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A simple quantitative approach for post earthquake damage assessment of flexure dominant reinforced concrete bridges

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ABSTRACT

Conventional methods for displacement based condition assessment of bridges solely rely on the maximum level of displacements experienced by the piers, and do not take into account the accumulated damage that result from cyclic loading. More advanced approaches take this into account by considering the structural damage as a linear combination of the normalized maximum displacements and hysteretic energy. Computation of the dissipated hysteretic energy requires monitoring of the lateral forces during the seismic events, which are not as practical as monitoring bridge pier deformations. This article reports on the development of a simple damage assessment method that considers the effect of cyclic loading on the state of damage and it is merely based on monitoring the bridge pier deformations. A fiber optic displacement serial array was designed for measuring the crack opening displacement reversals at the plastic hinge areas.

1. Introduction

Seismic design codes have gone through a number of transformations in order to assure safety by preventing collapse and maintaining serviceability [1]. Current ductile designs allow for the piers to go through inelastic deformations in order to dissipate energy. However, serviceability remains to be an issue, since this approach renders the columns vulnerable to large lateral displacements causing damage in the plastic hinge zones at the base and the pier cap connections [2]. It is imperative to develop methodologies that function beyond visual inspections in order to duly assess the safety and serviceability condition of the bridges following the earthquakes [3]. These methods will be essential to evaluate the level of damage, to formulate repair plans, and to make well-timed decisions regarding the traffic patterns [4]. One method for quantification of the state of damage in reinforced concrete bridges is the use of a damage index (DI). In general, damage indices have been based on a set of structural response parameters such as displacements, forces and hysteretic energy.

Some damage indices only use the structure's displacement ductility ratio to evaluate the damage. An example of such is the damage index proposed by Powell and Allahabadi [5]:

$$DI_{PL} = \frac{\delta_m - \delta_y}{\delta_u - \delta_y} \leq 1, \quad \delta_m \geq \delta_y \tag{1}$$

where, δ_m is the maximum lateral displacement of the bents experienced during the earthquake, δ_y is the yield displacement and δ_u is the maximum lateral displacement capacity of the bridge bent under monotonically increasing lateral deformations, and is computed by finite element static push over analysis.

Damage accumulated during the cyclic loading reduces the ductility capacity of the structure and therefore, condition assessments based solely on δ_m and δ_y underestimate the level of damage. Panagiotakos and Fardis [6], through laboratory experiments, observed that the deformation at the failure of reinforced concrete elements subjected to cyclic loadings can be reduced by as much as sixty percent of their ductility capacity. Bertero [7] recommended that the maximum ductility demand for the structure during ground motions should be limited to 50% of its ultimate ductility.

More advanced damage models take into account the accumulated damage that result from cyclic loading by including a dissipated energy term in the damage index equations. The method

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