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Pushover Analysis of Reinforced Concrete Frames with Mass Irregularity

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ABSTRACT

From past earthquakes it is observed that if the structures are not properly analysed and constructed with required quality, then they are fully or partially damaged due to its effect.In this work it is proposed to carryout linear static analysis andpushover nonlinear static analysis of 13 storied reinforced concrete moment resisting bare frame having mass irregularity at different floors. A total13 models of MRFout of which one having regular mass and other 12 with irregular mass situated at different level has been taken for study. A mass ratio of 2.5 and 5.0 has been used, for 12 irregular models mass irregularity is situated on 2nd, 4th, 6th, 8th, 10th and 12th floor respectively. All MRF considered in study has a total 5 bays in each direction with 5 m each, all storeys are of3 m height. For analysis and design of building Finite element tool SAP 2000 has been used. First a preliminary design of building with Indian code IS 456 and IS1893 (Part-I):2016 has been done. After linear static analysis and Pushover nonlinear static analysis has been done. For carrying out nonlinear static analysis, nonlinear hinges have been first assigned to beams and columns defined by ATC 40 [14]. The study aims to understand analysis results in the form of Storey drift, Time period, Base shear and Displacement has been evaluated of each model.

KEYWORDS: Pushover analysis, ATC 40, mass irregularity, SAP 2000, IS:1893(Part-I):2016.

I. INTRODUCTION

The availability of land for construction of Residential or commercial building in Metro city is a major problem now. Therefore, from last few decades high-rise building has come in picture. High rise building with creative elevation and plans are common now a days, sometimes due to other reason such as ventilation and light purpose setback buildings are also constructed. All such type of building leads to generate different type of irregularity such as Stiffness, Strength, Mass and Diaphragm irregularity. Building having any one of above irregularity behaves abnormally at the time of earthquake as compare to building having no irregularity. Further due to unavailability of the space sometimes swimming floor proposed on middle or upper storey of buildings. Therefore, huge mass of water at higher storey creates mass irregularity at that floor. Such type of mass irregularity can be also be generate due to presence of heavy mass such as library at upper storey or presence of heavy machinery at upper storey.Mass irregularity is an important type of irregularity to be considered at the time of analysis and design of midrise and high rise building to reduce risk of collapse of building during earthquake. At the time of earthquake at a floor sudden increase in mass as compare to adjacent floor mass increases inertial force at that level which leads to larger lateral displacement and shear force of that storey. When such inertia force increases beyond the capacity of structural members collapse occurs.When there is a higher mass difference between adjacent storeys then inertial forces are more and vice versa. Theseratios of mass vary with different international earthquake design codes.

So far, many researchers have investigated the effects of seismic response on structures having vertical and horizontal irregularities. Kamil Aydin (2007)[1] studied the effects of mass irregularity for 5, 10 and 20 storey two dimensional frames with the different mass ratios. After analysis it has been found that ductility demand changes linearly as mass ratio changes. Robert Tremblay et al (2005)[2] studied the dynamic behaviour of building frames with irregular distribution of mass. They have concluded that both static and dynamic analysis methods are ineffective in predicting the response of the frames having mass irregularity.

IS:1893(Part-I):2016[8] gives information about a number of parameters which influence the irregularity of the structure.However, in the present study the worst affected irregularity under the influence of irregular mass are studied in detail. The following objectives ware identified based on these parameters:

1) To Study the effect of irregular mass distribution situated at different storey floor of structures.
2) To study the comparison of effects of irregular distribution mass with the seismic response of a regular distribution of mass.
In the earlier versions of IS:1893 (BIS, 1962, 1966, 1970, 1975, 1984) there was no mention of vertical irregularity in building frames. However, in the recent versions of IS:1893(Part-I) (BIS, 2002, 2016), irregular configuration of buildings has been defined in detailed.
It has been observed after Bhuj, Gujrat earthquake that building having irregularity are susceptible more than regular building at the time of earthquake (10). Therefore, it is necessary to study mass irregularity in building. Anaccount of themajor earthquakes in India and the associated fatalities is provided in Table 1

Table1:Fatalities and damages due to earthquakes in India (M. Zameeruddin et al,2017[10])

Sr.No.	Earthquake	Year	Intensity	Fatalities
1	Latur (Khillari)	30, September 1993	6.2	9748
2	Chamoli	29, March 1999	6.8	103
3	Gujrat (Bhuj)	26, January 2001	7.7	20000
4	Off west coast(Northen Sumatra)	26, December 2004	9.1	15000
5	Kashmir	8, October 2005	7.6	1350
6	Gangtok (Sikkim)	18, September 2011	6.9	118
7	North India	25, April 2015	7.8	8900
8	North India	12, May 2015	7.3	04
9	Dibrugarh (Assam)	28, June 2015	5.6	03 injured

II. STRUCTURAL MODELING AND ANALYSIS

2.1 Example MRFs with Mass Irregularity at Different Storey Level.

In this study total 13 model of a 13 storey moment-resisting reinforced concrete bare frames (MRFs) with 5x5 bay of span 5.0 m in both directions are considered. Out of which one regular and 12 models having irregular mass distribution along height of structure has been designed and analyzed with using Finite element-basedtool SAP 2000 by Linear static and Pushover Nonlinear static method. These frames generally represent ahigh-rise office building located in the seismic zone IV and assumed soil type is medium soil possessing an impact factor of 1.0 with 5% damping, which is referred to in IS 1893: 2002 (Part-I). After the analysis results are evaluated for each model and compared.

2.2 Structural member design

The preliminary dimensions of the structural members were pre-assumed. For the pre-assumed cross-sectional dimension, the members were designed in accordance to the guidelines mentioned in IS 456:2000 (Revised)[13] and serviceability checks were applied. As per IS 13920: 1996[15] guidelines, were followed for a ductile detailing of the reinforced concrete sections. Following is the Description of Geometry of different Elevations used in Study.

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2.3 Model considered in Analysis:

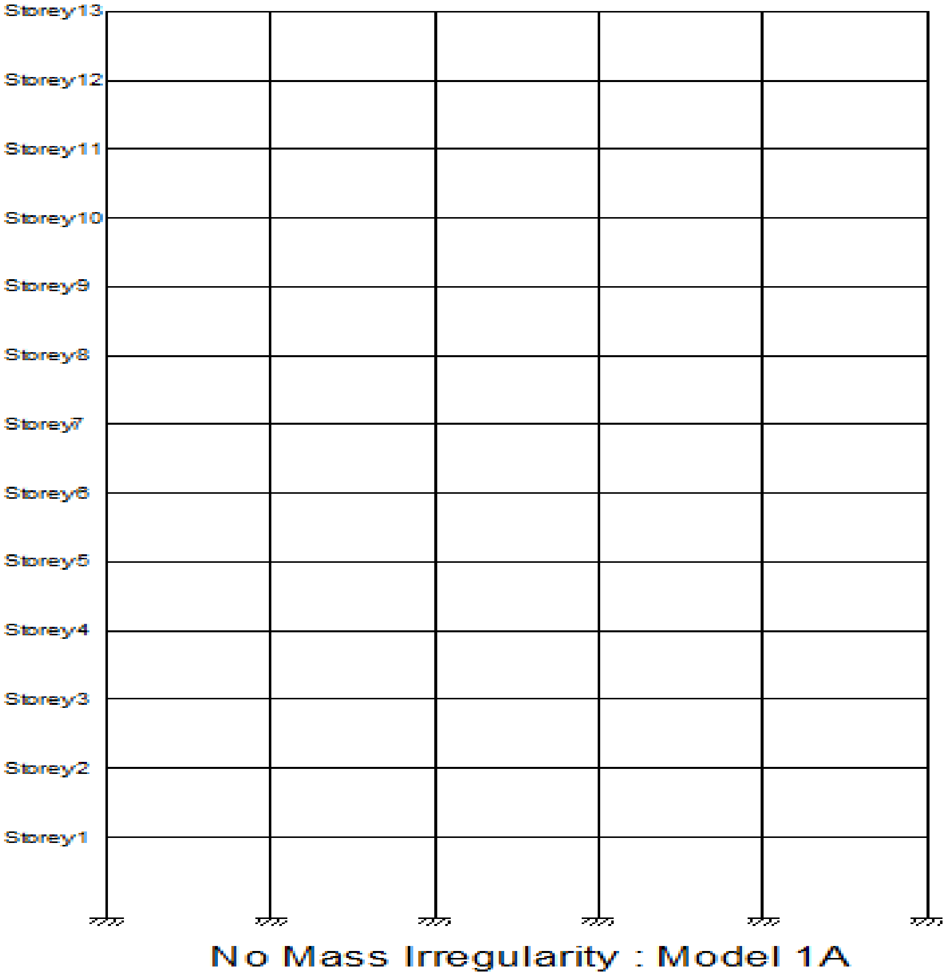

Fig 1: Elevation of 13 storey RC building without mass irregularity

2.4 Geometric, material descriptions, loading consideration of regular and mass irregular MRFs used in Study

Table 2: Loading, zone and material data considered for design and analysis

Description	Model 1A	Model 2A	Model 2B	Model 2C	Model 2D	Model 2E	Model 2F
Frame type	MRF	MRF	MRF	MRF	MRF	MRF	MRF
Zone of Earthquake	IV	IV	IV	IV	IV	IV	IV
Mass Irregularity @ Storey	NA	2nd	4th	6th	8th	10th	12th
Mass irregularity ratio	1.0	2.5	2.5	2.5	2.5	2.5	2.5
Zone factor	0.24	0.24	0.24	0.24	0.24	0.24	0.24
No of Storey	13	13	13	13	13	13	13
Floor height	3 m	3 m	3 m	3 m	4 m	5 m	6 m
Live Load (kN/m^2)	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Floor finish Load (kN/m^2)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Concrete grade	M30						

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Steel grade	Fe500
Concrete Density (kN/m^3)	25
Damping	5%
Soil Type	II
Beam Size (mm)	230x600

Table 3: Loading, zone and material data considered for design and analysis.

Description	**Model 5A**	**Model 5B**	**Model 5C**	**Model 5D**	**Model 5E**	**Model 5F**
Frame type	MRF	MRF	MRF	MRF	MRF	MRF
Zone of Earthquake	IV	IV	IV	IV	IV	IV
Mass Irregularity @ Storey	2nd	4th	6th	8th	10th	12th
Mass irregularity ratio	5	5	5	5	5	5
Zone factor	0.24	0.24	0.24	0.24	0.24	0.24
No of Storey	13	13	13	13	13	13
Floor height	3 m	3 m	3 m	3 m	3 m	3 m
Live Load (kN/m^2)	3.5	3.5	3.5	3.5	3.5	3.5
Floor finish Load (kN/m^2)	1.5	1.5	1.5	1.5	1.5	1.5
Concrete grade	M30					
Steel grade	Fe500					
Concrete Density (kN/m^3)	25					
Damping	5%					
Soil Type	II					
Beam Size (mm)	230x600					

III. RESULTS AND DISCUSSIONS

The analysis carried out are equivalent static analysis and pushover non linear static analysis, the results are obtained of each two-dimensionalmodel for the regular and mass irregular MRFs. The results of base shear, lateral displacement, storey drift, fundamental time period is presented for different mass ratios and compared with regular model.

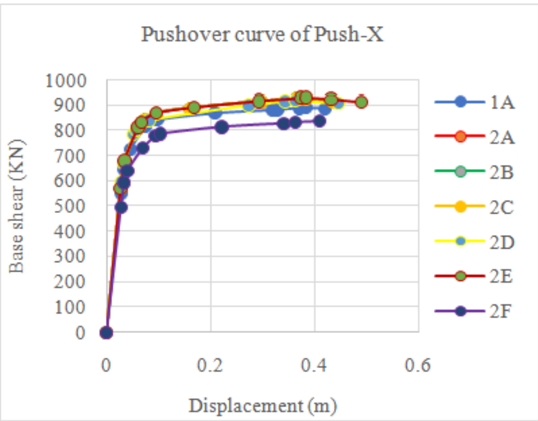


Figure 2: Base Shear Comparison 2.5 Mass Ratio

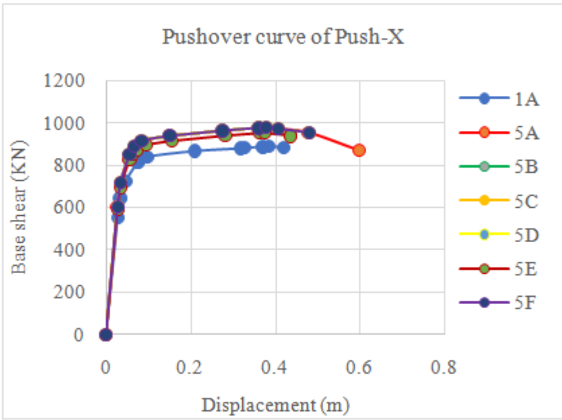
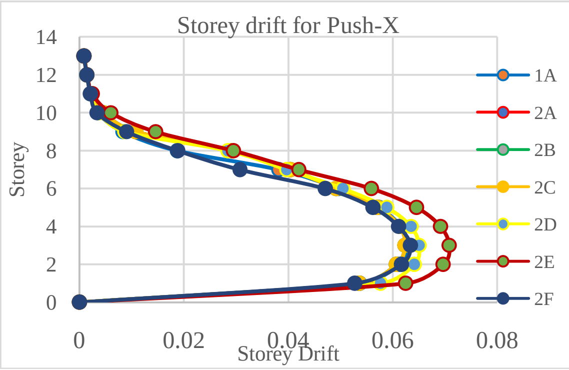


Figure 3: Base Shear Comparison 5 Mass Ratio

Fig. 2 and 3 shows the graph of pushover curves base shear v/s displacement of all models, it shows that for higher mass ratio base shear is more as compare to model having regular mass and model with less mass ratio. For model 1A and models with mass ratio 2.5 pushover curve is almost overlapped (except separation at top). But as the mass ratio increases to 5.0 the pushover curve can be seen separated from model 1A and model with 2.5 mass ratio. Model having higher mass ratio is having higher base shear value before failure.



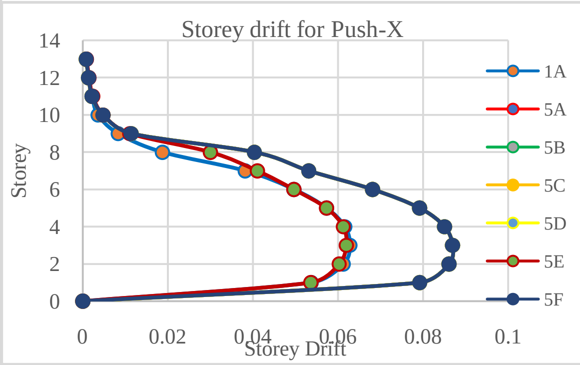
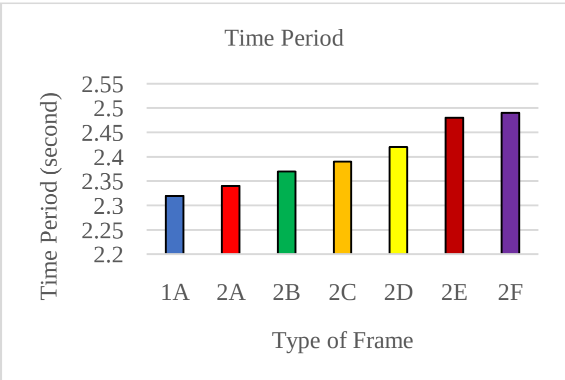


Figure 4: Storey DriftComparison 2.5 Mass Ratio**Figure 5:** Storey Drift Comparison 5 Mass Ratio

It can be seen from fig. 4 and 5 storey drift plots by pushover non linear static method in all 13 cases (1A, 2A, 2B, 2C, 2D, 2E, 2F, 5A, 5B, 5C, 5D, 5E and 5F) studied, in no case storey drift is exceeding allowable limit 0.004 as per IS 1893 (Part-I): 2016. The storey drift for plot for 2E and 5F is situated on right of all cases and case 1A plot is situated on left as compare to all other shown cases. This means that for building having regular mass is having least drift as compare to all cases of 2.5 and 5.0 mass ratio. The 5F model having mass ratio 5.0 and mass situated at 12th storey is having higher drift as compare to model having 5.0 mass ratio but on lower storey.



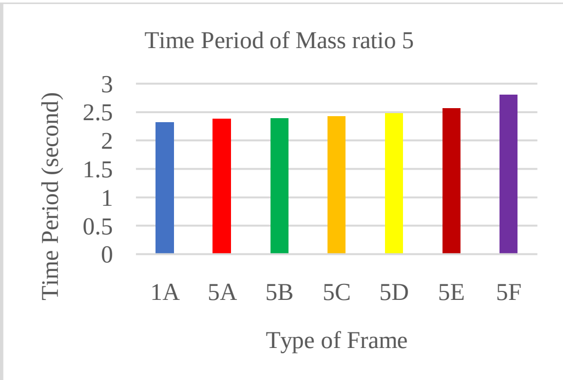


Figure 6: Time PeriodComparison 2.5 Mass Ratio**Figure 7:** Time Period Comparison 5 Mass Ratio

By fig. 6 and 7 observing the time period plot it can be seen that, as the heavy mass is moving from bottom to top storey time period is going to increase. For model with heavy mass on top storey is having time period higher than model having heavy mass ratio at lower storey.

IV. CONCLUSION

This study is to evaluate effects of irregular mass (heavy mass) with respect to mass ratio and position of heavy mass (level). After plotting and results observing following conclusions can be made.

i) Building having higher mass ratio will carry higher base shear before failure as compared to regular building.

ii) As the heavy mass move from bottom to top of building time period of building will increase. Means building having heavy mass at to storey will have a more fundamental time period as compared to building having heavy mass at lower storey.

iii) In no case storey drift has been exceeded allowable limit 0.004 as per IS 1893 (Part-I): 2016. For regular mass building 1A storey drift is less as compare to building having heavy mass on some storey.

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