Analysis on the influencing factors of Shear lag effect of Double-sided Box Girder

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Abstract: In order to research different width-span ratio and aspect ratio on shear lag effect of double-sided box girder, the simple supported and cantilever systems are taken as research object. Simulating the shear lag effect is based on the finite element analysis software ANSYS. The conclusions of research are as follows: when width-span ratio η is 0.25~0.5, the shear lag effect of the main beam varies the most under uniformly distributed load. With width-span ratio decreasing, the normal stress distribution tends to be more uniform. When aspect ratio decreases, the shear lag effect of double-box beam decreases gradually, but the variation amplitude is not big. Compared with aspect ratio, width-span ratio has a greater influence on the shear lag coefficient of double-sided box girder.

1. Introduction
In today’s society, with the progress of urbanization in our country, traffic volume is increasing and growing at the same time. Bridge span tends to be wider, which makes the dead load of bridge structure become bigger. With the innovation of technology and the emergence of new materials, thin-walled box girder from its strength, stiffness, economy and reducing weight considers as a reasonable and effective cross section form. The double-sided box girder is a kind of section extending from the thin-walled box girder, which is also called PK section. And it is suitable for long-span bridge with its unique advantages.

The shear lag effect of double-sided box girder is usually prominent. The shear lag effect is that the normal stress of the box girder section is not uniformly distributed, and the stress near the web is larger than that far away from the web[1]. At present, scholars at home and abroad have done plenty of research on the shear lag effect of box girder.

X. H. Hu etc. studied the influence of factors such as width-span ratio, high-span ratio, thickness of steel webs, wave height of steel webs, a number of steel webs, thickness of roof and thickness of bottom plate on shear lag of box girder[2]. H. L. Lu etc. used ANSYS software to study the variation rule of shear lag effect in single-box double-cell girder under the working conditions[3]. Based on the Timoshenko beam theory, X. Y. Li etc. made a correction to warp displacement function of single concrete thin-walled box girder. Considering the shear deformation amplitude difference among each flange plate of the box girder, axial force equilibrium condition across section, and the influence of shear deformation of webs, the warping displacement function is established reasonably, and the total potential energy function of the system is built[4]. Based on Gjelsvik displacement model and modified warping displacement function, P. Zhu etc. established an analytical model of steel-UHPC (ultra-high performance concrete) composite beam accounting for the slip between UHPC slab and
steel beam together with the shear lag effect in the UHPC slab[5]. By the traditional bar simulation method, only the shear lag effect of box girder with constant section can be analyzed. To improve the applicability of the existing method, Z. W. Guo etc. derived a new equivalent method of analogy bar areas and governing differential equations of shear lag effect for the variable box-section girder[6].

To sum up, scholars have mainly studied and stipulated the shear lag effect of the box girder section, but there is no criterion for the shear lag effect of the double-sided box girder. This paper studies the influence of design parameters on the variation law of shear lag coefficient, so as to accumulate basic technical data for the study of shear lag effect of double-sided box girder and the improvement of relevant specifications.

2. Research on the effect of shear lag effect of double-sided box girder with width-span ratio

Continuous beam bridges, continuous rigid frame bridges and cable-stayed bridges are statically indeterminate structures. It is difficult to analyze the shear lag effect of this structure directly. This paper considers dismembering a complex statically indeterminate system into several simple statically indeterminate systems by means of the dismemberment method, which is helpful to calculate the shear lag effect of statically indeterminate system.

The calculation conditions are as follows:
1. Uniformly distributed load \( q = 10kN/m \);
2. Boundary conditions: Simply supported beam, Cantilever beam;
3. Uniformly distributed load position: the top of the webs of the bilateral boxes, and the transverse distribution of load is shown in figure 1;
4. Width-span ratio is defined as the ratio of deck width to bridge span. Its value are 0.5, 0.3, 0.25, 0.2, 0.17, 0.14, 0.13, 0.11, 0.10;
5. Aspect ratio is defined as the ratio of the section width of the main girder to the height of the side box girder. Its value are 8.2, 9.5, 11.4, 14.3.

In this paper, six calculation points are selected in this paper (as shown in Figure 1). The loading location is shown in Figure 2.

Figure 1. Calculation points of shear lag coefficient

![Figure 1. Calculation points of shear lag coefficient](image1)

Figure 2. Uniformly distributed load position

| 1 | 2 | 3 | 4 |
|---|---|---|---|
|   |   |   |   |

2.1. The influence of width-span ratio on shear lag coefficient of simply supported beams

When the top of the web of the side box girder bears uniformly distributed load, shear lag coefficient of six calculation points of simply supported beam varies with width-span ratio, as shown in Figure 3 and Figure 4.
As can be seen from figure 3 and figure 4, when width-span ratio decreases from 0.5 to 0.1, the shear lag coefficient of six calculated positions gradually approaches 1. The maximum value of shear lag coefficient is located at the top of side box web, which decreases from 1.305 to 1.019. The variation range is about 21.9%.

2.2. The influence of width-span ratio on shear lag coefficient of cantilever beams

When the top of the web of the side box girder bears uniformly distributed load, shear lag coefficient of six calculation points of cantilever beam varies with width-span ratio, as shown in Figure 5 and Figure 6.

As can be seen from figure 5 and figure 6, when width-span ratio decreases from 0.5 to 0.1, shear lag coefficient of six calculated positions gradually approaches 1. The maximum value of shear lag coefficient is located at the top of the side box web, which decreases from 1.189 to 1.002. The variation range is about 15.7%.
3. Research on the effect of shear lag effect of double-sided box girder with aspect ratio

3.1. The influence of aspect ratio on shear lag coefficient of simply supported beams

When the top of the web of the side box girder bears uniformly distributed load, shear lag coefficient of six calculation points of simply supported beam varies with aspect ratio, as shown in Figure 7 and Figure 8.

![Figure 7. Shear lag coefficient of the mid-span roof of simply supported beams with different aspect ratios](image1)

![Figure 8. Shear lag coefficient of the mid-span bottom plate of simply supported beam with different aspect ratios](image2)

As can be see from figure7 and figure8, when the top of the web of the side box girder bears uniformly distributed load, the effect of aspect ratio on the shear lag coefficient of double-sided box girder is much less than that of width-span ratio to span. When aspect ratio reduces from 14.3 to 8.5, shear lag coefficient decreases from 1.333 to 1.305. The variation range is about 2.1%.

3.2. The influence of aspect ratio on shear lag coefficient of cantilever beams

When the top of the web of the side box girder bears uniformly distributed load, shear lag coefficient of six calculation points of cantilever beam varies with aspect ratio, as shown in Figure 9 and Figure 10.

![Figure 9. Shear lag coefficient of the mid-span roof of cantilever beams with different aspect ratios](image3)

![Figure 10. Shear lag coefficient of the mid-span bottom plate of cantilever beams with different aspect ratios](image4)
As can be seen from figure 9 and figure 10, when the top of the web of the side box girder bears uniformly distributed load, the effect of aspect ratio on the shear lag coefficient of double-sided box girder is much less than that of width-span ratio to span. When aspect ratio reduces from 14.3 to 8.5, shear lag coefficient decreases from 1.189 to 1.173. The variation range is about 1.4%.

4. Conclusion
(1) According to the results of parameter analysis, width-span ratio has a greater influence on shear lag coefficient of double-sided box girder.
(2) When width-span ratio of the main beam decreases, shear lag effect of double-sided box girder decreases gradually, and normal stress distribution of the section tends to be uniform.
(3) When aspect ratio of the main beam decreases, shear lag effect of double-sided box girder decreases gradually, and normal stress distribution of the section tends to be uniform, but the variation amplitude is not big.

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