Limiting slenderness values of smaller concrete tied arch bridges

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Summary
The assessment of the stability of concrete arch bridges is discussed through considering 4 heritage examples, which have no upper wind bracing. The relevance of this stability problem is due to the need of evaluating the load carrying capacity of older structures and also because of the increase of design loads, or in case of possible defects. The simplified method for verification of second order effects of Eurocode 2 suggests that all 4 cases show nonlinear behaviour. In the case of solid structures as concrete arches, the reduced stiffness method seems well adapted. The latter was combined with geometric nonlinear simulation, including imperfections. The results clearly demonstrate that second order effects are immaterial within the limits of ultimate limit conditions. However, the relation between the critical load factor and the arch slenderness fails to render clear results. Although the number of bridge cases is limited, it appears that the slenderness may not be an adequate factor for determining the arch stability and failure.

Keywords: Concrete arch stability, nonlinear analysis, arch slenderness, imperfections, heritage bridges.

1. Introduction

In the past century, concrete tied arch bridges have been built regularly to cross small rivers or roads. This type of structure was used for crossing spans, varying from 30 to 50 m. The examples being presented more extensively in the following section, demonstrate that these structures can no longer be built in an economical manner, but also their heritage value. Some of these arch bridges completely consist of reinforced concrete, while others have steel or iron hangers connecting the arches to the lower chord. In the former case, the hangers may show sufficient stiffness to obtain framework or Vierendeel-behaviour.

With ageing of these concrete structures, and because traffic loads are increasing constantly, the primary question about the load carrying capacity arises. Many bridge owners have doubts about the functionality of these valuable bridges, even if no major damage has been detected so far. Obviously, the main concern is about the effect of higher loads and not about material characteristics.

During structural assessment of arch bridges, lateral stability of the arches is of major importance. The upper bracing is not so much needed to resist wind actions, but merely to avoid lateral arch buckling. Due to the rather solid character of arch cross-sections, structural second-order effects are expected to be low. However, the use of bracings, connecting two parallel arches, apparently was found necessary for various bridges, although it influences aesthetics badly.

There are already many references about nonlinear behaviour of concrete arches. Nonlinear material effects have been thoroughly assessed (1) and the stability problem in particular loading conditions is well known (2). However, these results can mostly not be applied directly to tied arch bridges. In addition, most of the recent research has been concentrated on concrete filled steel arch bridges (3).

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