Evaluation of the Relative and Absolute Cumulative Input Energy Time History under Near-Fault Earthquake with Visible Pulse in Acceleration Time History

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ABSTRACT

The damage observed after the earthquakes in Northridge, Kobe and Chi-Chi showed the importance of evaluating the elastic and inelastic behavior of structures against near-fault earthquake. Several studies have been carried out to evaluate the impact of near-fault earthquake with fling-step motion effects. The obvious feature of such earthquakes is the existence of a pulse with a significant amplitude in the velocity accelerograms. In this article, in order to investigate the effect of pulse-type near-fault earthquakes on the elastic demands of steel moment frames, a 15stories was simulated. After verifying the modelling process, under the influence of 20 near-field and 2 far-field records were analyzed. The relationship between effective cyclic energy, ECE, and the displacement, velocity and hysteretic curve of SDOF systems in near- and far-fault earthquakes was evaluated. Then, studying the energy of relative and absolute cumulative input energy with kinetic energy in one section and maximum inter-story drift for 4 different levels of nonlinear behaviors (R = 1.0, 2.0, 4.0, 6.0) in the other section, the effect of higher modes was evaluated. Studying the inter-story drift profile for two near-fault earthquakes, with and without accelerated pulses, indicates the formation of the maximum drift, IDR_{max}, in upper stories for low nonlinear degrees (R=1.0 and R=2.0) in Records with visible pulses that verify the participation of higher modes. However, in accelerated pulse-free records, in addition to intensifying the IDR_{max} in the upper stories, a large-scale demand is imposed in the lower stories. In other words, in the lower stories, the first mode is mainly involved in these records.

KEYWORDS

Near-fault earthquake, Pulse-type effect, Fling-step motion, Input energy, higher modes.

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1 Introduction

This paper specifically examines the effect of progressive orientation on the energy input to the structure on the structure. The evaluation approach here is the concept of structural behavior coefficient of single degree of freedom.

It should be noted that in near faults earthquakes, two forms of motion effects and forward directivity are often classified [1]. The distinctive feature of these records is the presence of a noticeable pulse in the record of velocity and sometimes the acceleration of an earthquake. Recent studies on near faults earthquakes show that in the seismic design of structures, in addition to applying the effects of visible frequency content in the history of earthquake acceleration, special attention should be paid to the dominant pulse of velocity mapping [2]. For example, Cheng Fang et al. (2018) in a study examined the maximum floor acceleration and intercostal residual drift of steel bracing and bending frames under the impact of near-field earthquakes in projectile mode. They showed that structural responses are strongly dependent on spectral acceleration, PGV/PGA ratio, and accelerometer pulse period [3].

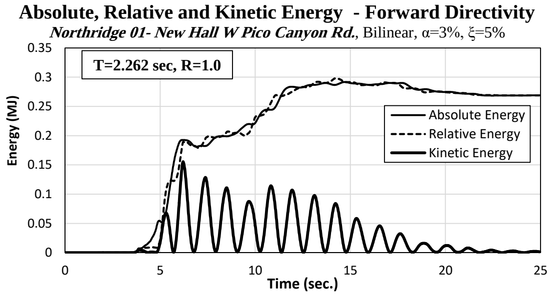
2 Material and Method

The basic research model, hereinafter referred to as FRN15B3, has 15 floors and 3 openings. In the studied models, the height of all floors is fixed and equal to 4 meters and the length of bays is considered constant and equal to 5 meters. Ductility for two-dimensional steel bending frames used in this study was selected as a special type.

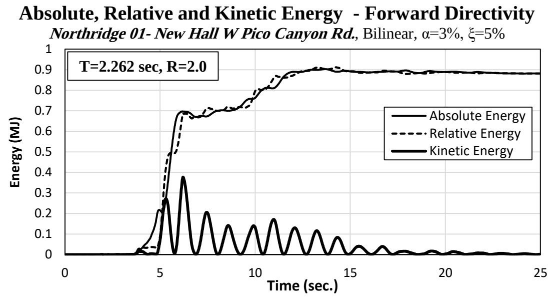
All the mentioned models have been designed using ETABS 2016 software [4] equivalent static analysis (in some models quasi-dynamic analysis and design-based shear synchronization) and by the method of Load and Resistance Factor Design method [5]. In addition to the design based on the criterion of strength, the stiffness distribution of the frames in height has been adjusted so that the maximum drift angle between the floors is limited to the allowable values specified in the 2800 edition of the fourth edition.

3 Results and Discussion

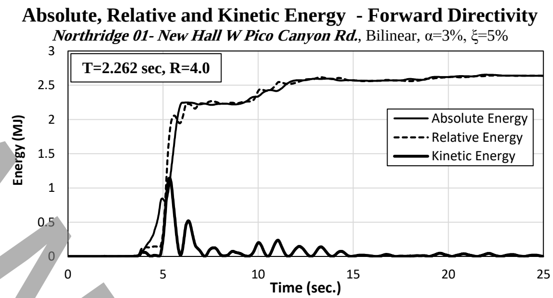
For R = 2, the results of the SN8 record (where the cumulative input energy gradually increases) show that in addition to activating the effect of higher modes in the upper floors, the drift needs in the lower parts of the structure are also significant. With increasing R corresponding to SN8 results, the accumulation of maximum needs is located in the lower floors and somehow the effect of the first mode overcomes the final response of the structure. The results obtained in this section are in good agreement with the study conducted by Young and Bertro (1990) [6] and Kalkan (2006) [7]. History of Relative, Absolute, and Kinetic Energy of Northridge-Newhall Earthquake (SN3) is shown in Figure (1).



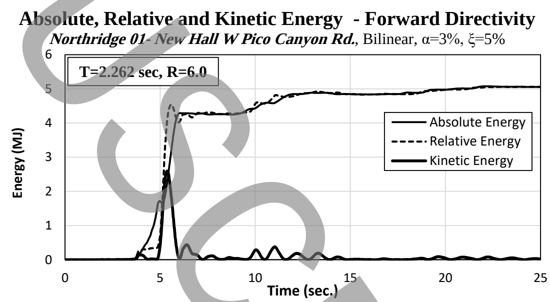
(a) R=1.0



(b) R=2.0



(c) R=4.0



(d) R=6.0

Figure 1. **History of Relative, Absolute, and Kinetic Energy of Northridge-Newhall Earthquake (SN3) for R = 1, 2, 4, 6, and FRN15B3 (T = 2.262 Sec)**

Examination of Figures (1) shows that a comparison of the relative and absolute input energies of the SN8 and SN3 records shows that the input energy level in the SN8 record is much larger than that of the SN3. However, for small Rs, the IDRmax of both accelerometers is equal. To justify this, it can be said that in the SN3 record, a significant amount of seismic input energy enters the structure in a short time (approximately 2 seconds). Therefore, the structure will not have enough time to react to this accumulated energy level; therefore, the higher the seismic input energy, the greater the requirements imposed on the structure. It is not a correct conclusion, but the size of the deformation demand depends on the effective time of the cumulative input energy.

4 Conclusion

While examining the history of relative and absolute cumulative input energy along with kinetic energy in one section and maximum interclass drift for 4 different levels of nonlinear behavior (R = 1.0, 2.0, 4.0, 6.0) in the other section, the effect of higher modes was evaluated. The results show that records with orientation effects that do not have an apparent acceleration pulse have a similar energy history spectrum (absolute and relative). However, the presence of an obvious pulse in the acceleration record causes a difference between the relative and absolute energy values in the short and long periods. In mid-periods the difference between the two types of energy is noticeable, but in long periods the relative energy is generally greater than the absolute energy.

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