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Evaluate the Effectiveness of the Intensity Parameter (Sa (5% and $_1$T) in IDA for Multi-degree of Freedom Structures in the Linear Behavior of Materials

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ABSTRACT
Incremental Dynamic Analysis (IDA) is developed for appropriate assessment of seismic demands and capacities for Earthquake Engineering based on performance. IDA curve is formed using this analysis by offering the severity of the damage parameters. **IDA** *requires a structural series of responses against a given set of ground motions that records of every step are magnified in different scales is to encompass all the structural behavior. IDA curve plot in classes balance better can identify the structural response. Finally, structures can be evaluated and designed based on their performance using this method.*
Keywords: Corrugated sheet steel shear walls, Shear capacity, Plasticity, Finite element

INTRODUCTION

Sophisticated methods were developed to study the behavior of structures against earthquakes concurrent with the growth in computer processing power and ability to perform accurate processing in the future. Incremental Dynamic Analysis (IDA) has emerged for the assessment of seismic demand and capacities for earthquake engineering [1]. Performance-based of structures is to design earthquake resistant structures with predictable performance. Performance methods development to improve of existing buildings and to design new buildings made the designer identify the performance level of damage to non-structural and structural components. IDA curve is made with intensity parameter (IM) and damage parameter (DM) by this analysis [2] IDA requires a structural series of responses against a given set of ground motions that records of every step are magnified in different scales is to encompass all the structural behavior (from linear to non-linear). Given the study of structure from the beginning of stimulation and the complete collapse of the structure, IDA provides a useful tool for the design. IDA curve plot in classes balance better can identify the structural response in different height as well as the hardness of various parts. By IDA several record analysis the question that how stable are a structure resistance characteristics from one record to another is responded. And finally, using this method structures can be evaluated and designed based on their performance [3].

As mentioned above, IDA curve is plotted using intensity (IM) and damage (DM) parameters, the IDA curve vertical axis is seismic intensity measure (IM) and the horizontal axis is a measure of structural damage (DM). The seismic intensity scale represents the seismic ability to stimulate the structure and measure of the degree to structure shows the damage to the structure.

Basically the aim of IDA analysis is to obtain a constant curve that represents the response of structures to earthquake loading. Due to the dynamic nature of the load applied to an IM various amounts of DM for a structure are obtained with a frequency distribution of a statistical distribution. Shome & Cornell (1999) [4] proved that this data scattering follow a lognormal distribution and by taking the logarithm of both IDA coordinate values present coordinate on a logarithmic scale. The distribution of DM against a particular IM follows a normal distribution in this axis. Thus, according to statistics, it is evident that for an appropriate statistical population we should have much of the analysis as far as possible to obtain a better distribution of the scattering data, this requires that a large number of nonlinear dynamical analysis done that is both time consuming and expensive, the dispersion can be reduced by selecting the appropriate IM [5].

Appropriate IM to be used in the IDA analysis is selected by IM benchmark performance study. Effective IM from the engineering perspective is an IM that its use leads to reduced amounts of DM distribution in a specific amount, IM performance is important in that reduces time-consuming and costly dynamic analysis [6].

Iran's seismicity and population growth as well as increased tall building construction requires a detailed analysis of structures behaviors against earthquakes. This need can be remedied by the IDA; in fact IDA curve is primarily targeted to obtain a fixed curve representative of earthquake loading on the structural response. This paper aims to investigate (Sa (5% and $_1$T)) as IM for IDA in terms of performance.

MATERIALS AND METHODS

A two-story moment frame is model according to the terms of the 2800 code for comparison between PGA and (Sa (5% and $_1$T)) . In the second stage, PGA considers a specific earthquake as an IM and the IDA curve is plotted for ten different scale factors, this curve shows the response of structures against earthquakes. The next step, two PGA intensity and (Sa (5% and $_1$T)) parameters are being selected to evaluate the performance as well as 5 different records for IDA curve.

These records of two stages are scaled at PGA and (Sa (5% and $_1$T)) and IDA curves are plotted. A two degrees of freedom frame is modeled in Etabs or SAP2000 software and time history analysis is done for it.

After the time history analysis the maximum displacement of vertex structures is obtained and the DM parameter of IDA curve is achieved.

RESULTS AND DISCUSSION

First five accelerograms were selected and scaled to PGA and Sa with ten factors, Table 1 shows their characteristics:

ChiChi Taiwan		El centro		Kobe		Loma prieta		Northrigde	
PGA(g)	Sa	PGA(g)	Sa	PGA(g)	Sa	PGA(g)	Sa	PGA(g)	Sa
0.5	1	0.5	1	0.5	1	0.5	1	0.5	1
0.65	1.3	0.65	1.3	0.65	1.3	0.65	1.3	0.65	1.3
0.75	1.5	0.75	1.5	0.75	1.5	0.75	1.5	0.75	1.5
1	2	1	2	1	2	1	2	1	2
1.5	3	1.5	3	1.5	3	1.5	3	1.5	3
2	4	2	4	2	4	2	4	2	4
2.5	5	2.5	5	2.5	5	2.5	5	2.5	5
3.5	7	3.5	7	3.5	7	3.5	7	3.5	7
4	8	4	8	4	8	4	8	4	8
5	10	5	10	5	10	5	10	5	10

Table 1. Used accelerograms Characteristics

A two degrees of freedom frame with the following characteristics is modeled in Etabs software to investigate the structural behavior of two degrees of freedom under the PGA and Sa scale records and time history analysis is done for it.

Figure 1- span of four meters, a height of three meters per floor, dead load of 900 kg/m, and live load of 300 kg/m

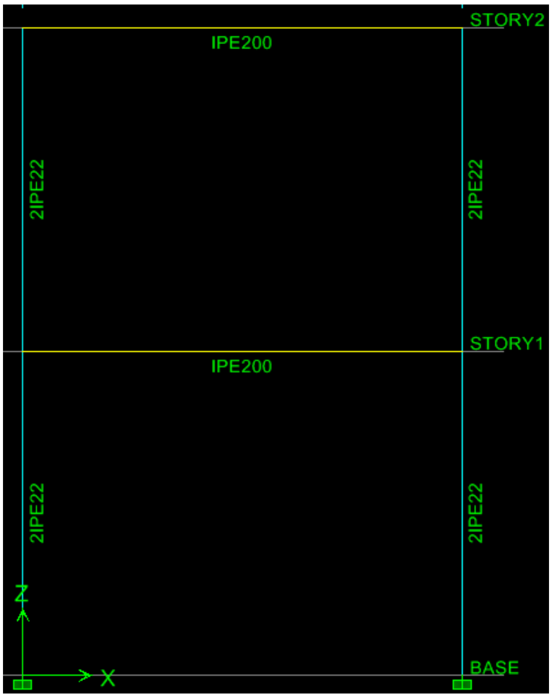


Figure 1 Frame view

After time history analysis on this model by the peak ground motion acceleration (PGA) parameters in the range of linear behavior of materials, the following results were obtained (Table 2):

Table 2 the extent of damage to the spectral acceleration corresponding to the first vibration modes of the structure (Sa (5% and $_1$T)) for five different earthquakes.

Loma prieta	Northrigde	Kobe	El centro	ChiChi Taiwan	
Displacement(cm)	Displacement(cm)	Displacement(cm)	Displacement(cm)	Displacement(cm)	PGA(g)
2.209	0.968	0.558	1.149	0.634	0.5
2.872	1.26	0.727	1.493	0.8246	0.65
3.313	1.453	0.839	1.722	0.9511	0.75
4.416	1.936	1.12	2.296	1.267	1
6.626	2.907	1.678	3.443	1.901	1.5
8.835	3.876	2.237	4.592	2.536	2
11.04	4.842	2.796	5.739	3.17	2.5
15.46	6.779	3.914	8.035	4.437	3.5
17.67	7.749	4.472	9.184	5.07	4
22.09	9.685	5.593	11.48	6.339	5

With above table's values, IDA curves will be drawn as follows:

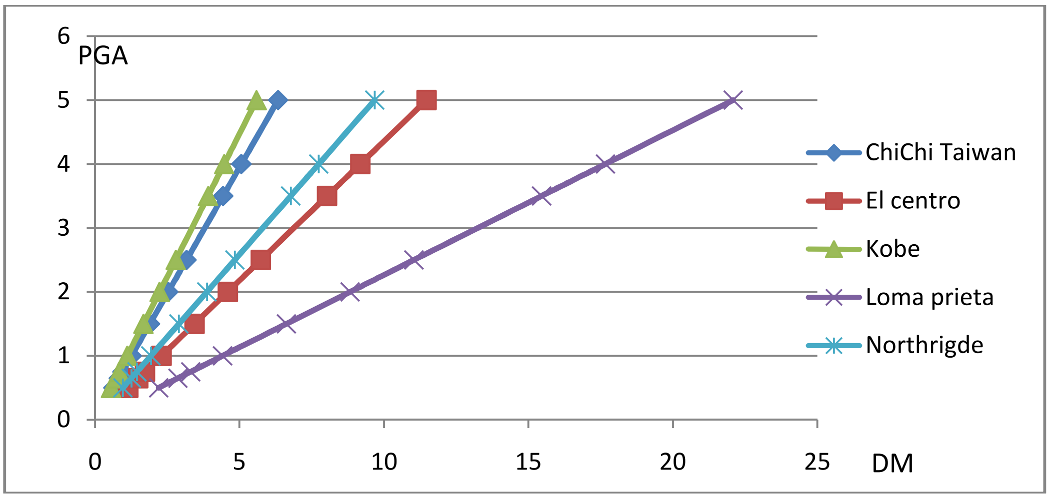


Figure 2 IDA graph for five earthquakes with PGA intensity parameter

Studying the above graphs show that though PGA is the same for all five earthquakes, seismic displacements obtained for structures are different against each of them. Non-efficacy of PGA that previously was proven in regard to one-degree of freedom structures is now again proved about two-degrees of freedom structures. Now we plot IDA curves with intensity parameter of (Sa (5% and $_1$T)) .

After time history analysis on this model by the intensity of spectral acceleration corresponding to the first vibration modes of the structure (Sa (5% and $_1$T)) of linear behavior of materials, the following results were obtained (Tables 3 and 4):

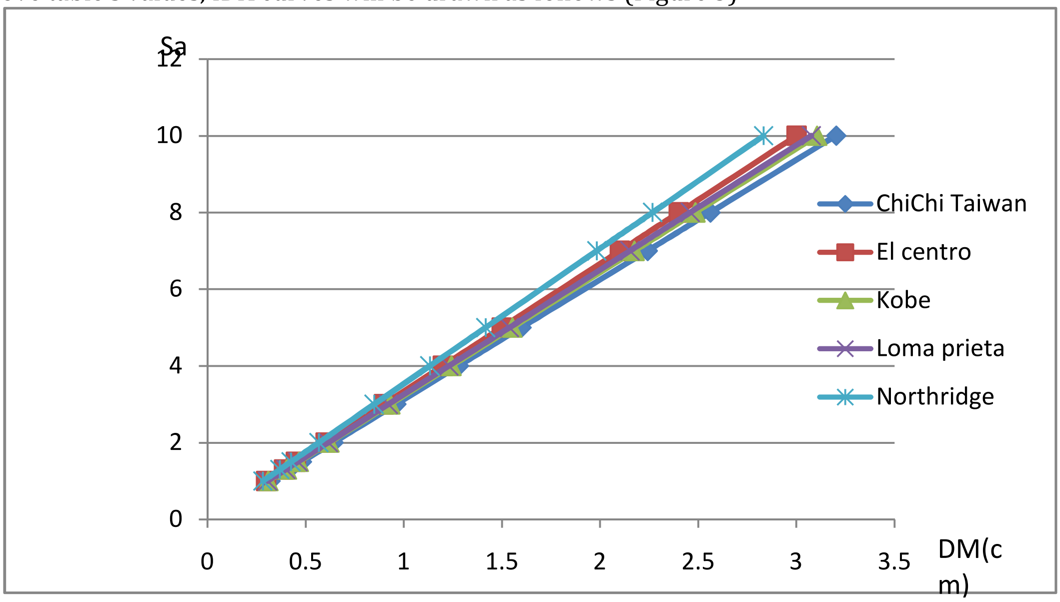
Table 3. Damage to the intensity of spectral acceleration corresponding to the first vibration modes of the structure (Sa (5% and $_1$T)) for five different earthquakes:

Table 4. Modes mass contribution percent

Loma prieta	Northrigde	Kobe	El centro	ChiChi Taiwan	
Displacement(cm)	Displacement(cm)	Displacement(cm)	Displacement(cm)	Displacement(cm)	Sa
0.2824	0.3069	0.3101	0.2989	0.3214	1
0.3688	0.3992	0.4044	0.3904	0.4177	1.3
0.4257	0.4606	0.4658	0.45	0.48	1.5
0.5673	0.6156	0.6211	0.6018	0.6413	2
0.849	0.9222	0.9312	0.899	0.9615	3
1.133	1.23	1.243	1.2	1.28	4
1.417	1.539	1.554	1.5	1.6	5
1.983	2.153	2.176	2.102	2.242	7
2.268	2.46	2.486	2.402	2.562	8
2.833	3.077	3.106	3.002	3.203	10

Mode	Modal Participating Mass Ratio
1	83%
2	17%

:With above table's values, IDA curves will be drawn as follows (Figure 3)



Studying the above graphs show that the two-degrees of freedom structure under earthquake with equal Sa demonstrated relatively similar behavior and thus the efficacy of spectral acceleration corresponding to first vibration modes of the structure (Sa (5% and $_1$T)) than the peak ground motion acceleration (PGA) that proved previously for one- degree of freedom structures is again proved about two-degrees of freedom structures.

Now, with the increasing mass contribution of the second structural mode efficiency of (Sa (5% and $_1$T)) will be re-examined.

A two degree off freedom model is modeled to increase the second mode mass contribution of the structure as follows:

First floor dead load of 1800 kg, second floor dead load of 600 kg, classes height of 3 m (Figure 4)

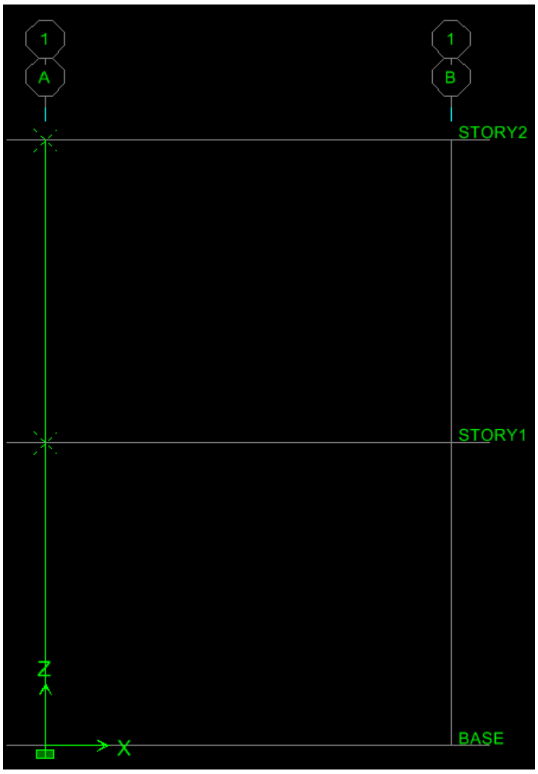


Figure 4 modeled two degree of freedom column in Etabs software

After time history analysis on this model by the intensity of spectral acceleration corresponding to the first vibration modes of the structure (Sa (5% and $_1$T)) of linear behavior of materials, the following results were obtained (Tables 5 and 6):

Table 5. Damage to the intensity of spectral acceleration corresponding to the first vibration modes of the structure (Sa (5% and $_1$T)) for three different earthquakes:

Kobe	El centro	ChiChi Taiwan	
Displacement(cm)	Displacement(cm)	Displacement(cm)	Sa
0.3446	0.3921	0.3425	1
0.4485	0.5131	0.4453	1.3
0.5161	0.5916	0.5128	1.5
0.6891	0.7908	0.6842	2
1.034	1.18	1.026	3
1.38	1.576	1.368	4
1.724	1.969	1.709	5
2.415	2.757	2.392	7
2.758	3.15	2.734	8
3.447	3.94	3.419	10

Table 6- Modes mass contribution percent

Mode	Modal Participating Mass Ratio
1	75%
2	25%

:With above table's values, IDA curves will be drawn as follows (Figure 5)

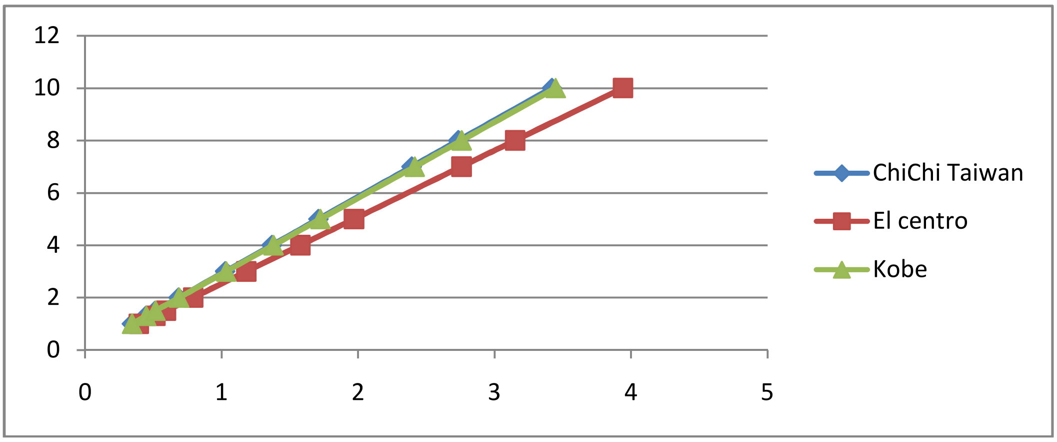


Figure 5 IDA graph for three earthquakes with intensity parameter (Sa (5% and $_1$T))
By studying the above graphs and comparing them with plotted graphs in previous section we realized some differences in results that are due to the increased mass contribution of the second.

CONCLUSION
Evaluations on the efficacy of spectral acceleration corresponding with the first period of the vibration modes of the structure (Sa (5% and $_1$T)) as a parameter of intensity (IM) for IDA brings us to the following conclusions:

1. Spectral acceleration corresponding with the first period of the vibration modes of the structure (Sa (5% and $_1$T)) as a parameter of intensity (IM) for IDA is relatively more effective than the peak ground motion acceleration (PGA).
2. Increased the higher modes mass contribution the efficiency (Sa (5% and $_1$T)) is reduced but the results show that (Sa (5% and $_1$T)) is still an effective IM.

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