Hybrid Analytical Modeling of Bridge Structures: An Innovative Approach

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Abstract

The origins of finite element method can be traced back to the 1960's and since then it has been used in solving several structural engineering problems. The direct result of finite element analysis is the calculation of the deformation and the stress fields in the structure. The stress results are not sufficient for performing the design checks which rely on force results. Hence, an integral approach is required where section forces are calculated from the stresses. This is a post-processing operation which involves complex interpolation, extrapolation, and integration functions. The first step in any structural analysis is the creation of a suitable analytical model. Beam analytical models are commonly used mainly because they are easier to create and the results are readily usable. Finite element models, on the other hand, can be time-consuming and complex because they require good understanding of the flow of forces, effects of stress concentration, and as mentioned before, aggregating stress resultants to produce sectional design forces. A novel concept of hybrid analytical model has been created and implemented in Bentley's RM Bridge software. The hybrid model is predominantly a beam model enhanced with FEM elements in the regions dominated by stress concentrations where "plane sections remain plane before and after loading" assumption may not be valid. The result is the best of the both worlds – simplicity and speed of beam models, and the realistic modelling of stress field flows.

Keywords: Hybrid Analytical Modelling; Finite Element Modelling (FEM); Beam elements; Stress distribution; Integral results; Bridge Structures; Bentley RM Bridge.

1 Introduction

The behaviour of bridges can be divided into two different responses: 1) the global response of the overall system (longitudinal bending of the bridge girder and columns), and 2) the local response of the individual components (e.g. bending of the deck slab). In most cases, the analysis of the overall system is based on the stiffness method and is performed on simplified models consisting of one-dimensional beam elements. These models allow for an adequate analysis of the general response of bridge structures but cannot resolve the importance of local behaviour. Such details must be analysed with finite element method (FEM). The finite element analyses are often very time-consuming.

For this reason, most bridge analysis software packages have been based on beam elements which the beam theory applies for the individual elements. This theory assumes that cross-sections remain plane and un-deformed with assumption of plane stress conditions. In practice, this approach