A STUDY ON SOME DAMAGEASSESSMENT METHODSBASEDONTHE DYNAMIC CHARACTERISTIC CHANGES

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ABSTRACT

In recent years many researchers have studied on the damage assessment based on dynamic characteristics. Alongside these researches, a lot of damage indices were proposed by researchers to locate and quantify the damage of the structures or to rank their vulnerability relative to each other. The variation of frequency and Softening indice are two methods to assess the damage based on dynamic characteristics. This paper studies on the performance of the frequency changes and Softening indices to assess the damage. In the paper three RC frames are modeled and nonlinear dynamic analyses are done. To identify the performance of the methods, the damage intensities which are measured by frequency changes and Softening indice, are compared to the damage intensities measured by Park-Ang indice. Park-Ang indice is one of the most widely used damage indices. Park-Ang is not based on the dynamic characteristics, but it can be a reliable indice to compare the results. The results show that in all the frames there are very strong correlations between frequency changes or Softening indice with Park-Ang. So it can be concluded that both of the methods are acceptable. Although the correlations between frequency changes and Park-Ang are a little more than the coefficients between Softening indice and Park-Ang, but the difference is negligible. The difference may be for inaccurate calculations of the final periods.

INTRODUCTION

Damage indices can provide information of damage intensity. In recent decades many researchers have proposed different damage indices to assess the damage of structures based on dynamic characteristics.The variation of frequency is one of the methods to assess the damage of the structures. Another method to assess the damage based on dynamic characteristics is Softening indice(DiPasquale and Cakmak., 1987), (DiPasquale and Cakmak., 1989), (DiPasquale et all., 1990). The final softening is based on fundamental period of the structure.

This paper studies on the performance of theses methods. In this regard, flexural reinforced concrete frames are modeled and analyzed by nonlinear dynamic analysis under 124 records of far-field. The damage of the frames are measured by frequency changes and Softening indice.To compare the results, Park- Ang indice (Park and Ang., 1985). Park- Angincorporates deformation and hysteretic energy absorption.Itis not based on the dynamic characteristics, but it can be a reliable indice to compare the results.

To compare the results of dynamic characteristic changes with Park- Angindice, Pearson correlation coefficient is used (Spiegel, 1992). Pearson correlation coefficient is used to evaluate the strength of the linear inter-relationship between two sets of data.Correlations betweendynamic characteristic changes and Park- Angindice shows the performance of the damage indices based ondynamic characteristic changes.

Damage assessment

To assess the damage of structures the variation of frequency, Final softening and Park- Angindiceare used in this paper. The variation of frequencyis defined as:

$$\Delta\omega=\omega_d-\omega_0 \quad (1)$$

where ω_0 is the initial frequency of the structure and ω_d is the frequency of the structure after the damage.
The final softeningis defined by the following equation:

$$FS=1-\frac{T_0^2}{T_d^2} \quad (2)$$

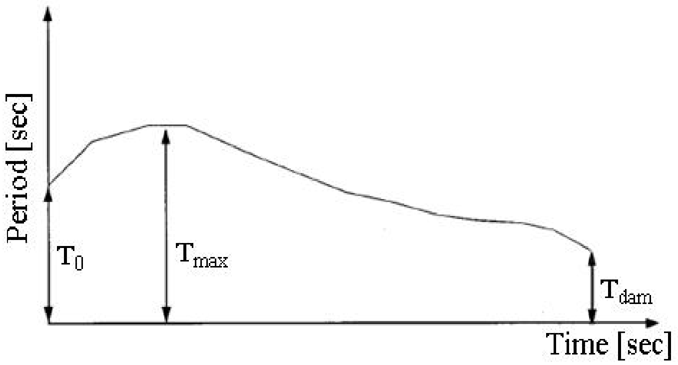

Figure 1. Time history of fundamental period (Villemure, 1995)

whereT_0 is the initial period of the structure and T_d is the final period of the strucure after the damage.
Park- Angis defined as:

$$D=\frac{d_m}{d_f}+\beta\frac{\int_{E=E_1}^{E=E_M} dE}{F_y d_f} \quad (3)$$

where the integral represents the accumulation of hysteretic energy absorbed. d_m is the maximum displacement and d_f is the final displacement. β is a strength degradation parameter which is proposed 0.1 for well reinforced concrete (Park and Ang., 1985). F_y is the yield strength of the structure. Park-Ang is not based on the dynamic characteristics, but it can be a reliable indice to compare the results.

Structural modeling and analysis

3 different RC frames were modeled by a computer program IDARC. The frames are 3, 9 and 12-storey, respectively. The height of each storey 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.

124 far-fault records of different earthquakes were selected from the PEER Strong Motion Database. The selected earthquakes have magnitudes between 5.9 to 7.6 in Richter magnitude scale. The details of earthquakes are shown in Table 1.

The Selected records were applied to the frames and Inelastic dynamic analyses were performed.The variation of frequency, Final softening and Park- Angindice were obtained as the response of the frames.

Analytical results and discussion

After the nonlinear dynamic analyses of frames, damage indices were obtained by the program.The correlation between $\Delta\omega$orFS with Park-Ang was identified by Pearson coefficient (Spiegel, 1992). Pearson correlation coefficient between two sets of variables X and Y, is defined as:

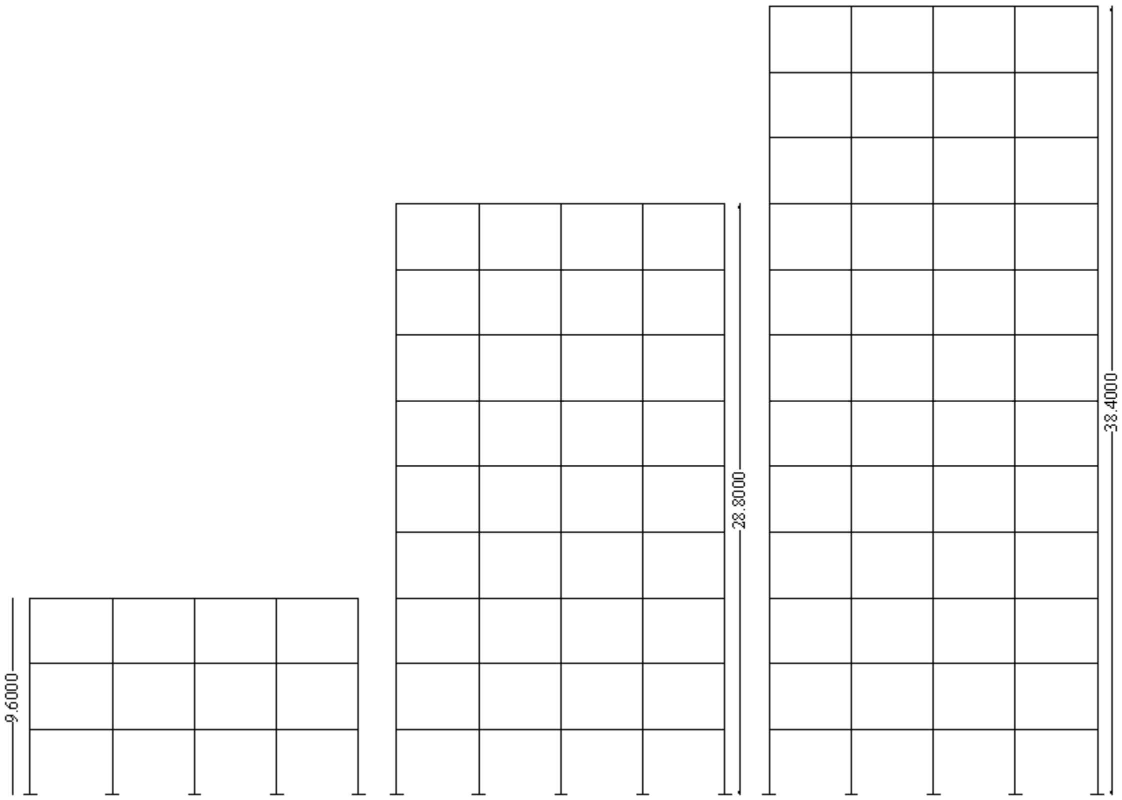

Figure 2. Schematic Representation of RC frames

Table 1. Data of Earthquakes Recordes

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	San Fernando	6.6	5
6	Northridge	6.7	21
7	Superstitn Hills (A)	6.7	10
8	Spitak, Armenia	6.8	2
9	Kobe	6.9	2
10	Loma Prieta	6.9	16
11	Irpinia, Italy	6.9	3
12	Cape Mendocino	7.1	2
13	Landers	7.3	6
14	Chi-Chi, Taiwan	7.6	26

$$\rho_{Pearson} = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2 \sum_{i=1}^{n}(Y_i-\bar{Y})^2}} \quad (4)$$

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 $\Delta\omega$ or FS and Park-Ang damage indexes are represented in Figures 3 and 4.

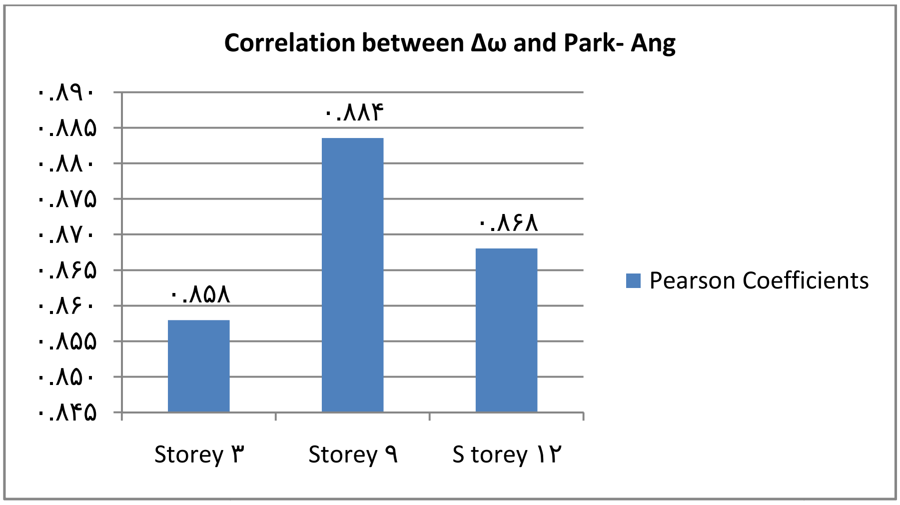

Figure 3. Pearson Coefficients between$\Delta\omega$ and Park- AngIndice

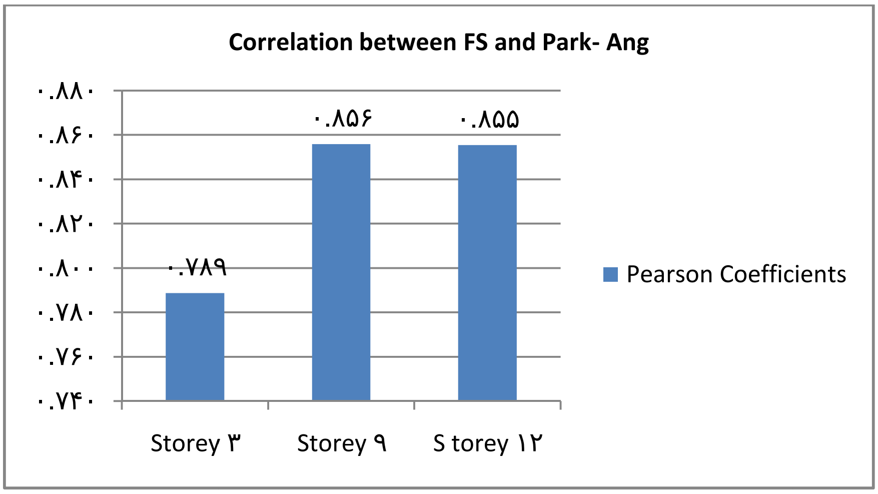

Figure 4. Pearson Coefficients between FS and Park- Ang Indice

It should be noted that If Pearson coefficient is grater than 0.7, there is very strong correlation between two sets of data. The results in Figures 3 and 4 show that in all the frames there are very strong correlations between $\Delta\omega$ or FS with Park-Ang. So it can be concluded that both of the methods are acceptable.

To compare the perfoemance of $\Delta\omega$withFS, the correlations between $\Delta\omega$ and Pak- Ang is compared to the correlations between FS and Pak- Ang in Figure5.

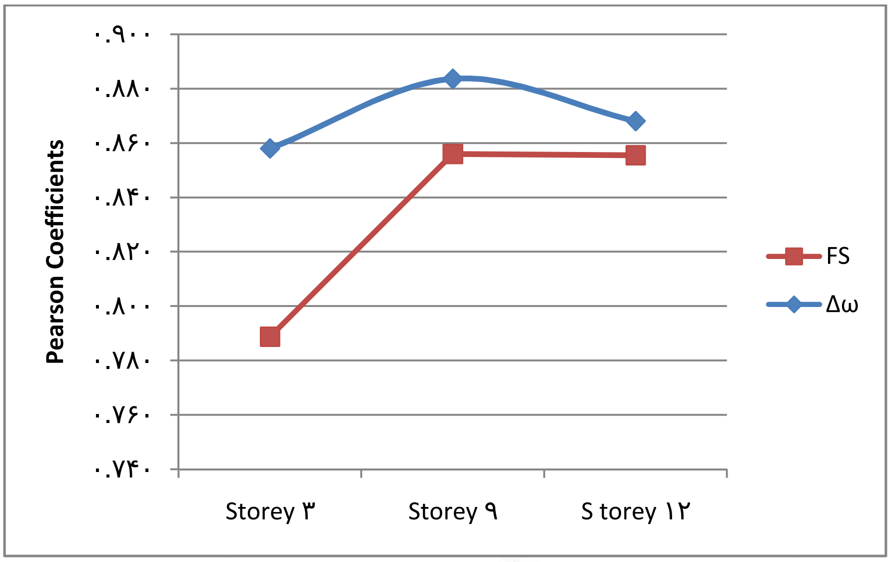

Figure 5. Comparison$\boldsymbol{\Delta\omega}$ and FS

The Pearson coefficients between $\Delta\omega$ and Park-Ang is 8.745, 3.271 and 1.520% more than the coefficients between FS and Park-Ang in 3, 9 and 12 story frame, respectively. Althoughthedifference is negligible but it may be for inaccurate calculations of the final periods in FS indice.

The values of $\Delta\omega$ or FSin terms ofPark-Angindice is represented in Figures 6 to 8. Also the linear regression equation $\Delta\omega$ or FS in terms of Park-Ang is shown in these figures.

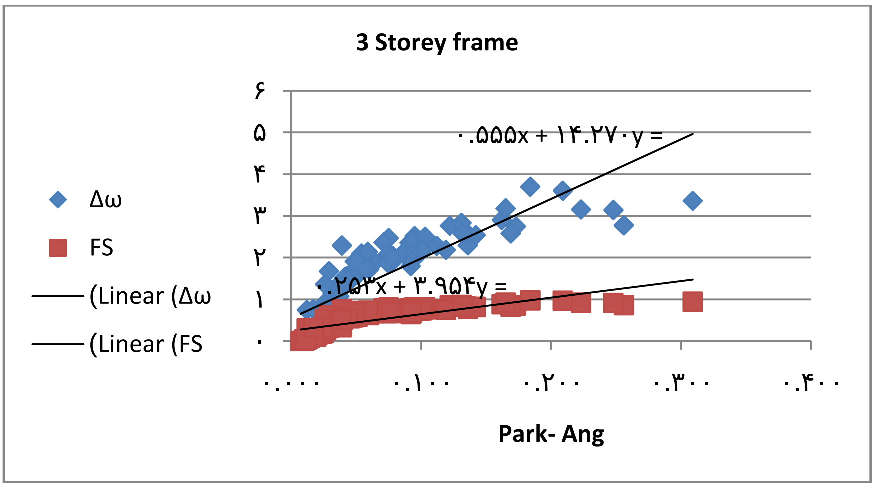

Figure 6. Values of Δω and FS in terms of Park-Ang in 3 Storey frame

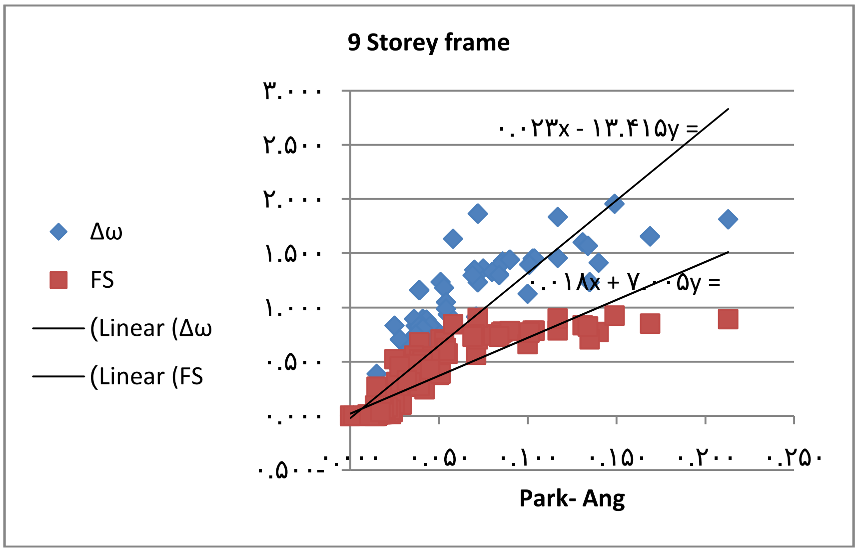

Figure 7. Values of Δω and FS in terms of Park-Ang in 9 Storey frame

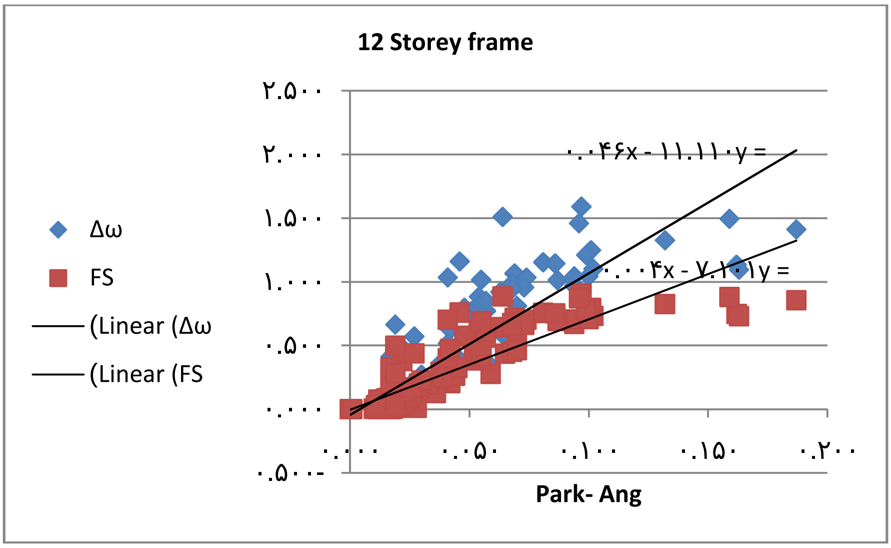

Figure 8. Values of Δω and FS in terms of Park-Ang in 12 Storey frame

As shown in Figures 6 to 8, the linear regression equations between $\Delta\omega$ and Park- Ang are almost similar to each other in 3, 9 and 12 storey frames. Also the linear regression equations between FS and Park-Ang in 9 and 12 storey frames are similar to each other. But the equation between FS and Park- Ang in 3 storey frame is different from the equations in 9 and 12 storey frames. Also the changes may be for inaccurate calculations of FS indice.

CONCLUSIONS

In this paper,3 RC frames with different height were modeled. They were subjected to the 124 far-fault records of earthquakes.Inelastic dynamic analyses were performed. Based on dynamic characteristic changes, the variation of frequency, Final softeningindices were calculated. Also Park-Angindice was obtained to assess the performance of the damage indices based on dynamic characteristic changes.The correlation between the variation of frequency or Final softeningindices with Park-Ang was identified by Pearson coefficient.

The results showthat in all the frames, there are very strong correlations between variation of frequency or Final softeningindiceswith Park-Ang. So it can be concluded that both of the methodsbased on dynamic characteristic changes are acceptable. Although the correlatons between variation of frequency and Park-Ang is a little more than the correlations between Final softening and Park-Ang, but the difference is negligible. The difference may be for inaccurate calculations of the final periods.

The results of the linear regression equation between variation of frequency or Final softening indices and Park-Ang show that the relationship between variation of frequency and Park- Ang is more identical in different frames in comparison to the relationship between Final softening and Park- Ang. It also may occur for inaccuracy in calculations of Final softening.

REFERENCES

DiPasquale E and Cakmak A (1987) Detection and Assessment of Seismic Structural Damage. National Center for Earthquake Engineerin Research, State University of New-York, Buffalo NY

DiPasquale E and Cakmak A (1989)On the Relation between Local and Global Damage Indices. National Center for Earthquake Engineerin Research, State University of New-York, Buffalo NY

DiPasquale E, Ju J, Askar A, and Cakmak A (1990). Relation between Global Damage Indices and Local Stiffness Degradation. *Journal of Structural Engineering, 116*(5), 1440-1456

Villemure I (1995) Damage Indices for Reinforced Concrete Frames: Evalution and Correlation. University of British Columbia

Park Y-J, and Ang A-S (1985) Mechanistic Seismic Damage Model for Reinforced Concrete. *Journal of Structural Engineering, 111*(ST4), 722-739

Spiegel M (1992) Theory and Problems of Statistics. London: McGraw-Hill: Schaum Publishing

Valles R and Reinhorn A (2010) IDARC-2D Version 7.0. Inelastic Damage Analysis of Reinforced Concrete Structures

Valles R, Reinhorn A, Kunnath S, Li C and Madan A (1996)A Program for the Inelastic Damage Analysis of Buildings, Technical Report NCEER-96-0010, State