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Discussion on Detection and Evaluation of Simply Supported Prestressed Concrete Small Box Girder Bridge After a Fire

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Abstract: The article takes a simply supported prestressed concrete small box girder bridge project as an example for inspection and evaluation after a fire incident. This includes appearance detection, concrete color hardness detection, concrete strength detection, concrete surface damage layer detection, reinforcement protective layer detection, and concrete carbonation detection. It is hoped that this analysis can be used as a reference for the detection and evaluation of future bridge projects with fire incidents to smoothen its subsequent repair and maintenance.

Keywords: Prestressed concrete box girder; Simply supported small box girder; Fire damage; Concrete testing; Reinforcement testing

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1. Introduction

After a simply supported prestressed concrete small box girder bridge structure suffered a fire, the quality inspection and evaluation of the bridge structure after the fire is a crucial task. The relevant inspection staff should take reasonable techniques, methods, and measures to evaluate the simply supported small box girder structure based on the specific project profile and fire situation. In this way, the damage situation can be more scientifically and accurately measured to smoothen the subsequent repair and treatment work.

2. Project overview

2.1. Basic situation

This study subject is a highway bridge project structure that suffered a fire incident. The upper part of the bridge is a continuous simply supported prestressed concrete small box girder, with a length of 25 m, and a single box girder is made up of five small simply supported box girders, while the lower part of the bridge is in the form of double-column abutments and pile foundation structure. The overall bridge loading level is highway-I class, and its main girder prestressing structures are designed according to class A with the application of C50 concrete.

After the bridge project suffered a fire accident, its main girder was burned by fire, damaging the whole girder body, so the inspectors need to perform a comprehensive testing of its specific damage to determine the degree of damage and bearing capacity for subsequent repair and reinforcement.

2.2. Fire situation

After the fire, the site inspection of the bridge project found that the whole bottom part of the simply supported prestressed concrete small box girder had been completely blackened, among which the bottom of the second to fifth box girder was most seriously affected by the fire, with its top plate, web, and bottom plate breaking off in large areas. There is a large amount of soil and concrete debris on the ground at about 0.5 m of the lower part of the bridge headroom span, in which the traces of soil and smoke are very obvious. Moreover, there are many combustible materials such as plastic and cardboard on the ground, as well as the broken concrete from the simply supported small box girder after the fire. The burning traces of the lower ground of the first girder are not obvious, but there are still a lot of combustible materials on the ground. The duration of the fire was determined to be about two hours through the investigation of the residents in the vicinity of the bridge.

3. The detection and evaluation of simply supported prestressed concrete small box girder after fire

The inspectors performed a scientific assessment of the damage of the burned simply supported prestressed concrete small box girder structure by first assessing its appearance to make clear the specific burn damage. Then, the concrete color, hardness, strength, thickness of the surface damage layer, the thickness of the reinforcement protective layer, and the thickness of concrete carbonation of the burned structure are scientifically tested and assessed based on specific test results [1]. In this way, the effective assessment of the structure can be a scientific reference for the subsequent repair treatment. The following is the specific structural assessment analysis in this project.

3.1. Appearance inspection

After the site visit and appearance inspection, it was found that the bottom of the simply supported prestressed concrete small box girder of the bridge span had been completely blackened due to the fire. The bottom of the first box girder has slight smoke traces, while the bottom of the second to the fifth box girder has the most serious burn damage, in which the bottom of the whole box girder has been blackened, and the top plate, web, and bottom plate have been broken off in a large area, with a depth ranging from 7 to 31 mm. The serious fire damage has also exposed the longitudinal main reinforcement and hoop reinforcement. Hence, it can be preliminarily determined that the second to fifth simply supported prestressed concrete small box girder in this bridge was seriously damaged after the fire.

3.2. Concrete color hardness detection

After completing the appearance inspection of the box girder structure, the inspectors also carried out a detailed inspection of the concrete color and hardness in the affected area to further confirm the burn effect on the concrete structure [2]. In this test, the inspectors first polished the soot on the surface layer of the concrete and observed the color change of the concrete exterior, then knocked the surface of the concrete member by hammering method to see whether it continued to fall off, and recorded the sound when knocking [3]. The following are the specific test results of the five box girder tested:

(1) The concrete of the first box girder smoky dense part is greenish gray, there is no obvious trace on the

surface when knocking, and the sound of knocking is loud.

(2) The concrete of the second box girder broken part is light gray and slightly pink, and there is a remarkable trace on the surface when knocking, and the sound of knocking is relatively loud; the concrete of the smoky dense part is greenish gray, and there is no obvious trace on the surface when knocking, and the sound of knocking is loud.

(3) The concrete in the damaged part of the third box girder is grayish-white, showing light red, and its surface will show traces when knocking, and the knocking sound is muffled; the concrete in the smoky and dense part is light gray, slightly pink, and its surface will show significant traces when knocking, and the knocking sound is relatively loud.

(4) The concrete in the damaged part of the fourth box girder is light grayish-white, showing light red, and its surface will show traces when knocking, and the knocking sound is muffled; the smoke and dense part of the concrete is light gray, slightly pink, and there is no significant trace on the surface when knocking, and the knocking sound is muffled.

(5) The concrete in the damaged part of the fifth box girder is light gray, and slightly pink, when knocking its surface has significant traces, and the knocking sound is louder; the concrete in the smoky part of the concrete is greenish grey, and there is no significant trace on the surface, and the knocking sound is louder [4].

Through the comparative analysis of the above bridge structure test results, it is shown that the concrete in the parts with less smoke impact is mostly greenish gray, the shedding situation when knocking is not obvious, and the knocking sound is relatively loud, while the concrete in the damaged parts is mostly light gray and pinkish red, and the shedding situation when knocking is more significant, and the knocking sound is relatively muffled. This shows that the fire had significant adverse effects on the concrete of the box girder.

3.3. Concrete strength test

The inspectors must pay enough attention when taking technical measurements of the concrete strength as the strength of the concrete girder after fire is an important factor [5]. In this project, the inspection staff mainly tested, compared, and analyzed the concrete strength of the parts both affected and unaffected by the fire on the bridge structure through ultrasonic rebound detection technology to determine the quality of the damaged area. The test results show that the intended and actual test concrete strength values of the parts unaffected by smoke are 50.0 MPa and 58.3 MPa respectively; the intended and actual test concrete strength values of the parts that are affected by slight smoke are 50.0 MPa and 55.6 MPa respectively; and the intended and actual test concrete strength value of the parts that are seriously affected by serious smoke are 50.0 MPa and 52.7 MPa respectively.

Based on this result, it is shown that the concrete strength of the overall box girder structure is not lower than the intended design, no matter whether it is affected by the smoke of the fire or not. It is shown that the concrete strength of the simply supported prestressed concrete small box girder structure has not been affected by the adverse effects of the fire, and its overall strength is still in line with the project design standards.

3.4. Concrete surface damage detection

The inspectors have performed technical measures to detect the surface damage layer to determine the concrete fire damage. In this project, the inspectors mainly use the ultrasonic detector to detect the thickness of the concrete surface damage layer in the box girder structure to fully analyze the concrete surface damage layer of the main girder in the slightly smoke-damaged part and seriously smoke-damaged part for the subsequent repair and treatment [6]. The following are the specific test results.

(1) The overall smoke impact of the first box girder is relatively low, and there is no damage to the concrete surface in the area affected by smoke.
(2) The depth of the surface damage layer of the second box girder is 2.2 mm, and the depth of the smoke-damaged layer on the concrete surface is 17.1mm.
(3) The depth of the surface damage layer of the third box girder is 4.4 mm, and the depth of the smoke-damaged layer on the concrete surface is 20.6 mm.
(4) The depth of the surface damage layer of the fourth box girder is 3.5 mm, and the depth of the smoke-damaged layer on the concrete surface is 23.1 mm.
(5) The depth of the surface damage layer of the fifth box girder is 3.7 mm. and the depth of the smoke-damaged layer on the concrete surface is 7.8 mm.

Through the comparative analysis of the above test results, it is shown that the box girder structure closer to the fire has greater smoke-damaged surface layer thickness.

3.5. Detection of the protective layer of reinforcement

The inspectors have performed a detection of the thickness of the protective layer of the box girder reinforcement to determine the corrosion of the protective layer of reinforcement and the durability of the overall structure [7]. In this project, the inspectors mainly carried out a comprehensive inspection of the thickness of the protective layer of steel reinforcement in each box girder structure by electromagnetic induction method. **Table 1** shows the detection results of the protective layer thickness of reinforcement in each box girder structure in this project.

Table 1. Test results of steel protective layer thickness of box girder structure in this project

Box girder position	Test result of steel bar protective layer thickness				
	Design value (mm)	Eigenvalue (mm)	Characteristic / design value	Evaluation scale	Durability of structure
1	20.0	19.5	0.98	1	Unaffected
2	20.0	20.0	1.00	1	Unaffected
3	20.0	21.9	1.09	1	Unaffected
4	20.0	22.9	1.14	1	Unaffected
5	20.0	20.9	1.04	1	Unaffected

The above test results show that the thickness of the protective layer of reinforcement inside the box girder after the fire still meets the architectural design standard and the overall durability of the structure is not adversely affected.

3.6. Concrete carbonation detection

The degree of concrete carbonation on the box girder structure will have a direct impact on its overall quality, durability, and safety. Therefore, the inspectors have performed detection of the concrete carbonation degree on the box girder after the fire to provide scientific data for the subsequent structural maintenance of the bridge project [8,9]. The inspectors mainly sample and test the concrete in structure areas according to the temperature zone at the time of the fire to understand the influence of different temperature conditions and combustion time on the carbonation depth of the concrete structure. **Table 2** shows the results of the carbonation depth of the concrete in each of the box girder structures in this project.

Table 2. Carbonation depth of box girder structures in this project

Box girder position	Test result of average carbonation depth of concrete (mm)	
	Areas heavily affected by smoke	Areas slightly affected by smoke
1	1.5	0.5
2	3.5	1.0
3	3.0	0.5
4	3.0	1.0
5	2.5	0.5

Through the comprehensive analysis of the above test results and the on-site situation, it is shown the carbonation depth of the box girder concrete is directly proportional to exposure duration and proximity to the fire, and vice versa. Therefore, in the subsequent structural maintenance treatment, the construction personnel need to prioritize the parts with a greater degree of fire damage to maintain the overall structural quality and durability [10].

4. Conclusion

In summary, fire will have a certain degree of adverse effect on the simply supported prestressed concrete small box girder bridge structure. Hence, the relevant inspection staff must carry out scientific and reasonable inspection and assessment of the damaged area when a fire incident occurs on a bridge project. This can timely and effectively determine the structural fire damage parts and smoothen the subsequent bridge structure repair work so the quality, durability, and safety of the bridge can be ensured.

Disclosure statement

The authors declare no conflict of interest.

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