The application of SAP2000 in the recheck of Traffic Bridge of a certain sluice

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Abstract. Using the bridge module of SAP2000 structure calculation software, can easily build bridge model, calculate bridge stress. Combination reinforcement module to check the condition of bridge reinforcement, thus to evaluate the whole safety of bridge. It is more convenient and reliable to use finite element software instead of traditional structure mechanics method.

1. Introduction
In addition to the main structure such as chambers, the safety appraisal of sluice often involves the recheck calculation of traffic bridges [1]. For some large and medium-sized sluices, the safety of the traffic bridge affects the safe operation of the entire project.

In the past, the recheck of traffic bridges was mostly based on the methods of material mechanics and structural mechanics, and the bridge was split into beam-slab structures for calculation [2].

FEM (finite element method) is a powerful tool in design, research and optimization for solving various complex engineering practical problems. It has become the most effective method and means for structural analysis. With the development and popularization of domestic computer technology, the finite element method is playing an important role in a wide range. SAP2000 is a general finite element program system for engineering analysis developed by the United States Computer and Structure Corporation (CSI). The system is widely used in the field of construction and civil engineering [3, 4]. Using the bridge module in SAP2000, overall modeling can be carried out, which is very convenient and quick.

2. Brief introduction to the Bridge Module of SAP2000
SAP2000 is an integrated general structure analysis and design software. It can analyze and design different types of structures such as building structures, bridges, pipelines, and dams.

The function of SAP2000 in bridge design is very powerful. It can carry out three-dimensional bridge design. Through the bridge module of SAP2000, a bridge model can be established, the analysis and design of the bridge live load can be automatically carried out, the bridge foundation seismic and bridge construction sequence analysis, the large deformation suspension bridge analysis and the Pushover analysis [4].

The operation steps of SAP2000 in bridge design are:
(1) First define Lanes;
(2) Define vehicle loads (wheel load groups such as trains, cars, cranes, etc.);
(3) Define vehicle class;
(4) define the moving load cases in Bridge Loads;
(5) Define load combinations according to specifications.

3. Example analysis

3.1. Calculation model
A sluice traffic bridge adopts a prefabricated T-beam assembly structure, with a total of 25 spans, of which 24 spans are 9.0m in length. The upper span of the sluice is 6.0m, with a total length of 222.0m, a width of 3.6m and a clear road width of 3.0m.

The cross section of the traffic bridge is shown in Figure 1. Modeling with the bridge module of SAP2000. The calculation model is shown in Figure 2.

Figure 1. Cross section of traffic bridge (unit: mm).

Figure 2. Traffic bridge calculation model in SAP2000.
3.2. Load calculation

According to the “Technical Standards of Highway Engineering” (JTG B01-2014), the vehicle load is divided into two levels: Highway-I and Highway-II. The car load grades designed for highway bridges and culverts at all levels should meet the requirements of the following table.

| Highway grade | Expressway | First grade highway | Second grade highway | Third grade highway | Fourth grade highway |
|---------------|------------|---------------------|----------------------|---------------------|----------------------|
| Vehicle load grade | Highway-I | Highway-I | Highway-II | Highway-II | Highway-II |

The calculation diagram of lane load is shown in the figure below.

![Figure 3. Schematic diagram of lane load.](image)

The standard value of uniform load for highway-I level lane load is: \( q_i = 10.5 \text{kPa} \). The concentrated load \( P_i \) is selected according to the following regulations: When the calculated span of bridges and culverts is less than or equal to 5.0m, \( P_i = 270 \text{kN} \). When the calculated span of bridges and culverts is equal to or greater than 50.0m, \( P_i = 360 \text{kN} \). When the calculated span is between 5.0m and 50.0m, the value of \( P_i \) is obtained by linear interpolation. The uniform distribution value and the standard value of the concentrated load of the highway-II lane load are 0.75 times of the highway-I lane load.

The sluice traffic bridge is checked in accordance with the fourth-grade highway, and the vehicle load grade is Highway-II. Considering the vehicle load, take the value according to the highway-II lane load and take the uniform load value: \( q_i = 7.9 \text{kPa} \), Standard value of concentrated load: \( P_i = 278.0 \text{kN} \).

Constant load: The beam and slab material are C25 concrete according to the original design, and the weight is automatically added by the software. Calculation conditions: Constant load + Vehicle live load combination.

3.3. Bending moment and shear force calculation results

Considering the constant load + Vehicle live load condition, the calculated bending moment and shear force envelope diagrams of the traffic bridge are shown in Figure 4 and Figure 5 respectively.

It can be seen that the bending moment check value is 1.2 times the maximum bending moment [5], i.e., \( M = 338.65 \text{kN} \cdot \text{m} \). The same can be obtained, \( V = 289.69 \text{kN} \).
3.4. Section reinforcement check
The section reinforcement of the main girder of the traffic bridge is shown in Figure 6.
Figure 6. Reinforcement diagram of main girder (unit: mm).

Carry out the ultimate state recheck of the bearing capacity of the traffic bridge girders in accordance with the "Design code for hydraulic concrete structures"(SL 191-2008). The recheck results are shown in Table 2

Table 2. Calculation results of main girder section bearing capacity.

| Load condition       | Main reinforcement | Stirrup | Moment capacity | bearing | Bending moment check value |
|----------------------|--------------------|---------|-----------------|---------|----------------------------|
| Constant load + Vehicle live load | 2B16+ 2B18+4B18+4B20 | A8@200  | 310.77 kN·m     | 338.65  kN·m |

It can be seen from the table that the moment bearing capacity is less than the bending moment check value. The section bearing capacity of the main girder does not meet the current code requirements. In accordance with the requirements of the "Design Specifications for Highway Safety Facilities"(JTG D81-2017), the traffic bridge is a single-lane fourth grade highway. According to the specification, the daily traffic volume should be less than 400 small passenger cars, and converted into medium-sized vehicles (2t < load mass ≤ 7t) should be less than 266 vehicles, large vehicles (7t < load mass ≤ 20t) should be less than 160 vehicles, the driving speed should not exceed 30km/h. In addition, for the overall safety of traffic bridges and sluices, this traffic bridge must be reinforced. Prior to this, the management department needs to add relevant load and speed limit signs at the bridge head and strictly restrict heavy vehicles from driving on the bridge [6].

4. Conclusions
The bridge module of SAP2000 software was used to recheck the bearing capacity of a sluice traffic bridge. The results showed that under the current code conditions, the main girder section bearing capacity can no longer meet the current code requirements and must be reinforced.
It can be seen that the SAP2000 software has powerful modeling, calculation and pre-processing capabilities. Using this software to recheck the structure of the traffic bridge in the sluice safety appraisal is more convenient and faster than traditional methods.

References
[1] Guidelines for sluice safety evaluation, SL 214-2015.
[2] Design specifications for sluices, SL 265-2016.
[3] TANG PU, The Application of SAP2000 Software in Bridge Engineering, 2006.
[4] SAP2000 Chinese version user guide, Beijing: People's Communications Press, 2012.
[5] Design code for hydraulic concrete structures, SL 191-2008.
[6] Design Specifications for Highway Safety Facilities, JTG D81-2017.