Analysis of Existing Masonry Arch Bridges using Finite Elements

Steve RHODES
Principal Bridge Engineer,
LUSAS, UK
steve.rhodes@lusas.com

Steve Rhodes is a Chartered Civil Engineer with 19 years experience in bridge engineering. Graduating from Univ. of Bristol (UK) in 1994, he also obtained an MSc at Univ. of Surrey (UK) in 2008.

Philip ICKE
European Regional Manager,
LUSAS, UK
philip.icke@lusas.com

Philip Icke received his civil engineering degree from the Univ. of Exeter (UK) in 1992. He specialises in the promotion and use of finite element modelling techniques.

Summary

Many of our oldest bridges – now subjected to traffic unimaginable to the original constructors – are masonry arches. Large and small, they collectively form a very significant part of the highway and railway networks, keeping our communities connected, whilst also being admired and enjoyed, in their own right, by people the world over.

Managing these vital transport links is therefore of great importance, and an understanding of the structural behaviour, together with an assessment of the load-carrying capacity, is fundamental to the process of identifying structures which require strengthening and planning suitable interventions. A sustainable approach for such infrastructure management requires engineers to draw deeply on the available intellectual resources to avoid unnecessary work or, worse, unplanned closures or collapses.

This paper explores the application of FE methods to analysis of masonry bridges, with emphasis on structural understanding and issues including soil-structure interaction. Issues of idealisation, material parameters and nonlinear behaviours are considered in the context of practical project work, highlighting the key considerations.

Keywords: Masonry; Bridges; Underground structures; Assessment / Repair; Computational Methods; Finite Elements

1. Introduction

The stone and brickwork arch bridges in our infrastructure are vital to our road, rail and communications networks and the majority of them are now more than 100 years old (see [1] section 1.4). It is widely appreciated that these structures have been subjected to traffic loads that have been incrementally increased over the life of the structure, long ago surpassing the magnitudes which might have been conceived at the time of their construction. At the same time, the strength of the structures will have generally fallen somewhat over the years.

Material deterioration will occur due to the eroding action of water, ice, salt crystallisation and wind – the speed and the significance of such effects being very much dependent upon not only climate but also the materials used, construction details and so on (see [1] section 3.2, [2] section 2.5.3). Other damage may be the consequence of human activity – deliberate vandalism, accidental impacts or even inappropriate interventions by prior bridge owners. Settlement, subsidence and scour are further important causes of defects (see [2] section 2.5.1).

Under cyclic loading, the “fatigue capacity” of multi-ring masonry arches has been found to be of the order 50% of the static strength (see [3] section 8.1.4.4 and [4]). Further, deterioration can arise under sustained loading (creep effects) [5]. Neither effect is often considered in assessment.

The presence, types and patterns of cracks, stains, efflorescence, loss of material, vegetation and fungal growth provide clues to not only the causes and likely consequences of damage, but also to hidden construction details (see [1] section 3.2.1), such as backing, haunching, or internal spandrels.

With all this in mind it is imperative to maintain robust inspection regimes and records, utilise suitable monitoring techniques, and furthermore develop a good understanding of the behaviour of

https://doi.org/10.2749/222137814814028089
Distributed by structurae