Probabilistic Shear and Bending Resistance Models for Assessment of Reinforced and Prestressed Concrete Bridges

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Summary

This paper presents newly established probabilistic models of ultimate shear and bending resistance of typical reinforced and prestressed concrete bridge section. The models have been developed using recently collected data regarding variability of mechanical properties of concrete, reinforcing and prestressing steel, and also variability of the section dimensions. The uncertainty of the mathematical models, used for the calculation of the sectional response, has as well been taken into account. The proposed models have been developed to be used in the load capacity evaluation of existing bridges by means of probabilistic methods. However, they can also be used for the calibration of the partial safety factor in the existing design or assessment codes.

Keywords: Concrete bridges; reliability assessment; load capacity evaluation; shear resistance; bending resistance; probabilistic methods.

1. Introduction

The verification of a load carrying capacity of a bridge or other structures in accordance with the existing design or assessment codes is usually performed on the sectional level. In this approach the structure safety is checked comparing load effects in each particular component obtained from global structural analysis with its resistance calculated separately using sectional analysis. The resistance of a component is typically a function of the mechanical properties of materials and cross-sectional geometry. All these quantities are uncertain and should be considered as random variables. Consequently, the resistance of a component is also a random variable.

In the traditional design methods this uncertainty in the section resistance is taken into consideration by using conservatively defined characteristic or design values of the parameters in the calculation, which are generally much lower than the values observed in the reality. This is rather good approach in the design of new structures. However, in the assessment of existing structures it can be too conservative. Therefore, in the assessment of existing structures the use of probabilistic assessment methods is becoming more and more popular. These methods, however, requires the adequate probabilistic models of loads and resistances.

The probabilistic models presented in this paper have been developed using modern non-linear sectional analysis methods and more accurate strain-stress relationships for steel and concrete. Furthermore, they are based on the probabilistic models of the variation in sectional geometry and in the mechanical properties of steel and concrete that were developed based on recent data. Thus, the presented models are more suitable for the assessment of modern bridges (constructed during last 20-25 years). They can also be used for the calibration of the partial safety factor in the existing design or assessment codes.

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2. Developed probabilistic models for flexural and shear response

The resistance R can generally be considered as a function of nominal resistance R_n (determined from a code rule) and three factors: material properties M, fabrication (geometry) F, and analysis (professional) P. Tables 1 and 2 shows the statistics for all these parameters [1].

Table 1. Statistics of bending resistance for precast concrete bridges

Type of structure	Resp.	*FM*		*P*		*R*	
		Bias	COV	Bias	COV	Bias	COV
Reinforced concrete	M_y	1.17	6.5%	1.02	6%	1.19	9%
	M_u	1.11	5.5%	1.02	6%	1.13	8%
Prestressed concrete	M_y	1.04	4%	1.01	6%	1.05	7%
	M_u	1.04	3.5%	1.01	6%	1.05	7%

Table 2. Statistics of shear resistance for precast concrete bridges

Type of structure	Resp.	*FM*		*P*		*R*	
		Bias	COV	Bias	COV	Bias	COV
RC slabs - no stirrups	V_c	1.53	20.5%	1.20	10%	1.80	23%
Reinforced concrete slabs with stirrups	V_c	1.60	21.0%	1.20	10%	1.90	23%
	$V_u^{(a)}$	1.11	9.5%	1.075	10%	1.20	15%
	$V_u^{(b)}$	1.07	4.5%	1.075	10%	1.15	12.5%
Poorly prestressed concrete - w/stirrups	V_c	1.60	21.0%	1.20	10%	1.90	23%
	$V_u^{(b)}$	1.15	10.0%	1.075	10%	1.23	15%
Prestressed concrete girders - w/stirrups moderately prestressed	V_c	1.45	18.0%	1.20	10%	1.70	21%
	$V_u^{(b)}$	1.10	7.5%	1.075	10%	1.18	12.5%
	$V_u^{(a)}$	1.10	4.5%	1.075	10%	1.18	11%
Strongly prestressed concrete - w/stirrups	V_c	1.30	16.0%	1.20	10%	1.55	19%
	$V_u^{(a)}$	1.15	4.5%	1.075	10%	1.23	11%

Note: (a) low shear reinforcement area; (b) high shear reinforcement area.

3. Conclusions

In this paper short overview of the existing probabilistic models of ultimate shear and bending resistance of typical concrete bridge sections is made. Nevertheless, the major focus is placed on the probabilistic models recently developed by the authors. These new models have been developed using the most recent data regarding variability in mechanical properties of material, in the section geometry and also in the mathematical models of the sectional response used commonly to calculate the member resistance. The models have been originally developed for precast concrete highway bridges. Nevertheless, due to the fact that in almost all of the cases the failure of concrete bridge sections is governed by steel yielding and rupture, they are also adequate for bridges constructed on-site. Furthermore, due to the fact that the models have been developed using quite recent data they are representative for bridges not older than 20-25 years.

4. References

[1] WISNIEWSKI, D.F., Safety Formats for the Assessment of Concrete Bridges - with special focus on the precast concrete. Ph.D. Thesis, University of Minho, Guimarães, 2007