Mechanical Behavior of Anchor Zone of Prestressed Box Girder

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Keywords: Prestressed Box Girder; Anchorage Zone; Mechanical Behavior; Anchorage Zone Pressure

Abstract: The pressure problem in the box girder anchorage area is a common problem in the construction of bridges. In order to improve the service performance of the bridge structure, it is often necessary to prestress the bridge structure during the construction period to reduce the structural damage caused by the excessive load during the bridge service. In order to study the mechanical behavior characteristics of the box girder anchorage zone, this paper takes the box girder top and web anchorage zones as examples, and establishes the corresponding stress by comparing and analyzing the local stress distribution law and characteristics of the box girder top plate and web under the anchor. The effective formula simplifies the stress calculation of the prestressed anchorage area of the box girder top plate, so as to provide reference and reference for solving the pressure problem of the anchorage area in the current bridge construction. The final study showed that the stress distribution curve of the anchored area of the box girder and the rectangular plate is roughly the same. The maximum normal stress of the box girder is 0.5 MPa, and the maximum normal stress of the rectangular plate is 0.4 MPa, and the stress ratio between the two is 0.5/0.4 =1.25, the stress distribution law of the box girder anchoring zone is similar to the stress distribution law of the rectangular plate anchoring zone of the same size.

1. Introduction

Prestressed box girder is a common girder structure in bridge construction in our country, and it is also the main form in the design of bridge engineering superstructure. This prestressed box girder structure can greatly reduce the bearing capacity of the bridge, help offset the bearing capacity of the wheels on the bridge deck, and play a great auxiliary role in stabilizing the bridge structure[1-2]. Anchorage is an important part of box girder. Generally, the box girder structure of bridge is composed of steel bar and concrete, and anchorage is to connect steel bar and concrete. The purpose is to make the two works together to bear various stresses and pressures and make the bridge structure stronger [3-4]. Prestress is often applied to the anchorage area of the bridge box girder, so studying the mechanical behavior of the box girder anchorage area can analyze the pressure-bearing capacity of the entire bridge [5-6].

In recent years, the country has continuously strengthened and improved infrastructure construction, and the mechanics of the pre-stressed box girder anchorage area in the engineering field has become a hot topic of research. Zhang, Gang and Zhu, Meichun stated that excessively high temperatures can cause cracks in the prestressed concrete (PC) continuous bridge with box girder on the top of the pier under the age of cement hydration. For this reason, they used the form of the computer program ANSYS to evaluate the behavior of the PC box girder in the early stage of hydration through the two-stage calculation model, that is, the 3-D temperature evaluation and the determination of the mechanical response of the PC box. They established a numerical model considering time-varying wind speed and ambient temperature to track the thermal and mechanical response of box girder [7]. Huang, Haidong et al. showed that long-span prestressed concrete (PC) box girder bridges can suffer excessive vertical deflection and cracking. The recent serviceability failures in China show that the current Chinese standard modeling methods cannot accurately predict the long-term deformation of large box girder bridges, which prevents inspectors from performing satisfactory structural assessments and making decisions on possible repairs and enhancements hard work. They proposed a method of updating the model, which aims to evaluate the models used in the current Chinese standards and improve the accuracy of numerical modeling of the long-term behavior of box girder bridges and calibrate them based on the data of in-service bridges. They first established a three-dimensional finite element model representing the long-term behavior of the box girder section, and then conducted parameter studies to determine the relevant influencing parameters, and quantified the relationship between these parameters and the behavior of the box girder bridge [8].

From previous studies, the mechanical analysis of the prestress in the anchoring area of the box girder has a great theoretical guidance for the construction of construction projects. The stability of the entire building structure can be well strengthened through the study of the stress in the anchoring area, and it can also improve and deal with problems that arise based on the results of the research [9-10]. This paper studies the mechanical behavior of prestressed box girder anchorage zone, aiming to guide the solution of pressure problems in bridge construction.

2. Method

2.1 Prestressed Box Girder

Prestress is the pressure applied to the precast structure during construction to improve the performance of the building. Currently, China's engineering technology generally uses reinforced concrete structures. The use of reinforced concrete can increase the hardness of the building, delay the appearance of cracks, and improve the durability and bearing capacity of the building. Box girder is a kind of bridge structure because the inside is empty and the outside is square, just like a box, called box girder.

2.2 Box girder

Box girder is a commonly used beam structure in bridge engineering construction. It is named because it is hollow inside and the outer structure is similar to a box. According to the material of the box girder, the box girder can be divided into two types: prestressed reinforced box girder and steel box girder. Steel box girder is also called steel box girder and is generally used on bridges with larger spans.

2.3 Anchorage Area

The part where the steel bar is wrapped by concrete is called the anchorage zone, which mainly functions to strengthen the connection between the steel bar and the concrete. Generally, the anchorage length of the steel bar refers to the total length of the solid steel bars of the beams, slabs and columns inside the support or foundation, including straight and bent bars.

2.4 Stress Calculation of Box Girder Anchorage Area

Generally, the cross section of the anchoring area is mainly rectangular and circular, but the box girder roof bundle anchorage studied in this paper is a box cross section, and the calculation of its stress is generally a normal stress calculation. First, set the normal stress intensity condition as

$$\sigma_{\max} = \frac{|M|_{\max} \bullet y_{\max}}{I_Z} = \frac{|M|_{\max}}{W_Z} \leq [\sigma] \tag{1}$$

Among them, $\sigma_{\max}$ represents the section with the largest bending moment of the equal section beam, $M_{\max}$ represents the farthest from the neutral axis, I_Z represents the neutral layer, and W_Z represents the neutral axis.

Second, select the cross section

$$W_Z = \frac{M_{\max}}{[\sigma]} \tag{2}$$

Finally, calculate the maximum bearing capacity of the beam, that is, the stress

$$M_{\max} = W_Z[\sigma] \tag{3}$$

3. Experiment

3.1 Decomposition of Box Girder Roof

Compared with the ordinary rectangular anchoring zone section, the stress distribution in the anchoring zone of the prestressed box girder top plate is more complicated. In order to analyze the prestressing characteristics of the box girder anchoring zone, we established a box girder top anchoring zone model through experiments. Since the stress distribution under the anchor of the box girder top and web is very similar to the distribution of the rectangular section, we can establish the stress relationship between the top and web of the box girder through calculation.

3.2 Establish a Box Girder Roof Model

In this experiment, the model box girder we selected is a simplified version of the structure. The top and web thickness of the box girder is set to 0.6m, the bottom plate thickness is 0.4m, the box girder section height is 5m, the top plate width is 15m, and the bottom plate width is 6m. The total stress bearing capacity of the box girder anchorage zone is 5000kg, and the area of the anchor pad is 400×400mm. The specific parameter values of each index of the model are shown in Table 1.

Table 1. Various parameter values of box girder model

Index	Roof thickness	Web thickness	Thickness of bottom plate	Box height	Top plate width	Bottom width	Anchor plate area	Maximum stress
Parameter value	0.6(m)	0.6(m)	0.4(m)	5(m)	15(m)	6(m)	400×400(m)	5000(kg)

3.3 Establish an Equivalent Formula

The purpose of this experiment is to establish a box girder model to analyze the distribution of prestress in the anchorage area and the characteristics of the anchorage area. Therefore, we will simplify the traditional pressure calculation by establishing an equivalent formula to make the pressure calculation of the box girder anchored area easier and more convenient, suitable for analyzing the stress distribution law. The corresponding decrease of the prestressed bearing capacity of the rectangular plate will produce the pressure value of both, and then there is

$$\begin{aligned} S_{x-x} &= \alpha S_{x-t} \\ S_{y-x} &= \beta S_{y-f} \\ q_{r1} &= \alpha q \\ q_{r2} &= \beta q \end{aligned} \tag{4}$$

4. Result

4.1 Deformation Calculation Results of Box Girder Model

In the experiment, we set the top plate and web of the box girder to a uniform load, and then calculated the deformation of the anchored area of the model box girder and recorded the maximum displacement of each anchored section of the two. The results are shown in the Table 2 and Figure 1.

Table 2. Maximum displacement of top and web of box girder with different anchoring segments

	1	2	3	4	5	6	7	8
Roof	0.48	0.75	0.88	0.91	1.10	1.14	1.23	1.26
Web	0.57	0.92	1.34	1.46	1.58	1.67	2.01	2.12

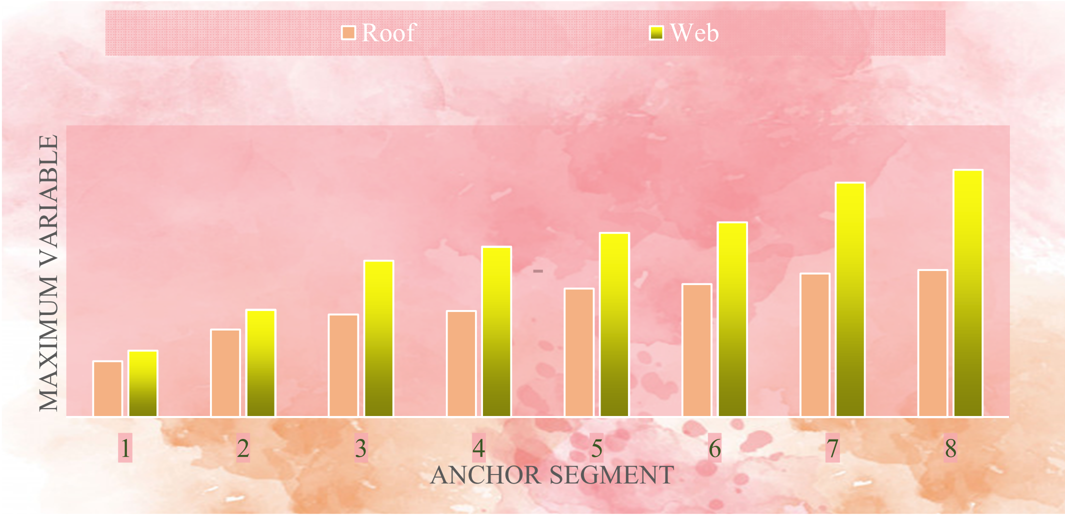

Figure 1. Maximum displacement of top and web of box girder with different anchoring segments

It can be seen from Table 2 and Figure 1 that the maximum deflection of the top plate of the box girder model is significantly smaller than that of the web area. The maximum deflection of the top plate at the eighth anchor section is 1.26, while that of the web is 2.12; and the top plate is the largest fluctuation of the displacement is also smaller; and as the segment increases, the maximum displacement of the two also gradually increases. This shows that the anchoring area of the prestressed box girder roof is stronger than the web, and the displacement of both tends to stabilize gradually with the increase of the anchoring section.

4.2Stress Distribution Law and Characteristics of Box Girder Top and Web

In the experiment, we found that the top plate and web of the box girder model have great similarities with the anchoring area prestress of the corresponding rectangular plate. In order to further study the stress distribution rules and characteristics of the two, we use Path3 to analyze the stress of the box girder and the rectangular plate, and the results are shown in Figure 2.

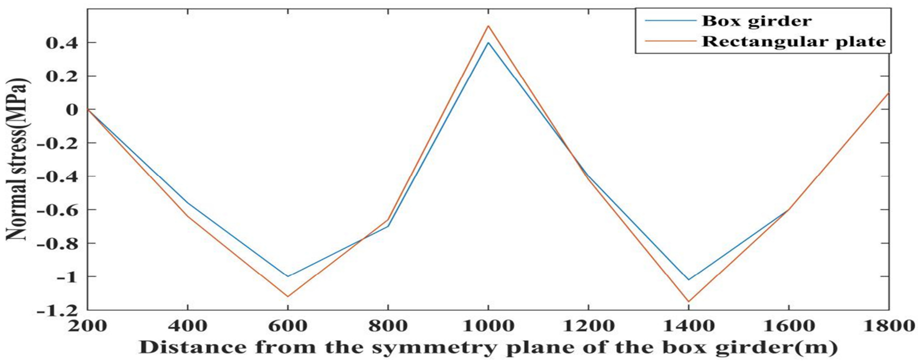

Figure 2. Stress comparison between box girder and rectangular plate anchored area

Figure 2 shows that the stress distribution curve of the anchored area of the box girder and the rectangular plate is roughly the same. The maximum normal stress of the box girder is 0.5 MPa, and the maximum normal stress of the rectangular plate is 0.4 MPa, and the stress ratio between the two is 0.5/ 0.4=1.25; the minimum normal stress of the box girder is -1.02MPa, the minimum normal stress of the rectangular plate is -1.15MPa, and the ratio of the two is 1.02/1.15≈0.89.This shows that the stress change law of the anchor area of the box girder roof and web is similar to the stress change law of the anchor area of the rectangular plate of the same size.

5. Conclusion

Prestress and anchoring are important construction parts in bridges and other engineering buildings. The stability of the building, the length of the building's service period and the amount of load of the building are inherently important to the prestress and anchor during construction. Studying the mechanical behavior of the anchorage area of prestressed box girder and exploring the distribution characteristics and laws of stress in the anchorage area of the box girder is conducive to the analysis of the bearing capacity of engineering buildings and can provide a theory for solving the pressure problem of the anchorage area in the construction of bridges to a certain extent guide.

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