Short-term Research Visits (Project No.:2019S-01)

Project name: Experimental and Analytical studies of data-driven reduced-order modeling techniques for detection of changes in Full-Scale Steel Moment Resisting Frame Building under Extreme Events
Principal Investigator: Mohamed Hassan Abdelbarr
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Name of DPRI collaborative researcher: Yoshiki IKEDA
Research period: January 3, 2020 ~ January 10, 2020
Research location: Ikeda laboratory, Disaster Prevention Research Institute, Kyoto University
Number of participants in the collaborative research: 3 (DPRI: 1 non-DPRI: 2)
- Number of graduate students: 0

Research report

(1) Purpose

The research project was motivated by the need to develop a toolkit of methods for change/damage detection and health monitoring of civil structures subjected to dynamic environments. The project will address the need to develop accurate numerical models based on realistic complex full-scale civil structure, exhibiting linear or possibly nonlinear behavior, in either existing or conceptual design stages.

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(2) Summary of research progress

In the present study, a high-fidelity 3D finite element model of a 52-story high-rise office building was created based on data acquired from state-of-the-art strong-motion accelerometers located at each floor. The detailed 3D model was used to develop different data-driven, input-output, reduced-order models based on non-parametric identification approaches (ChainID) that have been successfully applied to analytical and experimental data. The applied approach discussed here doesn't need to have prior knowledge of the system characteristics (i.e., linear versus nonlinear). It applies to linear, nonlinear nonhysteretic, and hysteretic systems, with no restriction on the type of probing signal used for identification purposes. However, it is limited to structures with chain-like topology.

Currently, the approach under discussion is implemented on actual data generated by the full-scale structure. The building and testing of a sophisticated, full-scale 18-story moment-resisting frame structure from E-defense, in realistic conditions until collapse provides an excellent opportunity for investigating generic types of complex changes/damages widely encountered in civil structures during earthquakes. Consequently, for such structures, the combination of experimental and numerical data analysis helps to improve the identification, localization, and quantification of damage/change in the structural systems.

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(3) Summary of research findings

Input-output data from a 52-story building structure under white noise base excitation and 18-story E-defense building structure were used to develop reduced-order models, for different structural configurations, by implementing two different approaches: the non-parametric chain-like system identification approach (ChainID) which is the focus of this study, and a global identification approach (NExT/ERA). The change in the estimated mass-normalized stiffness-like coefficients of the reduced-order models were employed to detect and locate the actual structural changes introduced in the building structures. The results of this study showed that the significant changes identified in the stiffness-like parameters of the reduced-order models built using the ChainID approach could be correlated to the presence and location of the actual physical changes/damage introduced into the building structure, even in the presence of modeling, measurement, and data processing

errors, using reduced-order representations.

The results of this study demonstrate that the structural health monitoring methodology presented herein is capable of accurately detecting, locating, and quantifying structural changes/damage in monitored systems, provided the needed data set is available. The advantage of using the simulated data utilized in this study was to test different damage scenarios without the need of introducing actual damage in the physical structure. However, the important effects of operational and environmental conditions and underlying damage mechanisms are not considered in this study to assess the potential of the subject methodology for field applications.

(4) Publications of research findings

We are currently working on publications.