Shrinkage Effect at Concrete Interfaces in Rigid-frame Bridges

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Summary

Cracking problems at interfaces between concrete with different ages are getting serious, and shrinkage characteristic difference is considered as the main reason. Stress due to shrinkage at typical interface parts was analyzed based on Chinese and American standards. Reasons for large difference between results under the two standards were also discussed. Results show that shrinkage stress level calculated under AASHTO standard is more reasonable than that under Chinese standard (JTG D62-2004) in concrete members with large thickness. Concrete at interface parts is easy to crack when casting time interval of concrete between interfaces is long. According to JTG D62-2004, stress at interfaces is still small under different casting time intervals, while stress at position with mutation section is more obvious. It is necessary to set an upper limit value to theoretical thickness in Chinese standard, and 300mm is recommended. Finally, some design and construction countermeasures are put forward.

Keywords: PC rigid frame bridge, finite element, interface, shrinkage, age of concrete, countermeasure

1. Introduction

With the trends of maximization and lightness, segmental and layered methods are always adopted in pouring concrete of bridge girders and piers. As concrete poured successively, shrinkage deformation of post-poured concrete at interfaces is constrained by early poured concrete. When tensile stress in post-poured concrete exceeds real-time tensile strength of concrete, cracks will appear. Correspondingly, service life of bridge will be shortened. Stress due to shrinkage at interfaces between concrete with different ages are analyzed. Typical interface parts, such as position between pier and bearing platform, layers in main girder segment No.0 and subsection position between main girder segments are selected. After comparing results under Chinese standard and American standard, reasons for large difference between them are also discussed.

2. Shrinkage Effect Theory and Analysis Method

2.1 Shrinkage effect theory

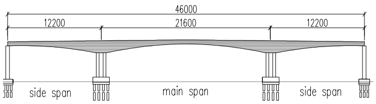
Concrete shrinkage strain, at time t, is always expressed as the product of terminal value and time function $f(t-t_0)$. Specifications are different in standards of different countries. Comparative analysis is carried out on shrinkage effects between AASHTO standard and Chinese standard in the paper.

2.2 Analysis method

Concrete strain variation path can be described as the step curve of time-interval. Strain increments in each time-interval are converted as temperature values in finite element method. Applying variable temperatures on concretes poured in different times are used to simulate effect of different concrete ages. The pouring process of concrete is simulated with life and death element method.

https://doi.org/10.2749/222137908796293839

3. Description of the Bridge and FEM Model



The bridge is a PC continuous rigid-frame bridge, with spans of 122+216+122m. Three typical concrete interfaces are selected in the shrinkage effect analysis Finite element models are built in ANSYS program.

Fig 1 Elevation drawing for bridge layout (cm)

4. Analysis of Shrinkage Effect at Concrete Interfaces under Chinese Standard

Firstly shrinkage effect at concrete interfaces with different ages is analyzed based on Chinese standard. During the analysis process, three years shrinkage is considered. Casting time intervals between segments and layers are 7 days.

Results show that stress level at concrete interfaces is slightly higher than that of the whole structures. Principal tensile stress in most regions is less than 1,5MPa. However, stress at interface parts with mutation sections is more obvious. Like interfaces between main pier and bearing platform, the maximum principal tensile stress is 2,4MPa. Analysis also shows that stress at concrete interfaces is still low with the increasing of casting time interval. Comparing 3 days and 90 days casting time intervals, principal tensile stress increases only 10 percent.

It is illustrated that influence on stress at concrete interfaces is small due to different casting time intervals according to standard JTG D62-2004. The result is not in accord with actual situation. It is necessary to investigate the rationality of specifications in Chinese standard.

5. Comparison of Shrinkage Effect under Different Standards

The maximum principle tensile stress due to shrinkage at concrete interfaces under Chinese standard and AASHTO standard are compared. When AASHTO standard is adopted, tensile stress at interface parts increases rapidly with casting time interval growing, and is easy to reach the cracking stress. The main reason may be that the parameter v/s in AASHTO standard must be less than 150 mm, which is equivalent to theoretical thickness ($h = 2A/u$) 300mm in Chinese standard. However, according to Chinese standard, theoretical thickness of main girder segment No.0 is much higher than 300mm. Therefore, to concrete members with large thickness, results of shrinkage effect under Chinese standard are always less than that of AASHTO standard. And the difference gets larger with the increasing of member thickness. Results calculated under Chinese standard are liable to unsafe to such concrete members. Therefore the author suggests that it is necessary to set an upper limit value to theoretical thickness in Chinese standard, and 300mm is recommended.

6. Conclusions and Recommendations

According to Chinese standard, influence on stress at concrete interfaces is small due to shrinkage character differences, while it is obvious by section mutation. Because of the different specifications on theoretical thickness, stress at interface parts under AASHTO standard is much larger than that under Chinese standard. Results calculated under Chinese standard are liable to unsafe to those concrete members with large thickness. Therefore it is necessary to set an upper limit value to theoretical thickness in Chinese standard, and 300mm is recommended.

To concrete structures constructed by layers or segments, casting time intervals should be shortened. Local structure should be strengthened during the process of design and construction. If allowanced of construction conditions, positions of section property mutation and concrete pouring layers should be staggered. Well curing should be adopted to retard shrinkage process or reduce shrinkage mass in early poured concrete.

7. Acknowledgements

The research is supported by National Hi-Tech Research and Development Program of China (863 Program), project number: 2007AA11Z103.