SEISMIC RESPONSE SIMULATION AND SLIDING INSTABILITY EVALUATION OF UNBONDED FIBER-REINFORCED ISOLATORS

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Fiber-reinforced elastomeric isolators (FREIs) are a relatively new type of isolators that comprise alternating bonded layers of elastomer and fiber reinforcement sheets. In an unbonded application these isolators can be placed between the substructure and superstructure without any bonding or mechanical connections. As such, shear forces between the isolator and its top and bottom supports will be transferred via friction at the contact surfaces of isolator. As a result of unbounded application and lack of bending stiffness in the fiber reinforcement layers, under lateral shear loads, the contact surfaces of the isolator are partially rolled off the contact supports (see Figure 1). This unique deformation is termed as "rollover deformation" (Toopchi-Nezhad et al., 2009). The lateral load-displacement relationship in an unbounded-FREI is nonlinear as the effective contact area, A_{eff}, is decreased with increasing lateral deformations.

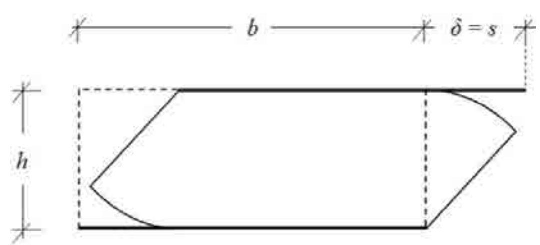

Figure. 1. Lateral rollover deformation in an unbonded fiber-reinforced isolator subjected to lateral displacement δ

The effective contact area in an unbonded isolator that is subjected to lateral displacement of δ can be evaluated with sufficient accuracy using (Toopchi-Nezhad, 2014).

$$A_{eff} = a\,(b - \frac{3}{4}\delta) \qquad (1)$$

where, *a* and *b* are the width and length of the isolator, respectively.

The effective contact area given by Eq. (1) may be employed in Eq. (2) to evaluate the effective secant horizontla stiffness of the isolator at any given lateral displacement δ.

$$K_H = \frac{G\,A_{eff}}{t_r} \qquad (2)$$

where, G represents the shear modules of the elastomer, and t_r is the total thickness of elastomer layers within the isolator.

The main objectives of this paper are to simulate the nonlinear seismic response history of a base isolation system consisted of a group of unbonded fiber reinforced isolators, and to verify the instant sliding stability of individual isolators within the system. In the time history analysis the horizontal stiffness of each isolator was evaluated at each time step using Eq. (2). Additionally, the unbonded application was taken into account in the model of the isolator.

To achieve sliding stability (i.e., to prevent any slip at contact surfaces of an unbonded isolator) at any instant in time, a minimum level of frictional resistance is required at the contact surface of the isolator. The criteria of sliding stability for any given elastomer can best be investigated by experimental studies on prototype samples of the elastomer. Results of an experimental study on a series of unbonded fiber reinforced elastomeric isolators indicate that to achieve sliding stability, a normal pressure of at least 0.5 MPa is necessary at the contact surfaces of the isolators (Russo and Pauletta, 2013). This value was assumed as a measure to assess the sliding stability of the isolators. To examine the sliding stability in the analysis, the effective normal pressure on each isolator was monitored continuously during analysis. At any instant in time, the effective normal pressure was calculated by dividing the vertical reaction of each isolator by the effective contact area of isolator given by Eq. (1). For the effective pressure values of less than 0.5 MPa, the isolator was regarded as instable, and ineffective in the base isolation system.

In order to evaluate the accuracy of numerical simulations, time history analysis under a scaled version of El Centro (1940) Earthquake was carried out, and the results were compared with those obtained in a previous shake table study (Toopchi-Nezhad et al., 2009). Figure 2 shows the time history of horizontal displacements in one of the isolators within the base isolation system. As seen in this figure, an excellent agreement can be observed between the Variable Stiffness Model developed in this paper and the experimental results. The efficiency of the Variable Stiffness Model was found to be significantly superior to a bilinear modelling of the lateral response of unbonded fiber reinforced isolators (see Figure 2).

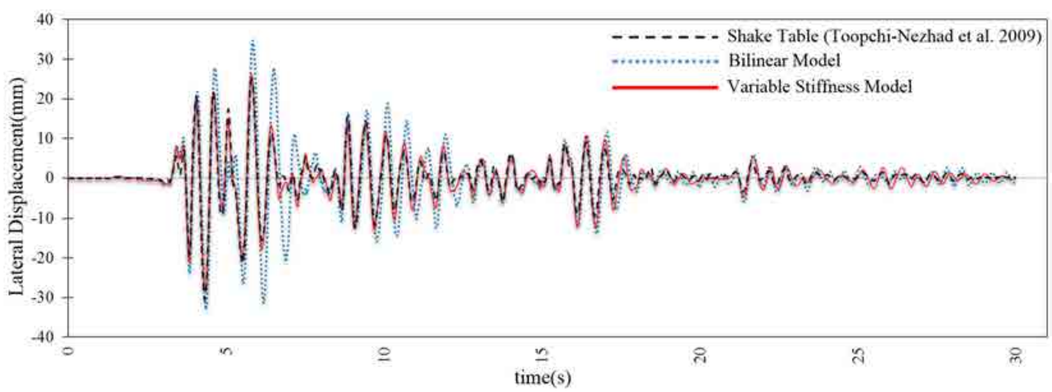

Figure. 2. Time history of isolator lateral displacements: a comparison between numerical and experimental values

The effective contact pressure was calculated to be between 1.05 MPa and 3.45 MPa. As such, no slip expected to occur at the contact surfaces of the isolators as the pressure values were larger than 0.5 MPa. This expectation was consistent with experimental observations (Toopchi-Nezhad et al., 2009).

The Variable Stiffness Model proposed in this paper for nonlinear response history evaluation of unbonded fiber reinforced isolators is effective due to its simplicity and accuracy. Additionally, the model provides an effective tool to evaluate the sliding instability of unbonded isolators.

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