Comparison between multinational criterions for stability of steel arch bridge

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1. Introduction

At present, more and more steel arch bridges with modern design and complex architecture have been built in the world due to the development of design theory and construction method. And a great deal of research on the critical flexure load of steel arch bridges has been carried out by the many researchers. The results show that rise to span ratio, residual stress, initial imperfection, type of the arch axis, loading procedure, boundary condition and so on are major causes of affecting the critical flexure load of the steel arch bridges[1)-4)]. Therefore, the specifications are drawn up by various countries according to their own practical situation of the design and fabrication. In this paper, the provisions for in-plane and out-of-plane stability of steel arch bridge in the Chinese code: *Fundamental code for design on railway bridge and culvert*[5)], Japanese code: *Specification for Highway Bridges*[6)], American code: *AASHTO LRFD Bridge Design Specifications*[7)] and Eurocode3: *Design of Steel Structure*[8)] are compared. The results provide a reference for the scholars and the revision of codes for steel bridges.

2. Synopsis of Example

Parameters reacting on the critical buckling load of in-plane and out-of-plane calculated according to multinational codes will be studied below by using the example of references 9). The model of steel arch bridge in references 9) is given as Figure 1, the main span of the bridge is 150m long with rise to span ratio of 0.15. Arch rib spacing was chosen as 20m, 10m, 5m respectively, and coefficient β for arrangement range of lateral brace was taken as 0.864, 0.733 and 0.48 based on statistics for existing steel arch bridges. The yield stress of steel σ_y is assumed to be 235MPa, the parameters of arch rib and lateral bracing are given as Table 1.

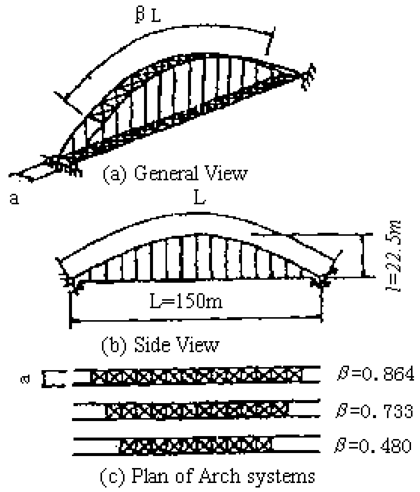

Figure 1 Model of steel arch bridge

Table 1 Dimensions of model（Units : mm）

Size / Member	Height	Width	Flange thickness	Web thickness
Arch rib	2880	480	12	6
Lateral brace	400	400	21	6.5

3. In-Plane Critical Flexure Load

Since the two hinged arch bridge and steel with yield stress of 235MPa in the references 9) are seldom adopted in the steel arch bridges nowadays, in this paper, fixed arch bridge with material of SM490Y specified in Japanese Industrial Standard will be used instead of them. In-plane critical flexure loads are calculated on the basis of multinational code by changing the rise to span ratio with invariant parameters of arch rib and lateral brace, the results are specified as Figure 2. It shows that the in-plane critical flexure load decreases along with the increase of rise to span ratio in Chinese code and Eurocode, while the rise to span ratio has no influence on the critical load in the American code. In-plane stability of the arch is checked with supposing the arch rib as a member subjected to axial compressive load for multinational codes, but the effective flexure length of arch rib is different from each other. With the same rise to span ratio, the maximum critical flexure load adopted by calculating in accordance of Eurocode, followed by Chinese code and American code comes minimum.

4. Out-of-Plane Critical Flexure Load

The out-of-plane critical flexure load of steel arch bride is shown in Figure 3 and Figure 4 for altering the arch rib spacing with supposing β=0.864, and changing the lateral brace spacing with the arch rib spacing of 20m, respectively. Overall, there is an obvious disparity between the results of multinational codes. Since the Japanese code is derived from the statistical regression on the results of nonlinear analysis, the critical flexure load according to Japanese code is smaller than those in accordance with Chinese code and Eurocode.

The Figure 3 shows that the out-of-plane critical flexure load according to Chinese code comes to a peak with arch rib spacing is approximately 5m, and the load diminishes in spite of the arch rib spacing increase or decrease on either hand of 5m; The critical flexure load in accordance with Japanese code decreases with the decrease of arch rib spacing, and tendency becomes more pronounced when distance is smaller than 5m (Assuming $k = 0.95$); The critical flexure load in line with Eurocode increases with the decrease of arch rib spacing. There are several reasons for this result: the Chinese code and Eurocode code on the basic of energy method, the lateral brace becomes more tubbiness when the length is smaller, and the restraint for the deformation of arch rib will more intensive also, thus the critical flexure load increase with the increase of integral deformation energy of two arch ribs. In contrast, the integral lateral stiffness is considered in means of transverse radius of gyration in the Japanese code, the integral lateral rigidity of arch rib is greater when the arch rib spacing is larger, therefore, the critical flexure load in line with Japanese code increase with the increase of arch rib spacing.

Figure 4 shows that the out-of-plane critical flexure loads according to Chinese code and Eurocode increase along with the increase of β, and β has a greater effect on results of Eurocode; The critical flexure load in terms of Japanese code does not change with the values of β. Here are some crucial reasons for this result: the Chinese code supposes the arch rib as a vierendeel truss with the length of arch axis approximately, thus achieves the maximum value; The height of end portals decrease along with the increase of β according to the Eurocode, then the height of equivalent frame structure will decrease, which lead to the out-of-plane critical flexure load increase; There is no parameter relates to the stiffness, location and influence of lateral bracing in equation of Japanese code, therefore the critical flexure load according to Japanese code is independent of β-value.

At present, the calculation formula of multinational codes for out-of-plane stability still have some defects. The influence of material nonlinearity, transverse initial imperfection and lateral displacement haven't been taken into account in Chinese code; The stiffness, location and influence of lateral bracing, transversal initial imperfection and lateral displacement haven't been considered in Japanese code; The Eurocode leaves the type of lateral brace without diagonal brace, transverse initial imperfection and lateral displacement out of consideration.

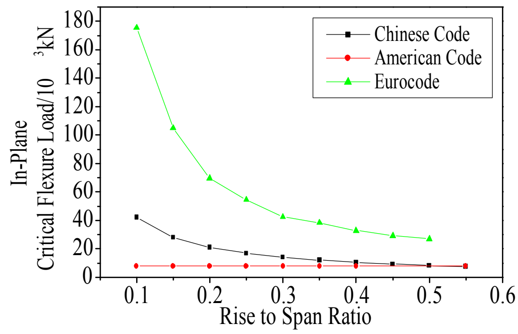

Figure 2 Relationship Between In-Plane Critical Flexure Load And Rise to Span Ratio

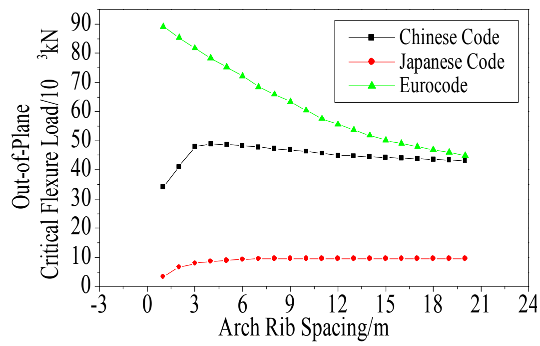

Figure 3 Relationship Between Out-of-Plane Critical Flexure Load And Arch Rib Spacing

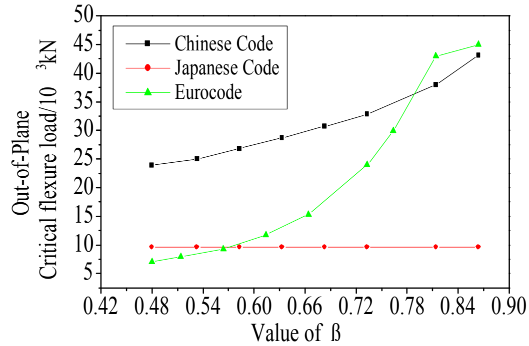

Figure 4 Relationship Between Out-of-Plane Critical Flexure Load And β

5. Conclusion

In-plane critical flexure load decreases along with the increase of rise to span ratio according to Chinese code and Eurocode, while doesn't change with the rise to span ratio in the American code. Out-of-plane critical flexure load comes to a peak with arch rib spacing is approximately 5m, decreases with the decrease of arch rib spacing, increases with the decrease of arch rib spacing according to Chinese code, Japanese code and Eurocode respectively. Out-of-plane critical flexure load increase along with the increase of β according to Chinese code and Eurocode, while in terms of Japanese code it doesn't change with the values of β.

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