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To cite this article: Zuo Yong-jian *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **310** 042061

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# Girder crack of concrete single pylon cable-stayed bridge

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**Abstract.** Taking the reinforcement and maintenance project of a concrete cable-stayed bridge as the background, aiming at the stress cracks on the web of the box girder of the main bridge after several years of operation, starting from the actual situation of design and construction, the integral calculation model of the bridge is established by Midas Civil and the local analysis and calculation model of the main girder is established by the general finite element software. Four kinds of analysis and calculation models are analyzed. Finally, it is shown that the web cracks of the bridge are caused by the cable tension when the bridge is cantilevered. On this basis, the concrete and feasible bonded steel plate method is proposed to repair and strengthen the cracks, which is of certain reference significance for the reinforcement and maintenance of the same type of bridge cracks in the future.

## 1. Introduction

Due to the imperfection of theoretical analysis, calculation means and construction technology, various diseases have appeared in the early-built concrete cable-stayed bridges in China after several years of operation, among which cracks in the main girder are particularly common[1-3]. Longitudinal cracks on the roof of box girder, diaphragm cracks, floor cracks and web cracks are the most common forms of cracks in the main girder of concrete cable-stayed bridges[2]. The high-pressure stress caused by prestressing tendons and cable-stayed index is the main cause of web cracking of box girder[4-6]. Because the vertical component provided by the cable is basically equal to the weight of concrete in each section, the horizontal component of the cable is larger in the section with larger inclination, and the shear force between the anchor block and the main girder is larger, so that the transverse cracks near the anchor block may occur, which may develop into web oblique cracks[7]. In addition, compared with symmetrical double-ylon cable-stayed bridges, asymmetrical single-ylon cable-stayed bridges generally have smaller Side-to-Middle span ratio and higher requirements for pylon self-stability[8]. Due to the different angle of oblique intersection between the cable and the main girder and the main tower, the tension form is generally asymmetric, and the influence of cable force on the main girder is more complex [9].

In this paper, the main girder web cracks of single tower cable-stayed bridge are analyzed in depth, and the size and location of bonded steel plate are proposed to enhance the safety of the bridge and prolong its service life.

## 2. Engineering overview

The main structure of a concrete cable-stayed bridge is a single-tower double-cable-plane concrete



cable-stayed bridge with pylon pier and beam consolidation. Its span is 89.2m+109.2m, and an auxiliary pier is set at the side span 67m away from the central line of the main pylon.

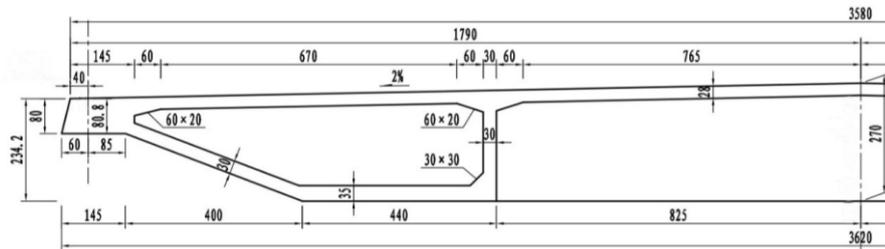


Figure 1. Half-size of the main bridge box girder.(Unit: cm)

The main girder is a prestressing concrete separated box girder with 35.8m top width, 36.2m top air nozzle width, 2% cross slope, 2.342-2.7m beam height and 3.2m tower root beam height. The thickness of single box roof is 28 cm, the width of bottom plate is 4.4 m, the thickness of bottom plate is 35 cm, the root of tower is increased to 65 cm, the inclined web thickness is 30 cm, the root of tower is increased to 60 cm, the web thickness is 30 cm, and the root of tower is increased to 60 cm. The distance between the boxes is 16.5m.

Cross beam: along the bridge, according to the distance between the cables, a cross beam is set between the ribs of the main beam. The width of the common cross beam is 0.4m, the width of the cross beam at the connection of the tower and the beam is 6.0m, and the width of the cross beam at the end of the main span is 1.6m. The width of common cross beam in cast-in-situ section of side span is 1.2m, that of auxiliary pier top cross beam is 1.2m and that of side span end cross beam is 3.5m. The crossbeams are all pre-stressed concrete structures.

### 3. Main diseases of box girders

After a comprehensive structural safety inspection of the bridge, it was found that cracks appeared in the webs, roofs, bottom plates and inner and outer diaphragms of box girders, and oblique cracks in webs and top plates of box girders accounted for the majority. Occasionally, cracks appeared in the bottom plates, diaphragms and tooth plates of box girders. According to the field test results, the cracks can be divided into the following categories.

#### 3.1. Oblique cracks in web of box girder

##### 3.1.1. Oblique web of box girder

There are generally stress cracks in the inside of the inclined web, mainly shear cracks in the inclined web, but all cracks have not crossed the construction cracks after checking. Only a few cracks have been found in the outside of the web due to the coating layer. There are 62 cracks in the inclined web. There are seepage paste in individual cracks. The typical crack pictures are shown in Figure 2. (a), (b).

##### 3.1.2. Straight web of box girder

There are local stress cracks in the straight web, but the cracks are relatively concentrated and mainly shear cracks, a total of 46 cracks in the straight web. Typical fracture photographs are shown in Figure 2. (c), (d).



Figure 2. Typical crack diagram of the box girder web.

### 3.2. Cracking at the bottom of box girder roof

There are 62 cracks on the bottom of the roof, and most of them are connected with the cracks on the inclined web. Most of them have the phenomenon of seepage and paste. There are 62 cracks on the bottom of the roof, and serious corrosion of bars is found. Typical fracture photographs are shown in Figure 3.(a), (b).



Figure 3. Typical crack diagram at the bottom of the box girder roof.

### 3.3. Box girder diaphragm

**3.3.1. Inner diaphragm of box girder.** There are 8 transverse cracks in the diaphragm beam at the pylon position. There are 74 vertical cracks in the conventional diaphragm beam part of the manhole position along the intersection of the section. Typical cracks are shown in Figure 4. (a), (b).

**3.3.2. Outer diaphragm of box girder.** The external diaphragm beam is a pre-stressed concrete structure. There are 16 transverse and longitudinal stress cracks at the bottom of individual external diaphragm beams, and there are local pockmarks, inclusion garbage, water seepage and whitening at the bottom of the external diaphragm beam. See Figure 4. (c), (d).



Figure 4. Typical crack diagram of the box girder diaphragm.

## 4. Cause analysis of cracks

In order to study the causes of cracks in the box girder of the bridge, according to the distribution characteristics of cracks, combined with the operation history of the bridge and the structural characteristics of the bridge, a comprehensive analysis of the bridge is carried out first, and then a local stress analysis is carried out on the basis of the analysis. Through theoretical analysis method, we can grasp the main disease of bridge, that is, the cause of cracking, and provide the basis for the formulation of targeted maintenance plan of cracks.

### 4.1. Overall Computational Analysis

The finite element model is established by Midas finite element program, in which the girder element is used for the main girder and the main tower, and the cable element is simulated by truss element. There are 377 beam elements and 60 truss elements. The model diagram is shown in the Figure 5.

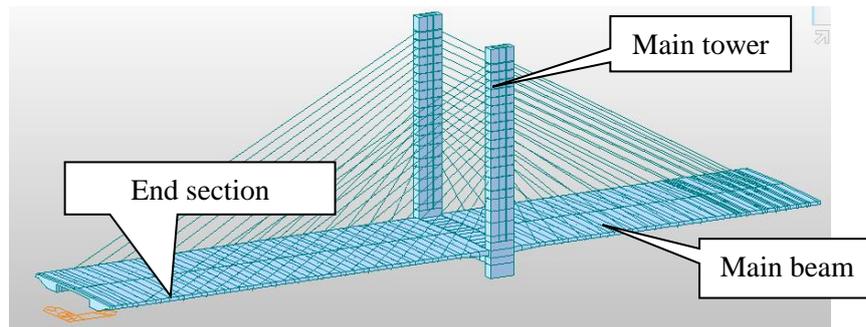


Figure 5. model of the rod system.

The load is taken from the design load, and the coefficient of increase of dead load is taken into account. The selection of cable force in construction stage and construction conditions are carried out according to the completed drawings.

Through calculation, the upper and lower edge stresses of the superstructure under short-term envelope condition are shown in Figure 6.

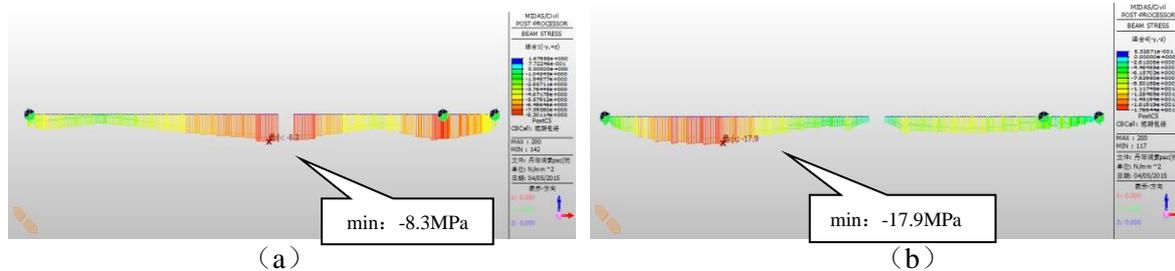


Figure 6. Short-term stress envelope diagram (unit: MPa)

From the stress envelope of upper and lower edges, it can be seen that there is no tension stress in the box girder in use stage, the whole section is in compression state, and the maximum compressive stress is 17.9 MPa, that is to say, normal use meets the requirements of the code.

#### 4.2. Local effect analysis

4.2.1. Modeling. The model is established by large-scale general finite element software. Solid45 element is used for solid element and Link8 element is used for strand. Eight blocks of main span are selected for analysis. The truncation position of blocks is loaded according to the measured internal force, and the anchorage zone of blocks is loaded according to the actual cable force. The model diagram is shown in Figure 7.

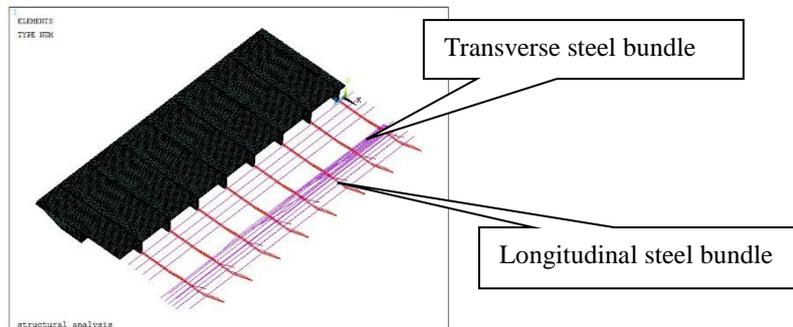


Figure 7. Schematic diagram of the mixed model unit

4.2.2. *Analysis.* According to the typical stage of bridge construction and use, the analysis is divided into four working conditions: cantilever casting condition, completed bridge condition, live load single working condition and constant live load overlapping working condition.

(1) Cantilever working condition

At present, the block is in cantilever state. Considering the dead weight, prestressing force and cable force, the cable force comes from the completed drawings.

(2) Bridge completion conditions

The completed bridge condition is the second stage after cable adjustment, considering the dead weight, prestressing force and cable force, and the internal force state comes from the pole system model.

(3) Live Load Conditions

Considering only the six-lane Lane load and the corresponding cable forces, the cable forces and internal forces are derived from the pole system model.

(4) Overlapping

Considering the superposition of the internal force state of the completed bridge and the internal force state of the service condition, the comprehensive analysis of the service stage is carried out.

## 5. Conclusion

In view of the crack disease of single tower and double cable plane concrete cable-stayed bridge, the overall and local stress analysis is carried out, and the following conclusions are drawn:

(1) When the bridge is analyzed as a whole under the original design condition, there is no tension stress in the box girder in the normal service stage, and the whole section is in the compression state, which meets the requirements of the code.

(2) Local high stress zones appear in the webs of the bridge after cable tension under cantilever condition during construction stage, which exceed or approach the standard value of tensile strength of concrete. If the strength of concrete does not meet the requirements during tension, cracks may occur inside and outside the inclined webs or straight webs, and cracks may extend to the roof.

(3) In order to ensure the service performance of the bridge, steel plate can be bonded to reinforce the bridge and effectively prevent the development of cracks.

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