Reliability levels and partial safety factors according to Eurocodes for evaluation of existing bridges

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Summary

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. These levels were used for determining partial safety factors for materials and loads.

Keywords: Existing structure; bridge; reliability levels; 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 approach for reliability levels determination

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 (β_d = 3.80), is given in a Eurocode [1, 2]. However, the reliability level for evaluation of existing bridges for remaining lifetime t_r is not given in the Eurocodes. Some recommendations for evaluation of existing structures are given in [3].

From the bridge reliability view point, the reduction of the load and resistance parameter uncertainties decreases failure probability of existing bridge structure that means the possibility to admit lower reliability level for evaluation of existing bridge than it is in the case of newly designed one.

In the theoretical analysis, it is considered that the bridge inspection was performed at the time $t_{insp} < T$ during which the observed structural element was found to be without relevant failure due to overcrossing its limit states. This positive information expresses that resistance R of the observed structural element satisfies the following relation

$$R > max\,(E_i) \quad for \;\; i = 1 \ldots\ldots N(t). \tag{2}$$

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 E_i using the following formula for complete probability [7]

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$$P_f(T) = P\left[\max(E_i)(i=1...N(T)>\mathrm{R}\right] = \int_{-\infty}^{\infty}\left(1-e^{-L(T)\Phi\left(-\frac{x-m_E}{s_E}\right)}\right)\cdot\varphi\left(\frac{x-m_R}{s_R}\right)\cdot\frac{1}{s_R}dx, \tag{8}$$

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 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.

This approach is important for bridge owner, because it gives to owner ability to save the funds. The results are shown in Fig. 1.

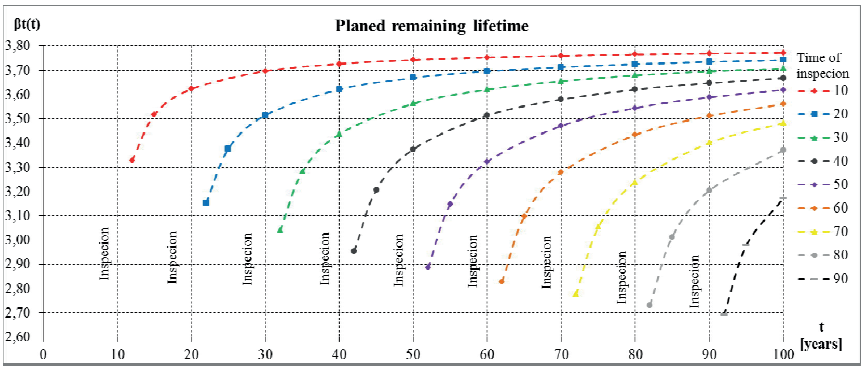

Fig. 1: The target reliability index β_t in dependence on time of inspection and planned remaining lifetime inspection

3. Partial safety factors

New modified reliability levels for evaluation of existing bridges given in Fig. 1 affect the values of partial safety factors for material resistance and for loads, also. In the practical design, the reliability levels are transformed to the design values of the material resistance and loads.

4. 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. Theoretical reliability basis for modification of partial safety factor method due to allowing for the major differences between existing bridge evaluation and design of the new ones is presented.

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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References

11 references are in the full paper.