Non-Linear Finite Element Analyses of Existing Reinforced Concrete Bridge Beams

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Summary

The Dutch Ministry of Infrastructure and the Environment initiated a project to re-evaluate the carrying capacity of existing bridges and viaducts. Within the project guidelines for nonlinear finite element analyses, that are considered as one of the alternatives for the carrying capacity verifications, have been developed in order to reduce model and user factors. The aim of the project well fits with the philosophy of the new Model Code 2010 that proposes analytical and numerical procedures for the evaluation of the design resistance of reinforced concrete structures. In the paper four reinforced concrete beams have been analyzed through the calculation methods proposed by the Model Code 2010 and following the Dutch guidelines. The results obtained have been compared with the experimental results available in literature. Furthermore, in order to focus on the main sensitive parameters that influence the results obtained from NLFEA, parametric studies have been carried out on the beams.

Keywords: reinforced concrete beams, nonlinear finite element analyses, shear resistance evaluation, guidelines.

1. Introduction

Three years ago the Dutch Ministry of Infrastructure and the Environment initiated a project to re-evaluate the carrying capacity of existing bridges and viaducts. Due to the increase of traffic and the reallocation of emergency lanes to traffic lanes, the safety verification of some concrete structures are not satisfied if the usual analytical procedures are followed. Nonlinear finite element analyses are considered as one of the alternatives for the verification of the structural carrying capacity. Building codes hardly provide specific guidance on how NLFEA should be carried out and reported. In the paper the main indication of the Dutch guidelines are presented.

2. Cases study and main results

In Fig. 1 an overview of the case studies is presented; the beams are denoted as RB1, RB2, RB3 and RB3A. Further geometrical and mechanical properties can be found respectively in [3], [4], [5]. The beams have been analyzed with the finite element software DIANA [6]. The relations used in the crack model implemented in DIANA, like in most other commercial software, are for a wide range of use and therefore based on simplified modelling of the nonlinear behaviour of concrete and steel. Parametric studies have been carried out on the beams by varying the main sensitive parameters of the crack model that can influence the results (e.g. biaxial stress-state, fracture energy, shear retention factor, Poisson's coefficient etc.) in order to calibrate the finite element model and to obtain reliable and safe results. The design resistance of the beams has been determined analytically and numerically according to the calculation methods proposed by the *fib* Model Code 2010 with different levels of approximation: by increasing the level of approximation the complexity and the

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accuracy of the results increases. Level of approximation I, II and III refer to analytical calculation methods, while the highest level of approximation, level IV, refers to numerical methods, performed with NLFEA. Within level IV the results obtained from NLFEA are properly reduced, in order to obtain the same safety level of analytical calculations, according to three alternative “safety format methods” denoted as Partial Factor method (PF), Global Resistance Factor method (GRF) and Estimation of Coefficient of Variation of resistance method (ECOV). In Fig. 2 the design resistances P_d obtained analytically and numerically, expressed as a percentage of the experimental ultimate load $P_{u,exp}$, are presented.

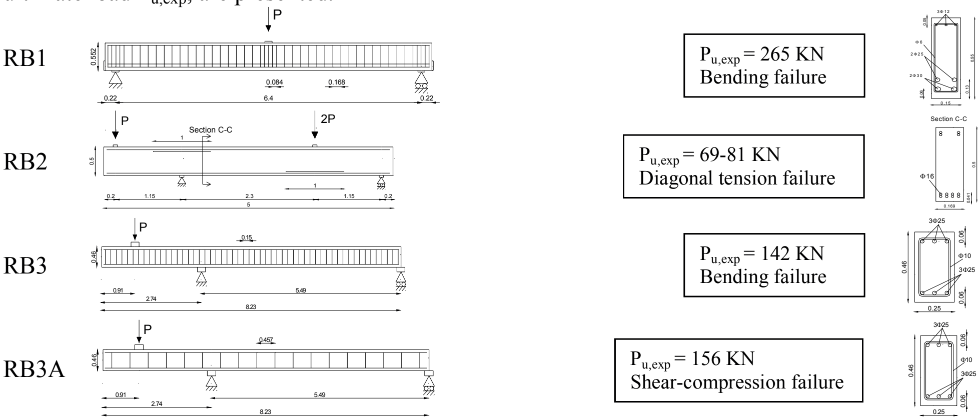
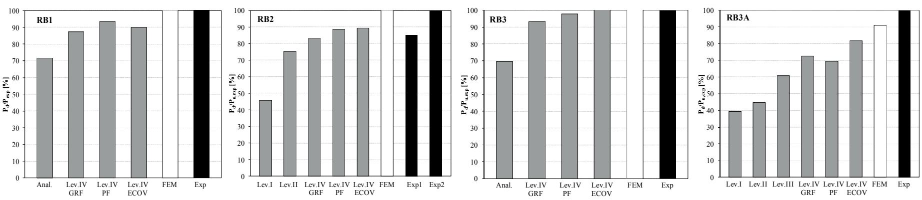


Fig. 1: Case studies: RB1, RB2, RB3, RB3A.



Anal.= analytical-from cross sectional analysis; FEM=from NLFEA without applying safety formats

Fig. 2: Design resistances P_d obtained analytically and numerically expressed as a percentage of the experimental ultimate load $P_{u,exp}$ for (a) RB1, (b) RB2, (c) RB3, (d) RB3A.

The results obtained are in good agreement with the philosophy of the MC2010 for all type of failure modes: level of approximation IV provides in fact substantially higher design resistances.

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