Experimental Study on Field Shrinkage of Deck Panel of Composite Girder Cable-stayed Bridge

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Abstract: In order to study the shrinkage performance of the deck panel of the composite girder cable-stayed bridge, the shrinkage test of the deck panel members of the real bridge was carried out in the field with the background of the Malukou Great Bridge, comparing the difference between the shrinkage values measured in the test and the theoretically calculated values of shrinkage in the various specifications, and finally the shrinkage equations and curves of the deck panel in 180d were fitted based on the test data. The results show that: on 180d, the shrinkage strain calculated by JTG D62-2018, the current design specification used for highway bridges in China, is only 66.30% of the test shrinkage, and the small prediction of bridge deck shrinkage may cause problems in terms of structural cracking; based on the large differences between various specifications for the shrinkage strain of bridge decks, It is recommended to use the actual shrinkage strain measured by the bridge deck shrinkage test as the real shrinkage curve as the data source to accurately assess the deformation and stress state of the bridge deck.

Keywords: cable-stayed bridge; deck panel; shrinkage test.

1. Introduction

Shrinkage of concrete is one of the main factors causing non-structural cracks. Cracks in concrete structures have many effects, including, but not limited to, stress-strain redistribution, changes in structural stiffness, reduced flexural and shear capacity, and reduced fatigue performance. In recent years, based on different field projects, many scholars have conducted a series of shrinkage tests, full-scale tests, and field tests, for instance, Zhang et al.[10] conducted the long-term effects of shrinkage and creep tests on reinforced concrete T-beams, and Xiong et al.[11] conducted the field concrete shrinkage and creep tests on large-span continuous rigid bridges, which have served as a reference for later researchers conducting shrinkage tests on solid structures or components.

Although more research has been done domestically and abroad on concrete shrinkage and cracking caused by shrinkage, many different calculation theories have been derived, and at present the domestic highway concrete bridge structure for concrete shrinkage calculation basically adopts the JTG 3362-2018 specification with reference to the CEB-FIP (1990) model[12]. The current research and test on concrete shrinkage is mostly carried out in the standard curing state with unchanged parameters, which is quite different from the real curing conditions in the construction stage, and cannot effectively guide the design and construction, especially when the structure has higher requirements for crack suppression, the above problems are more prominent, and some research and engineering applications show that it is still inapplicable[13]. Moreover, factors affecting concrete shrinkage are more than one in different engineering practices, so the shrinkage test for the actual structure or component needs to be investigated, and the effect of concrete shrinkage on the stress of bridge deck panels also needs to be studied urgently.

In this paper, based on the Mlukou Great Bridge, the shrinkage test of the real bridge deck members was carried out in the field, comparing the difference between the shrinkage value measured in the test and the theoretical calculation value of shrinkage in various specifications, and finally, based on the test data, the shrinkage equation and curve of the bridge deck panel within 180d were fitted.
2. Project Profile

Malukou Great Bridge is a very large cable-stayed bridge on the 7th section of Guanzhuang highway. The main girder of the bridge adopts an "I" type side main girder, cross girder and small longitudinal girder, which are connected by friction-type high-strength bolts to form a steel girder, prefabricated deck panel is erected, and the wet joints of cast-in-place concrete are joined, and a composite girder system is composed of shear-resistant pins welded to steel girders, and a standard cross-section of the main girder is shown in Fig. 1. The concrete deck panel is divided into precast and cast-in-place parts, with two precast panels symmetrically arranged on the center line of the main girder, and the form of the precast panel cross-section is shown in Fig. 2.

Fig. 1 Standard cross-section of the main beam (unit: mm)

Fig. 2 Schematic diagram of the bridge deck panel

3. Shrinkage Test

3.1 Shrinkage Test of Bridge Deck Panel

Two bridge deck panels were selected as test objects in the girder plant of Malukou Great Bridge, as shown in Fig. 3. The test devices were arranged in the longitudinal and lateral directions of the bridge decks, and the arrangement of the test devices is shown in Fig. 4. The test devices were installed after the precast bridge deck panels were demoulded, the initial reading of the micrometer was recorded, and the bridge deck panels were kept covered with geotextile fabrics under the condition of watering and moisturizing at regular intervals every day; thereafter, the values of the micrometer were read at regular intervals.

Fig. 3 Diagram of the bridge deck test device
3.2 Shrinkage Curve of Bridge Deck Panel

As the test measured shrinkage data for the concrete shrinkage, creep, and the external ambient temperature under the joint action of three factors, the temperature deformation of the bridge deck panel by the influence of reinforcement, relative to the free deformation will be reduced, Olukun et al.[14] proposed that the reinforcement rate has an effect on the temperature shrinkage deformation, so in the consideration of this paper, the reinforcement rate, this discount factor is taken to be 0.83. The effect of creep is considered in the form of creep coefficient, which is calculated with reference to Highway Bridge Specifications.

The shrinkage strain curves of the bridge deck panel after considering and removing the effects of temperature and creep are shown in Fig. 5.

![Fig. 4 Layout of the test device](image)

![Fig. 5 Measured shrinkage strains of bridge deck panels](image)

For instance, for the length direction of the bridge deck panel, comparing and analyzing the contraction curve of the bridge deck panel obtained from the actual measurement with the calculation results of each specification, and the results are shown in Fig. 6, and the comparison between the calculated contraction strain and the test value of the Chinese JTG D62-2018 specification is shown in Table 1. The results show that:

Under on-site co-culture conditions, the contraction of bridge deck panel grows rapidly in 1d~7d, the contraction strain reaches 44.6 με in 7d, and the ratio of contraction strain to 180d is 44.4%, the shrinkage curve enters into the buffer period in the time of 7d~60d, and the growth rate of shrinkage starts to decrease gradually, the shrinkage strain reaches 71.8 με in 60d, which is 71.5% of the shrinkage strain in 180d, and thereafter, The shrinkage grows slowly in 60d~180d, and the shrinkage strain reaches 100.4 με in 180d.

The shrinkage curves of each specification model show a more obvious divergence trend, the larger shrinkage strain is the European specification and Chinese JTG 023-85 specification, in which the European specification calculates the 180d shrinkage strain to be 190.6 με, and the lower shrinkage strains are the CEB-FIP modeling specification, the Chinese JTG D62-2018 specification, the U.S. ACI specification, the Japanese specification and the South Korean specification, and the lowest one is the American ACI specification, whose 180d shrinkage strain is 22.1με, while the measured curve is located in the middle of the range, and the 180d shrinkage strain is 100.4με. The results of the calculations of each specification are very different, and in the actual structural
calculations, evaluating the shrinkage strains of the deck panel with reference to different specifications will result in large fluctuations in the deformations and stress levels.

Compared with the shrinkage strain of bridge deck panels under on-site co-culture conditions, the shrinkage strain calculated by the Chinese JTG D62-2018 specification for 180d is only 66.30% of the measured value, which is obviously low in the shrinkage prediction of the bridge deck panels, and the low prediction of the shrinkage of the bridge deck panels may cause problems in terms of structural cracking.

Based on the large differences between the specifications for the shrinkage strain of bridge deck panels, it is recommended to use the measured shrinkage strain of bridge deck panel shrinkage test as the real source of shrinkage curve data to accurately assess the deformation and stress state of bridge deck panels.

Fig. 6 Shrinkage curves of bridge deck panels under test and various specifications

Table 1. Comparison between calculated shrinkage strain and measured values of JTG D62-2018 specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>180d shrinkage strain (με)</th>
<th>Specification value/Test value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test value</td>
<td>100.40</td>
<td>-</td>
</tr>
<tr>
<td>China JTG D62-2018 specification</td>
<td>66.57</td>
<td>66.30%</td>
</tr>
</tbody>
</table>

3.3 Shrinkage Curve Fitting

The shrinkage curves of the bridge deck panels during 180d of the girder storage period were measured by the field test of precast bridge deck members, and this conclusion can provide a reference for the pre-shrinkage of concrete under similar structure and proportion, so the shrinkage of the bridge deck members was fitted. The results of fitting the shrinkage curves of bridge deck panels are as follows:

Fig. 7 Shrinkage fitting curve of the bridge deck panel

The fitted shrinkage function is shown in Eq. (1):
4. Summary

In this paper, based on the Malukou Great Bridge, the shrinkage test of the real bridge deck members was carried out in the field, comparing the difference between the measured shrinkage values and the theoretical calculation values of shrinkage in various specifications, and finally, based on the test data, the shrinkage equations and curves of the bridge decks within 180d were fitted. The main conclusions are as follows:

- The shrinkage strain calculated by JTG D62-2018, the design specification used in China's current highway bridges, is obviously low for the shrinkage prediction of the bridge deck panel, and on 180d, the shrinkage strain calculated by JTG D62-2018, the design specification used in China's current highway bridges, is only 66.57 % of the experimental shrinkage, and the low prediction of the shrinkage of the bridge deck panel may result in the problems in terms of the cracking of the structure.

- The shrinkage curves of each specification model show a big difference after considering the size effect of components, and the calculation results of each specification model fluctuate a lot, in the actual structural calculation, the assessment of the shrinkage strain of the bridge deck panel with reference to different specifications will result in a big fluctuation of the deformation and stress level, and it is recommended to take the shrinkage strain measured by the shrinkage test of the bridge deck panel as the real source of the shrinkage curves data, in order to accurately assess the deformation and the state of stress of the bridge deck panel.

References


