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SHRINKAGE AND CREEP EFFECT ANALYSES OF DOUBLE COMPOSITE CONTINUOUS BOX-GIRDER BRIDGE CONSTRUCTED BY PRE-JACKING METHOD

SHUJIN DUAN, BIN WANG, YUANYUAN WANG, and RUNMING NIU

Research Institute of Structural Engineering, Shijiazhuang Tiedao University, Shijiazhuang, China

Continuous double steel and concrete composite beam is a new structural system developed on the basis of common steel and concrete composite beam. Controlling concrete slab crack width in a continuous double composite beam is a significant content in the bridge construction process. Jacking-up and landing bearing supports method is applied to a double composite girder bridge construction and its structural mechanical behaviors in the whole process will be simulated. By using of User Programmable Features and ANSYS Parametric Design Language, the commercial FEM software ANSYS was further developed. The exponential model of concrete creep and the implicit solution of concrete creep equation under the action of variable stress were introduced into ANSYS, to realize the concrete shrinkage and creep effect analysis of double composite continuous box-girder bridges constructed by pre-jacking method. The results show that it is improved that the stress state of the top concrete slab in the negative moment regions by pre-jacking method. Due to the effect of concrete creep, the concrete creep will cause tensile stress in the negative moment regions of the composite beam, which will reduce the compressive stress in the top concrete slab. The effect of prestressing is greatly affected by pre-jacking value, and the creep of the concrete also causes the stress redistribution of the concrete and the steel beam.

Keywords: Continuous double composite beam, Jacking-up and landing bearing supports, Negative moment region, Concrete shrinkage and creep.

1 INTRODUCTION

As a new type of structure, continuous double steel and concrete composite beams (Reiner 1996) are evolved from common composite beams. Controlling the negative moment region of concrete slab crack width is a significant content, and prestressing can effectively control the stress of the concrete slab (Gao 2005).

In the early, building continuous composite girder bridge mainly adopts the placement of prestressed reinforcement. However, due to its complex construction process and high degree of prestress loss, it is difficult to meet the requirements in terms of economy and performance. The Jacking-up and landing bearing supports method can link all parts of the composite beam more closely (Xiang *et al.* 2006). In Europe and Japan, interior supports are subjected to forced displacement by dropping those supports in most cases, and thus the prestressed force of

Continuous composite beams is generated. While the lifting of the side support is rare; this is due to the need for some temporary facilities. Several Japanese composite beams introduced by (Zhang 2000, Ogaki 1998) are used in the way of falling in the middle support to generate prestressing force. The field test results show that the prestress is successfully introduced into the concrete slab, and the results are in good agreement with the calculated results.

Concrete can creep under the long action of load. The of creep will make structures deformation and internal force redistribution, and it will generally make the composite girder bridge occurred prestress loss, especially in the design and construction of bridge with large span and complex structure, the creep effect is not negligible. A reasonable construction process was established for a double composite continuous box girder, and the creep effect was studied by Duan *et al*. (2013).

The finite element software ANSYS is used to simulate the construction process of jacking-up and landing bearing supports method, the creep analysis of the composite beam is realized by ANSYS Parametric Design Language, and the rationality of the above method is verified by an example.

2 COMPOSITE BEAM AND ITS CONSTRUCTION BY JACKING METHOD

Jacking-up and landing bearing supports method is also known as the support displacement method, including inner and side supports. Figure 1 shows the main construction procedures for a continuous double girder bridge.

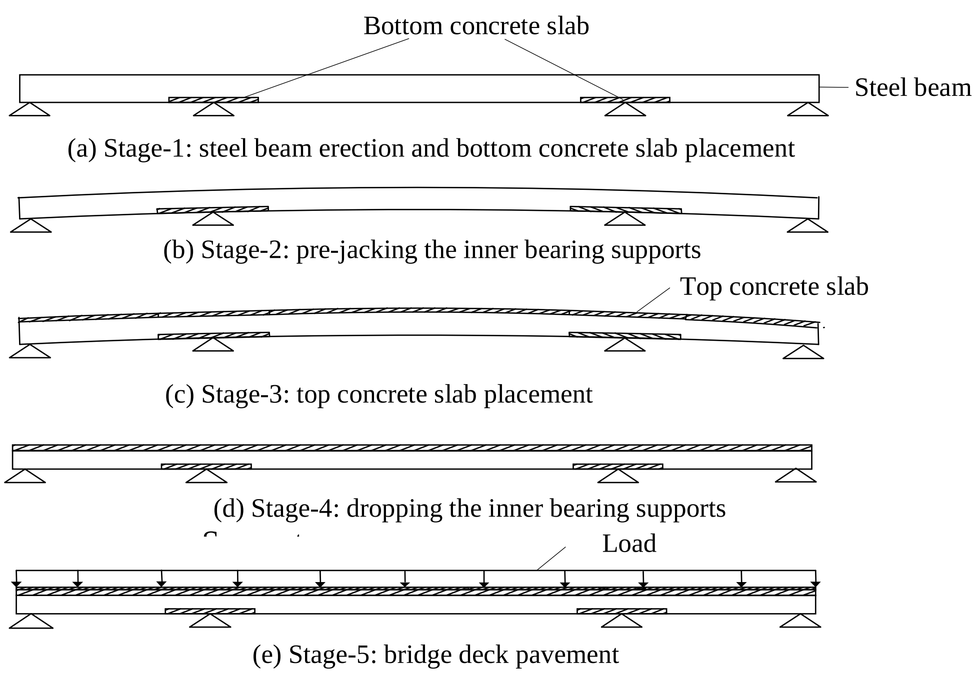


Figure 1. Construction sequence.

3 CREEP EFFECT ANALYSIS OF CONCRETE STRUCTURE

3.1 Concrete Creep Calculation in ANSYS

The creep behavior of materials can be simulated by ANSYS creep equation, which is expressed by creep rate (Eq. (1)).

$$\varepsilon_{cr} = A\sigma^{B}\varepsilon_{e}^{C}t^{D} \tag{1}$$

The explicit creep equation: (Eq. (2))

$$\Delta\varepsilon_{c} = C_{1}\sigma^{C_2}\varepsilon_{b}^{C_3}e^{-C_4/4}\Delta t \tag{2}$$

in which, $\Delta\varepsilon_c$ is the creep strain increment; σ is the equivalent stress; ε_b is the total strain of concrete; T is the absolute temperature; C_1-C_4 is the real constant, which can be input by command TBDATA; time Δt is the increment in the load step.

The linear creep theory is used, so $C_2=0$. When the strain hardening criterion is used, $C_3=1$. Without considering the influence of temperature, $C_4=0$. Finally, the expression of creep equation (Eq. (3)) can be simplified as:

$$\Delta\varepsilon_{c} = C_{1}\varepsilon_{b}\Delta t \tag{3}$$

Under the constant stress, the total strain is: (Eq. (4))

$$\varepsilon_{b}(t) = \varepsilon_{c}(t) + \varepsilon_{e} = [\varphi(t,t_0)+1]\varepsilon_{e} \tag{4}$$

in which, $\varepsilon_c(t)$ is for the creep strain of concrete; $\varphi(t,t_0)$ is the creep coefficient of loading age t_0; ε_e is for the initial elastic strain (Liu *et al*. 2013). Creep strain increment $\Delta\varepsilon_c$: (Eq. (5), Eq. (6))

$$\Delta\varepsilon_{c} = \Delta\varphi\varepsilon_{e} \tag{5}$$

$$C_1 = \frac{\Delta\varepsilon_c}{[1+\varphi(t,t_0)]\varepsilon_e\cdot\Delta t} = \frac{\varepsilon_e\cdot\Delta\varphi}{[1+\varphi(t,t_0)]\varepsilon_e\cdot\Delta t} = \frac{\Delta\varphi}{[1+\varphi(t,t_0)]\varepsilon_e\cdot\Delta t} \tag{6}$$

3.2 Finite Element Solution of Concrete Creep

The expression for the concrete creep degree is: (Eq. (7))

$$C(t,\tau) = \sum_{s=1}^{m}\psi_s\left[1-e^{-r_s(t-\tau)}\right] \tag{7}$$

The creep deformation increment of concrete can be calculated as follows: (Cheng 2009, Eq. (8))

$$\begin{aligned}
&\{\Delta\varepsilon_n^c\} = \{\eta_n\} + C(t,\bar{\tau}_n)[Q]\{\Delta\sigma_n\}\\
&\{\eta_n\} = \sum_{s=1}^{m}\left(1-e^{-r_s\Delta\tau_n}\right)\{\omega_{sn}\}\\
&\{\omega_{sn}\} = \{\omega_{s,n-1}\}e^{-r_s\Delta\tau_{n-1}} + [Q]\{\Delta\sigma_{n-1}\}\psi_s(\bar{\tau}_{n-1})e^{-0.5r_s\Delta\tau_{n-1}}\\
&\{\omega_{s1}\} = [Q]\{\Delta\sigma_0\}\psi_s(\tau_0)
\end{aligned} \tag{8}$$

Stress increments: (Eq. (9))

$$\{\Delta\sigma_n\} = \lfloor \overline{D}_n \rfloor \left(\{\Delta\varepsilon_n\} - \{\eta_n\} - \{\Delta\varepsilon_n^T\} - \{\Delta\varepsilon_n^0\} - \{\Delta\varepsilon_n^s\}\right) \tag{9}$$

3.3 UPFs Development Technology of ANSYS

ANSYS UPFs secondary development of the main process is as follows:

(i) Input the concrete material parameters in the USERMAT.F subroutine. The degree of creep and elastic modulus are defined as a function of time, and input the creep coefficient into the USERMAT.F subroutine.

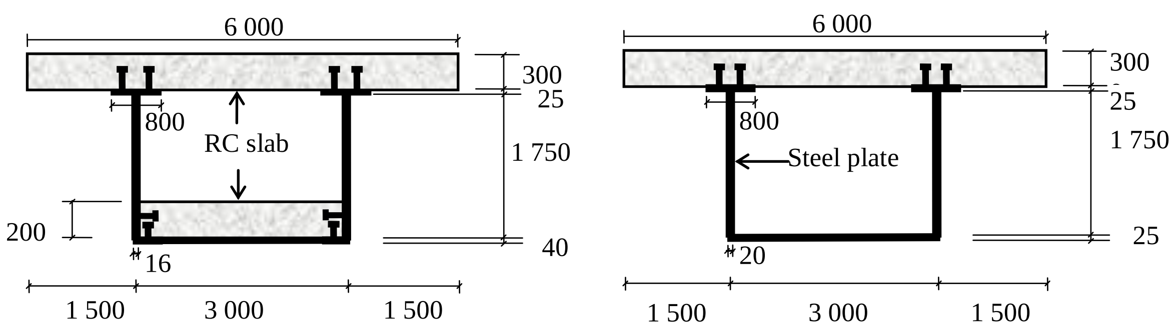
(ii) Recursive calculation about the $\{\omega_n\}$ and $\{\eta_n\}$, and storage the $\{\omega_n\}$.

(iii) Calculate the elastic modulus of concrete and elastic matrix of concrete.

(iv) The stress increment $\{\Delta\sigma_n\}$ at the present time is calculated and the total stress $\{\Delta\sigma_n\}$ is calculated by superposition of the stress increment.

4 AN EXAMPLE

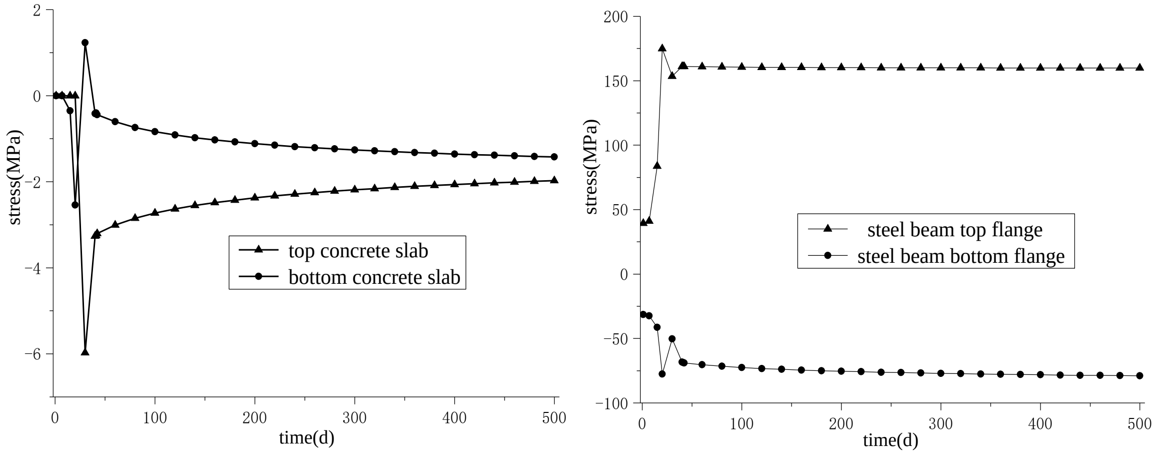
There is a span of 45m+60m+45m double composite continuous box-girder bridge. The cross sections of the negative moment region and the positive moment region are respectively shown in Figure 2. The used concrete strength is 50Mpa, the reinforcement strength is 400 Mpa, and the steel profile strength is 345 Mpa. The prediction model of concrete shrinkage and creep is based on the ACI code(ACI 209).



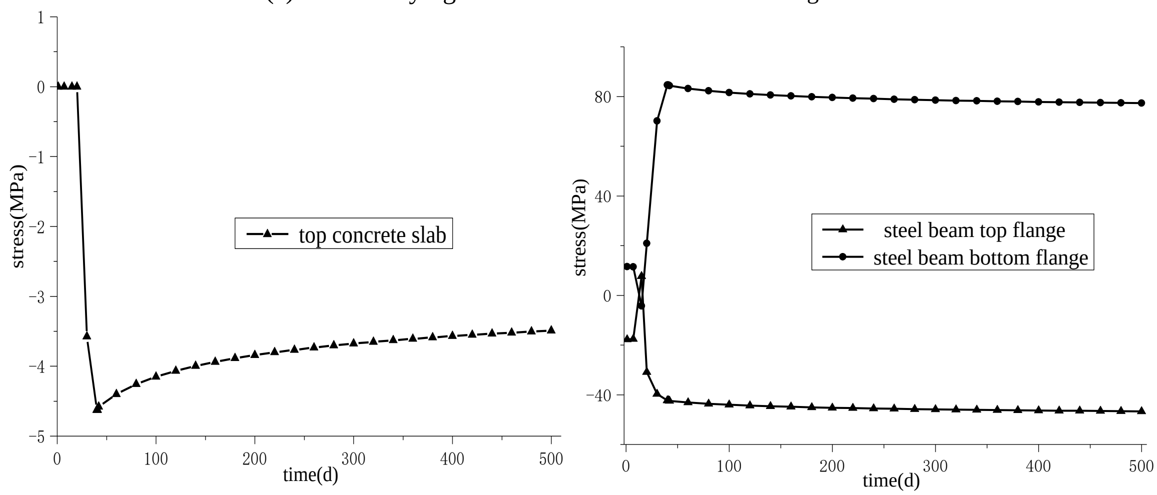
(a) Negative moment section. (b) Positive moment section.

Figure 2. Beam cross sections (mm).

Figure 3 shows the normal stress time variation curve when the jacking up value $\Delta = 0.3$ m. The calculated normal stress at the upper surface of the top concrete slab in the control sections at construction stage-d, stage-e and stage-f for the different jacking up values are shown in Table 1. Stage-f represents the stage of use of the bridge.



(a) Time varying curve of the stress in Inner bearing section.



(b) Time varying curve of the stress in the middle of the side span section

Figure 3. Time varying curve of concrete stress.

5 CONCLUSIONS

The study found that with the increase of the Jacking up value, which lead stress on the top concrete slab gradually from tensile stress into compressive stress. It is effective to apply pre-stressing for continuous double steel and concrete composite beam by pre-jacking bearing supports method. The pre-jacking value should be attentively determined according to the project details.

The creep and shrinkage of the concrete will cause the prestress loss. In the stage of use of the bridge, with the increase of time, in the positive moment region, the compressive stress on the top concrete slab gradually decreases. In the negative moment region, the compressive stress on the top concrete slab gradually decreases, which indicates that the creep and shrinkage effect of the concrete can reduced to the effect of the prestressing force of the jacking method, needs to take corresponding measures to reduce its influence.

In addition, in the positive moment region, with the increase of time, the compressive stress on the steel beam top flange increases with the increase of time, the negative moment region of steel girder tensile stress decreases with the increase of time. It is shown that the stress distribution of concrete slab and steel beam is caused by the creep and shrinkage of the concrete. the creep and shrinkage of the concrete will cause the stress distribution of concrete slab and steel beam.

Table 1. Normal stress of top concrete slab by ANSYS analysis.

Jacking up Value Δ/m	Control sections	Construction stage		
		d	e	f
0.00	Side span, mid-span	—	-1.0522	-0.9785
	Inner bearing	—	2.7114	2.4277
	Middle span,mid-span	—	-1.3982	-1.4138
0.10	Side span, mid-span	-1.1911	-2.2433	-1.8159
	Inner bearing	-1.9901	0.7204	0.9614
	Middle span,mid-span	-1.7089	-3.1072	-2.6796
0.20	Side span, mid-span	-2.3822	-3.4343	-2.6529
	Inner bearing	-3.9819	-1.2706	-0.5089
	Middle span,mid-span	-3.4179	-4.8161	-3.9451
0.30	Side span, mid-span	-3.5732	-4.6254	-3.4901
	Inner bearing	-5.9729	-3.2616	-1.9749
	Middle span,mid-span	-5.1268	-6.5251	-5.2107
0.40	Side span, mid-span	-4.7643	-5.8165	-4.3272
	Inner bearing	-7.9639	-5.2526	-3.4406
	Middle span,mid-span	-6.8358	-8.2340	-6.4762

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