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DURABILITY ANALYSIS OF A REINFORCED CONCRETE MEMBER USING PROBABILISTIC SBRA METHOD

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1. Introduction

Proposed application of the SBRA (Simulation-Based Reliability Assessment) method, documented e.g. in [1], [2] demonstrates its potential in durability analysis of reinforced concrete beam situated in a such environment leading to a carbonation of the concrete. In a certain time, the carbonation front reaches the reinforcement and the corrosion process of the reinforcement starts. The reliability of the beam from the viewpoint of bending is evaluated.

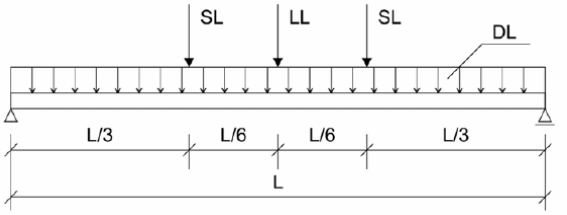

Fig. 1 Scheme of a simply supported reinforced concrete beam

2. Solved study

2. 1. Input data

The scheme of the beam is shown in Fig.1. The beam is loaded by three random variable independent loads (dead load, long-lasting load and short-lasting load) which intensities vary in time. The beam is reinforced by five reinforcing bars in the tension area. Material and geometrical characteristics are considered as random variables too.

2. 2. Calculation

The potential of Monte Carlo simulation allows in each simulation step to analyze an interaction of loads, geometrical characteristics, material characteristics and other possible quantities (see e.g. [3]-[6]) according to appropriate mathematical model. The model used in this study comes out of the limit equlibrium method, when elasto-plastic capacity of a concrete is considered (see e.g. [7]-[9]). The magnitudes of loads are supposed to be growing in time. Thus, the corresponding load effect (extreme bending moment) is growing in time too. The carbonation of concrete and consequent corrosion of reinforcements lead to decreasing bending resistance of the beam. The mutual relationship of the load effect and the bending resistance is shown in Fig. 2 on the left. The process of corrosion can be reduced if appropriate secondary protection is performed. The case, when two secondary protective paintings are applied (in the times $t = 35$ and 55 years), is shown in Fig.2 on the right. The filled regions in Fig.2 indicate time intervals where the member does not fullfil corresponding reliability criterion.

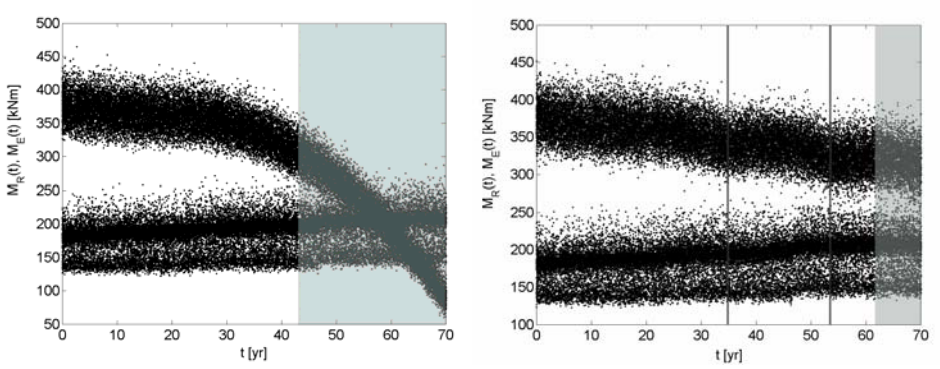

Fig. 2 The time dependency of the resistance and the load effect: (a) member without secondary protection, (b) member with two secondary protective paintings

The evaluation of reliability function $RF(t) = R(t) - E(t)$, where $E(t)$ is time variable load effect and $R(t)$ is time variable resistance, leads to determination of probability of failure $P_f(t)$. The calculation of the probability of failure $P_f(t)$ in suitable times allows to plot a curve of probability of failure. The resulting curves corresponding to the two cases shown in Fig. 2 are indicated in Fig. 3. The filled regions in Fig. 2 correspond to these resulting curves.

2. 3. Results

From the Fig. 3 on the left is clear that the beam is safe (from the viewpoint of bending) in the time interval $t = 0..43$ years (the target probability is considered $P_d = 0.00007$). The Fig. 3 on the right shows safe time interval $t = 0..63$ years. The two applied secondary protective paintings allow to enhance lifetime of the beam about 20 years against the case without secondary protection.

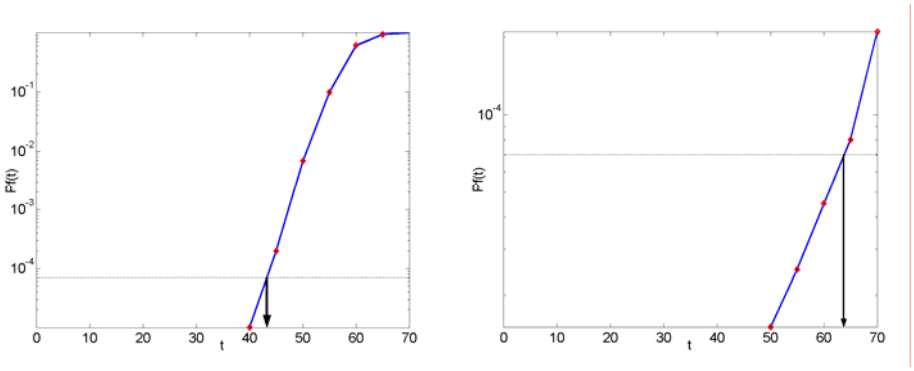

Fig. 3 The curves of probability of failure: (a) member without secondary protection, (b) member with the two secondary protective paintings

3. Conclusion

The presented paper briefly demonstrates potential of fully probabilistic approach in durability analysis of the reinforced concrete beam, where load effect as well resistance are random variables with probabilistic functions varying in time. The lifetime estimation can be updated by appropriate inspections and corresponding protections or repairs can be then effectively suggested. In this study there was used only theoretical model of carbonation of concrete, corrosion of reinforcements and secondary protection. But potential of probabilistic approach based on Monte Carlo simulations allows use models derived from appropriate tests (see e.g. [11]-[13]).

Acknowledgements

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References

[1] Marek, P., Guštar, M., Anagnos, T. Simulation-Based Reliability Assessment for Structural Engineers. CRC Press, Inc., Boca Raton, Florida, 1995.

[2] Marek, P., Brozzetti, J., Guštar, M., Tikalsky, P., editors. Probabilistic Assessment of Structures using Monte Carlo Simulation. Background, Exercises, Software (Second edition). ITAM Academy of Sciences of Czech Republic, Prague, Czech Republic, 2003.

[3] Korouš, J., Marek, P. Probabilistic Modeelling of Corrosion Process and Inspection using SBRA Concept. Proc of International Workshop Risk based inspection and maintenance planning. Zurich, 2001.

[4] Bradáč, J., Marek, P., Žídková, P. Durability of a concrete beam. Paper in the book [3].

[5] Pustka, D., Application of the Reliability Assessment Method SBRA in framework of Steel, Concrete and Composite Structures. PhD. Thesis. Technical University of Ostrava, Czech Republic, 2002.
[6] Tikalsky, J. P., Pustka, D., Marek, P. Statistical Variations in Chloride Diffusion in Concrete Bridges ACI Structural Journal, 2005, roč. 102, č. 3, s. 481-486.
[7] ČSN EN 1992-1-1 Eurokód 2: Navrhování betonových konstrukcí - Část 1-1: Obecná pravidla a pravidla pro pozemní stavby.
[8] Lawrence, M, John Purkiss Concrete Design to EN 1992. 2nd. ed. London : Butterworth-Heinemann, 2006. ISBN 978-0-75-065059.
[9] Procházka, J., Štěpánek, P., Krátký, J., Kohoutková, A., Vašková, J. Navrhování betonových konstrukcí 1. Prvky z prostého a železového betonu. ČBS, 2005.
[10] Bujňák, J., Furtak, K., Vičan, J. Navrhovanie konštrukcií podľa Eurokódov Žilina : Žilinská univerzita, 2003. ISBN 80-8070-078-8.
[11] Emmons, P. H., Drochytka, R., Jeřábek, Z. Sanace a údržba betonu v ilustracích. Brno : CERM, 1999. ISBN 80-7204-106-1.
[12] Priganc, S., Terpáková, E. Diagnostika prvkov betónových konštrukcií Košice : TU Košice, 2003. ISBN 80-7099-937-3.
[13] Bilčík, J. Sanácia betónových konštrukcií Bratislava : JAGA group, 1996. ISBN 80-967095-7-7.

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Anotace

Článek se zabývá analýzou trvanlivosti prostě podepřeného železobetonového nosníku, jenž je umístěn v prostředí vedoucím ke karbonataci betonu. Jakmile karbonatace dosáhne výztuže, započíná korozní proces této výztuže Spolehlivost uvažovaného nosníku je vyšetřována metodou SBRA (Simulation-Based Reliability Assessment) založenou na Monte Carlo simulační technice.