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PARTIAL SAFETY FACTORS FOR EVALUATION OF EXISTING BRIDGES ACCORDING TO EUROCODES

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Abstract: *In the paper, the partial safety factors for materials and load effects recommended according to Eurocode for bridge members subjected to bending are presented. In the frame of research activities of the Department of structures and bridges, the modified reliability levels for existing bridge evaluation were derived.*

Keywords: ***Bridge, existing structure, evaluation, partial safety factors.***

1. Introduction

The paper deals with the determination of the modified reliability levels for evaluation of existing concrete bridges. The theoretical approach taking into account the conditional probability was used. The modified levels depend on the age of the bridge and on the planned remaining lifetime and, moreover, influence the partial safety factors of materials and loads.

2. Reliability-based evaluation of existing concrete bridges

The reliability level for newly designed bridges for whole lifetime T_d ($T_d = 100$ years), which is represented by failure probability $P_{f,d}$ ($P_{f,d} = 7.2 \cdot 10^{-5}$) or by reliability index β_d ($\beta_d = 3.8$), is given in a Eurocode. However, the reliability level for evaluation of existing bridges for remaining lifetime t_r is not given in the Eurocodes.

Generally, the process of the existing bridge evaluation has various differences in comparison with the reliability assessment of newly designed bridge. In the case of the existing bridge structure, new information concerning the actual bridge condition is available which is unknown in the design phase. The extra information unknown in the design phase can be used not only for verification of the correct bridge performance or for detection of possible mistakes concerning the computational model assumptions or calculations but also helps to reduce some uncertainty related to the bridge member resistance and load parameters entering the evaluation process.

3. Reliability analysis

The failure probability $P_f(T)$, $P_f(t_{insp})$ can be obtained for normally distributed bridge element resistance R and normally distributed load effects Si using the following formulae for complete probability (Ditlevsen & Madsen, 1996)

$$P_f(T) = P\left[\max(S_i)(i = 1...N(T) > \mathrm{R}\right] = \int_{-\infty}^{\infty} \left(1 - e^{-L(T)\Phi\left(-\frac{x-m_S}{s_S}\right)}\right) \cdot \varphi\left(\frac{x-m_R}{s_R}\right) \cdot \frac{1}{s_R} dx \,. \quad (1)$$

The reliability level given by failure probability P_{ft} or by reliability index β_t depends just on the full remaining lifetime ($T - t_{insp}$) – from time of inspection t_{insp} to the end of the lifetime T. But

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practically, it is usually to evaluate the structure for shortening lifetime – us selected time interval. For example, it can be time between two inspections or if the structure does not satisfy for full remaining lifetime (T- t_{insp}). In this case, the structure can be evaluated on shortening remaining lifetime – planned remaining lifetime t_r.

4. Partial safety factors

New modified reliability levels for evaluation of existing bridges affect the values of partial safety factors for material resistance and for loads. In the practical design, the reliability levels are transformed to the design values of the material resistance and loads. In the partial safety factors method, the design values of material resistance and loads are determined by means of characteristic values and appropriate partial safety factors. Loads and resistance are treated as random variables.

4.1. Partial safety factors for material

Considering normally distributed random variable resistance, the partial safety factors of concrete and reinforcement (EN 1991-1-1, 2002) are given by formulae

$$\gamma_M = \frac{R_k}{R_d} = \frac{1-\beta_k \cdot v_R}{1-\alpha_R \cdot \beta_t \cdot v_R}. \tag{2}$$

4.2. Partial safety factors for loads

Permanent loads

The partial safety factors of permanent loads respecting the recommended modified reliability levels (expressed by β_t) considering normally distributed random variables were established using the formulae

$$\gamma_{G,i} = \gamma_{Sd} \cdot \frac{S_d}{S_k} = \gamma_{Sd} \cdot \frac{\mu_{G,i}.(1+\alpha_S \cdot \beta_t \cdot v_G)}{\mu_{G,i}} = \gamma_{Sd} \cdot (1+\alpha_S \cdot \beta_t \cdot v_{G,i}). \tag{3}$$

Variable loads

The variable loads are random variables with Gumble distribution according to STN EN 1990 (2009). The partial safety factors of variable loads respecting the recommended modified reliability levels (expressed by β_t) were also established using the formulae

$$\gamma_Q = \gamma_{Sd} \cdot \frac{S_s}{S_k} = \gamma_{Sd} \cdot \frac{\mu_Q \cdot \left\{1-v_Q[0{,}449+0{,}778 \cdot \ln(-\ln \Phi(\alpha_S \cdot \beta_t))]\right\}}{\mu_Q \left\{1-v_Q[0{,}449+0{,}778 \cdot \ln(-\ln(0{,}95))]\right\}}. \tag{4}$$

5. Conclusions

The paper presents the results of the research concerning the reliability levels for evaluation of existing bridges. The modified reliability levels for evaluation were determined and they depend on the bridge age and on planned remaining lifetime. The values of the levels are valid for members subjected to bending.

In final consequence, the lower reliability levels reflect into the partial safety factors of materials and loads. In the paper are shown determined partial safety factors for concrete γ_c, partial safety factor for reinforcement γ_s and partial safety factors for permanent loads $\gamma_{G,i}$ and variable loads $\gamma_{Q,i}$.

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