SEISMIC VULNERABILITY ASSESSMENT OF RC BRIDGE WITH UNEQUAL PIERS USING ENERGY-BASED DAMAGE INDEX

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Keywords: Damage index, RC bridge, IDA, Piers, Elastomeric bearings

Bridges are critical elements in highway transportation system, which are vulnerable to seismic excitements. Damage to bridge components during earthquakes may have severe consequences in terms of impaired emergency response and economic loss. Seismic vulnerability of bridges is strongly related to the behavior of their structural and non-structural elements like piers, bearings, joints, abutments and shear keys. Hence a reliable damage assessment of bridges requires a detailed damage analysis on the bridge components (Cardone, 2013). Using damage indices is a conventional approach for quantifying damage levels of a structure that is subjected to earthquake excitements. Damage indices are classified to displacement-based, force-based, low-fatigue-based and energy-based categories (Mahboubi and Shiravand, 2019a). Several damage indices have been utilized for damage assessment of the bridge structures. Bassam et al. (2011) developed a damage model for damage analysis on four-span bridge under earthquake ground motions. Jara et al. (2014) determined the demand-capacity relations in typical RC bridges in Mexico based on damage indices. Mahboubi and Shiravand (2019a) proposed an energy-based damage index for damage assessment of RC bridge piers using the concept of earthquake input energy distribution in a structural system. The damage index is defined as the ratio of the hysteretic energy to the external work done by the system as described by Equation 1:

$$DI = \frac{E_h}{E_i} = 1 - \frac{E_k + E_d + E_s}{E_i} \tag{1}$$

The damage index is classified into four damage levels for RC columns including slight, moderate, extensive and complete and two damage levels for bridge bearings, including sliding and failure, in accordance with the results obtained through a series of verification studies with experimental specimens (Mahboubi and Shiravand, 2019b).

In this paper, the proposed damage index is used for seismic assessment of columns and bearings of a skewed-RC bridge with unequal pier height. The bridge has three spans and multi-column bents. The bridge superstructure is composed of a 1.6 m deep deck with 12 I-girder. Elastomeric bearings are used for isolating the bridge superstructure and substructures. The bridge piers are composed of six circular columns with 1.2 m diameter. The middle columns are 29 m high and the columns on both sides of the bridge are 15 m high. The elastic stiffness of the bearings is 280 T-m. Seismic design of the bridge is performed based on AASHTO specifications (2014). Figure 1 shows the bridge elevation. Finite element model of the bridge is developed using OpenSees software. Incremental dynamic analysis (IDA) is performed using a series of earthquake records. The energy-based damage index is calculated for the bridge bearings and the piers and damage curves are developed for the bridge bearings and columns. The damage levels of the bearing and columns for design PGA values are also determined.

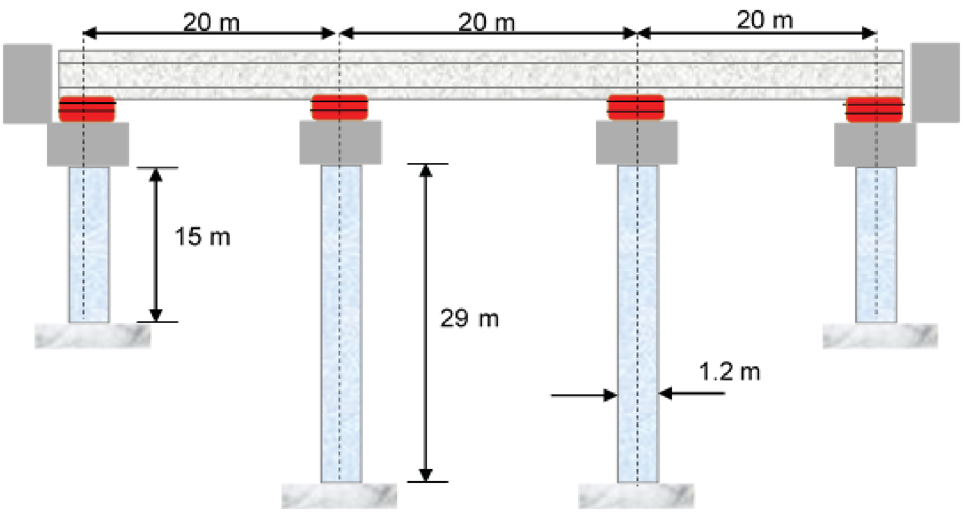

Figure 1. Elevation of the RC bridge.

The damage curves show that the bearings, which are located on the short columns, are more vulnerable to earthquake excitements than the bearings on the long columns. For a constant PGA value, the damage levels of the short piers are higher compared to the long piers for all records in accordance with the damage values of the bridge columns. Moreover, for the design acceleration the damage curves show that in some records the bridge piers reaches the moderate damage levels and the bearings are in failure threshold, which means the bridge components cannot withstand the design acceleration in these records.

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