

# The Crack Resistance of Prestressed Concrete Continuous Box Girder Bridge under the Effects of Shrinkage and Creep

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**Abstract.** Aiming at the crack phenomena in prestressed concrete continuous box girder bridges at present, on the background of Modaomen Bridge in Guangdong province, the influence of shrinkage and creep on crack resistance for PC box girder bridges is studied and discussed in this thesis. In the three-dimensional finite analysis of the whole model, the principal stress response of the structure under the permanent load (dead load and prestressing force) and shrinkage and creep is studied, and the shortage of the plane truss software is pointed out.

## Introduction

Cracking of concrete bridge is determined by the principal stress rather than the internal force. Therefore, an approvable internal force on structure can guarantee the safety of the whole bridge, but does not guarantee approvable crack resistance on part. Whether the structure will crack is determined by three-dimensional stress state of the structure and the ultimate strength of material, which is the spatial stress analysis method for crack resistance.

Shrinkage and creep on concrete is a long-term process, and have cumulative effect of time. In the bridge structure, impact of shrinkage and creep often cannot be ignored. If it not dealt with properly, the bridge component will crack due to the excessive local stress, which seriously affects the bridge safety and durability performance.

This paper is based on Modaomen Bridge in Guangdong province, which is a prestressed concrete continuous rigid frame structure system. Due to limited space, this paper only analyze the principal stress effected by permanent load(dead load and prestressing force) and shrinkage and creep, at the same time, the results from three-dimension finite element software and plane truss structure analysis software is compared.

## The Establishment of the Finite Element Model

According to the symmetry in longitudinal direction and lateral direction, 1/4 bridge finite element model of spatial entity is established in calculation. Concrete box girder is simulated with SOLID65, transverse diaphragm and thin-wall pier with SOLID45, prestressed tendons with LINK8, and initial strain in tendons is exerted to simulate the effect of the prestressing force.

With mapping network division technique, the model is properly divided into blocks and the most of blocks is hexahedral elements. In order to make boundary condition of the model consistent with the real constraint condition of bridge, fixed constraint is imposed on the bottom of the double thin-wall pier, bilateral constraint on side support, longitudinal symmetry constraint on the top of the middle pier.

The spatial crack resistance analysis is executed by ANSYS and the plane truss model is calculated by Dr. Bridge.

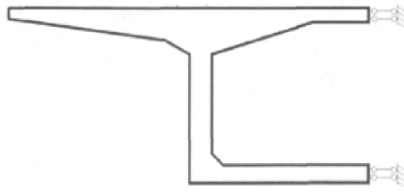


Fig. 1 Lateral Boundary Condition in Spatial Entity Model

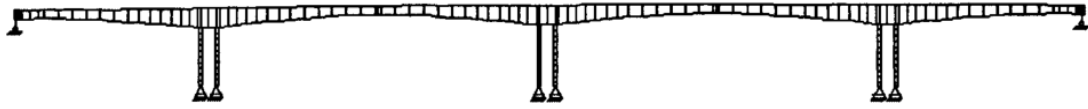


Fig. 2 Schematic Diagram of Plane Truss Model

## The Principal Stress Analysis under the Effects of Permanent Load and Creep and Shrinkage

### The Principal Stress Analysis under the Effects of Permanent Load

Except for the prestressed anchorage points where stress concentration phenomenon is significant, the principal stress on the upper edge of box deck ranges from  $-0.248\text{MPa}$  to  $0.201\text{MPa}$ . The value of principal stress changes little in longitudinal direction, no matter how it changes significantly in transverse section.

The principal stress on the bottom edge of box deck ranges from  $-0.248\text{MPa}$  to  $0.426\text{MPa}$ . As for the pier near 0# concrete block, stress concentration phenomenon appears on the joint region where deck meet web, the maximum stress value reaches  $1.1\text{MPa}$ .

The principal stress on the inner edge of web ranges from  $-0.273\text{MPa}$  to  $1.35\text{MPa}$ . Inner web first principal stress in the range of  $0.273\text{MPa}$ - $1.35\text{MPa}$ , the principal tensile stress increases from the 0# concrete block to middle span. As for the closure segment in the middle span, stress concentration phenomenon appears on the joint region where bottom slab meet web, the maximum stress value reaches  $2.0\text{MPa}$ .

The principal stress on the outside edge of web ranges from  $-0.273\text{MPa}$  to  $0.052\text{MPa}$ . Due to the coupling effect, the local stress distortion appears on the section of web from the  $1/4$  span concrete block to the 0# concrete block.

The principal stress on the upper edge of bottom slab ranges from  $-0.31\text{MPa}$  to  $0.37\text{MPa}$ . Stress concentration phenomenon appears on the joint region where deck meet web, the maximum stress value reaches  $2.0\text{MPa}$ . The remaining internal stress distribution is more homogeneous.

The principal stress on the bottom edge of bottom slab ranges from  $-0.461\text{MPa}$  to  $2.56\text{MPa}$  and in some areas on the closure segment in the middle span, the principal tensile stress ranges from  $3.17\text{MPa}$ - $3.77\text{MPa}$ . Because of the vertical prestressed tendons, compressive stress dominates the side edge of the bottom slab, and in the remaining parts, the principal stress increases from the 0# concrete block to the middle section.

### The Principal Stress Analysis under Effects of Both Permanent Load and Creep and Shrinkage

Along the longitudinal and lateral direction, the principal stress on some key points is selected to describe the principal stress distribution with a diagram. In the following diagrams, we adopt the convention that the  $1/2$  width of deck is denoted by the letter B, the  $1/2$  width of bottom slab is denoted by the letter B1, the height of web is denoted by letter H. In coordinate system, the X-axis refers to the distance (m) from the tested point to the side support and the Y-axis refers to the value of principal stress (MPa).

Except for the prestressed anchorage points where stress concentration phenomenon is significant, the principal stress distribution under the effects of permanent load and creep and shrinkage as shown in figure 1 to figure 3.

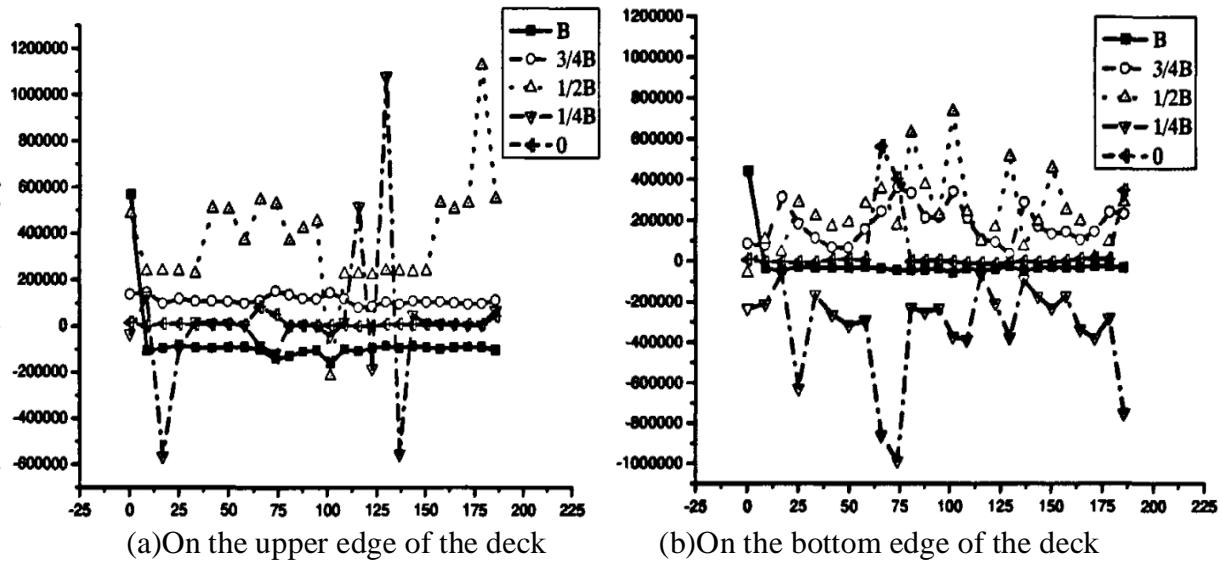


Fig. 1 the Principal Stress Longitudinal Distribution on the Deck under the Effects of Permanent Load and Shrinkage and Creep

The principal stress on the deck ranges from  $-0.200\text{MPa}$  to  $0.500\text{MPa}$ . Except for  $1/2B$ - $1/4B$  areas, the principal stress on the upper edge of deck changes little in longitudinal direction; the principal stress on the bottom edge of deck changes significantly when compared with the upper edge. Along the lateral direction, sign-alternating of the principal stress on the deck occurs.

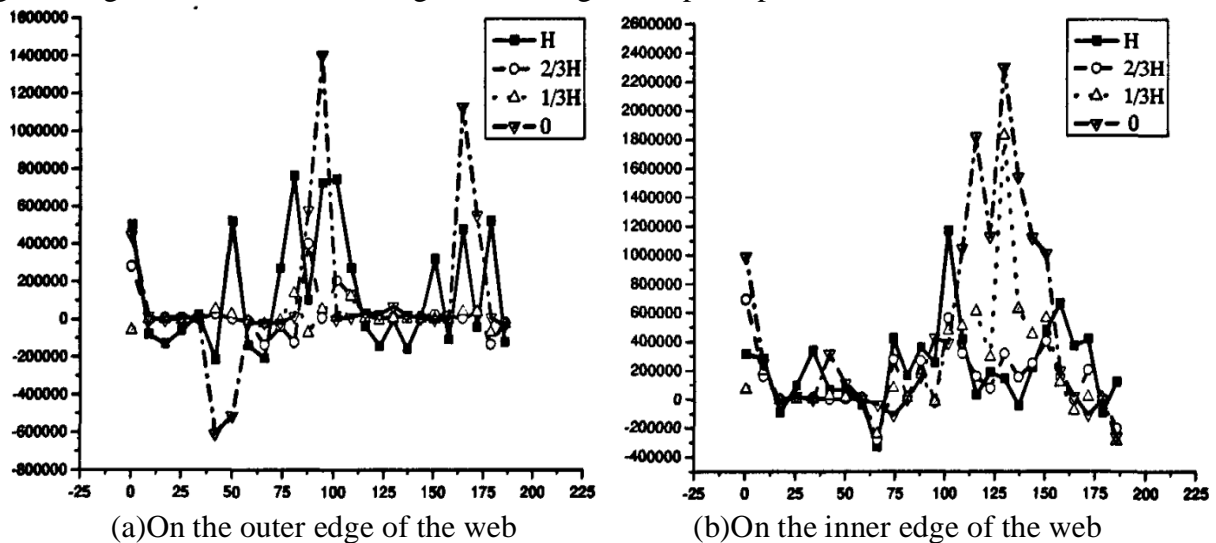


Fig. 2 the Principal Stress Longitudinal Distribution on the Web under the Effects of Permanent Load and Shrinkage and Creep

The principal stress on the web ranges from  $-0.200\text{MPa}$  to  $0.600\text{MPa}$ , the stress distribution on upper and lower side is consistent, the principal stress value on the inner side is greater than that of the outer side. From the figure 2, as for the stress value on inner side, the value of middle span is greater than that of side span, and it reaches a maximum on the middle of the middle span, in the range of  $2.2\text{MPa}$ - $2.4\text{MPa}$ . In the areas nearby pier, principal stress increases due to the coupling web reinforcement which results local stress distortion.

The principal stress distribution on the bottom side of bottom slab is not completely consistent with that of the upper side. The principal stress changes little in lateral direction and in the middle span, it changes significantly in the joint areas where web meet bottom slab, in the range of  $0.25\text{MPa}$ - $0.25\text{MPa}$ . As for the principal stress on the bottom edge of bottom slab, the stress distribution in lateral direction varies little and changes great in longitudinal direction, in the

range of slab of 0.430MPa-1.50MPa, and reaches a maximum of 3.51MPa on the middle of bottom slab locating on the middle of the middle span.

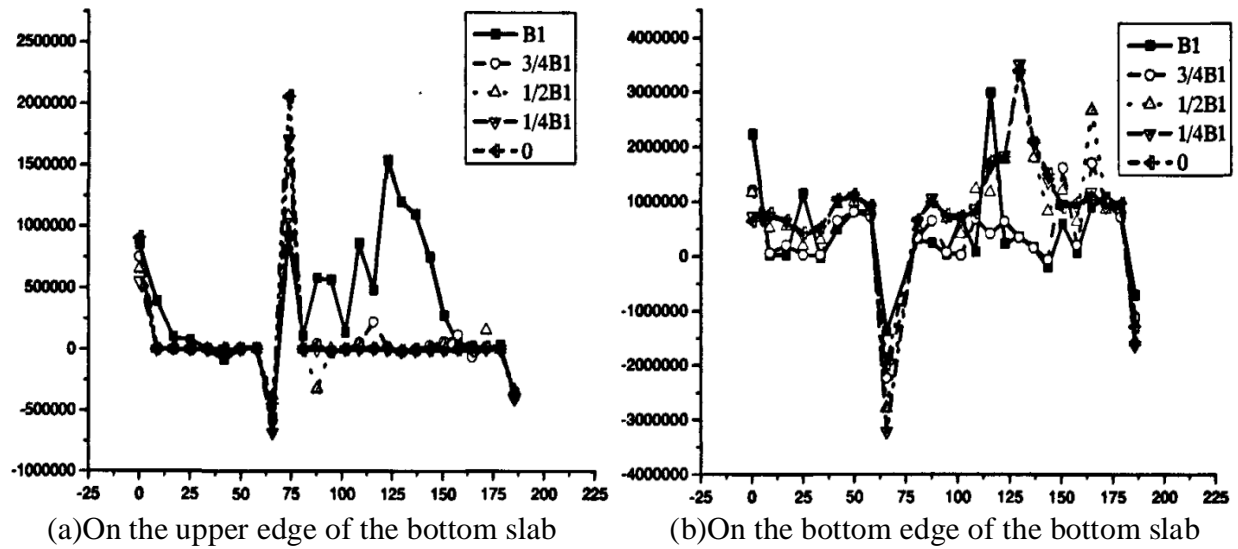


Fig. 3 the Principal Stress Longitudinal Distribution on the Bottom Slab under the Effects of Permanent Load and Shrinkage and Creep

## Conclusion

Tab. 1 the Maximum Principal Tensile Stress under the Effects of Permanent Load and Shrinkage and Creep[MPa]

Load	Position	Plane truss model				Spatial entity model			
		1/2L	3/8L	1/4L	1/8L	1/2L	3/8L	1/4L	1/8L
Permanent load	Deck					0.510-0.709	0.311-0.510	0.376-0.557	0.636-0.828
	Web	0.00	0.58	0.39	0.21	0.841-1.250	0.579-0.840	0.437-0.556	0.071-0.127
	Bottom slab					3.080-3.790	1.330-1.820	0.507-0.894	0.765-0.894
Permanent load+shrinkage and creep	Deck					0.242-0.663	0.155-0.423	0.490-0.682	0.570-0.753
	Web	0.00	0.64	0.48	0.37	1.330-1.790	0.710-0.995	0.520-0.655	0.102-0.164
	Bottom slab					3.190-3.900	1.390-1.780	0.600-0.993	0.600-0.993

According to the above analysis and data, the following conclusions can be made:

- (1) Shrinkage and creep have significant effects on principal stress. Due to the adoption of the simple calculation model, calculation value may be smaller than the real.
- (2) Because the local stress concentration is considered in spatial calculation model, the principal tensile stress is relatively greater. As a result, the stress in plane truss model is smaller than that in spatial model.

(3) Because of the different computational assumptions between spatial calculation program and plane truss program, the calculation value of principal stress differs with each other. The spatial model instead of plane truss model is closer to the real stress condition of the bridge.

## **References**

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