Fire Resistance Analysis of Steel-Concrete Composite Bridge Based on Abaqus

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Abstract: in Order to Find the Fire Resistance Law of the Steel-Concrete Composite Bridge, and Effectively Reduce the Fire Occurrence Probability and Loss Degree of the Composite Bridge, It is Urgent to Analyze the Fire Resistance Performance of the Steel-Concrete Composite Bridge. Based on the Previous Research Literature, This Paper Analyzes the Characteristics and Development Status of Steel-Concrete Composite Bridges Based on the Abaqus Related Theory. Furthermore, Using Abaqus Finite Element Analysis Software, the Fire Resistance Performance Analysis Model Was Established to Analyze the Fire Resistance of Different Steel-Concrete Composite Bridges.

1. Introduction

1.1 Literature Review

In recent years, with the continuous popularization and application of steel-concrete composite structures, the community's attention to the safety of steel-concrete composite buildings has increased. In this context, many scholars have studied the safety performance of steel-concrete composite buildings. In order to explore the elastic stress wave propagation law of steel-concrete composite structure and the variation law of measuring point displacement, 栾 lele et al. established a two-dimensional spectral element model of the section, and then the steel-concrete composite structure interface is intact or stripped. In the state, the model elastic stress wave field under single-point excitation is simulated (Luan et al, 2017). Chen Lihua et al. proposed a new type of double-steel-concrete composite shear wall with L-shaped pull-outs. The quasi-static test was conducted to study the seismic performance of the new composite shear wall (Chen et al, 2017). Liu Xiang and Wu Wen introduced the calculation method of bearing capacity of steel-concrete composite shear wall from the mechanism of force. The finite element method was used to analyze the concrete thickness, the high-thickness ratio and the span-to-height ratio of the steel plate, and the bearing capacity of the combined shear wall. Impact (Liu and Wu, 2017). Among them, many scholars used ABAQUS finite element analysis software to analyze the fire resistance performance of steel-concrete composite buildings. Yu Zhiwu and Ding Faxing studied the key issues of the fire resistance performance of steel-concrete composite structures based on the analysis of the existing fire protection design specifications and engineering applications in China (Yu and Ding, 2010). In order to correctly simulate the different fire resistance performance of steel-concrete continuous composite slabs under real fire, Xu Lei et al. used ABAQUS finite element software as a platform to establish a numerical model of steel and concrete continuous composite slabs under fire. The mechanical properties of steel-concrete continuous composite slabs under ISO-834 standard fire were analyzed (Xu et al, 2013). Ding Faxing et al. used the thermal coupled constitutive model of concrete and used ABAQUS finite element analysis software to compare and analyze the fire resistance performance of multi-layer steel-concrete composite plane frame structures, including frame beams, simply supported beams and fixed beams. (Ding et al, 2014). Based on the research foundation of the predecessors, this paper further studies the fire resistance performance of steel-concrete composite bridges by using ABAQUS finite element analysis software.

1.2 Purpose of Research

The fire is sudden, fluid and invasive, and it is one of the most frequent and most harmful disasters in real life. In recent years, with the rapid development of social economy and

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transportation, the scale of bridge construction has been expanding and the types are more diverse. Among them, many construction companies have begun to choose steel-concrete composite structures with high bearing capacity, plastic toughness and shock resistance. However, steel and concrete are not fire-resistant, and in the event of a fire, the building structure can easily be destroyed or even collapsed. On the bridge, there are occasions when a traffic accident such as a car collision or a fuel fire such as gasoline causes a bridge fire. Bridge fires can also impair the performance and durability of steel and concrete, significantly reducing the stiffness and bearing capacity of the bridge, thereby reducing the length of time the bridge is used or causing damage to the bridge (Liu et al, 2017). In recent years, the continuous improvement of the social economy, people's lives and needs has led to a sharp increase in the number of cars. At the same time, the frequency of bridge fires has gradually increased. Many accidents have caused serious damage to the bridge steel bars, which not only affected the normal travel of residents, but also caused serious economic losses. In view of this, it is of great theoretical and practical significance to analyze the fire resistance of steel-concrete composite bridges and provide useful ideas and directions for bridge construction.

2. Abaqus Related Theory

ABAQUS is a set of finite element software for engineering simulation. It has two main solver modules, namely ABAQUS/Explicit and ABAQUS/Standard, and includes a human-computer interaction before and after processing module ABAQUS/CAE, which can fully support the solver's graphics. User Interface. ABAQUS is more powerful and can be effectively solved for simple linear problems and complex nonlinear problems. Specifically, the advantages of ABAQUS are mainly reflected in the following aspects. First, ABAQUS has a diverse library of material models that simulate the performance of many typical engineering materials such as rubber, metal, reinforced concrete, soil and rock. ABAQUS can efficiently solve stress problems or displacement problems of a large number of building structures by simulating the mass diffusion process, heat conduction process and thermoelectric coupling process in the engineering field. For some special problems, ABAQUS can also provide a dedicated solution module. Second, at present, ABAQUS can be used for mechanical analysis of single parts, multi-physics analysis, and systematic research to solve many large and complex problems. Third, compared to other analysis software, ABAQUS system-level analysis is unique in its ability to perform static stress analysis, dynamic analysis of viscoelastic response analysis, nonlinear dynamic displacement analysis, underwater shock analysis, and fatigue analysis. therefore. ABAQUS is widely used in industries and research in various countries and is used in complex analysis such as fluid, electromagnetic field and multiphysics coupling. Among them, it is most frequently used in the analysis of fire resistance performance of bridges and buildings.

3. Characteristics and Development Status of Steel-Concrete Composite Bridge

The steel-concrete composite bridge refers to a structure in which a main bridge section is composed of two materials of steel and concrete, which are connected by shear bonds and work together. The steel-concrete composite bridge has four outstanding features: First, the combined bridge has strong integrity and stability, and can fully exert the tensile properties of the steel and the compression resistance of the concrete. Second, compared with steel bridges, combined bridges can save 20%-40% of steel and save 10%-30% of cost. Third, the steel and concrete composite bridge structure has relatively low self-weight and good seismic performance. Fourth, the steel plate of the combined bridge can also be used as a template for construction, reducing the amount of wood used, thereby accelerating the construction progress of the bridge. In the composite bridge, the steel beam under the bridge deck is mainly subjected to tensile force; the concrete slab acts as a bridge deck and mainly bears the longitudinal pressure caused by the bending moment, so the characteristics of the material are fully exerted, and the bridge structure system is further improved.

In order to reduce the difficulty of the high-altitude support of the bridge deck, Beijing first used the steel-coagulation composite composite beam to build the Guomao Bridge. After the construction of Guomao Bridge, the dual advantages of steel-concrete composite bridges have become increasingly prominent, which not only greatly accelerated the construction speed, but also ensured the integrity of the bridge deck, so it has received attention and praise from all walks of life. Under the background of increasing demand for infrastructure construction in China, the steel-concrete composite bridge has been vigorously built and developed. According to statistics, up to now, there are six large-span overpasses built in Beijing using this type of structure, and each bridge has brought significant economic and social value.

4. Analysis of Fire Resistance Performance of Steel-Concrete Composite Bridge

4.1 Overview of the Anti-Fire Experiment of Composite Bridge

According to the fire test method and the fire code design of the building design, two test pieces were produced for the fire resistance test of the combined bridge, namely the ordinary steel-concrete composite bridge test piece (L1) and the fire-resistant steel-concrete composite beam test piece (L2). Among them, L1 is used for comparison. The main material parameters of the two test pieces are as follows. The main parameters of the steel are shown in Table 1. The concrete is made of commercial concrete. The test period is 73d, the strength grade is C40, and the cubic compressive strength is 50.2 Mpa. The fireproof coating is a non-intumescent thick steel structure fireproof coating with a density of 400kg/m3, a heat capacity of 1000kj/(kg•°C), and a thermal conductivity of 0.113W/(m•K). The fire retardant coatings of L1 and L2 are different in thickness, 10mm and 25mm respectively.

Table 1 Steel Parameters For L1 and L2

	L1	L2
steel	Q345B	Q345-FR
Yield Strength	393Mpa	423Mpa
Ultimate strength	534Mpa	603Mpa
Initial elastic modulus	2.05X105Mpa	2.03X105Mpa

4.2 Finite Element Model

The high temperature tensile test of the test piece was carried out, and the mechanical properties of the two test pieces at high temperature were measured. The stress-strain relationship curves of the steel-concrete composite bridge specimens at various temperatures were obtained. The ABAQUS analysis method was used to simulate the fire resistance of the fire-steel-concrete composite bridge under standard temperature rise. The effect of the fire protection effect of the combined bridge is not considered under the condition that the fireproof coating and the fireproof board fall off and deform. In the ABAQUS analysis, it is assumed that there is no shear slip between the beam of the composite bridge steel and the concrete.

4.3 Parameter Analysis

Under the standard temperature rising conditions, the relevant parameters of the steel beam, fire protection layer, load ratio, longitudinal reinforcement in the concrete slab and the slab are analyzed, and the impact on the fire resistance of the composite bridge is analyzed. In the calculation, the mid-span deflection is 1/30 of the span as the criterion for the fire resistance limit of the combined bridge. The ultimate load at normal temperature is calculated by displacement loading of ABAQUS finite element analysis model. When the thickness of the fireproof layer is 10mm, the smaller the load ratio is, the longer the fire resistance limit time of the combined bridge is, and the influence is more significant. When the thickness of the fireproof layer is 25 mm, the fire resistance limit time of the combined bridge becomes long, and the increase is obvious.

When the concrete strength is different, the fire resistance limit of the composite bridge is small, and the deformation of L1 and L2 is very similar during the whole fire. This shows that the concrete strength grade can not significantly affect the fire resistance of the fire-resistant steel composite bridge. As the fire time increases, the load on the composite beam with thicker floors is greater, and the deflection of the composite beam is greater. When the composite beam reaches the critical limit of fire resistance, the steel beam basically loses the bearing capacity, and the thickness of the floor slab has little effect on the deformation resistance of the section. Therefore, the fire resistance limits of L1 and L2 are small.

The room temperature yield strength of steel-concrete has little effect on the fire resistance of the composite bridge. Under fire, the deformation performance of fire-resistant steel-concrete composite bridge is obviously better than that of ordinary steel-concrete composite bridge. When the load of the fireproof coating is different under the same load, the time limit of the fire resistance of the steel-concrete composite beam is also different. The fire-resistant coating has a thicker steel-concrete composite beam, and its fire resistance time is greatly elongated.

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