# 'Strengthening by Assessment' Using Finite Element Approaches – Case Studies of Rail Bridges

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## Abstract

This paper presents the 'strengthening by assessment' of bridges achieved by the implementation of finite element techniques. The use of more accurate analysis methods and the implementation of non-linear modelling and functions to better understand buckling modes and the structural behaviour of historic construction details are outlined. Three case studies are presented, demonstrating the effectiveness of the sophisticated Level 2 Assessment methodology using finite element analysis against conservative hand calculation approaches. One rail overbridge and two rail underbridges that did not achieve the required load rating by means of a Level 1 Assessment are examined and the increase in assessed capacities given by the Level 2 Assessment is outlined.

**Keywords:** Assessment; bridges; finite element analysis; strengthening; nonlinear modelling; buckling; sustainability.

## 1 Introduction

The United Kingdom has one of the oldest railway networks in the world dating back to 1825. It is commonly accepted that the successful operation of the network is vital for the economy of the United Kingdom, consequently the cost effective maintenance of the existing infrastructure is a high priority to maintain the operability of the network, prevent deterioration and to extend the service life of the assets. Each bridge is required to be assessed every eighteen years and a structured approach to assessments is adopted with three main types of progressively more detailed assessments used. These assessment types include Level 0 (standardized spreadsheet assessment tools), Level 1 (analytical hand calculations) and Level 2 (generally finite element analyses). There is a degree of conservatism in the first two types of assessment dictated to some extent by the relevant design standards being adopted for assessment and which can lead to some structures not achieving the required load rating. In these situations a Level 2 Assessment is often carried out using finite element analysis to uncover 'latent strength' and improve the load rating. If successful, the more sophisticated analysis can save on costly strengthening or replacement works and avoid disruption to the operational railway and the surrounding areas.

## 2 Assessment of Bridges

Bridges are crucial for a wide range of infrastructure networks (e.g. road, rail, water) because they serve as links and routes of passage [1]. In this case, the minimisation of risks related to public safety and disruption to service is vital. Especially when it comes to railway bridges, the preferred approach is the reuse and adaptation of existing structures and not the demolition and reconstruction. In order to do so, while simultaneously accounting for sustainability, bridges need to be assessed. Despite the fact that



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