Uncertainty Quantification and Calibration of Dynamic Models of Existing Bridges Considering Difference of Modeling Strategy

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Summary

This study presents one of strategies to deal with the uncertainties in the Model Verification and Validation for the modeling of existing structures by applying the Bayesian uncertainty quantification (UQ) and model calibration. Authors especially verified how the uncertain model parameters could be calibrated in different modeling strategies that must be determined by one who are constructing the model based on the purpose of numerical analysis. The target bridge was an existing seismic isolated bridge, and compared the performance of UQ and calibration between two finite element models; a detail and a frame models, using measured dynamic characteristics. It was then shown that the performance of UQ varied with the difference of the model because the description of parameters and their prior uncertainties were different. The results then provided some requirements in the nominal modeling of structures for appropriate Model V&V procedure.

Keywords: Model V&V, uncertainty quantification, model calibration, existing bridges, finite element model, dynamic measurement data

1. Introduction

The validated modeling of existing structures takes important role in working on existing bridges; such as the maintenance and repair, the reinforcement/retrofit design, and so on. However, the properties of existing structures have a lot of uncertainties due to deteriorations, seismic loading histories, and the other factors during their operations. One of strategies to deal with such uncertainties in the modeling is the Bayesian uncertainty quantification (UQ) and calibration of the model parameters. In this study, authors verified how the uncertain model parameters could be calibrated in different modeling strategies that must be determined based on the purpose of numerical analysis.

2. Target bridge and data acquisition

The target structure in this study was an existing seismic isolated bridge consists of two steel box-girders and a RC slab with the span of 50.8m. A picture of the bridge is presented in Fig.1. The dynamic characteristics and their statistical properties, which were the comparative features here, were identified from the dynamic data acquired by the impact tests, whose experimental configuration are also shown in Fig.1.

3. Uncertainty quantification and model calibration for two FE models

Two finite element models were constructed for the verification; one was a detail model using the shell-element for describing details of structural members as shown in Fig.2, the other was a frame model shown in Fig.3, which was used in the seismic reinforcement work conducted before. The UQ procedure was then applied to each modeling case using the resonant frequencies identified in the impact tests. Figures 4 and 5 are the estimated posterior distributions of model parameters that showed the sensitivities to the resonant frequencies in the global sensitivity analysis. Notice that the range of x-axis in each figure is just the range of the uniform prior distribution. In both cases, the parameters for the bending stiffness of superstructure; Young's modulus of the steel girders E_S in the detail model, and the stiffness of beam element E_B and the second moment of area I_B in the frame model, showed lower mean values than their nominal values. On the other hand, the parameters for the mass of superstructure; the density of the RC slab D_C and the weight per length of the beam W_B, showed the higher mean values. The calibrated models in both cases gave totally lower resonant frequencies than nominal ones, and the agreements with the experimental results were improved.

4. Conclusion

It was shown that the description of model parameters and their uncertainties was varied by the modeling strategy, and it influenced on the performances of the UQ and the model calibration. In addition, it was also considered that, when the nominal model was constructed so that the variability of comparative features under the prior uncertainty overlapped the experimental distributions, the uncertainties of model parameters could be successfully reduced and quantified by the posterior distributions.

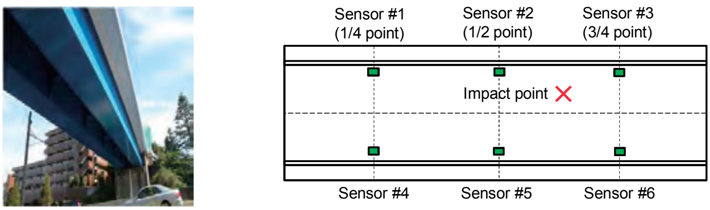


Fig. 1: The target bridge and the impact test configuration

Fig. 2: Detail FE model

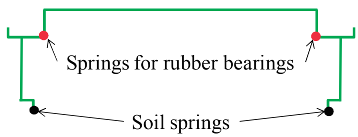
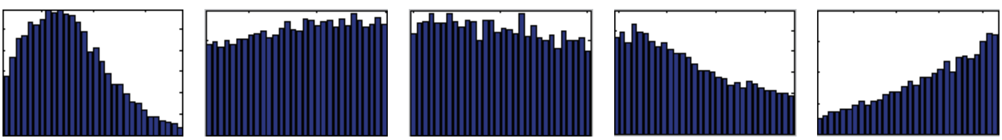
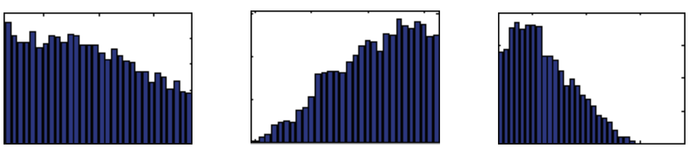


Fig. 3: Description of the frame model



E_S (μ=190.7GPa) D_S (μ=7.75g/cm3) v_S (μ=0.298) E_C (μ=20.8GPa) D_C (μ=2.56g/cm3)

Fig. 4: Posterior distributions of model parameters in the detail model



E_B (μ=197.9GPa) W_B (μ=10.11g/cm^3) I_B (μ=0.511m^4)

Fig. 5: Posterior distributions of model parameters in the frame model