COMPARISON OF INCREMENTAL DYNAMIC ANALYSIS CURVE WITH PUSHOVER CURVE

Pathan Hyderkhan [1], Dr. P. B. Murnal[2]

[1,2]*Department of Applied Mechanics Govt. College of Engineering Aurangabad, Maharashtra*

Abstract - *During the past earthquakes, different low ductile failure modes are observed in the structures and thus, the most of existing damage indices may fail to assess the damage of structures accurately in referring to the two main performance levels: serviceability and ultimate limit state.*

In order to estimate the maximum top story displacement, either the incremental dynamic analysis (IDA) or static push over analysis has been performed in the literature. Since the pushover analysis is a static analysis it cannot take into account the effects of energy content, duration and frequency content of an accelerograms while IDA analysis perform a dynamic analysis of structure under input accelerogram and then the effect of those parameters in the maximum top story displacement can be estimated. Therefore, this study we compare the pushover analysis curve with incremental dynamic analysis curve.

For this purpose we analyzed the G+3, G+6 and G+12 SMRF and OMRF structure with three different past earthquake time history data.

***Key Words*: Incremental dynamic analysis1, pushover analysis2, SMRF3, OMRF4.**

1. INTRODUCTION

1.1 Incremental dynamic analysis

Incremental dynamic analysis is a seismic analysis of structures based on performance which states the behavior of the structures in a range of different intensities of earthquakes. Due to the dynamic and non-linear nature of the earthquake, certainly the results of this method in comparison to the other types of analyses are closer to the reality of structural behavior and real earthquakes. From the papers, a review on the history and concepts and techniques of performing incremental dynamic analysis (IDA) is discussed with a record and multiple records. As it has been specified that the IDA curve with one record cannot fully express the structural behavior for future events, since IDA would be greatly dependent on the selected records. Then the Studying of multiple records - series of IDA studies with a record for a structural model under different accelerograms is necessary. Such a study will produce a series of IDA curves which can be plotted on a sheet by choosing the same IM and EDP. IDA curves, a set of IDA curves for structural models under different accelerograms that all of them are parameterized for the same IMs and EDPs.

1.2 Pushover analysis

Pushover analysis of multi-story RCC framed buildings subjected to increasing lateral forces is carried out until the preset performance level (target displacement) is reached. The promise of performance-based seismic engineering (PBSE) is to produce structures with predictable seismic performance. Pushover analysis is of two types, (i) force controlled and (ii) displacement controlled. In the force control, the total lateral force is applied to the structure in small increments. In the displacement control, the displacement of the top story of the structure is incremented step by step, such that the required horizontal force pushes the structure laterally. The distance through which the structure is pushed, is proportional to the fundamental horizontal translational mode of the structure. In both types of pushover analysis for each increment of the load or displacement, the stiffness matrix of the structure may have to be changed, once the structure passes from the elastic state to the inelastic state, the displacement controlled pushover analysis is generally preferred over the force controlled one because the analysis could be carried out up to the desired level of the displacement.

1.3 SMRF and OMRF struture

According to Indian standards moment resisting frames are classified as Ordinary Moment Resisting Frames (OMRF) and Special Moment Resisting Frames (SMRF) with response reduction factors 3 and 5 respectively. SMRF is a moment-resisting frame specially detailed to provide ductile behaviour and comply with the requirements given in IS 13920 and OMRF is a moment-resisting not meeting special detailing requirement for ductile behaviour.

2. MODEL DESCRIPTION

The structure analyzed in this study are G+3 SMRF and OMRF, G+6 SMRF and OMRF and G+12 SMRF and OMRF. All the frames have same floor plan with 4-5meter bays along longitudinal direction (X- Direction) and 4-4meter bays along transverse direction (Y-direction) as shown in fig.-1. The story height is 3 meter for all the stories. The live load taken as 3 kN/m2 on all the floors except roof and on roof it taken as 1.5 kN/m2. The floor finish for all the floor is taken as 2 kN/m2 except roof and on roof it taken as 1 kN/m2. The compressive strength of concrete is taken as 30 kN/m3 and yield strength of steel reinforcement is 415 N/mn2. The modulus of elasticity of concrete and steel are 25000 N/mm2 and 2x105 N/mm2 respectively. The elevation of G+3, G+6 and G+12 are shown in fig.-2 respectively.

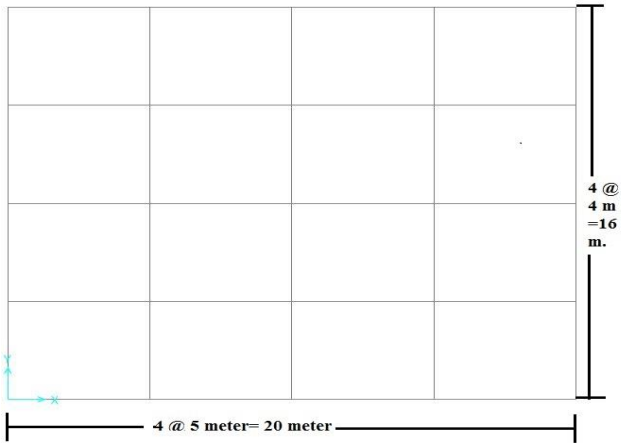

Fig -1: Typical floor plan for all structures

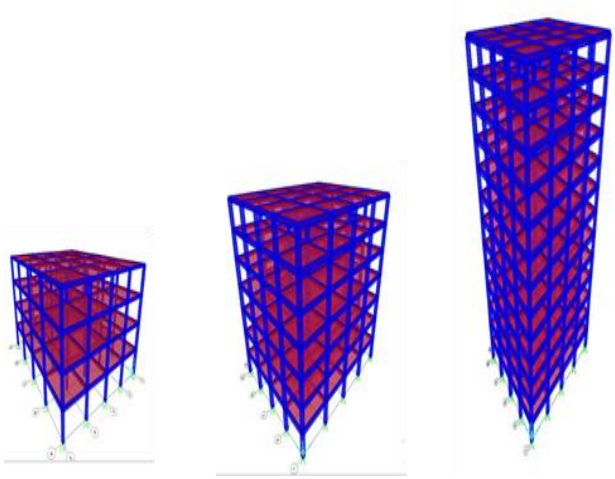

Fig -2: Elevation of all structures

All the structure mentioned above in which OMRF structure are designed as per IS 456-2000 and IS 1893 (part-I)-2016 and SMRF structure are designed as per IS 456-2000 and IS 13920-2016. All the structure are situated in seismic zone III with an importance factor 1 as per IS 1893(part I)-2016. The soil type is medium stiff soil. The cross-section details of beams and column of the frames are shown in the Table-1.

Table -1: Sizes of beam and column

Serial number	Structure	Beam size (mm)	Column size (mm)
1	G+3	300x300	300x350
2	G+6	300x450	450x450
3	G+12	450x550	450x600

3.0 METHDODLOGY

3.1 Incremental dynamic analysis

Incremental dynamic analysis is a nonlinear time history analysis of structures based on the structural performance which states the behavior of the structures in a range of different intensities of earthquake. In this method a structural model subjected to one (or more) ground motion record(s), each scaled to multiple levels of intensity, thus producing one (or more) curve(s) of response parameterized versus intensity level. Due to the dynamic and non-linear nature of the earthquake, certainly the results of this method in comparison to the other types of analyses are closer to the reality of structural behavior. However, this method is a time consuming method and like other kind of time history methods, is too dependent on the records. Moreover, selection of intensity measures and engineering demand parameters are important issues in incremental dynamic analysis. This method has accepted by the guidelines of Federal Emergency Management Agency (FEMA) and can be used as a method in order to determine the potential collapse capacity of the entire structure.

For incremental dynamic analysis past earthquake records of El-centro earthquake, Bhuj earthquake and Chamoli earthquake were used. This earthquake records (PGA) were scaled from .1g to 1.1g for this analysis using seismosignal software.

Table-2 Earthquake data used for analysis

Name of Earthquake	Date	PGA(g)
El-Centro	18-5-1940	Scaled from .1g to 1.1g
Bhuj	26-01-2001	Scaled from .1g to 1.1g
Chamoli	29-3-1999	Scaled from .1g to 1.1g

3.2 Pushover analysis

In Pushover analysis, a static horizontal force profile, usually proportional to the design force profiles specified in the codes, is applied to the structure. The force profile is then incremented in small steps and the structure is analyzed at each step. As the loads are increased, the building undergoes yielding at a few locations. Every time such yielding takes place, the structural properties are modified approximately to reflect the yielding. The analysis is continued till the structure collapses, or the building reaches certain level of lateral displacement. It provides a load versus deflection curve of the structure starting from the state of rest to the ultimate failure of the structure. The load is representative of the equivalent static load of the fundamental mode of the structure. It is generally taken as the total base shear of the structure and the deflection is selected as the top-story deflection. The selection of appropriate lateral load distribution is an important step. The first step then is to select a displacement shape and the vector of lateral loads is determined as

$$\{F\} = p[m]\{\Phi\} \qquad (1)$$

Where $\{\Phi\}$ is the assumed displacement shape, and p is the magnitude of the lateral loads. From equation (1), it follows that the lateral force at any level is proportional to the assumed displacement shape and story mass. If the assumed displacement shape was exact and remained constant during ground shaking, then distribution of lateral forces would be equal to distribution of effective earthquake forces.

4.0 RESULTS AND DISCUSSION

To compare the incremental dynamic analysis with pushover analysis the PGA values of incremental dynamic analysis are multiplied with the seismic weight of the structure. The calculated seismic weight of structures are shown in table below

Table 3 Seismic weight of Structures

Serial number	Frame	Seismic Weight(kN/g)
1	G+3	993.7883
2	G+6	2000.669
3	G+12	4401.574

The results obtained from incremental dynamic analysis (IDA) were multiplied with seismic weight and compared with pushover analysis. The obtained results of the structure for G+3, G+6 and G+12 structures with comparison on the same graph are shown below.

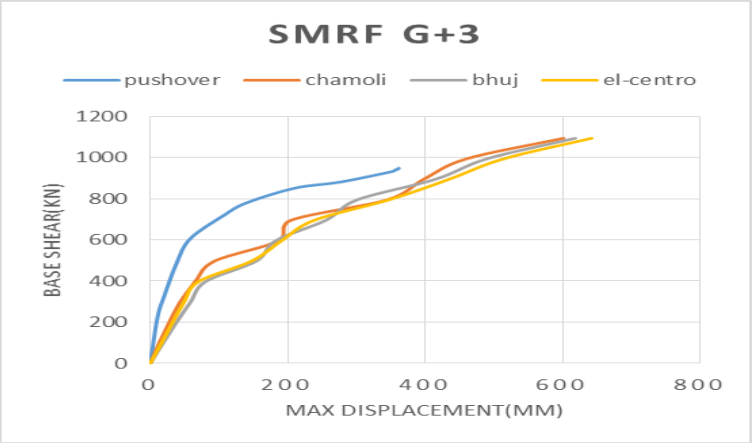

Chart -1: Comparison of IDA and pushover of G+3 SMRF structure

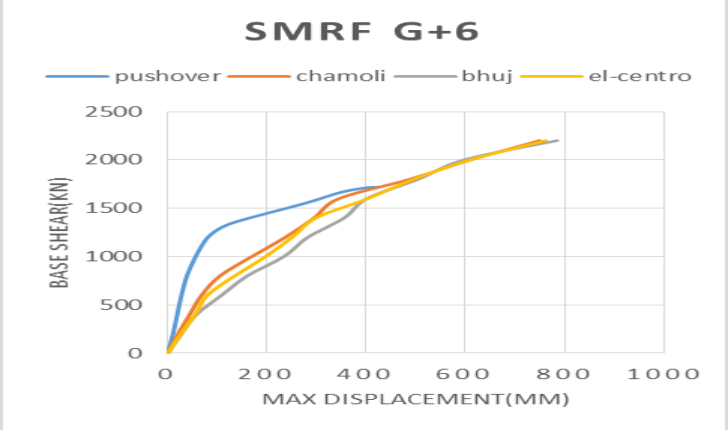

Chart -2: Comparison of IDA and pushover of G+6 SMRF structure

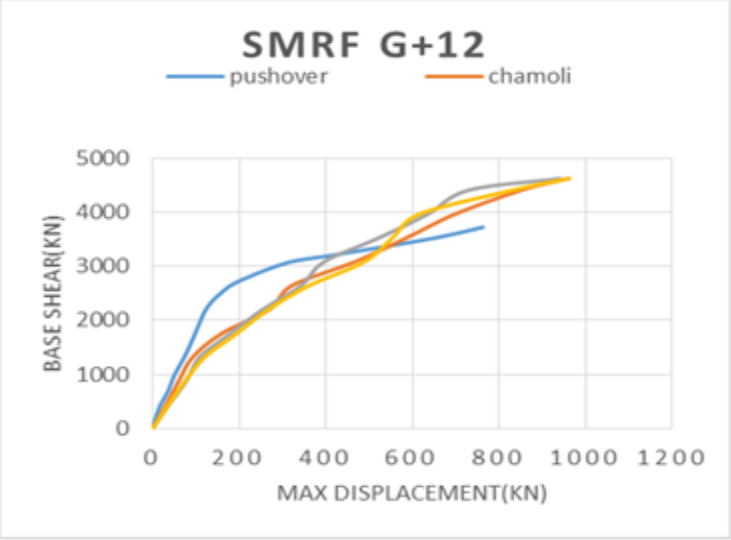

chart -3: Comparison of IDA and pushover of G+12 SMRF structure

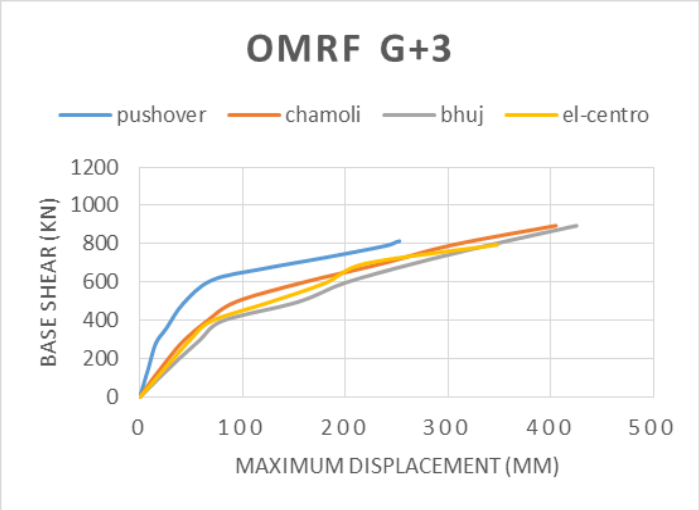

Chart -4: Comparison of IDA and pushover of G+3 OMRF structure

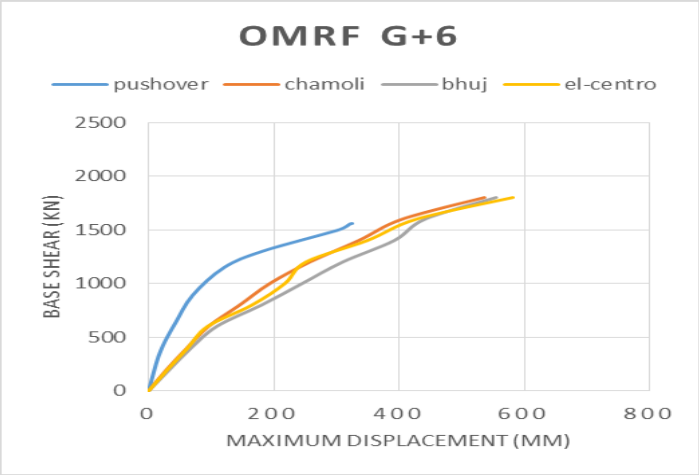

Chart -5: Comparison of IDA and pushover of G+6 OMRF structure

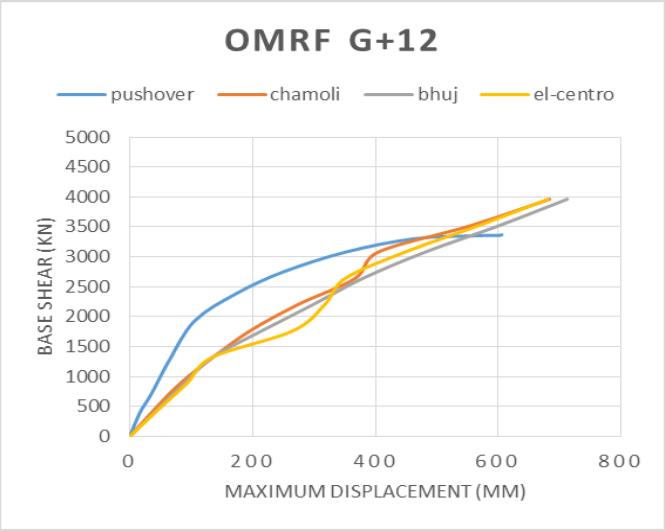

Chart -6: Comparison of IDA and pushover of G+12 OMRF structure

The comparison of pushover and incremental dynamic analysis shows that for G+3 structure the maximum top story displacement for time history analysis is 77.58% and 68.19% more compare to pushover analysis for SMRF and OMRF structure respectively. For G+12 structure this value decreased to 26.15% and 17.57% for SMRF and OMRF respectively. The base shear values for time history analysis are 15.28% and 22.15% more as compare to pushover analysis for G+3 SMRF and OMRF respectively. And for G+12 structures the base shear values for time history analysis are 24.22% and 30.68% more as compare to pushover analysis for SMRF and OMRF structure. It also shows that the displacement values with incremental dynamic analysis are always more as compare to pushover analysis.

5. CONCLUSIONS

Incremental dynamic analysis and pushover analysis were conducted for G+3, G+6 and G+12 with SMRF and OMRF frames considered in the study in-order to evaluate their seismic performance in terms of maximum top story displacement. From the obtained results it can be concluded as:

- The response of structures for the same base shear value is more from incremental dynamic analysis as compare to pushover analysis.
- The values obtained from incremental dynamic analysis are more realistic and higher as compared with nonlinear static pushover analysis

REFERENCES

[1] Hamed Arshadi, "An Overview on The Concepts And Methodologies of Incremental Dynamic Analysis IDA (With A Single Record and Multiple Records)" Journal of A Structural Congress (2016), Vol. 3, pp. 168-176.

[2] J. Marasingha, K.K. Wijesundara and U.I. Dissanayake "Comparison of Incremental Dynamic Analysis Curve with Pushover Curve", Journals of Symposium on Engineering Advancements (2013), Vol. 2, pp. 155-158.

[3] Athanasia Zacharenaki, Michalis Fragiadakis, Dominic Assimaki and Manolis Papadrakakis "Bias Assessment in Incremental Dynamic Analysis due to Record Scaling" Journal of Soil Dynamics and Earthquake Engineering (September 2014) Vol.37, pp. 236-248, Elsevier Science Ltd.

[4] Asghar Bahramirad, Mohsen Tehranizadeh and Amir Moshref, "Equating Incremental Dynamic Analysis with Static Nonlinear Analysis at Near-Field Excitation" Journal of Earthquake Engineering and Engineering Vibration (September, 2015) Vol.14, No.3, pp. 789-801.

[5] FEMA (2000) "Prestandard and Commentary for the Seismic Rehabilitation of buildings", FEMA 356, Federal Emergency Management Agency, Washington.