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Optimization of link member of eccentrically braced frames for maximum energy dissipation

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ABSTRACT

An optimization method is presented for design of an eccentrically braced frame (EBF), which is used as a passive control device for seismic design of building frames. The link member between the connections of beams and braces of EBF is reinforced with stiffeners in order to improve its stiffness and plastic deformation capacity. We present a method for optimizing the locations and thicknesses of the stiffeners of the link member. The optimal solutions are found using a heuristic approach called tabu search. The objective function is the plastic dissipated energy before failure. The deformation of the link member under static cyclic loads is simulated using a finite element analysis software package. It is demonstrated in the numerical examples that the dissipated energy can be increased through optimization within small number of analyses.

1. Introduction

Owing to recent development of computer technologies as well as the algorithms for analysis and structural optimization, we can optimize complex structures using sophisticated finite element (FE) analysis for evaluation of elastoplastic responses. For example, the body of a vehicle can be optimized considering crash properties [1,2]. However, most of the optimization approaches based on FE-analysis have been developed for application to problems with simple elastic responses [3].

In the conventional formulations of optimization problems in the field of building engineering, the stiffnesses of beams and columns of frames are optimized to minimize the total structural volume under constraints on elastic stresses and displacements against static loads [4]. However, one of the criticisms on optimization in building engineering is that the structures in this field should be designed considering large uncertainty in loads and materials, and the structures should be robust against all possible load types.

Substantial effort has been made over the decades for optimizing the structural parts and components such as beams, columns, and joints, in civil and architectural engineering. Recently, numerical optimization methods have been proposed using heuristic approaches and sophisticated finite element models [5]. It is worthwhile to spend much computational effort for optimization of structural parts, because they are mass-products and the design loads and deformation demands on structural parts are much simpler than those for the building structure. The authors optimized the cross-sectional shape of the clamping device of a frame-supported membrane structure [6]. The first author optimized the flange shape of a beam with reduced section for maximization of plastic energy dissipation under static monotonic loads [7] and cyclic loads [8]. However, in their study, a heuristic approach called simulated annealing is used, and more than thousand analyses are required for optimization. Therefore, it is important to develop a computationally efficient algorithm for optimizing structural parts considering complex elastoplastic responses.

Eccentrically connected braces are effectively used as a passive control device for dissipating seismic energy in the link member between the connections of beams and braces. A frame with such braces is called an eccentrically braced frame (EBF). The link member should have enough energy dissipation capacity before ductile failure to prevent collapse of the frame. Therefore, seismic performance may be improved through optimization of link member for maximizing ductility and energy dissipation. Prinz and Richards [9] studied the effect of web-opening in the link member of an EBF by carrying out parametric study on the number and locations of the openings. They concluded that opening holes in the web is not effective, because stress concentration may occur around the hole leading to premature failure of the link. Okazaki and Engelhardt [10] carried out cyclic loading tests for 37 specimens of link member with various types of stiffeners, steel materials, and loading protocols. They found that the fracture in the web of link member can be delayed by appropriately modifying the locations of stiffeners.

In this study, we present a method for optimizing the link member of an EBF. The deformation of the link member under static cyclic

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