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IDENTIFYING INCREMENTAL DYNAMIC ANALYSIS STAGES AND METHODS TO COPE WITH EARTHQUAKE RISKS

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Abstract. In recent years, the complexity of the structural model and the behavior of structures in the face of dynamic loads and, if necessary, more accurate estimation of demand and structural capacity, has led to the development of more efficient methods in structural analysis science. Thus, the investigations are gradually advanced from linear static to linear dynamic, nonlinear static, and eventually nonlinear dynamic. The basic problem at the time of the earthquake is the arrival of structures in the nonlinear region, which is associated with the creation of nonlinear deformations and the dynamic behavior which is the variable by time in the structure. Therefore, researchers are more inclined to carry out nonlinear analyzes to calculate more realistic behavior from the structure. In this research, we seek to investigate the incremental dynamic analysis stages and methods to address the earthquake hazards.

Keywords: Dynamic Analysis, Earthquake Hazards, Nonlinear Dynamics, Linear Dynamics, Structural Analysis

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1. INTRODUCCIÓN

As already stated, the incremental dynamic analysis is an emerging method, which is the ability to predict seismic demand and limit state capacity by using a dynamic analysis of a set of scaled earth motion records. In this research, the results of the PERFORM-3D software for two high-rise buildings with an outrigger braced system and a bracing core under the influence of near-fault records with a permanent displacement effect are presented and the dynamic analysis is being carried out. First, we study nonlinear model with linear model and then we introduce the proposed earthquakes for conducting a nonlinear analysis. The index of severity and index of damage is selected and then nonlinear dynamic analysis is performed using scaled records on the frames. Using the results of a nonlinear dynamic analysis as well as IDA curve interpolation techniques that are individually plotted for frames under close records of the fault, limit states such as uninterrupted use and dynamic instability, as well as the capacities of the limit states, calculated. In the following, using the appropriate methods, multiple IDA curves are summarized to estimate the potential distribution of frames demand against the expected severity indexes. (1)

2. Theoretical fundamentals of research

2.1 Modeling plastic joints

The total displacement force of the plastic joints used in the PERFORM 3D software is in Fig. 1. In the following graph, the FU is the ultimate strength and FR of the resistance rating.

Figure 1: Nonlinear model of plastic joints in the PERFORM

2.2 plastic joints of beams

In the modeling of the plastic joints of beams, after specifying the elastic properties of the section, the required parameters are entered using the data of tables (3-5) of the publication 360 edition 92. The Moment Himge model, the Rotation Type, has been used to define the nonlinear properties of the joints of beams. In this type of definition of the nonlinear model, we need to calculate the angular momentum of the beam. (2)

θ_y is the momentum fluid limit that is obtained for the beams from Eq.

$$\theta_y = \frac{ZF_{ye}I_b}{6EI_b} \qquad (1\text{-}1)$$

In Eq. (4-1), E is the elastic modulus, lb is the length of the beam, Ib is the moment of inertia beam and Z is the plastic section modulus. In order to determine the Dynamic Amplification Factor for the analysis of the entire structure, the smallest proportion of the angle of the plastic to elastic momentum should be used for the main members in the intensified gravitational load range. (3)

2.3 plastic joints of columns

In order to define the relation between nonlinear characteristics of the joints of columns, the FEMA Column, Steel Type model, which its joint exists in conjunction with axial force and moment anchor, is used. Inputs, based on table (5-3), publication 360 and as a coefficient of momentum surrender, are entered. Initially assuming 0.2. P/Pcl< specifications of joint are entered. Where P is the Pivot axis of column in the structure loading and Pcl is calculated from Eq.

$$P_{CL} = 1.7.Fa.A \qquad (2\text{-}2)$$

Fa is the allowable axial (compressive) stress and A is the column cross-section. After analyzing, it is controlled that the condition P/Pcl<0.2 is established; otherwise, if 0.2 <P/Pcl<0.5, the specification of joint is corrected and for P/Pcl >0.5 of the control joint is considered by force.

Figure 2: The column element used in the PERFORM

2.4 Specifications for plastic joints of braces

In order to take the non-linear behavior of braces in the PERFORM 3D, the Steel Bar / Tie / Strut-Simple Bar, which can only withstand axial force is used. For this purpose, firstly, in the nonlinear specification of materials, Inelastic Steel Material Buckling, have been used. In this type of material, behavior is different in tension and pressure. Thus, the tension and pressure characteristics are entered separately according to Table (1). (4)

Table 1: Nonlinear specification of plastic joints in braces

[6] POWER	FU [5]	[4] X	[3] L	[2] R	[1] R/F U
[12] ELASITY	1.1 [11] ×Fy	[10] 5ΔT	[9] 2DX	[8] 3D X	[7] .8
[18] FLUX	Fe [17] r=[0.658$^{Fy/Fe}$]×Fy	[16] 0ΔC	[15] .5Δ C	[14] ΔC	[13] .2

$$Fe = \frac{\pi^2 E}{\lambda^2}$$

The values of the FU division are obtained on the modulus of elasticity. Fe is also calculated from equation (3-4):

Where λ is the slenderness coefficient and E is the modulus of elasticity (5).

2.5. Nonlinear Model Examination

After completion of modeling in Perform, accuracy and validity of the model are required. For this purpose, verification of the 2-dimensional non-linear model of 40 and 60-story structures in Perform with a 3D model of the structure in this section using modal analysis We examined three periods of the first, second and third modes. (6)

As seen in the IDA curves, the stiffness of structures in some earthquakes increases with increasing severity, with the increasing or decreasing trend. The stiffness variations in such curves are justifiable in such a way that the structure sometimes increases the rate of damage accumulation and at times it can be reduced. This reduction can be powerful enough to stop or even reverse the damage accumulation for a moment, turning the curve towards less damage, and making the damage as a non-uniform function of severity. (7)

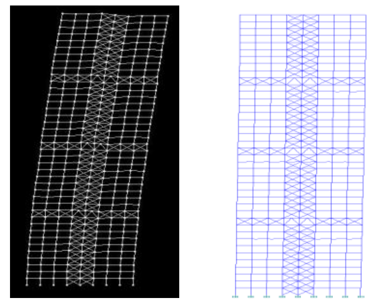

Figure 2: The first modulus of the 40-story structure in the ETABS software (on the right) and PERFORM (on the left)

2.6 Increasing dynamic curves and summarizing them

By calculating and drawing the IDA curve for each recorded data, a large amount of data is collected. IDA curves show a wide range of behavior. Also, they exhibit a lot of variability from a recorded data to another one, so it is necessary to summarize such data. To do this, we need to use appropriate summarization methods to convert these data to the IM distribution for the given DM and to eventually exceed the limit state for the given IM level. (8)

In addition, increasing dynamic curves with three statistical percentiles of 16%, 50% (center) and 84% of the corresponding two frames of the outrigger braced system under the near-fault records are shown separately using the damage index. In Figure (14-14), the summary is shown individually. (9)

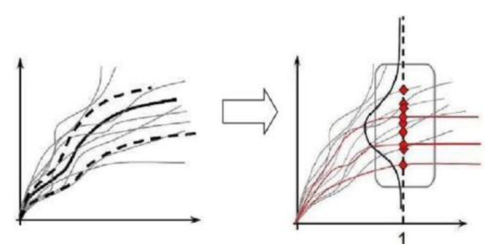

Figure 3: How to summarize IDA curves

In the next section, the results of the IDA curves for the 40- and 60-story outrigger braced system frames are presented. A summary of the functional levels of the special moment frame for the near-fault records are shown with the effect of orientation in the tables. In the following, the results of summarizing these curves are drawn as percentiles of 50%, 16% and 84% as numerical values of the damage, and the results are summarized in the table. The point to be made here is that by drawing up increasing dynamic curves in certain coordinates, some of the curves are not monotonous, that is, IDA in a given amount of severity index, there are several indexes of damage. (10)

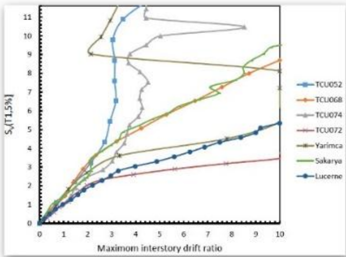

Figure 4: Multiple IDA curves for near-fault records with permanent displacement effect for the 40-story frame

Table 2: Summary of functional levels of the 40-story frame for near-fault records with a permanent displacement effect

Earthquake	Recording Station	IO		CP		GI	
		SV(m/sec)	θ_{max}	SV(m/sec)	θ_{max}	SV(m/sec)	θ_{max}
Chi-Chi	TCU052	3.2	0.02	10.88	0.035	16.32	∞
	TCU068	3.4	0.02	6.53	0.064	8.69	∞
	TCU074	2.5	0.02	9.5	0.044	11.9	∞
	TCU072	2.05	0.02	3.18	0.077	3.46	∞
Kocaeli	Yarimca	2.7	0.02	3.60	0.033	7.21	∞
	Sakarya	2.45	0.02	7.63	0.061	9.37	∞
Landers	Lucerne	1.8	0.02	3.04	0.039	5.34	∞

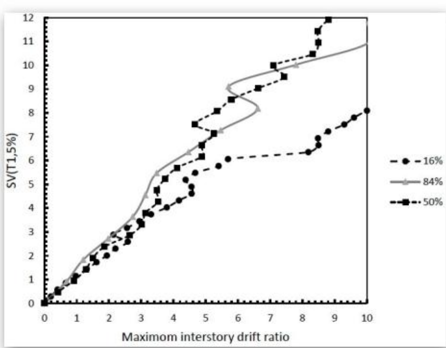

Figure 5: Summarized IDA curves fault records for 40-story frame and 50%, 16%, and 84% percentile limit states capacity

Table 3: Capacities summarized for each limit state of 40-story frame

Limit State	SV(m/sec)			θ_{max}		
	$IM^{C}_{16\%}$	$IM^{C}_{50\%}$	$IM^{C}_{84\%}$	$DM^{C}_{16\%}$	$DM^{C}_{50\%}$	$DM^{C}_{84\%}$
IO	2.02	2.45	2.8	0.02	0.02	0.02
CP	6.06	8.07	9.1	0.057	0.053	0.057
GI	8.09	13.34	10.9	∞	∞	∞

Using the above-mentioned method for summarizing, the capacities of the limit states were summed up to a series of mean values and an index of dispersion. (11) Percentile values of 50%, 16% and 84% are plotted as damage coefficients ($DM^{c}_{84\%}$, $DM^{c}_{50\%}$, $DM^{c}_{16\%}$) and numbers ($IM^{c}_{84\%}$, $IM^{c}_{50\%}$, $IM^{c}_{16\%}$) for intensity at each yield level 40-story frame was calculated. It can be concluded that in the speed velocity Sv (T1, 5%) = 8.07 m / sec or in the maximum demand for inter-class angular relative angles θ_{max} = 0.033 and 50% of the near-fault records with the effect of the permanent displacement of the 40-story frame forcing the class to CP function. (12)

3. CONCLUSION

With care in the IDA curves, it is noted that there are different behaviors of gentle reduction of intensity to softening and sudden instability of the structure among them. Each of the IDA curves represents the demand imposed by the earthquake on different levels of intensity. In a structure with several IDA curves, depending on the characteristics of the structure and the earthquake, each level of damage (DM) occurs at different levels of Intensity measure (IM), in which case the behavior of the IDA curve is very important. (13) When we look to the curves carefully, is observed that when the joint, in addition to being formed in the beam, also occurs in the column, the curve moves to the maximum relative displacement velocity, with a slight increase in the intensity level. In this case, the mechanism of erosion is formed in the structure, and this process indicates the commence of the dynamic instability. The characteristic sign of this instability is the high growth of the chart in the damage axis for a very slight increase in intensity. As a result, it gives an estimate of the dynamic capacity of the entire structural system. (14)

As seen in the IDA curves, the stiffness of structures in some earthquakes increases with increasing intensity with increasing or decreasing trend. The intense variations in such curves are justifiable in such a way that the structure sometimes face the increasing of damage accumulation rate and at times observe its reduction. This reduction can be powerful enough to stop or even reverse the accumulation of damages for a moment, turning the curve towards less damage, and exacerbating the damage as a non-uniform function.

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