Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 11, November -2017

A REVIEW ON PERFORMANCE EVALUATION OF RC MOMENT RESISTING IRREGULAR FRAMES USING NONLINEAR DYNAMIC ANALYSIS

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Abstract —*Engineering structures are very complex and difficult to analyze for their dynamic, or vibrational, behavior. With the incidental loss of life and property witnessed in the last couple of decades alone in India, due to failure of structures caused by earthquakes, now attention is given to neglect the adequacy of strength in RC framed structures to resist strong ground motions. To determine structural response beyond yield point, out of two types of nonlinearity material and geometrical, material nonlinearity is considered in present paper. As such, nonlinear analysis can play an important role in the analysis and design of new and existing buildings.*

In the present paper, RC Moment Resisting Irregular Frames (T Shape) of 5, 9,12 and 15 Story are analyzed for seismic Zone III and designed as per IS code provisions, considering both seismic and gravity loads. Further, performance evaluation of above frames is done using Non Linear Time History Analysis (NLTHA) in Seismostruct software.

Keywords*-RC Moment Resisting Irregular Frames, Performance Evaluation,Non Linear Time History Analysis, Seismostruct software.*

I. INTRODUCTION

Building codes require that structures should be designed to withstand a certain intensity of ground acceleration, with the intensity of the ground motion depending on the seismic hazard. Because of the high forces imparted to the structure by the earthquake, the structures are usually designed to have some yielding. The goal of earthquake engineering is to minimize loss of life due to the collapse of the yielding structure. However, the costs involved in replacing and rehabilitating structures damaged by the relatively moderate earthquakes have proven that the “Life-Safe” building design approaches are economically inefficient. As a result, the principle of “Performance Based Earthquake Engineering” (PBEE), which promotes the idea of designing structures with higher levels of performance standards across multiple limit states, has been proposed. In association with PBEE principles, a new analysis approach, called Incremental Dynamic Analysis (IDA), has been developed to assist the engineer in evaluating the performance of structures.

In performance based design, the response of structure is considered beyond elastic limit. Static and dynamic non-linear analysis are the analysis techniques used for performance based design. Elastic analysis gives a good indication of the elastic capacity of the overall structure and indicates where first yielding occur. It can’t predict failure mechanisms and account for redistribution of forces during progressive yielding. Inelastic analysis procedures helps to understand that how the building really works by identifying modes of failure & the potential of progressive collapse.

The capacity of structural members to undergo inelastic deformations governs the structural behaviour and damageability of multi-storey buildings during earthquake ground motions. From this point of view, the evaluation and design of buildings should be based on the inelastic deformations demanded by earthquakes, besides the stresses induced by the equivalent static forces as specified in several seismic regulations and codes. In general, the study of the inelastic seismic responses of buildings is not only useful to improve the guidelines and code provisions for minimizing the potential damage of buildings, but also important to provide economical design by making use of the reserved strength of the building as it experiences inelastic deformations.

II. LITERATURE REVIEW

A. Do We Really Need Inelastic Dynamic Analysis? Sep-2009

Amr S.Elnashai; “The paper examines the requirements for inelastic static and dynamic analysis applied to earthquake design and assessment. Conventional pushover, with various load distributions, as well as advanced adaptive concepts are examined and compared to incremental dynamic analysis. Regions of applicability of each are discussed and suggestions on which method is better suited under a given set of conditions are qualitatively made. In this paper, results from recent work on conventional and adaptive pushover analysis are displayed and discussed. Comparisons with dynamic analysis, applied incrementally to obtain a "dynamic pushover curve”. Finally, a qualitative assessment of the results is given, leading to suggestions for application of advanced pushover methods and where to employ dynamic analysis. Recent extensive work e.g. Mwafy, 2001; Mwafy and Elnashai, 20011 compared capacity curves obtained from fixed distribution pushover analysis, using various combinations of modes, and capacity curves obtained from running a large number of dynamic analyses, under increasing earthquake intensity. It is interesting to note that in this case, there is not a single static curve that traces the entire dynamic curve progression. An observation made to close, we do need inelastic dynamic analysis, but with necessary domain.

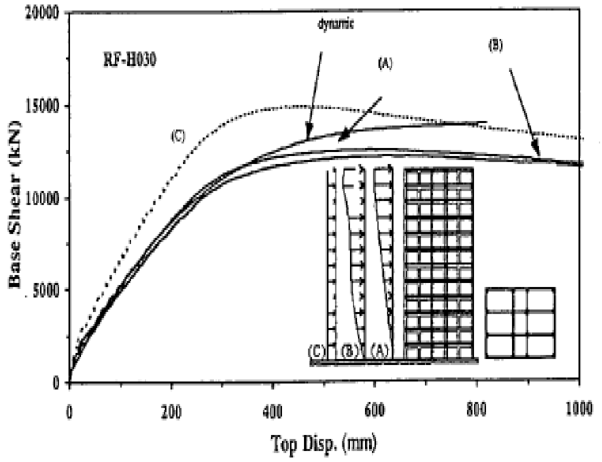

Fig. 1. Comparison of static and dynamic pushover curves with different force distributions [Mwafy and Elnashai, 2001].

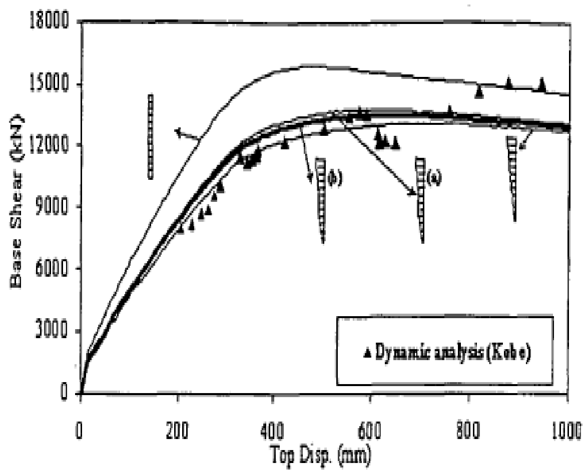

Fig. 2. Comparisons of static analysis with multimodal distribution and dynamic analysis [Mwafy and Elnashai, 2001].

B. Criteria For Performance Evaluation Of Rc Building Frames Using Non Linear Time History Analysis For Performance Based Design.

Jiji Anna Varughese, Devdas Menon;"Displacement-based design (DBD) is proceeding as the new trend for seismic design of buildings. The performances of buildings designed using these methods are usually proceeding by conducting non-linear time history analysis. The inadequacy of performance assessment depends on proper non-linear material modeling, selection of proper earthquake records and their appropriate setting up of acceptance states. In this paper discusses the provisions of various seismic guidelines including ATC 63, FEMA P695 (2009) and PEER Center report No 2010/05 and recent research findings on the above parameters. According to FEMA P695, there are many issues that are not resolved in the field of near-field hazard and ground motion effects. When they are to near-field pulses, they are considered to be near-field pulses. Time history analysis done on a 15-storeyed frame (which is designed as a DBD) shows an increase in roof displacement of the order of two and inter-storey drift amplification of about 2.7 near the base, when near-field ground motions are used for performance assessment."

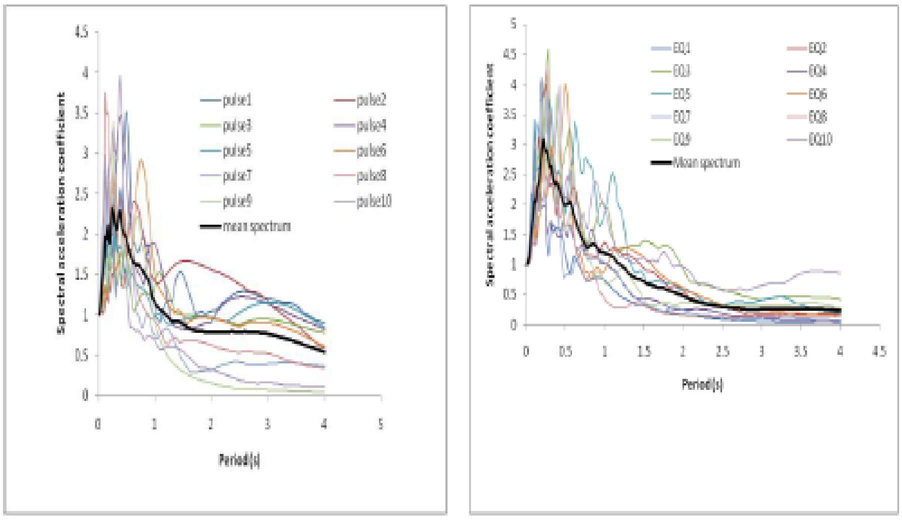

Figure 2 Normalized response spectra for (a) near-field ground motions, strike normal components (b) far-field ground motions

C. The Incremental Dynamic Analysis And Its Applications To Performance Based Earthquake Engineering.

Dimitrios Vamvatsikos, C.Allin Cornell; "An important issue in Performance-Based Earthquake Engineering is the estimation of structural performance under seismic loads, in particular the estimation of the mean annual rate of exceeding a specified level of structural demand or a certain limit-state capacity. A promising method that has recently risen to meet these needs is Incremental Dynamic Analysis (IDA), which involves performing nonlinear dynamic analyses of the structural model under a suite of ground motion records. Incremental Dynamic Analysis (IDA) is an well known analysis method that offers thorough seismic demand and capacity prediction capability by using a series of nonlinear dynamic analyses under a multiply scaled suite of ground motion records. Realization of its opportunities requires several innovations, such as choosing suitable ground motion Intensity Measures (IMs) and representative Damage Measures (DMs). IDA can provide intuition for the behavior of structures and shed new light on the connection between the Static Pushover (SPO) and the dynamic response. To illustrate all the above concepts, a complete walkthrough of the methodology is presented by using a 9-storey steel moment-resisting frame with fracturing connections as an example to explain and clarify the application of the IDA to Performance-Based Earthquake Engineering (PBEE). By available software it has become almost trivial to perform the analysis, generate the IDA curves, estimate limit-state capacities and summarize the results."

SET OF GROUND MOTION RECORDS

No	Event	Station	$\phi^{o\,1}$	Soil[2]	M[3]	R[4] (km)	PGA (g)
1	Loma Prieta, 1989	Agnews State Hospital	090	C,D	6.9	28.2	0.159
2	Imperial Valley, 1979	Plaster City	135	C,D	6.5	31.7	0.057
3	Loma Prieta, 1989	Hollister Diff. Array	255	–,D	6.9	25.8	0.279
4	Loma Prieta, 1989	Anderson Dam Downstream	270	B,D	6.9	21.4	0.244
5	Loma Prieta, 1989	Coyote Lake Dam Downstream	285	B,D	6.9	22.3	0.179
6	Imperial Valley, 1979	Cucapah	085	C,D	6.5	23.6	0.309
7	Loma Prieta, 1989	Sunnyvale Colton Ave	270	C,D	6.9	28.8	0.207
8	Imperial Valley, 1979	El Centro Array #13	140	C,D	6.5	21.9	0.117
9	Imperial Valley, 1979	Westmoreland Fire Station	090	C,D	6.5	15.1	0.074
10	Loma Prieta, 1989	Hollister South & Pine	000	–,D	6.9	28.8	0.371
11	Loma Prieta, 1989	Sunnyvale Colton Ave	360	C,D	6.9	28.8	0.209
12	Superstition Hills, 1987	Wildlife Liquefaction Array	090	C,D	6.7	24.4	0.180
13	Imperial Valley, 1979	Chihuahua	282	C,D	6.5	28.7	0.254
14	Imperial Valley, 1979	El Centro Array #13	230	C,D	6.5	21.9	0.139
15	Imperial Valley, 1979	Westmoreland Fire Station	180	C,D	6.5	15.1	0.110
16	Loma Prieta, 1989	WAHO	000	-,D	6.9	16.9	0.370
17	Superstition Hills, 1987	Wildlife Liquefaction Array	360	C,D	6.7	24.4	0.200
18	Imperial Valley, 1979	Plaster City	045	C,D	6.5	31.7	0.042
19	Loma Prieta, 1989	Hollister Diff. Array	165	–,D	6.9	25.8	0.269
20	Loma Prieta, 1989	WAHO	090	–,D	6.9	16.9	0.638

[1] Component [2] USGS, Geomatrix soil class [3] moment magnitude [4] closest distance to fault rupture

D. Evaluation Of The Seismic Performance Of Existing RC Buildings: A Case Study For Regular And Irregular Buildings.

Christos Zeris, Elisabeth Vintzileous; "In order to assess the performance evaluation a methodology was developed, based on inelastic static pushover (SPO) analysis, following an initial design and a series of failure Limit Criteria (LC) evaluations in order to establish the limiting deformability of the structure. This methodology is applicable to both modern and existing RC frames of interest herein. The details of the evaluation process, the modeling conventions and the LC adopted were described in this paper. The results are presented, concerned with the evaluation of the structural over-strength, the global ductility and the available behavior factor of existing reinforced concrete (RC) buildings designed and constructed according to past generations of earthquake resistant design codes in Greece. A collection of 85 typical building forms is considered. The influence of various parameters is examined, such as the geometry of the structure (number of storeys, bay width etc.), the vertical irregularity, the contribution of the perimeter frame masonry infill walls, the period of construction, the design code and the seismic zone coefficient. The results from inelastic pushover analyses indicate that existing RC buildings exhibit higher over-strength than their contemporary counterparts, but with much reduced ductility capacity. The presence of perimeter infill walls increases considerably their stiffness and lateral resistance, while further reducing their ductility. Fully infilled frames exhibit generally good behavior, while structures with an open floor exhibit the worst performance by creating a soft storey. Shear failure becomes critical in the buildings with partial height infills. It is also critical for buildings with isolated shear wall cores at the elevator shaft. Out of five different forms of irregularity considered in this study, buildings with column discontinuities in the ground storey exhibit the worst performance. Furthermore, buildings located in the higher seismicity zone are more vulnerable, since the increase of their lateral resistance and ductility capacity is disproportional to the increase in seismic demand."

E. Performance Evaluation Of RC Moment Resisting Symmetric Frames Using Nonlinear Dynamic Analysis.

Assistant Prof. Palak Trivedi; "For this study 4, 6, 9, 12, and 15 storey 2bay x 2bay frames are considered for performance evaluation. The above frames are designed as per provisions of IS-456:2000, IS-1893(Part1):2002.
Twenty Ground Motions are selected, in which there are seven past Indian ground motions and thirteen artificial ground motions. Due to faster solver system and fiber based concept, amongst all softwares, SeismoStruct software is selected to perform Nonlinear Dynamic Analysis. The linear drift limit as per IS: 1893 (Part 1): 2002 is 0.4% and frames were designed with response reduction factor of 5. The target drift limit for frames comes out to be 2% as per IS: 1893(Part1):2002. It is observed from the plots that target inter-storey drift limit of 2% is not crossed in any of the frames when evaluated by Indian and Artificial ground motions. Hence it can said that frames shows satisfactory performance under dynamic loading."

III. CONCLUSION

From the above literature we conclude that

1) A qualitative assessment of the results is given, leading to suggestions for application of advanced pushover methods and where to employ dynamic analysis.
2) Conclusion is justified through the non-linear time history analysis of a 15-storeyed frame using far-field and near-field earthquakes and found that there is considerable increase in base shear demand, maximum roof displacement and inter-storey drift due to near-field earthquake.
3) Conclusion is drawn that a successful prediction of the response of RC structures exposed to strong earthquake effects requires as realistic as possible definition of the primary curve presenting their strength and deformability characteristics.
4) The linear drift limit as per IS: 1893 (Part 1): 2002.The target drift limit for frames comes out to be 2% as per IS: 1893(Part1):2002.

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