Design methods for buckling of steel tied arch bridges

Amelie OUTTIER
Post-doctoral Researcher
Ghent University
Ghent Belgium
Amelie.Outtier@UGent.be

Hans DE BACKER
Assistant Professor
Ghent University
Ghent Belgium
Hans.DeBacker@UGent.be

Ken SCHOTTE
PhD Student, Researcher
Ghent University
Ghent Belgium
Ken.Schotte@UGent.be

Dries STAEL
PhD Student, Researcher
Ghent University
Ghent Belgium
Dries.Stael@UGent.be

Philippe VAN BOGAERT
Full Professor
Ghent University
Ghent Belgium
Philippe.VanBogaert@UGent.be

Summary

Determining for the structural behaviour of steel tied arch bridges is the introduction of a large compressive force in the arch section. As a consequence, slender steel arches are highly sensitive to not only in-plane but especially out-of-plane buckling. At present, no specific buckling curves for out-of-plane buckling exist for non-linear or curved elements in international codes and calculation methods. Hence, the buckling curves for straight columns, as determined by ECCS, are used, which can leads to some inaccuracy in the assessment of the critical buckling load for arch bridges, resulting in heavier cross sections.

This manuscript presents two practical calculation methods to design for the buckling behaviour of slender steel tied arch bridges. The first one follows the empirical calculation method as proposed in the Eurocodes. However, an alternative definition of the buckling factor is necessary. This allows for a better representation of the out-of-plane stiffness of the arch cross section and of the influence of the wind bracings between both arches.

In addition, a second calculation method is proposed, based on the use of simplified finite element models to determine the relative slenderness of the bridge structure. Both methods are validated using results from much more detailed three dimensional finite element models of several tied arch bridges. These models include variations of the bridge length, dimensions of the arch cross-section, boundary condition, load type, etc.

Comparing the results of both methods with realistic simulation, it becomes quite clear that a higher buckling curve can be used than proposed by the Eurocode, thus resulting in a more economic and aesthetic bridge design.

Keywords: steel arch bridge; buckling, out-of-plane

1. Introduction

The fundamental behaviour of tied arches is based on the fact that a large compressive force is developed in the arch cross-section. Because of this, steel arches in particular can become highly sensitive to the out-of-plane buckling phenomenon. However, there is no clear and generally accepted calculation method to predict numerically this stability problem. On one hand, the buckling strength of a steel tied-arch bridge can be calculated by considering the non-linear elastic-plastic behaviour. As the imperfections of the arches highly influence the non-linear behaviour, these geometrical imperfections need to be known before starting this analysis. On the other hand, a linear calculation, resulting in an elastic buckling factor for the compression force, can be carried out. A multiplication factor for the occurring stresses can be found based on this calculation, using an adequate buckling curve, as mentioned for straight beams [1, 2 and 3]. In this case as well, the arch imperfections should be known beforehand. However, the imperfections in slender steel arch bridges are not related to those of a straight beam or column which makes it fundamentally impossible, or at least overly safe, to use the standard buckling curves, derived for straight beams, as proposed by the Eurocodes.

https://doi.org/10.2749/222137810796024402
Distributed by structurae