Semana da Escola de Engenharia
October 24 - 27, 2011

ADVANCED EVALUATION OF CIVIL ENGINEERING STRUCTURES BEHAVIOUR

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KEYWORDS

Structural behavior; Bayesian inference; Numerical identification.

INTRODUCTION

The development, maintenance and operation of infrastructures are central tasks on continued success of society. The decision processes involved in these tasks concern all aspects of managing. The main objective from a societal perspective is to improve the quality of life of individuals both for present and future generations. On the other hand, from the owner point of view, the main objective is to maximize the economic return of investments.

If all aspects of decision problem would be known with certainty, the identification of optimal decisions would be straightforward by means of traditional cost-benefit analysis. However, our understanding of problems involved in decision analysis is often far less than perfect. In fact, the decision problem in engineering is subject to significant uncertainty.

Infrastructures are constituted by civil engineering structures disposed in a series system. Accordingly, in any time instant, to decide about the optimal decision, the operator should evaluate each structural behavior. A structural analysis based in a probabilistic model is always preferable than in a deterministic one, as all possibilities of structural behavior are considered. Accordingly, within this research project, a methodology for advanced civil engineering structures evaluation, which scheme is presented in Figure 1, was developed.

METHODOLOGY

This methodology starts with measured data from real structure. The first step consists in calibrating a numerical model. In order to do that, critical parameters, the ones that present higher influence on structural behavior, are modified in an automatic way so that obtained numerical results best fit measured data (numerical identification).
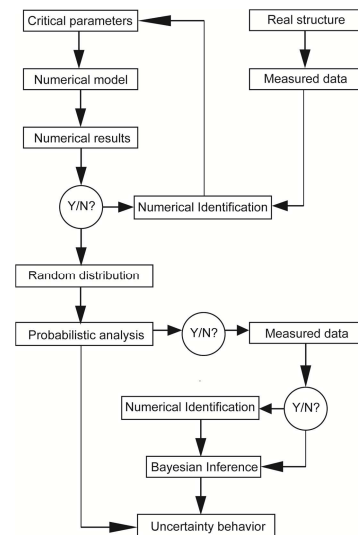

Figure 1: Developed methodology

In order to execute it, the fitness function value, which indicates the distance between numerical and measured data, is minimized. To perform that, it will be used an optimization algorithm designated by evolutionary strategies. The algorithm precision is proportional to the global error, obtained by considering both numeric and experimental epistemic uncertainty sources.

The randomness in each critical parameter is introduced by means of a distribution function. The mean value is considered to be the one, previously obtained from numerical identification, while the coefficient of variation is defined according to existent bibliography (JCSS, 2008). A full probabilistic analysis is then developed, being the structural behavior, evaluated from a probabilistic point of view.

In some situations, additional measurements are performed during the structure life cycle. This information can be considered in previous developed probabilistic numerical model, by using a Bayesian inference procedure. Accordingly, previous defined distribution function parameter values, and, indirectly, the structural behavior, are automatic inferred.

The output of developed methodology is an updated probabilistic numerical model which takes into consideration all uncertainty types. Such model is then used to interpret the civil engineering structure behavior by obtaining updated resistance curves.

CONCLUSIONS AND FURTHER RESEARCH

The developed methodology is applied within this research project in the study of the behavior of two sets of reinforced concrete beams. Figure 2 presents the numerical and experimental failure mode, bending with concrete crushing, for pinned-pinned beams batch.
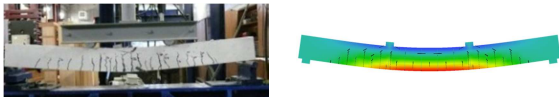

Figure 2: Tested beams (Matos *et al.*, 2010)

Principal conclusions are: (1) Developed methodology is working with success; (2) Very good curve fitting can be achieved with numerical identification (Figure 3); (3) Model parameters can be automatic inferred; (4) Results from probabilistic analysis are improved with model identification and Bayesian inference procedures.
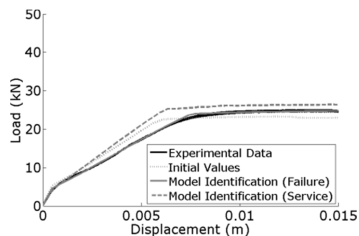

Figure 3: Numerical identification (Matos *et al.*, 2011)

The former conclusion is expressed in Table 1, which indicates the resistance curve parameters and respective improvement by comparing with experimental data. The methodology is also employed in the evaluation of laboratory tested composite beams. Further, it will be used in the evaluation of a real bridge structure.

Table 1: Probabilistic evaluation: Failure load

Numerical Model	μ [kN.m]	σ [kN.m]	Improvement [%]
Nominal Values	27.791	4.190	92.818
+ Bayesian Inference	29.072	3.790	96.119
Model Identification	28.493	3.837	94.582
+ Bayesian Inference	31.691	3.710	97.090

The possibility of evaluating the measured structural response, or to preview it by an extrapolation process, using a probabilistic numerical model which can be continuously updated with time, constitutes a very important tool for infrastructure management.

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ACKNOWLEDGMENTS

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