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Composite steel and concrete bridge trusses

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ABSTRACT

Distribution of longitudinal shear along an interface between steel and concrete parts of various composite truss bridges from elastic phase up to plastic collapse is presented. With respect to the authors' previous experimental research reported in references, the numerical analysis and the Eurocode approach concerning distribution of the longitudinal shear flow is studied in detail. The main interest is devoted to elastic and elastic–plastic distribution of the flow corresponding to the design level of bridge loading and plastic collapse. The analysis covers both the common elastic frame 2D modelling of the shear connection used by designers and the 3D GMNA (geometrically and materially non-linear analysis) using ANSYS software package. Results of the various models are mutually compared and confronted with provisions of Eurocode 4 for composite bridges. The non-linear distribution of the longitudinal shear, required for correct design of shear connection of composite steel and concrete bridges (in both ultimate limit state including fatigue and serviceability limit state) significantly depends on rigidity of the shear connection and densification of the shear connectors above truss nodes. These issues are analysed in parametrical studies, commented and finally some recommendations for practical design are suggested.

1. Introduction

Composite steel and concrete trusses are widely used both in buildings as primary or secondary beams and in bridge structures. Behaviour of steel trusses acting compositely with concrete slabs has been investigated since the sixties both experimentally and theoretically. Experimental investigation by Galambos and Tide [1] and Azmi [2] together with practical applications by Iyengar and Zils [3] pointed to new opportunities in structural design and enabled the use of composite trusses as large span floor beams. Extensive research performed in Canada and USA (e.g. by Brattland and Kennedy [4], Kennedy and Woldegiorgis [5], Viest [6]) resulted in wide use of steel and concrete composite trusses in North America. Recent further development in the USA has been described by Leon [7]. Research of novel shear connector types suitable for composite truss floors were presented by Mujagic et al. [8] and economic advantages of composite trusses were emphasized by Kravanja and Silih [9]. Further development in recent years enabled plenty of excellent composite truss bridge structures (see e.g. [10]).

Distribution of the shear flow between steel truss and concrete slab along the span of a composite truss girder was found to be highly non-linear and simplified approaches were searched for. In the nineties, the research by Neal and Johnson and SCI publication [11] led to design recommendations, showing a wide range of design aspects important for composite steel and concrete trusses. In compliance with these recommendations, the plastic design can be done identically as for a common plate girder, including the design of a steel–concrete shear connection, provided, the shear connectors are adequately ductile and the bending rigidity of the upper steel flange of the truss is sufficient.

The elastic design, however, is necessary for class 3 and 4 cross sections and rigid shear connectors with respect to their limited deformation capacity. In addition, one must take into account the highly non-uniform distribution of longitudinal shear force in the composite truss girder due to the transmission of the shear force to a concrete slab locally in truss nodes and due to local loading. Local effects of a concentrated longitudinal force introduced into the concrete slab of a composite continuous girder due to prestressing were investigated by Johnson and Ivanov [12] and introduced into Eurocode 4 (EN 1994-2, or ENV 1994-2 in more detail), see [13]. The Eurocode proposes formulae for the local effect of a concentrated longitudinal force and distribution of the longitudinal shear force into shear flow between steel section and concrete slab, which may appropriately be used in the design of composite trusses. The analysis [12] was based on linear behaviour of shear connection and gives largely conservative results.

A simple worked example using these formulae and a comparison with non-linear analysis using ANSYS software was presented

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