and other parts are relatively small, and the possibility of collision is very small.

| key position      | Maximum (mm) | Time of occurrence (s) |
|-------------------|--------------|------------------------|
| Top of control room | 64.2         | 14.7                   |
| Top of column     | 75.0         | 15.8                   |
| Bottom of column  | 29.8         | 15.1                   |

In addition, considering that the height of double-column machine bridge may affect the relative displacement value between structures, four finite element models with the height of 7.3m, 10m, 15m and 20m of frame bridge column are also used for collision analysis. The relationship between the maximum relative displacement value and the height of the structure is obtained to correspond to this. The calculation results are shown in Fig.5. It can be seen from the graph that the relative displacement between structures increases with the increase of the height of the frame bridge, and the higher the height of the frame bridge is, the faster the relative displacement increases.
5. Conclusions

(1) Compared with the ordinary machine bridge, the design method of double-column machine bridge has obvious advantages in both construction cost and mechanical properties. It can improve the seismic performance of machine bridge to a certain extent and can be popularized in engineering.

(2) It can be seen from the results of three-dimensional dynamic time history analysis that the root and the top of the column have large tensile stress, and local small-area damage will occur under the action of M8 earthquake. Therefore, in practical engineering, methods such as structural measures can be taken to make up for it. The other parts of the machine bridge bear relatively small stress, which basically meets the requirements.

(3) In the collision analysis of double-column machine bridge, the adjacent machine bridge can maintain similar dynamic response because they are on the same pier. Therefore, the possibility of collision is relatively small. According to the results of collision analysis, it is suggested that in the design and construction of spillway gates, the width of expansion joints between adjacent bridges should be 100 mm, which not only meets the maximum relative displacement of dangerous position, but also conforms to the actual situation.

References

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