Research on Rigidity Distribution between Arch and Girder for Tied Arch Bridges with Trough Girder

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Abstract. In order to explicitly specify the force characteristics of tied arch bridge with trough girder, this paper focus on the tied arch bridge vertical stiffness analysis under different rigidity distribution between arch and girder. The paper based on a tied arch bridge with trough girder which the span is 96 meters, changing the rigidity distribution between arch and girder by different arch rib section. Contrasting the force characteristics on the premise of conforms to the national standards, and then gets the most suitable rigidity distribution between arch and girder.

Background Information

Tied arch bridge refers to the bridge bear the arch horizontal thrust by tied girder which is separated with the driveway girder. Prestressed concrete tied arch bridge is a new type of girder and arch combination bridge, this type of bridge shares load by the arch ribs which mainly bear the stress and the driveway girder. The tied girder makes use of tendon to resist the thrust at arch foot which not only overcomes the traditional bridge huge arch thrust, but also reduce the girder bridge bending moment and shear force.

The Common Mode of Rigidity Distribution between Arch and Girder

Tied arch bridge is a structure with zero thrust which statically determinate outside but statically indeterminate inside.

Rigid arch and flexible girder

Generally, when $(EI)_{\text{arch rib}}/(EI)_{\text{tied girder}} > 100$, the tied arch bridge is called rigid arch and flexible girder. This type of tied arch bridge once has been used a lot, the flexible girder mainly has been used to resist the thrust at arch foot. The vertical load is transferred from the bridge panel to cross beam, then through the suspender transferred to the arch rib. With the increase of arch bridge span, rigid arch and flexible girder is shortly been used.

Flexible arch and rigid girder

When $(EI)_{\text{arch rib}}/(EI)_{\text{tied girder}} < 1/100$, the tied arch bridge is called flexible arch and rigid girder. Actually, this type of tied arch bridge mainly suffer the stress by girder not arch rib, the arch rib provides elastic support on main beam with the help of suspender, but the construction is inconvenient in some places.

Rigid arch and rigid girder

When $1/100 < (EI)_{\text{arch rib}}/(EI)_{\text{tied girder}} < 100$, the tied arch bridge is called rigid arch and rigid girder, this type of tied arch bridge have a high integral stiffness, the vertical load is undertook by both arch rib and tied girder , the bridge suffer the force uniformly and looks beautiful, so the rigid arch and rigid girder is very popular today.

Research on Rigidity Distribution between Arch and Girder for 96 Meters Tied Arch Bridge with Trough Girder

The arch rib of tied arch bridge with trough girder usies the equal cross section concrete-filled steel tube structure and adopts the longitudinal single rod, the internal of transverse brace steel pipe does not filled with concrete. The tied girder real length is 97.5 meters, the calculated span is 96 meters, The ratio of rise to span is f/l=1/5, so the rise of the arch rib is 19.2 meters and the shape of arch is two times parabola functional image. The steel tube is filled with C50 Non shrink concrete and the tied girder adopts C50 concrete. Arch rib steel tube is made of Q345qD steel, the rest of the steel is made of Q235qD steel.

The calculation model chooses four different arch rib sections but keep other structure parameters same ,so variable can be controlled but just change the rigidity distribution of arch and girder, the following data is drew from the model calculation and analysis result.

Table.1 Different Arch Rib Section Influence on Vertical Stiffness Under Train Load [mm]

Arch rib section	Arch rib max displacement (a)	Girder max displacement (b)	Rigidity distribution of girder and arch (c)
Dumbbell shaped(d=1000)	4.365	14.734	2.375
Three limb shaped(d=1000)	3.739	14.383	2.847
Dumbbell shaped(d=1500)	2.027	14.017	5.915
Three limb shaped(d=1500)	1.885	13.886	6.367

The rigidity distribution of arch and girder is calculate by Eq.1

$$c = (b-a) / a \tag{1}$$

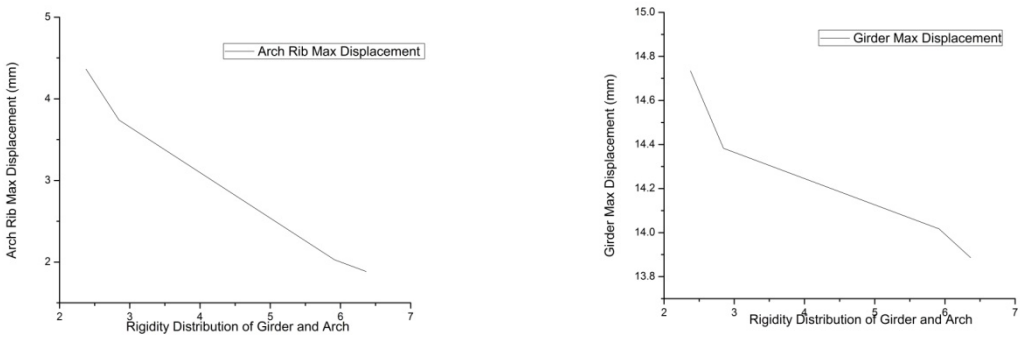

Fig.1 Different Arch Rib Section Influence on Vertical Stiffness Under Train Load [mm]

Conclusion

From the data in the table above, with the arch girder stiffness ratio increases, the bridge's vertical displacement under train load shows a decline trend obviously. But on the contrary, if the arch rib section is too large, it will not only waste a lot of steel and concrete which is harmful to the economic benefits, but also increase the whole bridge's dead weight which goes against the force characteristics. Therefore, rigidity distribution between arch and girder for tied arch bridges with trough girder should choose a moderate value, not too big nor too small.

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