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Pinching hysteretic response of yielding shear panel device

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ABSTRACT

The paper describes a modeling technique of the hysteretic response of yielding shear panel device (YSPD). This device is used for seismic energy dissipation in frame structures. The generalized Bouc–Wen–Baber–Noori (BWBN) hysteretic model is adopted in this work. Simulink is used to develop the BWBN model of the YSPD. The model parameters are calibrated based on experimental results conducted on the YSPD. The developed hysteretic model of the YSPD is then incorporated in state-space approach to evaluate the response of dissipative structures. Assessment of effectiveness of the YSPD in alleviating structural response and the effect of pinching on the overall response of the structure is made.

1. Introduction

Traditional seismic design approach relies on energy dissipation as a consequence of inelastic deformation of particular structural zones. The resulting damage is often so serious that necessitates demolition of the entire structure. Passive energy dissipation devices can be effectively used to minimize structural damage. By strategically locating these devices in the structure, repair and/or replacement of the damaged devices following an earthquake can be carried out. A number of energy dissipation devices that rely on hysteretic plastic response have been proposed. Among these devices are ADAS [1], SSD [2], YSPD [3,4] and TTD [5].

The yielding shear panel device YSPD [3,4] can be incorporated in an existing frame structure by connecting it between an inverted V-brace and a beam in a frame panel as shown in Fig. 1. The resulting brace-device lateral stiffness is equivalent to the stiffness of the device and the brace connected in series. The inclusion of the YSPD will alter the structural response of the parent frame since the device will introduce hysteretic damping and some stiffness.

The YSPD consists of a short segment of a square hollow steel section (SHS) with a steel diaphragm plate welded inside the SHS as shown in Fig. 1. The YSPD acts in shear as the parent frame structure undergoes lateral deformation. Energy is dissipated through shear yielding of the diaphragm plate while the SHS provides anchoring restraint to the resulting tension field in the diaphragm plate. A special test setup was used to experimentally obtain the hysteretic response of the YSPD as shown in Fig. 2. The experimental results of 19 tests carried out on the YSPD were reported in [4]. Generally the YSPD offers good energy dissipation and ductility with a shear strain ranging between 15% and 20% and an equivalent damping ratio in excess of 30% [4].

In order to simulate the structural response of frame structures equipped with YSPDs, a constitutive model of the YSPD is required. A typical hysteretic response of the YSPD is shown in Fig. 3. The hysteretic response is generally stable and shows no obvious stiffness or strength degradation. However, the response exhibits some pinching. The pinching is attributed to plastic buckling of the diaphragm plate and to bolt slippage.

A number of analytical hysteresis models are available [6–10]. The generalized Bouc–Wen (BW) model [6] provides smooth hysteresis but does not account for pinching or strength/stiffness degradation. This model was later extended to include pinching and degradation [7–9],the resulting model is Bouc–Wen–Baber–Noori (BWBN) hysteretic model.

In this paper a BWBN model of the YSPD that accounts for pinching is developed using Simulink [11]. For this purpose, experimental results of the YSPD [3,4] are used to calibrate the hysteretic model parameters. The hysteretic model is then used to predict the structural response of a frame structure equipped with YSPD.

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