Creep behavior of precast segmental box girder bridge

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Abstract: The concrete creep effect is more obvious when the box girder is assembled by segment. It is necessary to consider the influence of the loading value of the section at different time and the different age of concrete at different stages. In this paper, ACI209R-92, CEB-FIP MC90 and B3 and other concrete creep models are compared. The results show that the B3 model has many factors to consider and the calculation accuracy is high. Secondly, this paper discusses the influence of the segmental construction technology on the creep calculation, and puts forward the characteristics of the stress analysis of the segmental box girder. Finally, on the basis of the B3 model of concrete creep, the Midas software is used to establish the calculation model of segmental box girder, and the internal force and deformation of the box girder are calculated. The results show that the internal force and deformation of the box girder is too large due to the poor integrity of the segmental assembling process, which will seriously affect the normal service performance.

1 Introduction

Due to the construction of precast segmental box girder bridges, the age, the load and the geometric characteristics of each section of the box girder concrete are constantly changing, and the conversion of several structural systems should occur. Coupled with the impact of solid concrete time-dependent characteristic, will cause the geometric shape and internal force state of the bridge structure changed with time, or even a bridge structure cannot be designed according to the expected linear closure, so the bridge after the bad alignment will affect traffic and bridge safety. Therefore, the correct calculation of the various stages of the bridge construction is to achieve the basis of construction control. The time-varying characteristics of concrete creep and shrinkage have a great influence on the calculation of deformation in the construction process, especially when the cantilever is assembled. For the segmental bridge, creep analysis must consider the influence of the section on the loading value at different time and the different age of concrete at different stages.

According to the numerical analysis of concrete thermal creep theory of long term performance of the prestressed concrete bridge, Huang Qiao[1] consider the temperature gradient and the material properties of concrete and steel bridge section on the change over time, predict the entire life of the performance of PC continuous beam bridge, simply supported beam and T shaped rigid frame bridge. The influence of the distribution of the beam on the long-term performance of the bridge is analyzed, and a series of problems in the beam distribution of the main beam of the large span prestressed concrete beam bridge are presented, and the method of optimizing the distribution of the beam is put forward by Zhao Qin[2]. Chen Min[3] regularly measured under extreme climate conditions of Longtan River Bridge after two years of operation during the girder stress change control section, by comparing the existing creep prediction model analysis, JTGD62 model is selected to simulate the bridge by
using the finite element software, and the model calculation results and the test results validated by the good agreement, and this model is used to analyze the long-term effect of creep and shrinkage of Longtan River bridge. Xiang Yiqiang[4] is also a typical small box girder bridge as the object, will compare the long-term performance of the finite element numerical model and experimental model shows that: under long-term load, structure deflection increasing, the prestress can reduce long-term additional deformation and stress variation of long beam.

Creep is one of the most important characteristics of concrete materials. Due to its many factors, its mechanism and calculation are considered to be quite complex. The concrete material currently carried out in the study of degradation process and cracking conditions, although it can simulated bridge structure characteristics, but cannot represent the structure of stress state and considering the actual operation characteristics of precast segmental box girder structure with time-varying effect. Therefore, this paper will be of different concrete creep models are compared, based on the analysis of characteristics of the construction technique of segmental analysis on segmental box girder stress characteristics, establish segmental box girder deflection calculation model using finite element software, and for the construction and operation of this type of structure are proposed.

2 Calculation methods for concrete creep of Precast Segmental Box Girder

2.1 Creep models of concrete

At present, the commonly used creep prediction models are ACI209R-92 [5], CEB-FIP MC 90[6] and B3[7]. Because of the different experimental conditions and the different emphases of the statistical test data, the shrinkage and creep coefficient of the shrinkage creep model is different. The models can be applied within the scope of the test conditions, and beyond this range, the accuracy of the prediction results will not be guaranteed. In addition, the actual engineering load and environmental conditions and the model test conditions are very far, so the theoretical results and the actual results of the deviation are generally larger.

2.2 Comparison of creep models

Structure designers always concern about if the main parameters of concrete to the creep are put into account as much as possible in a prediction model. Parameters required for the prediction of creep strains in concrete by the three analytical models are presented by Bazant [8]. According to Bazant [8], the B3 model requires more parameters for the prediction of creep strains than the other two models.

The statistics of the errors of ACI209R-92 model, CEB-FIP 1990 model and B3 Model in comparison to the test data sets in the RILEM data bank are given in Table 1 and Table 2[9,10]. It shows that the statistics of errors of various models is more than 20% and B3 model is the best in accuracy among the all.

Tab.1 Coefficients of variation of errors σ for various models (%)

| Model       | Basic creep | creep at drying | shrinkage |
|-------------|-------------|-----------------|-----------|
| ACI209R-92  | 58.1        | 44.5            | 55.3      |
| CEB-FIP1990 | 35.0        | 32.4            | 46.3      |
| B3          | 23.6        | 23.0            | 34.3      |

Tab.2 Statistics of errors σ of various models for basic creep and creep at drying, calculated separately for different ranges of age at loading and creep duration (%)

| t−t' | ACI  | CEB  | B3   | ACI  | CEB  | B3   | ACI  | CEB  | B3   | ACI  | CEB  | B3   | ACI  | CEB  | B3   |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| t−t' ≤ 10 | 60.3 | 40.5 | 17.8 | 30.7 | 23.1 | 24.0 | 33.3 | 11.2 | 19.8 | /    | /    | /    | /    | /    | /    |
| 10 < t−t' ≤ 100 | 45.7 | 25.8 | 13.7 | 36.7 | 23.5 | 23.1 | 49.9 | 21.2 | 25.3 | 97.1 | 40.8 | 29.3 | /    | /    | /    |
| 100 < t−t' ≤ 1000 | 34.6 | 17.5 | 13.9 | 39.9 | 22.8 | 20.5 | 51.7 | 25.0 | 22.6 | 93.9 | 41.3 | 33.6 | /    | /    | /    |
| t−t' > 1000   | 36.8 | 11.6 | 12.7 | 39.9 | 20.5 | 14.6 | 40.9 | 24.7 | 17.8 | /    | /    | /    | /    | /    | /    |
2.3 Effect of precast segmental erection of box girder on creep

When the precast segmental box girder is loaded, the beam is in the state of compression of the whole section, and the tensile stress produced by the load cannot offset the pre pressure exerted by the prestress. With the increase of the load, the joint section of the stress state by compression becomes tension, because the joints only under compressive stress, when pressed into tension, the segmental prestressed structure immediately showed obvious nonlinear contact. Before the opening of the box girder joint, the integrity of the section is good, and the cross section strain is basically consistent with the plane section assumption. As the load increases further, the joint began to open, the neutral axis is constantly on the move, and the shaft to move away from the roof recently, reaching the ultimate load, such as the increase in the load, concrete roof crush, beam damage. The greater the proportion of external prestressing tendons, the ultimate bearing capacity, the more close to the wheelbase of the beam, the beam cracks are mainly concentrated in the joints between the concrete section. The mid span joint along the beam high width shows that the strain in the middle section of the joint is still in line with the plane section assumption\textsuperscript{[11]}.

In the computation of segmental box girder, the assumption of member under bending formula presented by Li Guoping\textsuperscript{[12]}, Wang Chunsheng\textsuperscript{[13]} and Yuan Aimin\textsuperscript{[14]}, The precast segmental box girder has experienced 3 stages which are similar to that of the ordinary concrete beam in the course of loading to failure. The box girder joint open before the segment overall is good, the cross-section strain basically meet the plane section assumption; joint open, segmental joints along the beam direction is consistent with the assumption of plane section, concrete crack mainly from the segmental joint near the glue. When the precast segmental box girder prestressed tendons total is certain, the greater the proportion of external beam configuration, the neutral axis of the farther away from the beam roof, the height of compression zone is smaller; in the larger proportion of beam joints, the cracking load is higher; the body to carry out beam can effectively inhibit the joints, and the beam body more joints cracking the width of the uniform beam on the joint opening effect in vitro. The bottom section of the precast box girder tensile area of reinforced bearing capacity of box girder bending effect is not obvious improvement suggestions of Precast Segmental Box Girder in the Flexural Design of reinforced by structural reinforcement configuration.

3 Numerical examples

Take a precast segmental box girder bridge as an example. Precast box girder segment is a single box double room structure, the top width of 20m, span 62.5m, beam height of 3.6m, bottom width of beam of 10.4m, segment length of 2 to 3.7m, the maximum segment weight 173.9t. The body comprises a cantilever prestressed beam, fight attire, closure of the pier top block vertical beam and horizontal beam of several, 15.2mm with high strength and low relaxation steel strand stretching control stress of pier top block vertical beam is 1302MPa, the others were 1395MPa. The yield strength of external prestressing tendon is 1860MPa, Phi 15.2mm filled low relaxation epoxy coated steel strand, and the tension control stress is 1209MPa. The cantilever assembly is adopted, that is to say, the external prestressing force of the bridge is started after the completion of a joint assembly.

Based on the B3 model, the internal force and deformation of a box girder are calculated by Midas software. The results are shown in the following figure.
Fig. 1 Support reaction of bridge closure (unit: kN)

Fig. 2 Moment of a box girder under operating condition (unit: kN·m)

Fig. 3 the deflection curve of a box girder after 10 years (unit: m)

Preliminary calculations using Midas civil finite element software, ten years back in mid span the maximum bending moment of 1682kN·m, the maximum deflection of box beam is about 83.7cm, beyond the scope of normal use, cannot meet the applicability of bridge structure. Therefore, the monitoring of bridge segmental box girder of long term performance is very necessary.

4 Conclusions
At present, there are still few researches on the long-term performance of the precast bridge. This paper considers the precast segmental box girder structure time-varying effect influence analysis of shrinkage and creep effects on the performance of structure, according to the material strength, elastic modulus, shrinkage and creep of time-varying changes lead to structural stress distribution and deformation performance calculation has been conducted research. The calculation results show that because of the poor integrity of the segmental assembly process, the internal force and deformation of
the box girder are too large, which will seriously affect the performance of the structure. It is recommended to monitor the structure during construction and operation to ensure its normal operation.

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