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SHAPE OPTIMIZATION OF SHEAR PANEL DAMPER UNDER CYCLIC ELASTO-PLASTIC BEHAVIOR

Sho KOZONO*[1], Masatoshi SHIMODA[2] and Yang LIU[3]

[1] Graduate Student, Toyota Technological Institute, 2-12-1, Hisakata, Tempaku-ku, Nagoya, Japan, sd13414@toyota-ti.ac.jp

[2] Professor, Toyota Technological Institute, shimoda@toyota-ti.ac.jp

[3] Post-Doctoral Researcher, Toyota Technological Institute, liuyang@toyota-ti.ac.jp

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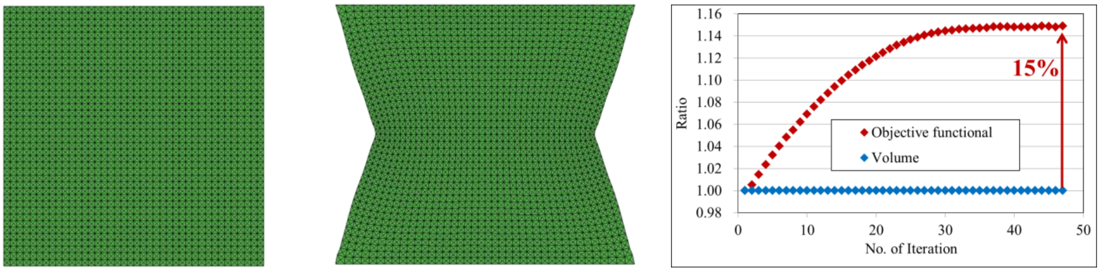
ABSTRACT

Shear Panel Damper (SPD) has been applied to the civil engineering structures such as bridges and buildings for the dissipative response against seismic energy by an earthquake. The SPD made of low yield steel can dissipate seismic energy by plastic deformation, and has been received considerable interest in the last two decades. Most of previous research for SPD showed the optimal location or the numbers to improve dissipative capacity. To satisfy a design condition, the best shape was chosen from the combinations in prepared models by repeating an experiment or Computer-Aided Engineering analysis. [1] There are few reports on shape optimization for SPD. Liu reported optimal shape design methodology by using the Response Surface Methodology (RSM) and the Design of Experiment (DOE) technique. [2] It is categorized into the parametric shape optimization method. There are no reports on the non-parametric shape optimization method for SPD. The distributed-parameter shape optimization method for elastic problem was presented by Azegami and Shimoda. [3][4] Ihara expanded it to elasto-plastic problem. [5] The behavior after yielding is extremely important for shape design of SPD under cyclic load. In this paper, we present a distributed-parameter shape optimization methodology for the design of low yield steel SPD. The optimization was carried out to maximize the total plastic work under a volume constraint. We used the accumulated equivalent plastic strain energy as the shape variation index instead of the theoretical sensitivity function involving the adjoint variables for simplicity since it takes too much computational cost to calculate the adjoint variables under cyclic elasto-plastic loading. We used the traction method as re-shape technique. With the traction method, finite element nodes are properly mapped, while maintaining their regularity.

Fig. 1 shows the optimization results of SPD. A cyclic shear enforced displacement was applied at the top with the bottom was clamped. The constant volume condition was applied. The initial and obtained shapes are shown in Fig. 1(a) and (b), respectively. Fig. 1(c) shows the histories of objective functional and volume. The total plastic work was maximized by 15% of the initial shape while satisfying the volume constraint.



(a) Initial (b) Optimal (c) Histories

Fig. 1 Optimization results of SPD

In summary, a non-parametric shape design optimization method for designing SPD was presented, where accumulated equivalent plastic strain energy was employed as the shape variation index for simplicity. The traction method was also employed to maintain the mesh regularity. With this method, the optimal smooth shape of SPD can be obtained without any shape parameterization, and as the dissipative capacity against seismic energy was improved by 15%.

REFERENCES

[1] K. Tanaka, Y. Sasaki, Hysteretic performance of shear panel dampers of ultra-low-yield-strength steel for seismic response control of buildings, Twelfth World Conference on Earthquake Engineering, New Zealand, 2000

[2] Y. Liu, M. Shimoda, Multi-objective design optimization of the low-yield steel shear panel damper, 10^{th} World Congress on Computational Mechanic, 2012.

[3] H. Azegami, Zhiqiang Wu, Domain Optimization Analysis in Linear Elastic Problems, JSME International Journal Series A, 39 (2), 1996, pp. 272-278.

[4] M. Shimoda, H. Azegami and T. Sakurai, Traction method approach to optimal shape design problems, SAE 1997 Transactions, Journal of Passenger Cars, Section 6, 106, pp2355-2365,1998.

[5] H. Ihara, H. Azegami, M. Shimoda, Solution to Shape Optimization Problems Considering Material Nonlinearity, Computer Aided Optimization Design of Structures VI, Chap. 3, Sec. 4, edited by Hernandez, S. and Kassab, A. J. and Brebbia, C. A., WIT Press, Southampton, UK, 1999, pp. 87-96