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Topology Optimization of Structural Stiffness Distribution under Stochastic Seismic Loading

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ABSTRACT
With the improvement of living requirements, serviceability and habitability issues, namely occupant comfort, must be considered when designing structures besides efficiency and effectiveness, especially for high-rise and medical buildings. Acceleration is unanimously recognized as the better-related response parameter to occupant comfort than interstory drift. Therefore, one of the main serviceability requirements is acceleration control. Stiffness distribution is of great significance to a structure's behavioral characteristics under seismic lateral loading, which is a typical stochastic procedure. Under minor seismic excitation, acceleration minimization is required besides satisfying interstory failure demand. Present study concentrates on optimizing the stiffness distribution to minimize the acceleration response of frame structures, subjected to random earthquake input represented by the Kanai-Tajimi model. The objective and constraints of the stiffness distribution problem are too complicated to be ensured continuous or differentiable. With the development of optimization, many efficient algorithms have been proposed to solve this kind of highly non-convex problems with nonlinear constraints. Among which, generalized pattern search (GPS) algorithm does not require gradient value for optimization direction. In the present study, optimization approaches are formulated using the generalized pattern search algorithm to conduct drift and acceleration minimization for its easy convergence, computational efficiency, and convenient application. Optimization results are compared with solutions subjected to equivalent static loading, and white noise input. The numerical examples involve a full-scale three story steel frame structure and a scaled down six story structure. The comparisons indicate that higher modes play a key role in minimizing acceleration, while the first mode contributes most to optimizing interstory drift. The difference of interstory drift optimized results under random excitation and equivalent static loading does not exceed 10%. Besides, optimized acceleration value decreases rapidly with the first 10% drift constraint looseness. Scilicet, engineers can significantly decrease acceleration response with relatively minor sacrifice of drift in practice.

KEYWORDS: *Stiffness distribution, Structural optimization, Stochastic excitation, Generalized pattern search*