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ScienceDirect

Procedia Engineering 156 (2016) 515 – 522

Procedia Engineering

www.elsevier.com/locate/procedia

9th International Conference „Bridges in Danube Basin 2016“, BDB 2016

Shear resistance of existing concrete bridges

Radoslav Vida[a]*, Jaroslav Halvonik[b]

[a]*MSc., Faculty of Civil Engineering STU, Radlinského 11, Bratislava 810 05, Slovakia*
[b]*prof. MSc., Phd., Faculty of Civil Engineering STU, Radlinského 11, Bratislava 810 05, Slovakia*

Abstract

Simple comparison of models for assessment of shear capacity has shown that EC2 model provides significantly lower shear capacity than models based on the theory of allowable stresses. Therefore, some existing concrete bridges designed according to previous standards in Slovakia have lower loading capacity than is required if Eurocodes are used for their assessment. The paper deals with comparison of shear capacity of slabs without shear reinforcement determined by using several models which are currently available in EC2 format with capacity assessed by using theory of allowable stresses. The comparison is then extended to an actual bridge deck slab subjected to traffic load that is used for assessment of loading capacity as well as for design of new bridges.

Peer-review under responsibility of the organizing committee of BDB 2016

Keywords: shear resistance; bridge slab

1. Introduction

Loading capacity of a bridge is a very important indicator for road management which is used for decision to permit presence of abnormal vehicles on a bridge or for decision whether a bridge should be repaired, strengthened or even exchanged by a new one. With transition to the new European standards (Eurocodes) the procedure for assessment of loading capacity of existing bridges in Slovakia has changed. In order to maintain the three existing loading capacities, which are normal, exclusive and extraordinary, the traffic load models remained the same as in the past, but the bending, shear and torsion capacities shall be assessed using models introduced in current Eurocodes with level of safety required by EN 1990. Since previous standards for design of concrete bridges were based on the theory of

* Corresponding author. Tel.: +421 2 59 274 555.
E-mail address: radoslav.vida@stuba.sk

Peer-review under responsibility of the organizing committee of BDB 2016
doi:10.1016/j.proeng.2016.08.329

allowable stresses, the impact on the loading capacity can be very high and for shear and torsion even adverse. The problem of shear capacity is very hot nowadays in all countries where theory of allowable stresses has been used for design of bridges in past, e.g. Austria, Germany, Switzerland, Netherland or France. France has even decided to increase minimum shear capacity v_{min} of deck slabs subjected to concentrated loads (wheel load or axle load) in National Annex to EC2, in order to exclude shear reinforcement in bridge deck slabs for most of the cases. Road bridges designed according to old standard with TT or cellular cross sections are also in Slovakia without shear reinforcement in deck slabs, which may significantly influence their loading capacity if Eurocode rules are applied in their assessment.

2. Comparison of shear resistances

Comparison of shear capacity of reference slab without shear reinforcement has been carried out using several models. Current EC2 model has been taken as the basis. The second is EC2 model updated by a German group, the third model is based on the Critical Shear Crack Theory and the fourth Marí & Cladera model. All these models are based on the theory of limit states, are written in EC2 format and calibrated on the safety level required by EN 1990. Further model is ČSN 731201/86 (limit states) and the last one, for design of concrete bridges according to ČSN 736206/67, which is based on the theory of allowable stresses.

The tested structural element was slab with thickness of 280 mm and effective depth of 250 mm cast from concrete C30/37 (B400) and reinforced by reinforcing steel B500B. The amount of reinforcement was expressed by reinforcement ratio ρ, which was the main variable changing from 0.2 % to 2%. For simplification, the slab has been simply supported with an effective length of 4.0 m and loaded by uniformly distributed load.

The comparison of results has been carried out at the level of characteristic values, because theory of allowable stresses does not work with partial safety factors. The characteristic value of maximum load was determined using formula (1)

$$\frac{R_k}{\gamma_R} = \gamma_F . E_k \rightarrow E_k = \frac{R_k}{\gamma_R \cdot \gamma_F} \tag{1}$$

where: R_k is characteristic value of a resistance
γ_R – partial safety factor for resistance ($\gamma_R = \gamma_C = 1.5$)
E_k – characteristic value of load effect
γ_F –partial safety factor for load, $\gamma_F = 1.35$ (1.25 for ČSN 731201/86)

3. Models for assessment of shear resistance

3.1. Model EN 1992-1-1

Basic principles of current EC2 model has been set by Zsutty (1968). Zsutty proposed empirical approach on the basis of available test data for beams. The model has been later refined and adopted in Model Code 1990. The MC1990 model became the basis for current EC2 model. The design value of shear resistance without shear reinforcement can be determined by formula (2)

$$V_{Rd,c} = C_{Rd,c} .k.(100.\rho. f_{ck})^{1/3} .b.d \tag{2}$$

where: b is width of cross-section (b = 1m)
d – effective depth (d = 0.25 m)
$C_{Rd,c}$ – empirical factor, 0,18/γ_C
k – size effect, $k = 1 + (200/d)^{0.5} \leq 2.0$
ρ – reinforcement ratio
f_{ck} – characteristic strength of concrete