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INFLUENCE OF THE SLOPE FOR THE DISTORTION EFFECT OF PRE-STRESSED SKEWED BOX-SECTION GIRDER BRIDGE

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In order to analyze the distortion effects of the skewed PC box-section girder bridge, a simply-supported and three-span continuous skewed PC box-section girder bridge models are built by using the finite element analysis software ANSYS in this paper. First of all, the distortion effects in the longitudinal direction are analyzed for the bridge models and the most disadvantage section are found. Then the longitudinal distortion effects how to vary with the slope is discussed. The results show that the influence of slope is remarkable, with the increase of slope, distortion is becoming more and more large, and it is proportional to the slope degree, the distortion angle of 1/4 span and 3/4 cross section of the bridge is the largest. Therefore, in the process of design, construction and maintenance, the deformation of unfavorable cross section should be paid special attention.

Keywords: ANSYS, Longitudinal distortion effect, Distortion angle, Deformation.

1 DISTORTION EFFECT OF BOX-SECTION GIRDER

As it is shown in Figure 1, box-section girder structure would produce distortion deformation under bias load or anti-symmetric load (Guo *et al.*2008), then its shape will become irregular. When the distortion effect of box-section girder is analyzed, we often put the box-section girder structure into four vertical plate girder and a series of horizontal in the direction of the girder span frame mechanical model. The evaluation index of distortion effect is distortion angle. In this paper, the evaluation index is longitudinal distortion angle vale of angular point 2 of box-section girder structure when the structure suffered anti-symmetric load. The unit of distortion angle is radian, and distortion angle is said by r. Then:

$$\gamma = \frac{v_2 + v_4}{a_1 \sin\theta} + \frac{v_1 + v_3 + 2v_2 \cos\theta}{a_2 \sin\theta} \tag{1}$$

v_1 and v_3 are the displacement along the web of angular point 1 and 3, and v_2 and v_4 are the horizontal displacement of angular point 2 and 4, a_1 and a_2 are the length of left web and floor of the structure, and then the apex angle is θ. When the angle of reference point reduces, the distortion angle is positive.

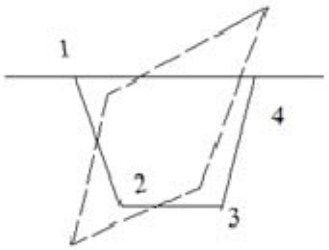

Figure 1. The distortion deformation of box-section girder.

2 ENGINEERING SITUATION

Box-section girder cross section is shown in Figure 2. The height of girder is 3.05 m, the width of girder roof is 13.4 m, the width of floor is 5.5 m, the width of flange plate is 3.35 m, the thickness of floor is 0.574 m. The material is C50 concrete, which density is 2.5×10^3 kg/m^3, elasticity modulus is 3.45×10^4 MPa, and the Poisson ratio is 0.3. 8 cluster low relaxation pre-stressed steel strands are evenly arranged in the web of structure, which the ultimate tensile strength of steel strand is 1,860 MPa, the tension control stress is σ = 1,395 MPa, the cross section of pre-stressed reinforcement is S = 22 cm^2, the modulus of elasticity is E = 195,000 MPa, and the Poisson ratio is 0.3.

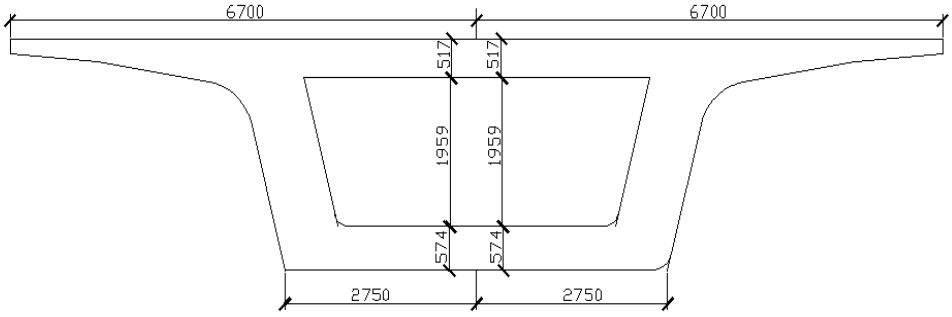

Figure 2. The cross section of box girder (mm).

3 THE DISTORTION EFFECT ANALYSIS OF SKEW BOX GIRDER

3.1 The Deformation Analysis of Skewed Box-Section Girder

The mechanical characteristics (Zou and Yu 2011) of skew box-girder bridge have much difference to orthogonal bridge. Its stress is the result of torsion and flexture coupling effect. The elementary beam theory cannot be used to calculate the force. When the external factors change, such as slope, pre-stressed or wide span ratio change, angular point 2 would generate the corresponding distortion effect, thin-walled box girder distortion angle and displacement distortion will change accordingly (Lu, 2013). The change of the slope will increase the torsion and flexure coupling of bridge, which increases the longitudinal bridge distortion effect.

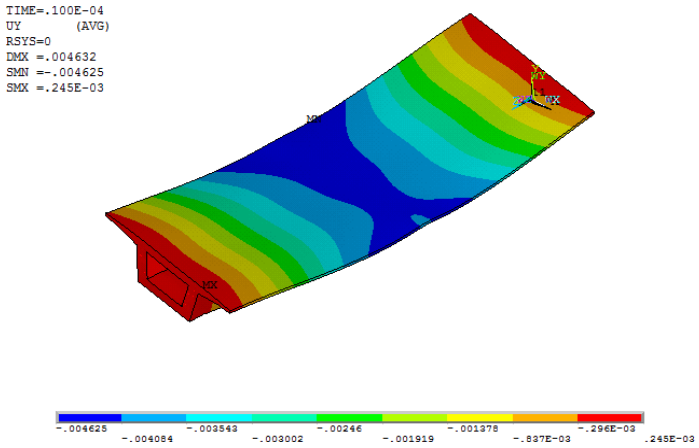

Figure 3. The deformation of skewed box-section girder bridge with 10 degree slope.

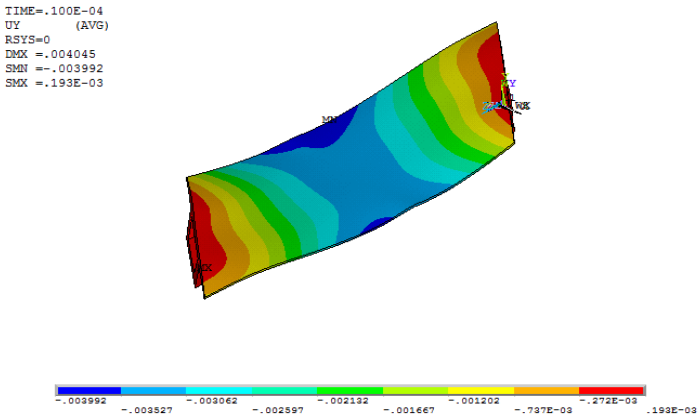

Figure 4. The deformation of skewed box-section girder bridge with 30 degree slope.

Under the action of gravity with pre-stressed, the mid-span cross section of skewed box-section girder bridge has the vertical deformation of down. Comparing the vertical deformation of mid-span cross section of 10 degree and 30 degree skewed box-section girder bridge: when increasing the slope of the skew box girder bridge, location in the cross of downward vertical displacement will increase. The mid-span vertical displacement whose slope is 30 degree is smaller than 10 degree skewed box-section girder bridge. The deformations are shown in Figure 3 and Figure 4.

In addition to the vertical deformation, skew box girder-bridge will produce vertical deformation, horizontal deformation and torsional deformation under the action of gravity and pre-stress.

3.2 The Longitudinal Distortion Effect of Skewed Box-Girder Bridge

The distortion angle of longitudinal distribution of angular point 2 in Figure 1 is analyzed with the software of ANSYS (Wang, Li and Xu 2011). The floor of skew box girder bridge span is 6.5 m. The slopes are 10 degree, 20 degree, 30 degree and 40 degree. In order to analyze the distortion effect, this paper takes some points along the longitudinal spacing of the structure, then each point of the distortion angle is shown in Table 1.

According to the distortion angle of different slope degrees in Table 1, we can conclude: with the increase of slope, the absolute value of longitudinal distortion angle increases great, and distortion angle value changes in direct proportion with slope. For the spatial structure, it is difficult to calculate distortion angle value with the elementary beam theory. Although the simulated distortion effect with ANSYS can't conform to the actual results perfectly, its change rule is accurate and credible.

Table 1. Longitudinal distortion of pre-stressed skewed box-girder bridge (10-5 rad).

Longitudinal location(m)	Slope			
	10 degree	20 degree	30 degree	40 degree
0	-0.20	0.03	-0.04	0.04
1.3	-0.18	-0.31	-0.24	-0.38
4.3	-1.46	-3.64	-4.22	-7.87
7.3	-1.34	-4.06	-6.85	-9.64
10.3	-0.60	-3.04	-5.57	-8.09
13.3	0.71	-0.76	-2.31	-3.75
16.3	2.42	2.76	2.74	2.85
19.3	3.73	4.51	7.44	9.14
22.3	4.31	7.01	9.92	12.61
25.3	4.13	7.07	10.16	13.03
28.3	3.02	5.35	7.71	9.62
31.3	0.18	0.17	0.45	0.50
32.6	-0.17	0.00	-0.24	-0.18

Figure 5 depicts the longitudinal distortion angle between the junction of the web plate and the bottom of the structure when slope varies, the slope are set 10, 20, 30 and 40 degrees, respectively. From Figure 5, we can conclude that the changes of the slope affect the distortion effect of skew box-girder bridge.

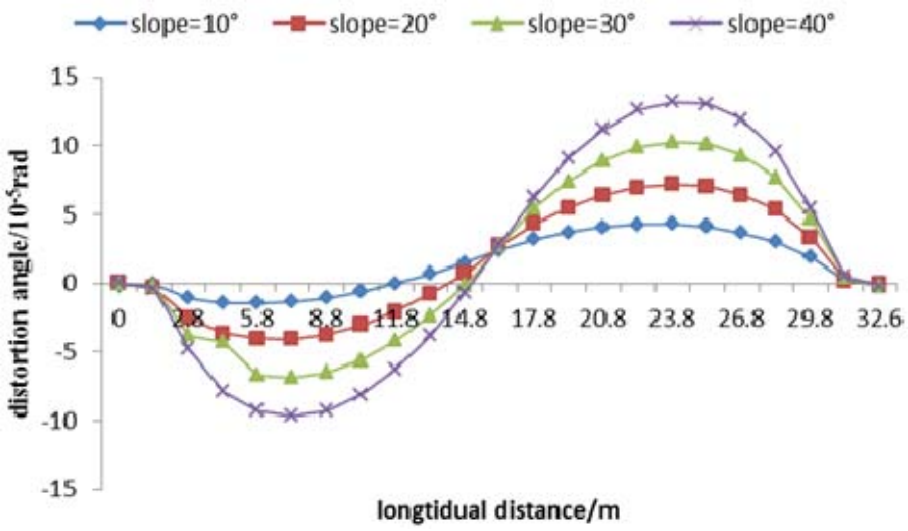

Figure 5. Slope to distortion effects of skew box-girder bridge.

(1) Slope has a great influence on the distortion angle of cross section of the bridge and the distortion angle for 40°slopes is about 4 times of that 10°slope.

(2) For the skewed girder bridge with 30° slope, the vertical curve of distortion angle presents certain regularity. The distortion angle of cross section of mid-span is small, distortion angle of a quarter of the cross section and three quarters turns to extreme value. It is much different from the laws of shear lag effect of skewed box-section girder bridge. For skewed box-section girder bridge, the disadvantage section is mid-span, and then one quarter and three quarters.

According to the above, the effect of slope is obvious. The more slope varies, the bigger distortion angle will be, then the greater damage of the bridge will be. Based on the relevant research of shear lag effect, a quarter of the cross section and three quarters cross section of the skew box girder bridge have great damage, so the cross section in the design and construction should be worthy of attention.

4 CONCLUSIONS

A simply supported skewed box-section girder bridge 3-D FE model was established by ANSYS. Through simulation we can conclude the longitudinal distortion effect analysis of between the web plate and the bottom of structure. The following conclusions are drawn from the simulation studies:

(1) The vertical deformation of 5the mid-span is the largest. With increase of slope, the deformation of mid-span cross section has a tendency to decrease. Because of the obvious effect of bend torsion coupling, with the increase of slope, other deformation will correspondingly change.

(2) When the slope is constant, the longitudinal distortion angle curve of skewed box-girder bridge is on the cross section symmetry, the distortion angle of the mid-span is small, and one quarter and three quarters of the cross section are rather large, and then in this cross section, shear lag effect of skewed box-girder is also obvious. So, in the early period of the bridge design, construction and maintenance, one quarter and three quarters cross section of the bridge should be given more attention.

Acknowledgments

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