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Finite Element Analysis of Shrinkage and Creep of Concrete Bridges

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Abstract: With the continuous improvement of bridge construction technology in China, a large number of bridge projects emerge in an endless stream. Most of the building materials used in these projects are concrete. The shrinkage and creep of concrete have a certain influence on the quality of bridges. Because it is not easy to analyze the shrinkage and creep of concrete through the whole bridges, the finite element calculation is used to analyze the shrinkage and creep of concrete bridges. Based on the finite element analysis method, this paper designs specific calculation steps, and compares the calculation results with the values of ANSYS program, which shows that the finite element calculation and the ANSYS program have less error. At the same time, the finite element analysis method meets the design requirements of the prestressed concrete box girder with ballasted track, which verifies the rationality of the finite element analysis.

Keywords: Concrete; Creep; Bridge; Finite element

1. Introduction

When constructing large-span bridges, most of the construction units adopt the cantilever method to carry out construction. Therefore, the concrete service life of each unit is different[1]. The properties of concrete are determined by their age, so their material properties are different on the same bridge. For example, in the construction process of concrete cable-stayed bridges, the cantilever segmental construction method is adopted, and the formation and self-weight of the bridge structure change with time. Therefore, the shrinkage and creep of concrete cannot be ignored in the calculation of bridge structure and self-weight. If the errors caused by these two factors are not taken into account in the calculation process, the safety of the bridges will be affected. Therefore, these two factors must be taken into account in the calculation. However, the shrinkage and creep of concrete are relatively difficult to calculate in the calculation of bridge structure, so the finite element calculation based on displacement method is mostly used. Through this calculation method, the shrinkage and creep phenomena can be controlled accordingly to ensure the safety of bridges, improve the service life of bridges, and provide convenience for the construction parties[2].

2. Design of finite Element Calculation Program for Shrinkage and Creep of Concrete Bridges

2.1. The division of finite element time units

In the division of time units, we take the cable-stayed bridge as a blueprint for analysis. Most of the cable-stayed bridges are constructed by cantilever method. The construction steps of a whole bridge are carried out from the foundation to the pier and then to the main beam. The main beam is constructed by using the front fulcrum hanging basket, and the standard beam section of the whole bridge is divided into 7 construction states[3]. During the whole construction process, in about ten days, the basket should be moved forward, the tension cables should be stretched three times and the concrete should be poured twice. For the general construction stage, the time step subdivision according to the construction conditions is sufficiently refined. However, for a individual large-scale project, secondary refinement is required. Usually, the time in the calculation and operation stage is about 5-6 years. All shrinkage and creep must follow the law of function. Therefore, the selection of time step can be made automatically according to function[4].

$$Z = (\ln Tq - \ln Tp) / a, \ln Tm + 1 = \ln Tm + Z \quad (1)$$

In the above formula, the bridge formation time is set to Tp; the final moment of shrinkage and creep is set to Tq; the calculation step of the operation period is a; Z is the time log step; the corresponding Tm, Tm+1 (m = 0, 1, ..., n) are the time (d) corresponding to the m and m+1 time step, respectively, and m=0 corresponds to the Tp time. For example: Tp=600 d, if 6 years after bridge formation is calculated, then Te= 600+ 6×365= 2790 d, take a=10, then Z=(ln2790- ln600)/10= 0.16729, 10 selected time nodes are: 702, 986, 997, 1171, 1286, 1521, 1679, 1903, 2186, 2790.

3. Design of finite Element Calculation Method for Shrinkage and Creep of Concrete Bridges

3.1. Design of the calculation method of creep index

When designing the method, we first need to divide the whole beam according to the position of the variable section, and then build a calculation model suitable for the beam based on the division results[5]. For the calculation model, jisuan@. The ITlaC macro file is used to save it, where @ represents the beam segment number. At the same time, the nodal force is applied to the node on the beam at the a-th time interval to obtain the nodal force. Popularly speaking, it is the nodal force in elastic calculation. After calculating the result, it is saved in the macro file zaihe. mac. After that, any time interval is set to a. Starting from node a, all nodes in the calculation model are locked, node forces are calculated, and the results are saved in the macro file dingdian. mac. Finally, according to the construction process, ta-m is set as the start time of construction for each main beam, the end time is set as ta, and the start time is set as ta-1. The simpler explanation is that the loading age during this period, and the time at which the creep ends is the calculation time of the loading process. The parameters of creep coefficient, elastic modulus and relaxation ratio adjusted according to time[6] are stored in shijian.mac. The equivalent load force caused by creep is calculated by macro command bianhua.mac, and the equivalent load force caused by creep is applied to model jiasuan @. Mac to calculate the displacement of nodes caused by creep. (The process is shown in Figure 1)

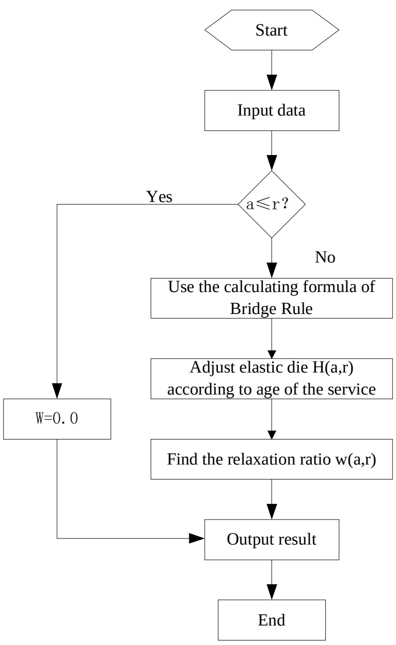

Figure 1. Program flow chart for calculating creep coefficient, elastic modulus, and relaxation ratio

3.2. Design of finite element calculation method

According to the calculation method of creep index, firstly, the increment of node force and displacement caused by creep at a certain time node should be calculated. Then, the increments are superimposed on the force and displacement of the corresponding nodes at the beginning of the time interval, and the state of the node force and displacement of the unit at the end of the time interval can be obtained. Accordingly, the calculation of the next time interval can be entered. From the beginning of creep to the end of any time, the above steps are cycled, and every node force and displacement state of the unit can be obtained. Figure 2 shows the flow chart of creep finite element calculation.

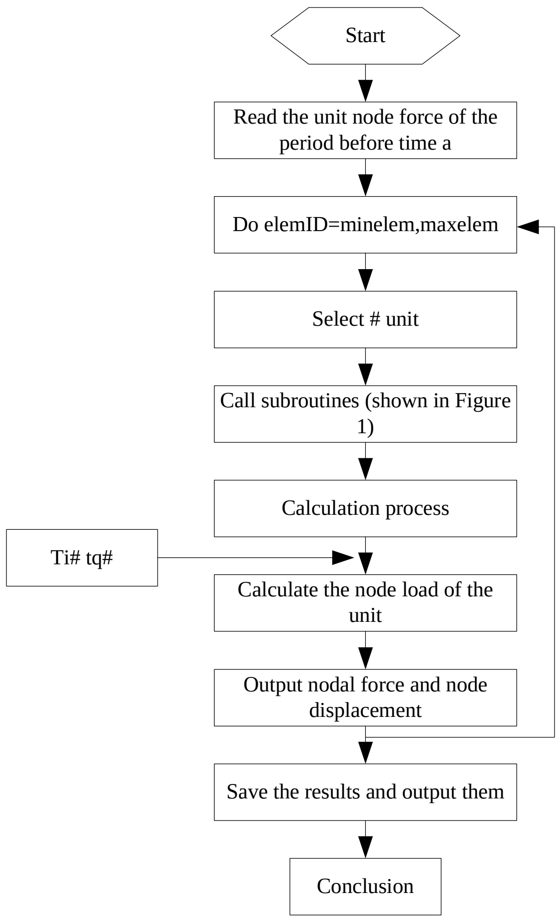

Figure 2. Flow chart of creep calculation

4. Argumentation and Analysis of Finite Element Calculation Method

The finite element calculation and analysis method proposed in this paper is experimentally demonstrated.

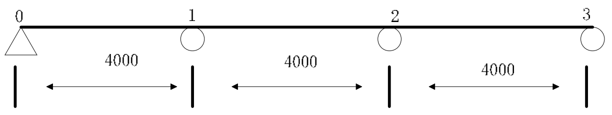

Figure 3. Calculated structure diagram / cm

The fixed cross-section beam at both ends of the main beam (3×40m three-span equal-section concrete continuous beam with as shown in Figure 3) is set, and the moment of fulcrum in the experimental section is obtained by finite element calculation method. The bending moments of the two pivots in this paper are -5000 and -7000, respectively, without considering creep. In order to ensure the validity of the data, the values of the bending moments of the two pivots in the 5th year are calculated as -8049 and -9000. The data in this paper are compared with the data of ANSYS program mentioned in the literature. The concrete results are shown in Table 1.

Table 1. Comparison of Pivot Bending Moments / kN•m

Content		This Paper	ANSYS Program
Without considering creep	Bending moment of pivot 1	-5000	-4990
	Bending moment of pivot 2	-7000	-7084
Considering creep In the 5th year	Bending moment of pivot 1	-8049	-7921
	Bending moment of pivot 2	-9000	-8934

According to the research, the relevant literature adopts an effective elastic modulus method based on age adjustment. From the data in Table 1, it can be seen that the error of numerical comparison between this method and the relevant literature is very small, and the error calculated by finite element analysis is relatively small compared with the theoretical numerical value in the literature. The finite element calculation analysis meets the design requirements of the prestressed box girder with ballasted track, which further verifies the validity of the finite element calculation results. And the finite element analysis can reduce the amount of cumbersome calculation process in creep reducing and improve work efficiency. At the same time, the analysis shows that the influence of creep on concrete bridge cannot be ignored and must be taken seriously.

5. Conclusion

With the improvement of construction technology, the materials for constructing bridges have been continuously updated, and various large bridges have emerged in an endless stream. The use of such large concrete bridges has met the growing transportation industry in China and has also brought corresponding problems. For example, under the action of concrete creep, the quality of bridges will be affected. By using the finite element to calculate and analyze the shrinkage and creep of the concrete bridges, the qualification rate of the bridges can be improved finitely and the driving safety can be effectively guaranteed.

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