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# Evaluation of elder and historical bridges

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**Abstract**

Bridge structures are designed on lifetime, which is given in standards and relevant time of design. The design lifetime of bridge structures was 80 years according to expired Slovak standard STN. New design lifetime of the newly designed bridges extends to $T_d$ = 100 years by establishing Eurocode STN EN. In the frame of research activities of Department of Structures and Bridges, the theoretical approach for evaluation of existing bridge structures was developed taking into account Eurocodes. However, the problems occur in the case of elder bridges with real lifetime over 100 years, or in the case of remaining lifetime extension over 100 years.

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## 1. Introduction

The bridge is a part of communication, in which it replaces an earth solid in place of some barrier. It is designed especially for trains, motor vehicles, pedestrians, animals (Green Bridge), bridging a watercourse, or for technical equipment (eg. the pipe bridge). Their primary function is mainly to ensure reliable operation of transport so not to be the limiting element of performance and capacity of traffic communication. Bridge owners and managers ensure the performance of its function by quality and qualified maintenance, repairs, or even capital-intensive reconstructions within a bridges management system that is in its administration.

In the case of bridges on the road net, the statistics database SRA (Slovak Road Administration) [1] and the available sources [2] shows that about 34.2% of the existing bridges do not satisfy the current criteria for reliability

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and 2.5% is in very poor and breakdown conditions. That represents about 195 bridges and directly about 15 are in breakdown conditions, which need to be reconstructed. In the case of railway bridges, the situation is very similar [3]. Approximately 27.9% of bridges are older than 77 years, and 17.8% are even older than 100 years, and 2.4% are in a bad technical condition. Within the ambit of modernization, the state of existing bridges, which are part of new corridors, is partially improved. This situation arises not only due to old way of the bridges management, but mainly due to insufficient funding, maintenance, repair and reconstruction of bridges.

## 2. Reliability of existing bridge structures

The reliability of newly designed structure is its ability to perform required functions throughout its lifetime. For existing bridge structures, it is valid that the reliability of existing bridge structures is ability to perform required functions under normal conditions of structure and maintenance, without the necessary repairs and reconstruction of the required technical condition during its remaining lifetime. The differentiation is based on considerations of the possible assumption of different reliability levels for newly designed structures and for existing structures.

In the theoretical approach, it is considered that the element has resistance R and it is exposed to load effect E. According to [4, 5], the reliability margin G is used in engineering probability method

$$R > \max(E_i) \tag{1}$$

The structure is reliable if $G \geq 0$. The failure occurs when maximal load effects max ($E_i$) exceed the resistance R.

The bridge inspection is considered to be performed at the time $t_{insp} < T$, during which an observed structural element does not exceed its limit states. The theoretical model allows for small deterioration due to the corrosion of structural steel or reinforcement. This positive information indicates that the resistance R(t) of the observed structural element satisfies the following relation

$$R\left(t_i\right) > \max\ \left(E\left(t_i\right)\right) \text{ for } i\ =\ 1\ \ldots\ldots\ N\left(t_{insp}\right) \tag{2}$$

Generally, failure probability of structure $P_f(T)$ can be expressed using formula for full probability in continuous form

$$P_f(T) = \int_{-\infty}^{\infty} \left( 1 - e^{-L(t)\cdot\left(1 - \int_0^t F_E(x,\tau)\cdot f(\tau)d\tau\right)} \cdot \int_0^t f_R(x,\tau)\cdot f(\tau) \right) d\tau dx \tag{3}$$

where φ is the density of standardized normal distribution N(0,1).

The failure probability $P_f(T)$ can be also obtained for a normally distributed resistance $R(t_i)$ of a bridge element and normally distributed load effects $E(t_i)$ using the following simplified equation for complete probability

$$P_f(T) = P\left[\max(E(t_i)(i = 1...N(T) > R\left(t_i\right)\right] = 1 - \int_{-\infty}^{\infty} F(x)\cdot \int_0^t \varphi\left(\frac{x - m_R(\tau)}{s_R(\tau)}\right)\cdot \frac{1}{s_R(\tau)}\cdot f(\tau)d\tau.dx \tag{4}$$

Probability condition that the structure survives up to time T, providing that it has survived to inspection time $t_{insp,}$ is equal to