Pushover Analysis of A Symmetric Structure With Reference To IS 1893:2002

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Abstract- *The effect of higher modes of vibration on the total non-linear dynamic response of a structure is a very important and unsolved problem. To simplify the process the static non-linear pushover analysis was proposed, utilizing a load pattern proportional to the shape of the fundamental mode of vibration of the structure. The results of the pushover analysis, with this load pattern, are very accurate for structures that respond primarily in the fundamental mode. But when the higher modes of vibration become important for the total response of the structure, this load pattern loses its accuracy. To minimize this problem a new multimode load pattern is proposed based on the relative participation of each mode of vibration in the elastic response of a structure subjected to an earthquake ground motion. This load pattern is applied to the analyses of symmetric frames as well as to stiffness asymmetric and mass asymmetric irregular building frames, under seismic actions of distinct orientations, permitting to draw significant conclusions.*

Keywords- pushover analysis, multimode load pattern, non-linear dynamic analysis, asymmetric irregular structures.

I. INTRODUCTION

Inelastic time-history analysis is a powerful tool for the study of structural seismic response. A carefully selected ground motion records can give an accurate evaluation of the predictable seismic performance of structures. Regardless of the fact that the accuracy and efficiency of the computational tools have improved considerably, there are still some uncertainties about the dynamic non-linear analysis, which are mainly related to its complexity for practical design applications. Since the non-linear dynamic analysis of building structures is not realistic for most practical applications, many researchers are trying to extend more rational analysis methods that would achieve a satisfactory balance between required reliability and applicability for everyday design use.

Many of these attempts suggest obtaining the main characteristics of the seismic behavior with a non-linear static analysis under monotonically increasing loads (pushover analysis). The non-linear static pushover analysis is a simple option for estimating the strength capacity in the post-elastic range. This procedure involve applying a predefined lateral load pattern that is distributed along the building height.

The lateral forces are then monotonically increased in constant proportion with a displacement control in the top of the building, until a certain level of deformation is reached. The method allows tracing the sequence of yielding and failure of structural members, as well as the progress of the overall capacity curve of the structure.

The scope of this research is to evaluate the effect of the above-mentioned approximation in three dimensional asymmetric frame structures, for which the higher modes are important in the dynamic response of the structures. For this type of structures a different lateral force distribution is proposed for the pushover analysis, based on a multimode combination of the vibration modes obtain from a linear elastic analysis of the structure. The performance of the proposed multimode load pattern is evaluated by comparing the results of the pushover analyses, with either the conventional lateral load proportional to the shape of the fundamental mode of vibration or the multimode load pattern, and the results obtained from the non-linear dynamic analysis of structures subjected to earthquake excitations in different directions.

II. THE AMENDMENTS IN IS 1893

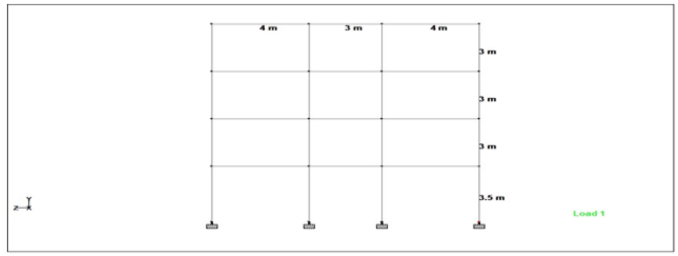
The Indian seismic code IS 1893 has now been split into a number of parts and the first part containing general provisions and those pertaining to buildings has been released in 2002. There has been a gap of 18 years since the previous edition in 1984. Considering the advancements in understanding of earthquake-resistant design during these years, the new edition is a major up gradation of the previous version. This research reviews the new code; it contains a discussion on Clauses that are confusing or vague and need clarifications immediately. The typographical and editorial errors are pointed out. Suggestions are also included for next revision of the code. With rapid strides in earthquake engineering in the last several decades, the seismic codes are becoming increasingly sophisticated. The first Indian seismic code (IS 1893) was published in 1962 and it has since been revised in 1966, 1970, 1975 and 19841 . More recently, it was decided to split this code into a number of parts, and Part 1 of the code containing general provisions (applicable to all structures) and specific provisions for buildings has been published.

III. IMPORTANT MODITLCATIONS MADE IN THE FIFTH REVISION

1. The seismic zone map is revised with only four zones, instead of five. Erstwhile Zone I has been merged to Zone 11. Hence, Zone I does not appear in the new zoning; only Zones II, III, IV and V do.
2. The values of seismic zone factors have been changed; these now reflect more realistic values of effective peak ground acceleration considering Maximum Considered Earthquake (MCE) and service life of structure in each seismic zone.
3. Response spectra are now specified for three types of founding strata, namely rock and hard soil, medium soil and soft soil.
4. Empirical expression for estimating the fundamental natural period Ta of multi-storeyed buildings with regular moment resisting frames has been revised.
5. This revision adopts the procedure of first calculating the actual force that maybe experienced by the structure during the probable maximum earthquake, if it were to remain elastic. Then, the concept of response reduction due to ductile deformation or frictional energy dissipation in the cracks is brought into the code explicitly, by introducing the ‘response reduction factor’ in place of the earlier performance factor.

IV. PROBLEM FORMULATION

This study proposes to analyze the relative effectiveness of the critical torsional provisions as prescribed by the IS 1893:2002 (Part 1). The study tries to analyze the use of the provision and their effectiveness by designing a structure without considering the torsional provisions and then comparing its ability to resist the effect of earthquake forces in comparison to a structure designed in accordance to the necessary torsional provisions. The structure was modeled in ETABS for the purpose of analysis the building design and other analysis were also conducted with ETABS. The structures are also modeled on of 4 stories of 12.5m in height.



The structure was modeled in ETABS for the purpose of analysis the building design and other analysis were also conducted with ETABS. The structures are also modeled on of 4 stories of 12.5m in height and other is of 10 stories with 30.5m in height structure with 4 bays in the X direction of spans lengths of 4m at the 2 spans at the periphery and the central span is about 3m in length. The structure has 3 spans in the Y direction with the 2 spans at the periphery being 4m each and the central span is about 3m in length. The material assumed is Concrete of grade M20 and the Steel used is Fe 415. The Beams are considered to have a cross-section size of about 300x600m and the columns are made of the same cross section sizes with the longer side along the longer span. The Structure is loaded with a live load of about 3KN/m^2 as per the live load requirements form **IS 845 Part II** assuming the structure to be a residential building. The load was applied to the center of mass at the first try for symmetric building. The center of mass (CM) was then applied at a point 1.9m away from the Centroid of the structure. The design of the structure was designed in ETABS as per IS:456. The designed reinforcements were then taken imported into the SAP 2000 software and Pushover analysis was conducted on the structure.

V. CODAL PROVISIONS

As per [IS 1893 (Part 1), 2002] the Static Eccentricity (e) is defined in the design codes as the distance between the Center of Mass (CM) and Center of Rigidity (CR) of the structure. The Center of Rigidity is defined as “The point through which the resultant of the restoring forces of a system acts.” . The Center of Mass is defined as “The point through which the resultant of the masses of a system acts. This point corresponds to the center of gravity of masses of system.”The Design Eccentricities (e_{di},e_{si}) are obtained based on the values of the static ec- centricity after accounting for the dynamic amplification of torsion and allowance for accidental torsion induced by rotational component of ground motion. Most design eccentricities are based on the formula

$$e_{di} = \alpha e + \beta b$$

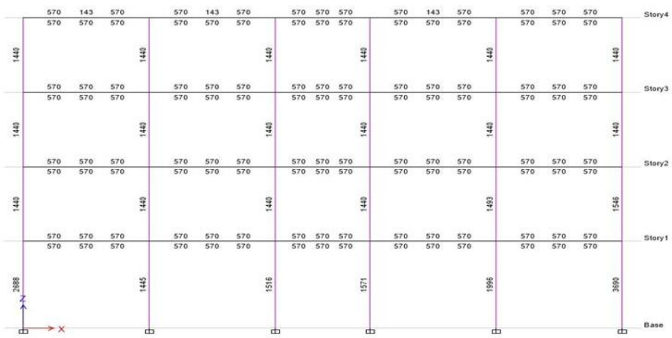
$$e_{si} = \gamma e - \beta b$$

Table 1: Values in different codes

	IS 456	IBC 2003	NZ 4203:1992	NBCC 1995
α	1.5	1	1	1.5
β	0.05	$0.05A_x$	0.1	$.01A_x$
γ	1	1	1	0.05

VI. RESULTS AND OBSERVATIOBS

Reinforcements required for 12.5 m Model, considering Mass Eccentricity (Outer Face)



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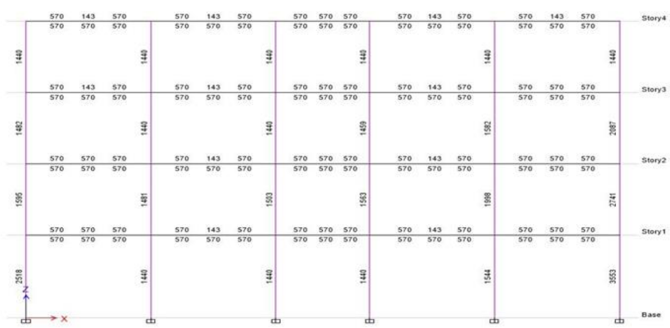
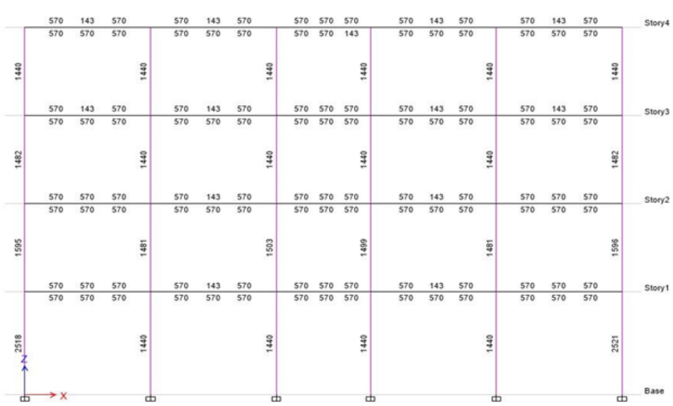


Reinforcements required for 12.5 m Model, considering Mass Eccentricity (Outer Face)



Reinforcements required for 12.5 m Model, considering Mass Eccentricity (Inner Face)

Reinforcement required for 12.5m model without considering Mass Ec- centricity(Inner Face)

The minimum value of the reinforcement for a column section is .08% of the gross area for a compression member which in this case amounts to 1400 mm2. Most of the section in involving the control section still retains the minimum reinforcement as in Table 7.2. After applying the Earthquake Load the reinforcements at the base change to a higher value although they remain symmetric as shown in Table 7.2. The application of a mass eccentricity causes the columns to have an eccentric reinforcement with the columns at the far end having lower reinforcements than the near end of the structure in the direction of the eccentricity. The beam reinforcements remain almost constant irrespective of the application of the lateral forces. Now considering the change in reinforcements in all the respective models, for the purpose of reference lets us number the columns form right to left as 1 to 6 as in the Figure 5.1 . The Figures 7.1,7.2,7.3,7.4 7.5,7.6,7.7 and 7.8, show the reinforcement area required for the particular section based on the design loads. The section shown is the base of the buildings so as to show the maximum change in reinforcement for the models based on the loads. The section is observed in the XZ plane as this is the plane with the maximum of columns visible at any point and the Y coordinate is varied, the origin is considered near the middle of the building span.

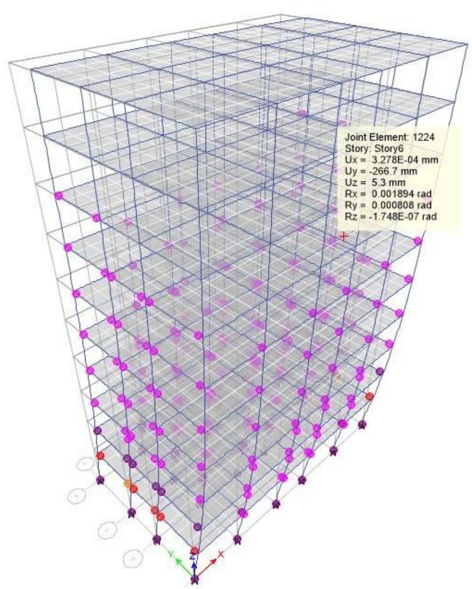
When only the dead and live loads are applied the models tend to have the same re- inforcements at the columns which is the minimum reinforcement which is .08% of the Gross area of the column. In this case it amounts to 1440mm^2.

Columns		Reinforcements		
	Y	Control	As1	As2
1	-6	1440	2930	2930
	-2	1440	2808	2808
	1	1440	2808	2808
	5	1440	2930	2930
2	-6	1440	1520	1520
	-2	1440	1440	1440
	1	1440	1440	1440
	5	1440	1620	1520
3	-6	1440	1494	1507
	-2	1440	1440	1440
	1	1440	1440	1440
	5	1440	1494	1507
4	-6	1440	1494	1549
	-2	1440	1440	1440
	1	1440	1440	1440
	5	1440	1494	1549
5	-6	1440	1521	1688
	-2	1440	1440	1488
	1	1440	1440	1488
	5	1440	1521	1688
6	-6	1440	2931	3280
	-2	1440	2801	3224
	1	1440	2801	3224
	5	1440	2931	3280

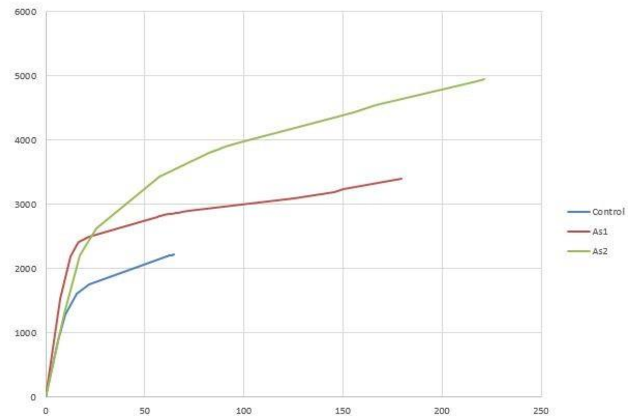
Reinforcement Comparison Table for 12.5m model

PUSHOVER ANALYSIS

The Pushover analysis is a Nonlinear Static analysis in which the structure is subjected to a displacement controlled lateral load pattern which continuously increases till the structure is forced form its elastic behaviour to non-elastic behaviour till the collapse condition is reached. The above modeled structure was subjected to pushover analysis and following results were obtained:



Pushover Analysis of Asy2 Structure.(8th Time step)



Pushover Analysis for 12.5m Model

VII. CONCLUSION

As per the data presented in the previous Section it can be concluded that though the impact of the earthquake force is great on the 12.5 m model the resultant effect of the eccentricity is small for the 12.5 story model while the the higher model experiences a more significant change when the mass eccentricity is applied . Hence the useful for tall structures like the 30.5m model but not so effective for the smaller 12.5m model. The change in the inner section of the building is small for the 12.5 and the higher model , while the difference increases as we approach the periphery hence it is proposed that to save time the inner most columns can be designed for the column to the periphery and the design can be applied to all the innermost columns as the variation is very small while the outer columns at the buildings periphery need to be designed separately. The rise in the reinforcement required with the height of the building makes it possible for a simpler formula for calculation of the reinforcements of the structure thought the exact formulation of the formula will require study of more models and further study.

REFERENCES

[1] SEISMIC ANALYSIS OF ECCENTRIC BUILDING STRUCTURES BY MEANS OF A REFINED ONE STOREY MODEL : Mario DE STEFANO1, Barbara PINTUCCHI2, 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada,August 1-6, 2004, Paper No. 72

[2] COMPARATIVE STUDY OF CODAL PROVISIONS IN IS 1893 (PART 1): 2002 & IS 1893 (PART 1): 2016 Urunkar S. S.1, Bogar V. M.2, Hadkar P. S.3

[3] EARTHQUAKE LOADS ON MULTISTOREY BUILDINGS AS PER IS:1893-1984 AND IS: 1893-2002: A COMPARATIVE STUDY S.K. Ahirwar1, S.K. Jain2 and M. M. Pande3

[4] K Rama Raju, A. Cinitha, Nagesh R. Iyer, Seismic performance evaluation of existing RC buildings designed as per past codes of practice, Indian Academy of Science, Sadhana, vol. 37, part 2, 281–297.
[5] Azhar Bagadia, Comparison of response of industrial structure as per IS 2893-1984 with IS 1983 part 4 – 2005, International Journal of Advanced Engineering Research & Studies, Vol. I, issue III, 95-97.
[6] Dr. H. Sudarsana Rao, Comparative study of seismic lateral forces as per IS 1893- 1984 & IS 1893- 2002, International Journal of Emerging Trends Engineering & Development, issue 4, vol. 4,282-299.
[7] Ravikant Mittal et.al., Response Spectrum Analysis of buildings using spread sheets, International Journal of Modern engineering research (IJMER), volume 2, Issue 6, NovDec 2012, ISSN-2249-6645, page no’s 4207-4210.