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Correlations between Earthquake Parameters and Variation of Fundamental Period in RC Frames

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Abstract

In recent decades many researchers have studied on the damage assessment of structures after a seismic event. To assess the damage of structures after an earthquake, it is so important to study the correlations between earthquake parameters and damages of the structures. Variation of fundamental period is one of the methods to identify the damage of the structures. In this paper correlation between earthquake parameters and variation of fundamental period is studied.To characterize a seismic event, a lot of parameters have been defined. In this paper several earthquake parameters are chosen to study. Two RC frames are analyzed under far-fault earthquake records by nonlinear dynamic analyses. The correlations between earthquake parameters and variation of fundamental periods are calculated. The results show that some of the earthquake parameters have high correlations with Variation of fundamental period. The most correlations are for those earthquake parameters which some researchers have shown high correlations between damage indexes of structures and them. So some earthquake parameters which have high correlations with variation of fundamental period can be proper indices to estimate the damage potential of an earthquake.

Keywords: Earthquake parameters, Variation of Periods, Correlation, RC frames, Damage.

1. Introduction

There are a lot of methods to assess the damage of the structures. Variation of dynamic characteristics is of the main methods to identify the intensity of damage. To characterize a seismic event a lot of parameters have been proposed. No single ground motion parameter provides an ideal index of damage. The correlation of some earthquake parameters with actual damage has shown a complicated multi-parameter subject of research [1]. Elenas and Meskouris studied correlations between different earthquake parameters and damage intensity in a 8-storey RC frame [2]. They extracted earthquake parameters from 20 records of earthquakes. They concluded that earthquake energy parameters provide good correlation with damage intensity. A 6-storey RC frame was modeled by Nonos et al and correlation between different earthquake parameters and damage intensity was investigated [3]. The parameters were extracted from 450 different synthetic records. The results showed high correlations between earthquake energy parameters and damage intensity. Elenas et al showed that spectral acceleration and energy parameters have the highest correlation with damage [4] and [5]. Danciu concluded that peak ground velocity, Arias Intensity, and also spectral intensity have the highest correlation with damage [6]. In this paper intensity of damage is identified by the variation of fundamental periods. Some earthquake parameters which are extracted from far fault records of earthquakes are considered to study. The records are applied to two RC frames. Inter-relations between variations of fundamental periods and the selected earthquake parameters are studied.

2. Earthquake parameters

A lot of earthquake parameters are proposed by researchers. In this paper five earthquake parameters are studied. Theses main parameters are widely used by researchers.

2.1 Root mean square of accelerations (a_{RMS})

Root mean square of accelerations takes into account amplitude and frequency content of an earthquake record. It is defined as [6]:

$$a_{RMS}=(\frac{1}{T_d}\int_0^{T_d}[a(t)]^2dt)^{\frac{1}{2}}=(\lambda_0)^{\frac{1}{2}} \tag{1}$$

Where T_d is the duration of the earthquake record and $a(t)$ is the acceleration at the time of t. λ_0 represents the average intensity.

2.2 Arias intensity (I_a)

Arias intensity is a parameter to measure the intensity of ground motion [7]. Arias intensity represents the total energy at the recording station. It is defined as:

$$I_a=\frac{\pi}{2g}\int_0^{T_D}a^2(t)dt \tag{2}$$

where T_d is the duration of the earthquake record and $a(t)$ is the acceleration at the time of t. The unit of Arias intensity is similar to velocity.

2.3 Housner Intensity (HI)

The response spectrum intensity was first proposed as an indicator by Housner [8]. It describes the area under pseudo velocity response spectrum between periods of 0.1 and 2.5 seconds, as follows:

$$HI=\int_{0.1}^{2.5}PSV(\xi,T)dT \tag{3}$$

where PSV is pseudo-velocity at natural period T. Since many structures have fundamental periods of 0.1 and 2.5 seconds, the response spectrum in this period range can provide information about damage potential of a seismic event for these structures. The HI can be calculated for any structural damping ratio.

2.4 Velocity Spectrum Intensity (VSI)

Velocity Spectrum Intensity is the response spectrum intensity for a damping coefficient of 5%. It was first proposed by Von Thun et al for earth and rock fill dams [9], which generally have fundamental periods between 0.6 and 2.0 seconds.

$$VSI=\int_{0.1}^{2.5}S_v(\xi=0.05,T)dT \tag{4}$$

where S_v is velocity for a damping coefficient of 5% and natural period T.

2.5 Predominant Period (T_p)

The predominant period is the period at which the maximum spectral acceleration occurs in an acceleration response spectrum calculated for a damping coefficient of 5%. Motions with the same different frequency contents can have the same predominant period. This may lead to errors in estimation of frequency content.

3. Modeling RC frames

Two different RC frames (3 and 6 story) were modeled by a computer program IDARC [10]. The height of each story in all the frames is 3.2 m. All the frames have 4 bays which the length of each bay is 4.0 m. The frames are designed corresponding to the 2800 Standards of Iran Earthquake and Iranian National Building Codes, Part 9: Design and Construction of Reinforced Concrete Buildings [11] and [12]. The frames were subjected to the far fault records of earthquakes and nonlinear dynamic analyses were carried out.

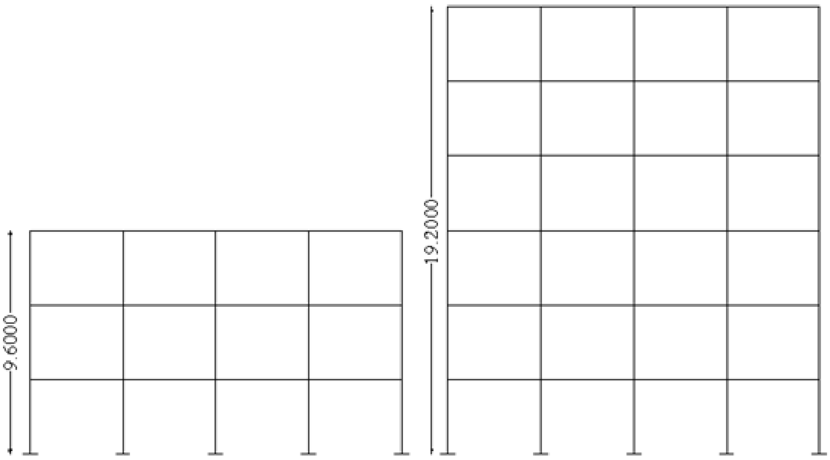

Figure 1: Schematic representation of RC frames

3.1 Verification of the results

Based on shaking table tests which were done by Cecen [13], a ten story frame was modeled. The comparison of the analytical and experimental results in terms of peak accelerations is shown in Figure 2. The maximum displacements reported in Cecen are based on one-half the double amplitudes, while the IDARC values are absolute peak. The comparison of the analytical and experimental results shows the verification of the IDARC results.

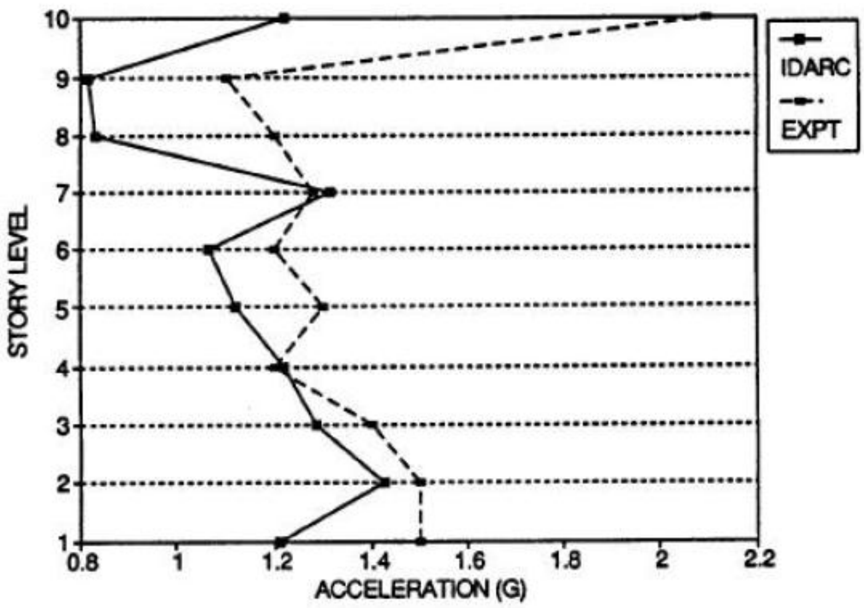

Figure 2: Computed versus observed peak acceleration response

3.2 Records of earthquakes

Far-fault records were selected from different stations of 9 earthquakes. They were obtained from PEER Strong Motion Database [14]. The details of 110 selected records are shown in Table 1.

Table 1: Records of earthquakes

No	Earthquake	Magnitude	Number of records from different stations
1	Taiwan SMART1	5.9	7
2	Whittier Narrows	6	15
3	Coalinga	6.4	5
4	Imperial Valley	6.5	4
5	Northridge	6.7	21
6	Superstitn Hills (A)	6.7	10
7	Loma Prieta	6.9	16
8	Landers	7.3	6
9	Chi-Chi, Taiwan	7.6	26

The earthquake parameters were extracted from selected records. The records were used as input for the analyses.

4. Analytical results and discussion

After the nonlinear dynamic analyses of frames, variation of the fundamental periods were measured by the equation (5):

$$\Delta T = T_d - T_0 \tag{5}$$

where T_0 is the initial period of the structure and T_d is the final period of the structure after the damage.

The correlation between ΔT and earthquake parameters was identified by Pearson coefficient [15] and . Pearson correlation coefficient between two sets of variables X and Y, is defined as:

$$\rho_{Pearson} = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2 \sum_{i=1}^{n}(Y_i-\bar{Y})^2}} \tag{6}$$

where $\bar{X}$ and $\bar{Y}$ represent the mean values of X_i and Y_i and n represents the number of pairs (X_i, Y_i).
The results of Pearson correlations between ΔT and earthquake parameters are represented in Figure 3 and 4.

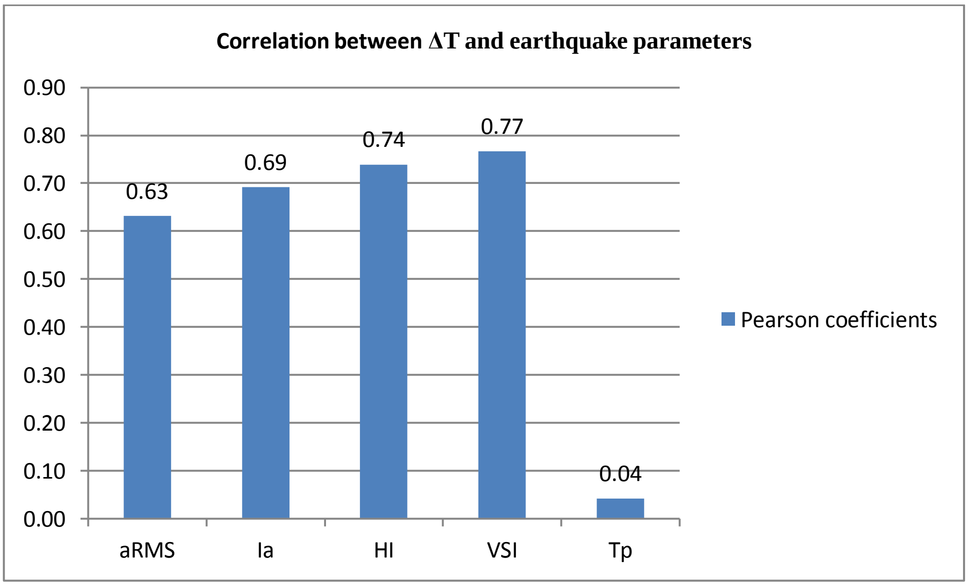

Figure 3: Correlation between ΔT and earthquake parameters in 3-story frame

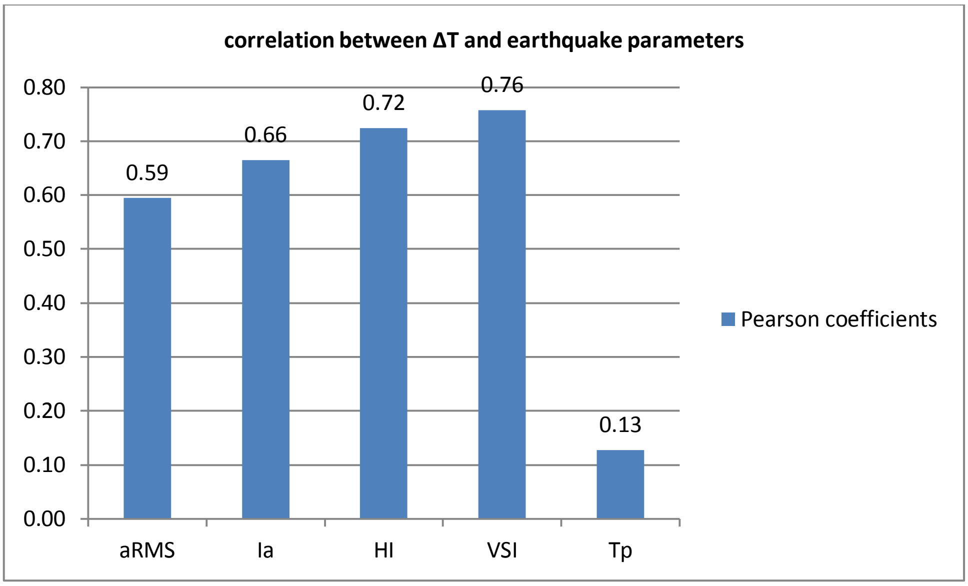

Figure 4: Correlation between ΔT and earthquake parameters in 6-story frame

It should be noted that If Pearson coefficient is more than 0.6, there is strong correlation between two sets of data. Also there is weak correlation between two sets of data, if Pearson coefficient is less than 0.3. The results in Figure 3 show that in 3-story frame there are strong correlations between ΔT with a_{RMS}, I_a, HI and VSI. But there is too weak correlation between ΔT and T_p. Figure 4 represents that in 6-story frame there are strong correlations between ΔT with I_a, HI and VSI. Also it can be seen than a_{RMS} has almost strong correlation with ΔT, too. Similar to 3-story frame, T_p has weak correlation with ΔT in 6-story frame.

5. Conclusion

In this paper, two RC frames with different height were modeled. They were subjected to the far-fault records of earthquakes and inelastic dynamic analyses were performed. Five earthquake parameters were extracted from the records: a_{RMS}, I_a, HI, VSI and T_p parameters. Based on dynamic characteristic changes, the variation of fundamental periods (ΔT) were calculated. Correlations between earthquake parameters and ΔT were studied by Pearson coefficients.

The results show that in both of the frames, there are strong correlations between ΔT with a_{RMS}, I_a, HI and VSI. Because their Pearson coefficients with ΔT are more than 0.6. But T_p has weak correlation with ΔT. Because its Pearson coefficients with ΔT is less than 0.3. As variation of fundamental period can present the damage intensity of a structure, It should be concluded that a_{RMS}, I_a, HI and VSI can describe damage potential of an earthquake.

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