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Detection and Genesis Analysis of Cracks in Prestressed Box Girder of a Certain Project

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Abstract

This paper introduces a crack detection example of the prestressed box girder in a certain project. The morphology of the box girder cracks was surveyed and mapped. The length, width, and depth of the cracks were inspected, and the strength and reinforcement configuration of the components were tested. The test results indicate that the strength and reinforcement configuration of the inspected components meet the design requirements. The crack at the end of the top plate of the box girder is a local compressive crack at the anchorage end. The width and length of the crack on the bottom surface of the top plate are not significant, and the depth is relatively shallow. Judging from the crack morphology, this crack is identified as a temperature crack. Additionally, based on the treatment measures for cracks of different widths, the treatment measures for the cracks of the components in this project are derived, providing a reference basis for similar projects in the future.

Keywords

Prestressed Box Girder, Crack Detection, Cause Analysis, Treatment Measures

1. Introduce the Article

Prestressed concrete box girders are widely employed in bridge and tunnel projects due to their strong flexural strength and stiffness characteristics. During the construction process, cracks inevitably occur on the surface of the box girders. With the propagation of these cracks, the durability of the box girders will be reduced. If not dealt with promptly, it is likely to affect the bearing capacity of the box girders eventually and endanger the normal use of the structure.

There are numerous factors contributing to the generation of cracks, and the causes are rather complex. It is necessary to conduct meticulous investigations of the morphology and characteristics of the cracks, and carry out summary analysis and cause inference. Meanwhile, it is essential to determine the degree and scope of the influence of the cracks on the structure, and promptly implement targeted treatments for different cracks in a timely manner to economically and effectively ensure the safety and normal usage of the structure [1]-[3].

2. Project Overview

In a certain project, the left box girder of DY42-DY43 underwent the initial tensioning of prestressing tendons three days after pouring, and the final tensioning was carried out five days after the initial tensioning. After the tensioning was completed, crack defects were found on the side and bottom surfaces of the end of the top slab of the box girder. To grasp the crack morphology, causes and treatment suggestions of the box girder, the left box girder from DY42 to DY43 was subjected to crack and structural inspection.

3. Field Inspection

3.1. Detection of Crack Width and Length

On-site crack detection of the left box girder of DY42-DY43 in a certain project was carried out using tools such as a tape measure and a crack width observation instrument. The specific crack descriptions are detailed in **Figure 1** to **Figure 2**, and the crack detection results are shown in **Table 1**.

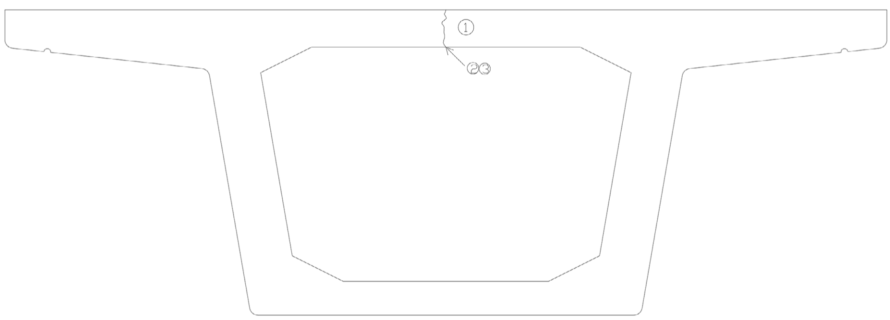

Figure 1. Diagram of side crack at the end of the top slab of left box girder DY42-DY43.

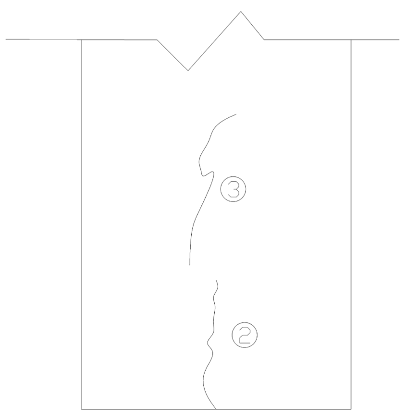

Figure 2. Diagram of bottom crack at the end of the top slab of left box girder DY42-DY43.

Table 1. Detection results of cracks in this project.

No.	Crack Length (mm)	Maximum Crack Width (mm)
1	342	0.40
2	891	0.60
3	1030	0.20

3.2. Detection of Crack Depth in the Roof Slab

The ultrasonic method was adopted on-site to detect the depth of the cracks on the top plate of the box girder. The test results indicated that the depths of the top plate cracks were 0.24 mm and 0.22 mm, respectively.

3.3. Structural Testing

Steel bar configuration and concrete strength of the box girder components were inspected on site. The inspection results indicated that the steel bar configuration of the inspected components satisfied the design requirements, and the strength of the inspected components met the requirements of the design C50 strength grade.

4. Analysis of Crack Causes

4.1. Common Crack Analysis

For prestressed concrete structures, since concrete is a brittle material with very low tensile capacity and the beam has a large volume, cracks are more likely to occur during construction and usage. The following briefly describes the characteristics and causes of several common types of cracks.

4.1.1. Shrinkage Crack

Concrete shrinkage cracks are the most prevalent in practical engineering, which are triggered by the plastic shrinkage and water loss shrinkage of concrete. The early shrinkage cracks all occur before the final setting of concrete. They are mainly distributed on the concrete surface. The early shrinkage cracks are irregular, and after hardening, they mainly present a crack state that is narrow at both ends and wide in the middle. Generally, the shrinkage cracks vary in size, are not large in size, and are not deep in depth. The shrinkage deformation of concrete is an inherent characteristic of this engineering material. Its shrinkage amount is mainly associated with cement types, aggregate types and mud content, concrete mix ratio, types and dosages of admixtures, medium humidity, curing conditions, etc. Additionally, it is positively correlated with the maximum continuous side length during component construction. Since the dry shrinkage and shrinkage of concrete are gradually formed, shrinkage cracks evolve over time. However, when concrete is immersed in water or exposed to moisture, its volume will expand, thus, shrinkage cracks vary with the environmental humidity. The form of shrinkage cracks is presented as shown in **Figure 3** [4] [5].

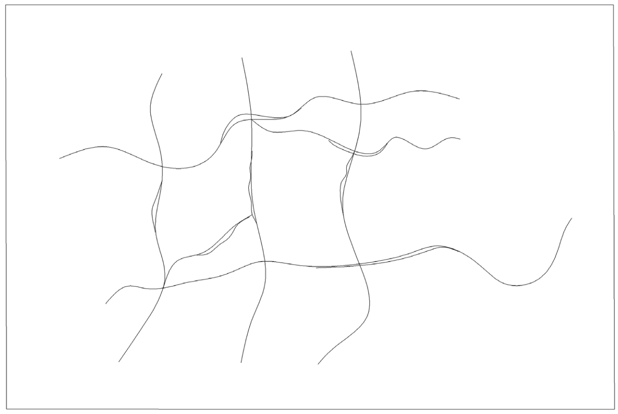

Figure 3. The form of shrinkage cracks.

4.1.2. Temperature-Induced Crack

Temperature cracks arise due to the heat generated during the cement hydration process, which causes a temperature difference between the inner and outer surfaces of concrete and leads to stress variations. When the temperature stress exceeds a certain level, temperature cracks are formed. The width of temperature cracks has no fixed value. They are numerous, generally narrow, and the depth varies significantly, including surface and deep ones. Generally, these cracks appear or enlarge after summer or winter and change with the increase or decrease in temperature. However, such cracks do not expand and deteriorate indefinitely. When the temperature in nature changes or the material undergoes shrinkage, components will produce different deformations, restricting each other and generating stress. When the stress exceeds its ultimate strength, different forms of cracks will emerge, the morphology of temperature cracks is depicted in Figure 4 [6] [7].

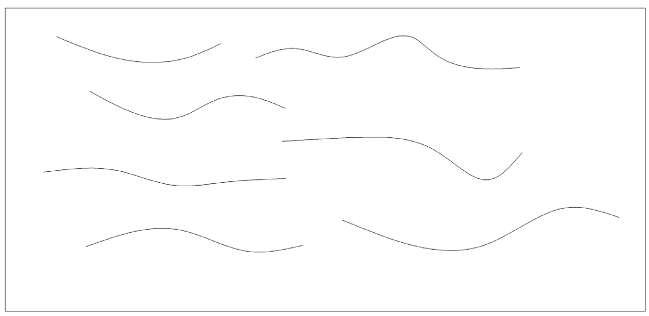

Figure 4. The form of temperature cracks.

4.1.3. Load-Induced Crack

Load-induced cracks refer to the cracks that occur in concrete under normal static, dynamic loads, and secondary stresses. They mainly may arise in the following stages:

1) Design stage: If there is an insufficient design section, an unreasonable calculation model leading to insufficient overall stiffness of the structure, or a mismatch between the assumed and actual force conditions of the structure, along with incorrect reinforcement calculation due to missed loads, resulting in an

insufficient structural safety factor, load-induced cracks may occur during the subsequent usage process.

2) Construction stage: Failure to follow the construction drawings, unrestrained stacking of construction machinery and materials, random lifting and transportation, unauthorized changes to the construction sequence, or poor management during the construction process and rough construction causing random trampling of reinforcing bars may all potentially give rise to load-induced cracks.

3) Usage stage: Heavy vehicles exceeding the designed load can cause components to exceed their bearing capacity, or contact and impact with vehicles and ships; natural disasters such as strong winds, heavy snow, earthquakes, and explosions can directly lead to local cracking of components. Additionally, in bridge structures, local openings and chiseling are often required for the structure. Stress concentration is likely to form near the holes after excavation of the stressed components, resulting in secondary stress cracks [8].

The morphology of the load-induced cracks is presented in **Figure 5**.

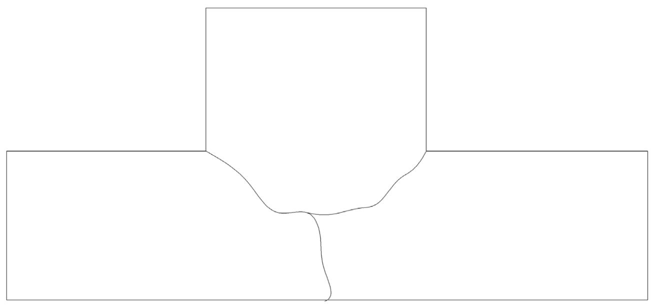

Figure 5. The form of load-induced cracks.

4.2. Analysis of the Main Causes for the Generation of Cracks in This Structure

4.2.1. Cracks at the end of the Roof Slab

During on-site inspection, it was discovered that a vertical crack existed at the end of the top slab of the left box girder from DY42 to DY43 in a certain project. Along this crack, two longitudinal cracks formed on its bottom surface, and the crack width gradually decreased from the port to the deep part.

Since the anchorage end of prestress often arranges a large number of prestressing tendons in a very small area in a concentrated manner, when the tensioning force is applied, the pressure on the local bearing surface is too large, causing longitudinal cracking along the direction of prestress. It usually develops longitudinally along the direction of the prestressing tendons and disappears after the local bearing stress diffuses outside the anchorage area.

In view of the above analysis, it is initially inferred that the crack at the end of the box girder top slab is a local bearing pressure crack at the anchorage end. The generation of this crack is also related to the early strength of the box girder and the tensioning quality. To avoid adverse effects of the crack on the durability of the anchorage agent of the prestressing tendons, the crack should be repaired and treated.

4.2.2. Cracks at the Bottom of the Top Plate of the Beam

Cracks caused by temperature variations typically emerge or intensify after passing through summer or winter. Significant temperature differences can induce cracking in components. This section has been poured for a considerable period and has undergone temperature change cycles, being influenced by certain temperature variations. There exist branch-shaped cracks inside the longitudinal direction of the left box girder from DY42 to DY43, with small widths, short lengths, and the surface cracks conform to the morphological distribution of temperature cracks. Hence, it is inferred that the cause of the branch-shaped cracks at the end of the box girder top slab is related to temperature.

5. Measures for Crack Treatment

5.1. Treatment Method

The common treatment methods for cracks are as follows:

1) Surface repair: Commonly used methods include compacting and smoothing, applying epoxy adhesives, spraying cement mortar or fine aggregate concrete, pressing and smearing epoxy putty, adhering glass fiber cloth with epoxy resin, adding an overall surface layer, and stitching with steel anchor bolts, etc.

2) Local repair method: Commonly used methods include filling method, prestressing method, partial chiseling and re-pouring concrete, etc.

3) Cement pressure grouting method: Applicable to stable cracks with a width of ≥0.5 mm.

4) Chemical pressure grouting: Can be used to infuse cracks with a width of ≥0.05 mm.

5) Treatment of circumferential through cracks: Through cracks are of greater hazard and effective treatment methods must be adopted. Chisel a V-shaped groove 5 cm wide and 3 cm deep along the crack direction. Drill holes every 0.15 m within the groove. The depth of the holes is 1/2 or 2/3 of the lining thickness, generally not less than 15 cm, and must not penetrate the lining to prevent slurry leakage. After cleaning the debris and dust in the groove with clean water, insert a grouting pipe with a diameter of less than 10 mm into the hole, anchor it with epoxy resin cement mortar, and compact and smooth the mortar with a trowel. When the epoxy resin mortar has reached a certain strength, inject cement-sodium silicate slurry or epoxy resin slurry at a pressure of 0.15-0.12 MPa. After grouting, check the grouting effect under a pressure of 0.12 MPa and check for leakage. Finally, treat the crack surface with scraping material and color-matching material.

6) Structural reinforcement: Commonly used methods include adhering carbon fibers and externally applying a local steel mesh and covering it with cement mortar for reinforcement, etc [9] [10].

5.2. The Treatment Method for Structural Cracks

According to the relevant regulations in GB/T 50010, "Standard for Design of

Concrete Structures", for components with a crack control level of three, cracks are allowed at the tensile edge. The maximum allowable crack width of the component when working in a cracked state is 0.2 mm. The crack width inspected in this project does not satisfy the limit requirements and therefore, requires treatment. As the crack depth in this project is less than 0.1 H (the thickness of the component), the surface repair method should be adopted for treatment.

6. Conclusion

Through the inspection and analysis of structural cracks presented in this paper, the following insights can be derived for reference in subsequent similar projects. Onsite, it is necessary to conduct overall structural parameter inspections and specialized crack inspections on the components. Through the structural inspection, it can be determined whether the causes of the cracks are related to human factors such as construction or design. After eliminating human factors, the specific causes of the cracks can be identified through specialized crack inspections. Subsequently, different treatment measures should be adopted based on the width and depth of the cracks to achieve the purpose of structural safety and durability [11].

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Ding, X.J. and Sun, Y.H. (2007) Detection Analysis and Reinforement of Box Beam. *Northern Transport*, **6**, 35-37.

[2] Liu, W.-Z. (2022) Detection and Treatment of Prestressed Box Girder of an Approach Bridge. *Construction*, **10**, 76-77.

[3] Yan, Y. (2024) Causes and Prevention Measures of Cracks in Concrete of Road and Bridge Engineering Structures. *Management of Transportation Enterprises*, **39**, 91-94.

[4] Liu, J. (2024) Analysis of Causes and Construction Prevention Measures for Concrete Cracks in Buildings. *Sichuan Architecture*, **44**, 234-235.

[5] Yang, W. (2024) Causes and Control Strategies for Concrete Cracks in Construction Engineering. *Residence Industry*, **9**, 64-66.

[6] Wang, Y.P., Fan, F., Zeng, H.H. and Shi, B.C. (2023) Analysis of Typical Cracks in Prestressed Concrete Box Girder Bridges. *Journal of Highway and Transportation Technology*, **40**, 240-247.

[7] Wu, C.F. (2023) Research on the Causes and Mechanism of Cracks in Prestressed Concrete T-Beams. Yunnan University.

[8] Ding, C.Y. (2024) Analysis of Large Volume Concrete Construction Technology and Crack Prevention Measures in Road and Bridge Engineering. *Value Engineering*, **43**, 141-144.

[9] Ma, Y.-X. (2024) Techniques for Controlling Large-Volume Concrete Cracks in Construction Engineering. *Residential Industry*, **10**, 25-27.

[10] Liu, Y.J. (2024) Construction Technology of Repairing Cracks in Concrete Floor Slabs Cast in Place. *Stone Materials*, **7**, 48-50.

[11] Wang, J.J., Li, L.L. and Niu, Z. (2024) Research Progress on Concrete Crack Repair and Monitoring Technology. Modern Salt Chemical Industry, 51, 36-37+51. https://doi.org/10.194/65/j.cnki.2095-9710.2024.02.034