Probabilistic Assessment of Historic Reinforced Concrete Bridge

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Abstract: More than 50 % of investments in construction are related to existing structures. This ratio is even greater for bridges due to continuous degradation, ever increasing traffic intensities and general lack of authorities for rehabilitations. That is why effective assessment of the load bearing capacity of existing bridges is becoming a crucial issue. Respecting this situation the paper is aimed to the probabilistic assessment of historic reinforced concrete bridge and the comparison of obtained results with the partial factor method.

Methods for assessment of existing bridges

In the Czech Republic the assessment of an existing road bridge is based on determination of load bearing capacity V_i in accordance with ČSN 73 6222:2013 which assumes three different types of traffic conditions:

- V_1 is determined for the crossing of a defined two-axle vehicle with a uniform loading representing common traffic,
- V_2 is determined for the crossing of defined single three-axle or single six-axle vehicle with restricted access of other vehicles (a more unfavourable vehicle is taken into account) and
- V_3 is determined for the crossing of a special nine-axle vehicle with defined track on a bridge and prescribed speed.

The most adverse transversal position of the vehicles for V_1 and V_2 and of the uniform load for V_1 is taken into account.

Partial factor method. Nowadays existing bridges are mostly assessed by the partial factor method. This method is calibrated for new structures and it can hardly reflect real bridge-specific conditions in reliability analysis. Conservative values of these factors have been intentionally proposed to cover most situations in design when information about real material properties and/or structural geometry are unavailable. Therefore, this method may be inappropriate for the assessment of an existing bridge.

Probabilistic method. Probabilistic assessment is based on target reliability index β derived from probability of failure P_f according to ČSN EN 1990:2010 and ČSN ISO 13 822:2015. Partial, reduction and combination factors, and characteristic values are not considered in the probabilistic analysis. Basic variables for assessment of load bearing capacities V_i are described by a probabilistic distribution with specified characteristics.

Assessment of load bearing capacity

The case study is focused on a single span bridge built in 1908. The bridge consists of four main longitudinal reinforced concrete girders stiffened by several transversal bracings, reinforced concrete slab and stone masonry abutment. The load bearing capacities V_i are assessed for the main load bearing structure (reinforced beams and slab). Statistical parameters of basic variables are based on previous experience and measurements.

Assessment by partial factor method. Assessment of the load bearing capacities V_i by the partial factor method is conducted for all the girders at each cross section in the grid of 0.5 m. The partial

factors for bridge design according to ČSN EN 1990:2010 are taken into account. The critical load bearing capacities for a critical cross section are shown in Table 1.

Table 1: Load bearing capacities V_i for the applied methods

	Load bearing capacity of the bridge [t]				
	Partial factor method	Probabilistic method			
		$\beta = 2.3$	$\beta = 3.1$	$\beta = 3.8$	$\beta = 4.3$
V_1	40	66	58	52	48
V_2	56	100	88	78	72
V_3	106	188	165	148	138

Assessment by probabilistic method. The probabilistic assessment is performed only in critical cross sections identified by the partial factor method due to computational demands. Table 1 provides the load bearing capacities V_i for different target reliability indices β. It appears that V_i decreases with increasing β.

Comparison of applied methods. It appears that the probabilistic method leads to 40 % higher results of the load bearing capacities V_i for a commonly accepted β = 3.8 (middle failure consequences) than the partial factor method. However, this may be different in case of severe conditions of a bridge. It is foreseen that the probabilistic method provides more accurate estimates of load bearing capacities than the partial factor method for new structures when statistical parameters of basic variables are available. Comparison of load bearing capacities V_1 for different target reliabilities β is shown in Fig. 1.

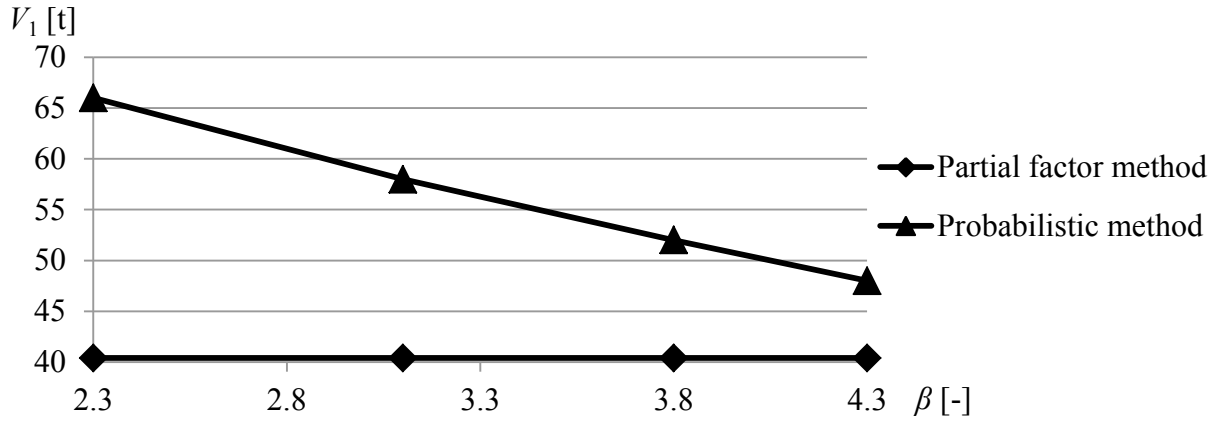

Fig. 1: Load bearing capacities V_1 for different reliability indices β

Conclusions

The assessment of the load bearing capacities of the historic bridge indicates that:

- Partial factor method for structural design is easier to compute than the probabilistic method, but in most cases it is overly conservative,
- Probabilistic method facilitates straightforward consideration of different target reliability indices,
- Load bearing capacities assessed by probabilistic method are about 40 % higher for the commonly accepted target reliability index 3.8.

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