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Safety Assessment Method for Heavy-Cargo Transportation on Bridges in Service

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Abstract. In order to accurately evaluate whether large transport vehicles can safely pass the bridge on the transport route, the load effect comparison method and the actual load checking calculation method are introduced, and the safety assessment of a prestressed continuous small box girder bridge is analyzed with a case study. The results show that using the load effect comparison method can not distinguish whether large vehicles have the right of way. Based on the actual load checking method, it is found that the flexural capacity of the combined effect of the structure and the maximum and minimum stress under normal use meet the design requirements, and the large vehicle with a total weight of 755t meets the traffic requirements.

Keywords: Heavy-cargo transportation; Bridge condition assessment; Safety assessment; Bearing capacity.

1. Introduction

With the continuous advancement of China's industrialization and urbanization, more and more large and extra-large basic industry and infrastructure projects are put into construction, many heavy components such as generators, transformers, reactors and oil storage tanks and other large equipment transportation is becoming more frequent.The transportation tonnage has been increasing year by year, with weights ranging from over a hundred tons to thousands of tons. These large equipment items have high value and weight, and the transportation guarantee task is heavy. The safety assessment of the bridge is very important when the heavy and heavy transport vehicles pass through the bridge[1,2]. There are some bridges that have been in operation for several years on the lines passed by the heavy-cargo vehicles. Under the influence of various factors such as the natural environment and the growing traffic flow, the bearing capacity of the bridges will decline to a certain extent, and the role of the heavy-cargo vehicles of transport equipment will often exceed the load grade of the bridge design and construction[3,4]. Therefore, it is necessary to entrust professional institutions to carry out special inspection and evaluation of the bridge before large transportation, and only after meeting the traffic requirements can the transportation work be carried out.

At present, the bridge traffic assessment mainly adopts the load effect comparison method and the actual load checking method[5, 6]. The load effect comparison method is to compare the load effect of the large transport vehicle with the design car load effect of the bridge. If the load effect of the large transport vehicle is less than or equal to the design car load effect of the bridge, it indicates that the large transport vehicle can safely pass the bridge. The actual load checking method refers to the comparison of the combined internal force effect of the structure and the bearing resistance of the structure when the large transport vehicle crosses the bridge. If the combined internal force effect is less than the bearing resistance of the structure, the large transport vehicle has the right of way. The actual load checking method is a more accurate method to judge whether the large transport vehicles pass safely, but the calculation workload is large. Based on the load effect comparison method, Bao[7] developed relevant procedures to judge whether large transport vehicles have the right of way to cross the bridge;; Jiang[8] used the actual load checking method to evaluate the safety of the bridge, and put forward the real-time monitoring system combined with the finite element method to evaluate the safety of the bridge for heavy vehicles.

This paper first discusses the concrete evaluation method of large transport vehicles passing the bridge, and then studies the feasibility of large transport vehicles with a total weight of 755t passing the bridge through a calculation example.

2. Overview of large transport vehicles

Large transport vehicles refer to the over-limit transport vehicles carrying non-disintegrating items, and the total length, total width, total height and total mass of the vehicles and goods have at least one in line with the conditions stipulated in the "Regulations on the Management of Highway for over-limit Transport Vehicles"[9], which stipulates that the total height of the vehicles and goods exceeds 4.5 meters from the ground, or the total width exceeds 3.75 meters, or the total length exceeds 28 meters, or the total mass of more than 100,000 kg, are defined as class III large transport.

Large transport vehicles are generally composed of tractor and trailer group, according to the weight and size of the cargo, the common trailer group is mainly flat trailer, concave plate trailer and long cargo trailer and other types. The actual transport of large vehicles is shown in Figure 1.

Figure 1. Large transport vehicles

3. Evaluation Methods

At present, the checking calculation of large transport vehicles is generally divided into two stages. In the first stage, the load effect comparison method is applied, that is, the actual load effect of large transport vehicles is compared with the design load effect. When the load effect of large transport vehicles is less than the design load effect, it is considered that the vehicles can pass safely. If the first stage of the checking calculation does not pass, then the actual load checking method. In addition, when the technical status of the bridge is assessed as the third class, the actual load checking method should be used for detailed checking and calculation, and the bridge is monitored in real time during the passing process.

3.1. Load effect comparison method

The load effect comparison method is to compare the load effect of large vehicles (considering the partial coefficient 1.1) and the load effect of designed vehicles (considering the impact and the partial coefficient 1.4). When the ratio between the load effect of heavy vehicles and the load effect of vehicles under the designed load is less than 1.05, the bearing capacity of the bridge should be judged to meet the traffic requirements, and the calculation formula is shown in (1).

$$\mu = S_c / S_Q \tag{1}$$

Where: S_c- Load effect value of large vehicle;

S_Q - vehicle load effect under design load.

Its criterion is:

When μ≤1.05, the large vehicle has the right to allow passage;

When μ>1.05, the right of way should be determined according to the actual load checking method.

3.2. Actual load checking method

The actual load checking method is to combine the permanent load effect of the bridge structure with the special live load effect of large transport vehicles after considering the corresponding sub-coefficients. The combined load effect must be less than the structural resistance *R* to meet the vehicle passage, and the calculation formula is shown in (2).

$$S_c^{'} = 1.2S_G + 1.1S_c \le R \quad (2)$$

Where: S_G- the effect value of permanent action load.

4. Analysis of numerical examples

4.1. Project Overview

The total weight of a large transport vehicle is 755t, of which the weight of the cargo is 552t, and the maximum axle weight of the pallet car is 18t. The longitudinal arrangement of the large transport vehicle is shown in Figure 2. The superstructure of the bridge adopts 3×35m prestressed concrete continuous small box girder, and the height of the single box girder is 1.8m. Four beams are arranged across the bridge. The design load level is highway -I level, and the technical status level of the bridge is one level.

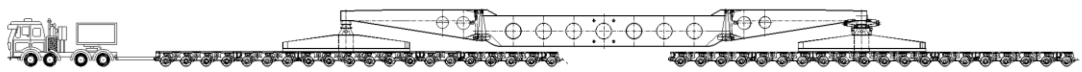

Figure 2. Longitudinal layout of large-sized transport vehicles

4.2. Finite element model establishment

The finite element software is used to establish the bridge calculation model, the main beam is simulated by beam element, and the support is simulated by node elastic support. The small box beam adopts C50 concrete, the bulk weight$_1$ γ=26 kN /m^3, the nominal diameter of the prestressed steel strand 15.2mm, the standard strength f_{pk}=1860MPa, the elastic modulus E_P=1.95× 10^{5}MPa, and the ordinary steel bar adopts R235 and HRB335. The calculation selects the medium traffic condition of large truck, does not consider the impact coefficient.

4.3. Load effect comparison method of traffic discrimination

The internal forces of the small box girder in the middle span and the fulcrum section are shown in Table 1. and the data in the table are the calculation results of the single piece small box girder in the most unfavorable state. It can be seen that the positive bending moment of the small box girder span and the negative bending moment of the fulcrum load effect of the large car are greater than the design load effect, and the ratio is more than 1.05. The preliminary judgment can not meet the passing conditions, and the actual load checking calculation method needs to be further applied to distinguish.

Table 1. Comparison of internal force effect of prestressed concrete continuous small box girder

Items	Load[kN·m]		Ratio ②/①	Right of way
	Highway - Class I ①	Large transport vehicle ②		
Maximum positive bending moment in span	3775	4356	1.15	Further judgment required
Maximum negative bending moment of fulcrum	-3207	-4413	1.38	Further judgment required

4.4. Passage discrimination of actual load checking method

4.4.1. Calculation of flexural capacity

The maximum bending moment and minimum bending moment of the combined effect of the limit state of the bearing capacity under the action of large vehicles are calculated respectively, and compared with the design resistance of the structure, as shown in Figure 3 and Figure 4. It can be seen from the data in the figure that the maximum positive bending moment load effect of side span (8956.3kN▪m)is less than the structural resistance (13339.6kN▪m); the maximum negative bending moment load effect of the fulcrum (- 9501.5kN ▪m) is less than the structural resistance (-11710.7kN▪m). Therefore, the flexural bearing capacity of the structure meets the design requirements when passing through large vehicles.

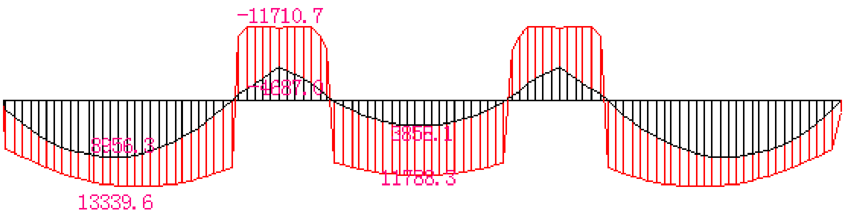

Figure 3. Comparison of maximum bending moment and structural resistance of combination effect of large vehicles [kN▪m]

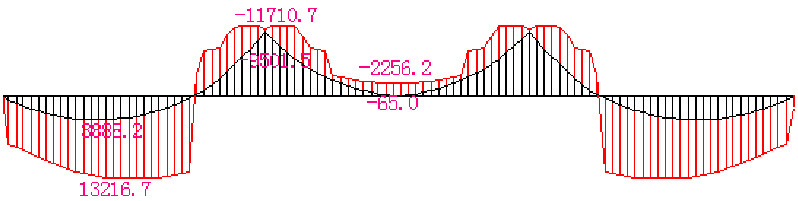

Figure 4. Comparison of minimum bending moment and structural resistance of combination effect of large vehicle [kN▪m]

4.4.2. Stress calculation

The maximum and minimum stresses on the upper and lower edges of the combined effect structure under normal use limit state under the action of large vehicle are calculated respectively, as shown in Figure 5 and Figure 6. It can be seen from the data in the figure that the maximum compressive stress of the concrete structure under the action of the combined effect is 14.9MPa, which meets the requirements of the design limit value of $0.5f_{ck}$=16.2MPa; The maximum tensile stress of the lower edge is 0.8MPa, which meets the requirements of the design limit value f_{td}=1.83MPa.

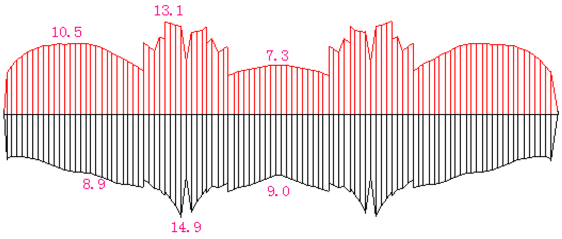

Figure 5. The maximum stress [MPa] on the upper and lower edges of the combination effect of large vehicle

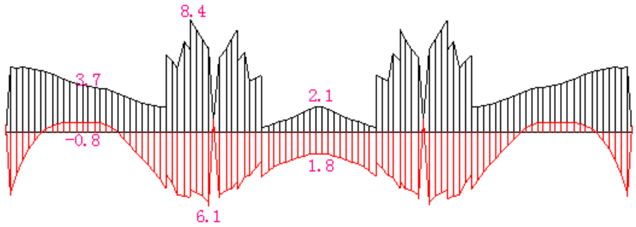

Figure 6. Minimum stress [MPa] on upper and lower edges of combination effect of large vehicle

5. Conclusion

The capacity assessment of bridge structure is the key link of large transportation projects. The assessment work should not only ensure the safety of bridge structure, but also ensure no damage to the structure. In this paper, based on the load effect comparison method and the actual load checking method to carry out the structural safety checking evaluation, and for a prestressed continuous small box girder bridge for example analysis, based on the actual load checking method calculation found that the structural combined effect bending capacity and the maximum and minimum stress under normal use state meet the design requirements, large vehicles meet the passing requirements.

However, the actual load checking method assumes that the bridge structure is in a state without any damage, and it is necessary to test the actual state of the bridge. By introducing the checking factor, deterioration factor, reduction factor and so on, the bearing capacity of the structure is revised, and the revised bearing capacity can objectively reflect the real state of the bridge.

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References

[1] J.Li,M.Q.Zhong,H.J.Wu, et al. Impact of bridge technical state on bearing capacity of large-cargo transport [J]. Highway,vol.61,no.11,pp. 84-89, 2016.

[2] X.Zhou, Structural and economical impacts of heavy truck loads on bridges [D]. Louisiana: Louisiana Tech University, 2007.

[3] S.H.Li,Z.Y.Xu,H.W.Jiang. Impact of heavy vehicle on highway bridge safety[J]. Highway Transportation Science and Technology,vol.32,no.9,pp,74-79, 2015.

[4] G. K.FU, C. FU. Bridge rating practices and policies for overweight vehicles, NCHRP Synthesis 359 [R]. Detroit: Wayne State University, 2006.

[5] G.L.Zhou, Rapid evaluation of bridge crossing capability of large transport vehicles [J]. Highway Transportation Technology,vol.34,no.5,pp,73-77, 2018.

[6] A. GHEITASI, D. K. HARRIS. Overload flexural distribution behavior of composite steel girder bridges [J]. Journal of Bridge Engineering,vol.20,no.5,04014076, 2015.

[7] W.G.Bao, Software compilation for checking and analyzing the bridge crossing capacity of large transport vehicles [J]. Highway,vol.9,pp,107-109, 2003.

[8] X.Jiang, H.J.Song,and S.Zhao, et al. Safety assessment method and case study of customized transportation vehicle passing through bridges in service[J]. Building Structures, vol.52,no.S2,pp,1942-1931, 2022.

[9] The Ministry of Transport of the People's Republic of China. Regulations on the management of highway for over-limit transport vehicles (Order No. 12 of 2021 of the Ministry of Transport) [S] Beijing: Ministry of Transport of the People's Republic of China, 2021.