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UNCERTAINTY EVALUATION OF CIVIL ENGINEERING STRUCTURAL BEHAVIOR

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INTRODUCTION

The development and management of the societal infrastructure is a central task for the continued success of society. The decision processes involved in this task concern all aspects of managing and performing the planning, investigations, designing, manufacturing, execution, operations, maintenance and decommissioning of objects of societal infrastructure, such as traffic infrastructure, housing, power generation, power distribution systems and water distribution systems. The main objective from a societal perspective by such activities is to improve the quality of life of the individuals of society both for the present and the future generations.

Decision making for the purpose of assessing and managing the risks should be seen relative to the occurrence of hazards, i.e., risk management in the situations before, during and after the event (JCSS 2008). This is because the possible decision alternatives or boundary conditions for decision making change over the corresponding time frame. Before a hazard occurs the issue of concern is to optimize investments into so-called preventive measures such as e.g. protecting societal assets, adequately designing and strengthening societal infrastructure as well as developing preparedness and emergency strategies. During the event the issue is to limit consequences by containing damages and by means of rescue, evacuation and aid actions. After a hazard, the situation is to some degree comparable to the situation before the event; however, the issue here is to decide on the rehabilitation of the losses and functionalities and to reconsider strategies for prevention measures.

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, due to the fact that our understanding of the problems involved in the decision problem is often far less than perfect and that we are only able to model the involved processes of physical phenomena as well as human interactions in rather uncertain terms, the decision problems in engineering is subject to significant uncertainty. Due to this, it is not possible to assess the outcomes of decisions in certain terms. There is so, no way to assess with certainty the consequences resulting from decisions we take. Accordingly, there is not one certain optimal decision but a set of feasible decisions which are acceptable. However, this interval can be reduced as the knowledge about studied societal infrastructure increases. Analyzing Figure 1, by minimizing such interval, the possibility of taking the right decision, the one that maximizes the respective utility, is higher.

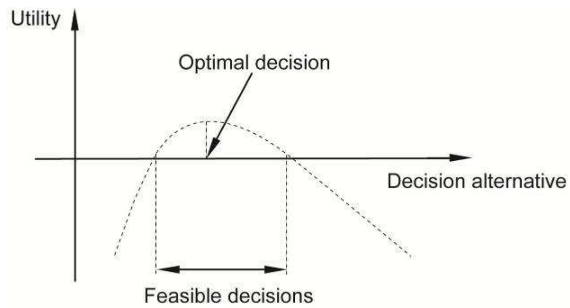


Figure 1:Decision vs. Utility

A methodology for the evaluation of any societal infrastructure that considers both uncertainty and variability sources, present in numeric and experimental data, is developed within this research. Such methodology is based in a numerical model, which can be used to support any decision before, during and after the hazard, and that can be updated and calibrated in a continuous way as more information regarding the studied infrastructure is collected.

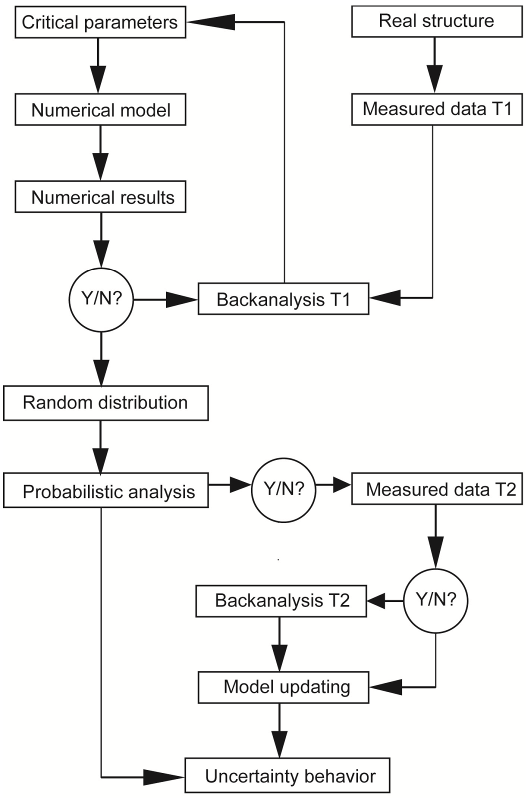
METHODOLOGY

Figure 2 presents a flowchart of developed methodology. In order to evaluate the behavior of studied infrastructure, a numerical model is first developed and calibrated with measured data, collected by any implemented monitoring system (measured data T1). In order to do that, critical parameters, the ones that present a higher influence on the structural behavior, are continuously modified so that obtained numerical results best fit measured data. This process is designated by structural identification (St-Id), and defined here as backanalysis T1, was first introduced by Liu and Yao (1978).

The backanalysis process is based in a function, designated by fitness function, which determines the difference between numerical results and experimental data:

$$f = \sum_{i=1}^{n} \sqrt{\left(y_i^{*num} - y_i^{*\exp}\right)^2} \Big/ \max\left(y_i^{*num}\right) \qquad (1)$$

The aim of backanalysis T1 is to minimize fitness function (1). However, such function presents, in several situations, a high non linearity and an extremely large number of critical parameters to be optimized. Minimization process, in this situation, gets longer, presenting a high computational cost, and obtained results that are far from the most suitable ones. In order to overpass such difficulties, different kind of optimization techniques were first tested and the most appropriate one is then chosen.



Figures 2: Developed methodology

In a further step, a random distribution is considered for each critical parameter. The mean value is, in this situation, the one obtained from backanalysis T1, being, the standard deviation defined according to existent bibliography. A full probabilistic analysis is finally developed, being, the structural behavior, evaluated from a probabilistic point of view.

In some situations there exist additional measurements (measured data T2) that may be considered in previous developed numerical model. In order to perform that, a Bayesian inference concept is introduced (Bernardo and Smith 2004):

$$h(\theta|x) = \frac{f(x|\theta)\cdot h(\theta)}{\int_{\theta} f(x|\theta)\cdot h(\theta)\,d\theta}, \ \theta \in \Theta \qquad (2)$$

where h(θ) indicates the prior distribution, f(x|θ) the likelihood and h(θ|x) the posterior distribution. The prior represents the existent model, the likelihood the collected data and the posterior the updated model. The critical parameters distribution and, consequently, the numerical model are updated by using expression (2).

Further, a full probabilistic analysis is developed. Sometimes, measured data T2 is considered as indirect. In other words, in such situations, such measurements correspond to parameters that are output of developed numerical model. In these situations a backanalysis T2 may be executed. For these situations, the numerical model is updated in an indirect way. After critical parameters distributions being correctly defined, it is possible, again, to develop a full probabilistic analysis.

The developed methodology will be used with a set of reinforced concrete and composite beams that were tested till failure in laboratory, and, also, a real structure, a bridge, that was submitted to a load test (Figure 3). In this paper it will be presented the results obtained from reinforced concrete beams.


Figure 3: Örnsköldsvik Bridge (Sweden)

CONCLUSIONS AND FURTHER RESEARCH

Part of developed methodology, respectively backanalysis T1 and the full probabilistic analysis, were already tested with success. However, there is some research that must be further developed. It is necessary to choose the most suitable optimization algorithm for backanalysis procedures, and the implementation of backanalysis T2. The developed method was only applied with a set of reinforced concrete beams, tested at laboratory. It is proposed to apply it with a set of composite beams and with a real structure.

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