

# Incremental Dynamic Analysis of RC Framed Structures by adopting Site Specific Data

<sup>[1]</sup> Abhijeet A. Galatage, <sup>[2]</sup> Sastish B. Patil  
MIT School of Engineering, Pune

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**Abstract:** -- Due to improper knowledge of seismic hazards buildings designed using modern principles observe earlier failure. This leads to loss of property as well as lives. Structures subjected to the earthquake are supposed to be analysed by possible practical methods for forecasting seismic demands. Hence such methods which are based on the behaviour of structures need to be developed prior to design. The exact analysis can be obtained by imparting site-specific data to predict the performance of the structure along with nonlinear analysis. Ground motions are scaled to get SSD using SEISMOMATCH 2016 to perform incremental dynamic analysis of structures using SAP 2000 subjected to several ground motions. Pushover curves are plotted for each structural model. The study is carried out considering earthquake-prone region of north India on 5, 12 and 18-storey moment resisting RC frames. The structures analysed for selected ground motion found to be more efficient for absorbing like actual vibrations and also make the analysis procedure more effective.

**Keywords:** Seismic demands, SSD, IDA, Scaling, Pushover Curves.

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## I. INTRODUCTION

Nowadays the Performance Based Earthquake Engineering (PBEE) approach has been successfully developed to do the same. It promotes the idea of designing structures with higher levels of performance standards across multiple limit states. Apart from PBEE, a new analysis approach, called Incremental Dynamic Analysis (IDA), has been developed to evaluate the performance of structures. It involves subjecting a structural model to one (or more) ground motion records, each scaled to multiple levels of intensity, thus producing IDA curves of response versus intensity level. Many studies have been conducted in this domain to improve the accuracy of prediction of response of the structure. However, the ground motions used in IDA play important role in increasing the efficiency of the method. These ground motions are scaled using various scaling methods such as frequency matching, spectral matching etc. to obtain suitable scale factors. The selection and scaling of earthquake ground motions is an important step in defining the seismic loads that will be applied to a structure during structural analysis and serves as the interface between seismology and engineering. Lamperty and Abrahamson [3] investigated limits on scaling of ground motions by comparing traditional magnitude-distance based ground motion selection with the post scaling selection of ground motion. The study considered reference event of the magnitude of MW =7 and compared it with 10 time series

of similar magnitudes which were applied with scale factors ranging from 3.5- 12.6 and parameter considered was Newmark's displacement. The study observed that for post scaling time series selection having magnitude Mw ranging from 6.19 to 6.93 accuracy of response prediction with nearby values of Newmark's displacements as design event was increased. Reyes and Kalkan [4] investigated the ASCE/SEI-7 ground motion scaling procedure to determine the number of records such that scaled records provide accurate, efficient and consistent estimates of true median structural responses. Records were selected based on magnitude, distance, soil type and period. The authors examined cases like fewer than seven and more than seven ground motions. It was concluded that the above procedure was neither efficient nor consistent for less than seven records. It was also found that increasing the number of records from 7 to 10 had a minor effect on the accuracy of procedure and use of 7 records was found efficient. Tayyebi S. [9] performed and compared different types of nonlinear analysis methods for evaluating the seismic performances of structures. The study considered three models representing low-rise, medium-rise and high-rise structures consisting of a moment resisting reinforced concrete structures with no shear walls, located in a high-seismicity region of Turkey. The capacity curves of the structures, as derived by both DAP and FEMA440 pushover curves were compared with

the IDA envelopes by using the SeismoStruct software. Both Adaptive Pushover Analysis as well as Incremental Dynamic Analysis were performed using 20 ground motions. The study concluded that IDA provides an optimal solution over ADP.

Pasticier et al. [11] investigated the application of SAP 2000 for incremental dynamic analysis of masonry building. Two walls modelled using equivalent frame modelling analyzed and compared with analysis of an existing two story building having stone masonry walls located in north-east Italy. The static and dynamic pushover analyses were performed to plot dynamic pushover curves followed by fragility curves. The study considered a two story existing building in North-east of Italy. Plastic hinges, nonlinear links were introduced in building and static pushover analysis, time history analysis was performed. The study observed that the minimum base shear strength was always obtained when the triangular distribution of seismic forces is applied.

Vamvatsikos and Cornell [14] compared Incremental Dynamic Analysis with the nonlinear static pushover and R-factor methods for prediction of response of the structure. The study illustrated single record IDA as well as multi-record IDA by analyzing 20 storey steel moment resisting frame and 5-storey steel chevron braced frame including P-delta effects. The study showed that for elastic range SPO and IDA had nearly equal displacements while IDA proved to be an effective tool as it addressed both capacities as well as demand. Moniri [16] evaluated the seismic performance of RC framed buildings using IDA for near field earthquakes. The study considered three buildings of 6, 10 and 15 storey designed as per ACI code specifications using ETABS software. Also, the non-linear structural analysis was carried out using OpenSees software by applying 14 near -field and 14 far-field ground motions scaled using ASCE 07-05 standard. The results of study observed parameters like storey shear, storey drift, and inter-story displacement. The study showed that Near-fault conditions produce higher requirements' when compared to far-fault conditions and proved to be less efficient at higher periods. Javanpour M. and Zarfani P. [20] investigated the application of IDA for studying the dynamic behavior of steel structures during the earthquakes. The two same-order steel structures with two types of structural systems (coaxial moment frames and moment frame) were modeled using OpenSees software. Seismic loading was based on the Fourth Edition of Iranian 2800 instruction. The study showed that depending on the type of IM and DM

parameters, 20% to 90% of vulnerability values of steel moment frames were less than coaxial braced frame structures (cross).

## II. OBJECTIVE

Following are the objectives of the proposed work:

1. To learn the extraction of time history data from PEER NGA-WEST ground motion database and COSMOS VDC.
2. To select and scale ground motions using the appropriate method to match the target spectrum.
3. To perform the incremental dynamic analysis for a building using scaled ground motions.
4. To understand the concept of EDP parameters using IDA curves for base shear, spectral displacement, storey displacement, storey drift.

## III. METHODOLOGY

### 3.1 Probabilistic Seismic Hazard Analysis (PSHA)

PSHA provides a frame work in which these uncertainties can be identified, quantified and combined in a rational manner to provide a complete picture of the seismic hazard. The accuracy of PSHA depends on the accuracy with which uncertainty in earthquake size, location, recurrence, and effects can be characterized. Although models and procedures for characterization of the uncertainty of these parameters are available they may be based on data collected over periods of time that, geologically, are very short.

### 3.2 Incremental Dynamic Analysis (IDA)

IDA is able to estimate limit-state capacity and seismic demand by performing a series of nonlinear time history analyses under a suite of multiple scaled accelerogram records of earthquake ground motion acceleration. In IDA method, the intensity of selected ground motion is incrementally increased until the intended limit state seismic capacity of the global structural system is achieved. Besides, it contains plotting an intensity measure (i.e. first mode spectral acceleration.) Moreover, the accuracy of IDA results depends on the number of chosen accelerogram records. According to research performed by Shome and Cornell (1999), it is usually enough to select ten to twenty accelerograms records to estimate limit-state capacity and seismic demand of structures with sufficient accuracy. Appropriate post processing can present the results in terms of IDA curves, one for each ground motion record, of the

seismic intensity, typically represented by a scalar Intensity Measure (IM), versus the structural response or Damage measure(DM), as measured by an Engineering Demand Parameter (EDP).

### 3.3 PEER Strong Motion Database

The web-based Pacific Earthquake Engineering Research Center (PEER) ground motion database provides tools for searching, selecting and downloading ground motion data. All downloaded records are unscaled and as-recorded. The scaling tool available on this site is to be used to determine the scale factors to be used in the simulation platform. These scale factors can be found with the record metadata in the download. However strict limit has been imposed on the number of records that can be downloaded within a unique time window. The current limit is set at approximately 200 records every two weeks, 400 every month.

**NGA-West2 -- Shallow Crustal Earthquakes in Active Tectonic Regimes** The NGA-West2 ground motion database includes a very large set of ground motions recorded in worldwide shallow crustal earthquakes in active tectonic regimes. The database has one of the most comprehensive sets of meta-data, including different distance measure, various site characterizations, earthquake source data, etc.

### NGA-East -- Central & Eastern North-America

The objective of NGA-East is to develop a new ground motion characterization (GMC) model for the Central and Eastern North-American (CENA) region. The GMC model consists of a set of new ground motion models (GMMs) for median and standard deviation of ground motions (GMs).

### 3.4 Seismo Match 2016

SeismoMatch2016, V1.3.0 is an application capable of adjusting earthquake accelerograms to match a specific target response spectrum, using the wavelets algorithm proposed by Abrahamson (1992) and Hancock et al. (2006). Some of its features are:

- i. Simultaneous matching of a number of accelerograms, and then the creation of a mean matched spectrum whose maximum misfit respects a pre- defined tolerance.
- ii. The possibility of using this software in combination with records selection tools and record appropriateness verification algorithms to define adequate suites of records for nonlinear dynamic analysis of new or existing structures.
- iii.
- iv. The capability of reading single accelerograms defined in both single- or multiple-values per line formats or of reading a number of accelerograms at the same time.

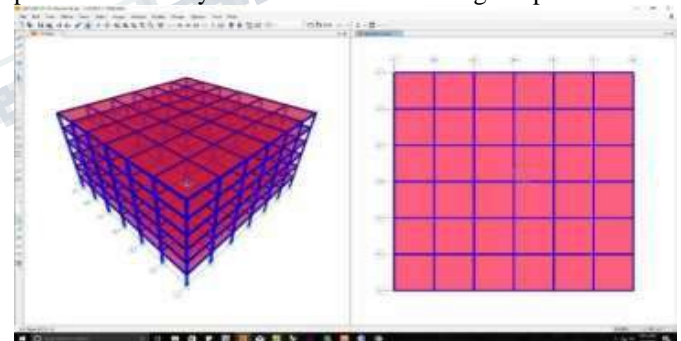
- iv. Creation of the target spectrum by following Eurocode 8 rules, by computing the spectrum of a specific accelerogram or by simply loading a user- defined spectrum.

### 3.5 COSMOS Virtual Data Centre

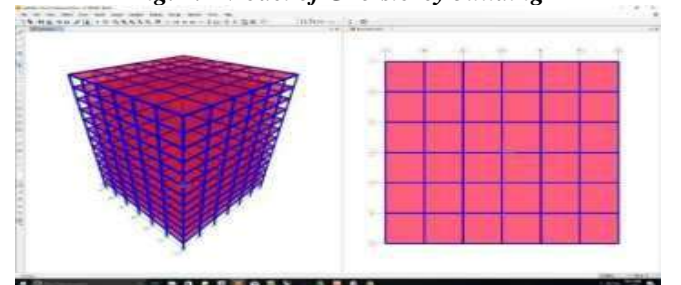
The VDC is a public, web-based search engine for accessing worldwide earthquake strong ground motion data. While the primary focus of the VDC is on data of engineering interest, it is also an interactive resource for scientific research and government and emergency response professionals. The VDC was developed at University of California Santa Barbara with funds from the National Science Foundation, with initial support provided by the Southern California Earthquake Center. Subsequent support has been provided by the US Geological Survey and the California Geological Survey. The VDC was incorporated as a part of the Center for Engineering Strong Motion Data (CESMD) in 2012. The Consortium of Organizations for Strong-Motion Observation Systems (COSMOS) serves as a liaison in facilitating data access from international strong-motion networks.

## IV. PRESENT STUDY

The present study aims at performing IDA using scaled ground motion records for three models from low, medium and high rise category. The structural elements which are provided for analysis of RC framed building are presented .

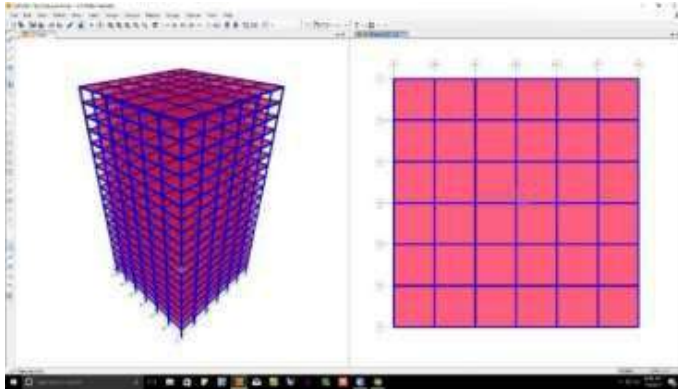


**Fig. 4.1 Model of G+5 storey building**



**Fig. 4.2 Model of G+12 storey building**





**Fig. 4.3 Model of G+18 storey building**

### V. CONCLUSION

Incremental Dynamic Analysis of three RC framed buildings of a different number of stories i.e 5, 12, 18 have been carried out using commercially available SAP 2000 V.15 software. The purpose of the analysis was to predict the behavior of the structures under a suite of seven ground motions scaled using SeismoMatch 2016 program. The results are presented in form of Storey displacement, story drift, and IDA curves.

Following conclusions were obtained from results:

- 1) All the ground motions were properly extracted from PEER Strong motion database as well as COSMOS VDC to input in SeismoMatch 2016 successfully.
- 2) Use of SeismoMatch 2016 for scaling of ground motions have yielded good results and accurate scale factors were obtained by using Spectral matching for all the ground motions as shown in table 4.2. Maximum Scale factor was found to be 9.85 for Chamba.
- 3) Storey displacement and Storey drift for the 12-storey building was found to be maximum for Chamba earthquake record having PGA of 0.47g and scale factor of 9.85.
- 4) The minimum value of Storey displacement and Storey drift was obtained for El Centro earthquake record having PGA of 0.41g and scale factor of 0.79
- 5) The earthquake records having more PGA and scale factors produced greater displacement as well as drift as Compared to those having least values, hence one can conclude that behavior of the structure is highly dependent on the magnitude of the earthquake.
- 6) The selection of earthquake records should be done carefully to increase the efficiency of the procedure. i.e. No aftershocks should be selected.

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