# Identification of Base-Isolated Structures Considering Nonlinearity and Identifiability

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It is well documented that the rubber bearings of base-isolated structures possess strong hysteretic nonlinearity during severe earthquakes in both site and experiment observation. This thesis is devoted to discuss and present identification methods for base-isolated structures considering nonlinear behavior and identifiability in order to track and monitor the state and characteristics of the base isolation layer.

Firstly, a new method for estimating the restoring force estimation of the isolation layer in a based-isolated system is proposed. The whole base-isolated structure is separated into two substructures, the linear superstructure and the nonlinear isolation layer. The hybrid motion equation involving the modal coordinates of the superstructure and the physical coordinates of the isolation layer is derived by component mode synthesis. This significantly reduces the number of unknown parameters after the mode shape information of the superstructure is substituted and makes it possible to identify the isolation layer directly and locally. The effectiveness of this method is validated in a simulation example. It is shown that the proposed method is not sensitive to the mass distribution and the expanded mode shapes but will be scaled by the total mass.

Secondly, identifiability condition for substructural identification is investigated in the framework of closed-loop systems by spectral analysis and parametric methods. Substructures governed by linear and nonlinear feedback laws are both considered. The feedback law mechanism is shown to have greater influence on identifiability than does the model structure or the identification method.

And we investigate the performance of reverse path methods applied to identify the underlying linear model of base-isolated structures. The nonlinear rubber bearings are considered as nonlinear components attached to an underlying linear model. The advantage of reverse path formulation is that it can separate the linearity and nonlinearity of the structure, extract the nonlinearity and identify the underlying linear structure. The difficulty lies in selecting the nonlinearity function of the hysteretic force due to its multi-valued property and path-dependence. In the thesis, the hysteretic force is approximated by the polynomial series of displacement and velocity. The reverse path formulation is solved by Nonlinear Identification through Feedback of Output (NIFO) methods using least-square solution. Numerical simulation is carried out to investigate the identification performance.

Finally, the proposed restoring force estimation method is applied to identify real base-isolated structures. The restoring force of the isolation layer is estimated reasonably. The difficulty lies in how to describe the state of a nonlinear device of a real structure. The amplitude-dependent equivalent stiffness and damping coefficient are adopted to describe the nonlinearity of the isolation layer. The identified results by the proposed method reconfirm the experimental observation of nonlinearity in the isolation layer made up of rubber bearings.