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An innovative stiffened I-shaped damper to improve the behavior of the concentrically braced frames

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ABSTRACT

The Concentrically Braced Frames (CBFs) are prone to buckling under cyclic loads, which causes their degradation in energy absorption. Using steel dampers is an economical and efficient solution to improve their performance. Therefore, in this paper, an innovative metallic damper is considered numerically and parametrically to enhance the behavior of the CBF system. Accordingly, an I-shaped shear damper (stiffened diagonally by stiffeners) directly attached to the diagonal member of the CBF is proposed and studied parametrically and numerically. Results indicated that adding the diagonal stiffeners considerably enhances the ultimate strength and stiffness. By increasing the stiffener's thickness from 2.5 mm to 20 mm, the ultimate strength is enhanced by 1.47 to 4.5, 1.48 to 4.33, 1.43 to 3.81, 1.39 to 338, and 1.33 to 2.65 times respectively for models with $\rho = 0.25$, 0.18, 0.13, 0.11 and 0.09. Also, the overstrength ratio, Ω, was affected by the stiffener's thickness. Accordingly, by increasing stiffeners thickness, the Ω was enhanced by 11 % to 75 %. Since local bucking of the stiffeners affects the behavior of the proposed damper, to prevent the local buckling of the stiffeners, the ratio of length to thickness, λ_L, and ratio of wide to thickness, λ_b, was recommended as $30 < \lambda_b < 60$ and $30 < \lambda_L < 80$.

1. Introductions

The Concentrically Braced Frames (CBFs) as a conventional system against lateral loads, despite their high elastic stiffness and strength, do not have a ductile performance under cyclic loading [1]. Also, they faced degradation in stiffness and strength in inelastic zones. These weaknesses made the researchers introduce the CBFs as a non-successful system for high seismic risk zones. Using Eccentrically Braced Frames (EBFs) with horizontal link beams, the main shortcoming of the CBFs was solved. Researchers showed that the length of the link beam accounted for the most important parameter to distinguish its mechanism. A short link has a shear mechanism, a moderate length exhibits a shear-flexural mechanism, and a long beam exhibits a flexural mechanism. In other words, according to the AISC-360–16 [2], the parameter $\rho = \frac{e}{M_p/V_p}$ is measured as one most important parameters to design the EBFs. Based on the ρ parameter, the behavior of the EBF system is categorized into a) shear ($\rho < 1.6$), b) shear-flexural ($1.6 < \rho < 2.6$), and c) flexural ($\rho > 2.6$) mechanisms. Researchers showed that the links with the shear mechanism pertain to greater stiffness, strength, and dissipating energy without any degradation in inelastic zones. Therefore, it has been used as a fundamental issue for lots of dampers to achieve a ductile performance. Despite the suitable performance of EBFs, replacing the link beam is the main problem and is complicated. This problem is created because the link beam is a segment of the main floor beam (that may carry the gravity loading too). On the other hand, replacing the link beam is not possible due to its cost and hardships. Emerging dampers especially metallic ones because of their economic aspects solved the problems of the braces. Among the metallic dampers, shear damper had shown a suitable performance in numerical studies as well as experimental tests.

Generally, dampers utilized to enhance the performance of the CBFs are ordered into two categories; a) installed between the CBF's diagonal elements and floor beam and b) directly installed on the diagonal brace element. For the types of Added Damping and Stiffened (ADAS) [3,4], Triangular ADAS (TADAS) [5,6], shear damper introduced by Rai [7], Vertical-EBF [8–10], shear-bending damper [11,12], Arc corregated dampers [13,14] are the most famous dampers among the researchers.

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