Calibration of partial safety factors for the assessment of existing bridges

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Summary

The design codes use safety margins which, in general, exceed those that are reasonable to accept for the assessment of existing bridges. Knowledge abour strength and loading can be improved by further investigations and this can justify modifying partial safety factors. In this context, the Technical Centre for Bridge Engineering (CTOA) of the Technical Department for Roads, Road Safety and Bridges (SETRA) has initiated in 2009 a large study for the calibration of partial factors adapted to the assessment of existing bridges. Based on the reliability theory, its objective is to provide modified partial factors based on tabulated experimental in-situ results. The present paper highlights the preliminary results obtained for reinforced concrete slab bridges.

Keywords: Reinforced concrete slab, partial factor updating, reliability analysis.

1. Introduction

Bridge assessment is very similar to bridge design. The same basic principles lie at the heart of the process. An important difference nevertheless lies in the fact that when a bridge is being designed, an element of conservatism is generally a good thing that can be achieved with very little additional costs. When a bridge is being assessed, it is important to avoid unnecessarily conservative measures because of financial implications that may follow if a bridge is designated as sub-standard without good cause. The design codes show safety margins generally exceeding those reasonably acceptable for the assessment of existing bridges. Thus partial safety factors can be reduced while maintaining the same level of structural reliability. Knowledge of the structures can be increased by further investigations and this can justify modifying partial safety factors. Based on the reliability theory, its objective is to provide modified partial factors based on tabulated experimental in-situ results.

This paper is dedicated to the reliability analysis of reinforced concrete slabs as used for designing overpass bridges. They usually have rectangular cross-sections although other designs are available. The slabs are cast in-situ and may be composed of 2, 3 or 4 spans. Fourteen slabs have been considered in the present study. They have been designed according to EN 1992-1-1 and EN 1992-2 [1-2]. Minimal reinforcement areas are calculated at critical cross-sections.

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2. Calculation of a target reliability index

For the reliability analysis, the limit state function is derived from the design requirements:

$$g = \mathrm{M}_{\text{strength},k}\left(A_s\right) - \mathrm{M}_{\text{load},k} \quad (1)$$

The resisting moment is depending on the cross-section geometry, the bar characteristics (area, yielding stress, positioning), and the concrete properties (compressive strength).

To perform a reliability analysis, it is necessary to probabilistically model the various variables introduced in the limit state function (1). Four significant variables have been identified based on sensitivity factors. The target reliability index for a specific bridge is calculated with the minimal reinforcement area $A_s = A_{s,0}$ [3]:

$$\beta_0 = -\Phi^{-1}\left(P_{f,0}\right) = -\Phi^{-1}\left(\mathrm{P}\left(\mathrm{M}_{\text{strength}}\left(A_{s,0}\right) < \mathrm{M}_{\text{load}}\right)\right) \quad (2)$$

3. Partial safety factor updating

The approach consists of updating partial factors for each individual variables. For reinforced concrete slab bridges, four variables have been highlighted as significant and four tables have been given for different bias and coefficients of variation. When data are available at least for two variables, the partial factors from these tables are combined. This strategy is particularly interesting because it leads to introducing one table per variable, although, in theory, combinations must be analysed. In turn, it is essential to check that the reliability indexes when crossing the individual tables remain equal or larger than the initial target reliabilities. 95% fractiles are calculated for final partial factors updating (Table 1). Preliminary verification highlights that some case studies may introduce combinations that may induce allowable reliability indexes no more than 7% smaller than the target reliability indexes. Further investigations are still necessary to consolidate the tables for partial factor updating for reinforced concrete slab bridges as well as other studied ones.

Table. 1: Grids of partial safety factors for reinforced concrete slabs

		Coefficient of variation						Coefficient of variation		
	Bias	2%	5%	8%	10%		Bias	2%	5%	7%
Yield strength	0.900	1.132	1.323	1.726	2.069	Concrete density	0.900	1.351	1.374	1.433
	1.150	1.132	1.323	1.726	2.069		1.000	1.327	1.350	1.434
	1.200	1.132	1.323	1.726	2.069		1.100	1.308	1.350	1.436
	Bias	2%	3%	6%			Bias	10%	15%	20%
Reinforcement area	0.800	1.000	1.052	1.630		Fixed load moment	0.800	1.170	1.231	1.320
	0.900	1.000	1.052	1.630			1.000	1.170	1.244	1.351
	1.000	1.000	1.050	1.630			1.200	1.179	1.272	1.451

4. References

[1] EN 1992-1-1, *Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings*, European Standards, CEN, 2004.

[2] EN 1992-2, *Eurocode 2: Design of concrete structures - Part 2: Concrete bridges - Design and detailing rules*, European Standards, CEN, 2005.

[3] CREMONA C., *Structural performance: a probability-based assessment*, Wiley-ISTE, London, 2011.