Pushover Analysis With and Without Infill Stiffness Consideration in Two Different Zones

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Abstract— The need for assessing the seismic capability of buildings has been highlighted by recent earthquakes that badly devastated many reinforced concrete structures. Simplified linearelastic approaches are insufficient for such an assessment. The non-linear static analysis, also known as the Pushover analysis, sometimes known as collapse analysis, is believed to be a convenient way for evaluating the performance, despite the fact that multiple procedures are conceivable. The use of static pushover analysis to analyze the seismic performance of existing and new structures is becoming more common. The pushover study is expected to offer sufficient information on the seismic demands put on the structural system and its components by the design ground motion. The goal of this research is to use software SAP2000 to perform nonlinear static pushover analysis and assess the nonlinear behaviour of the building frame when the dimensions of the RCC frame structure (i.e. number of bays and storey height) are changed for two different earthquake loadings (i.e. Seismic Zone III and Zone IV). The main purpose of masonry infilled walls in a building is to fill the gap between the horizontal and vertical resisting elements of the building frame, where it is assumed that. As a result, masonry infilled walls are not considered a structural element, and the structure is designed as a bare frame only. However, these brick infilled walls have a significant impact on structural strength and stiffness capabilities, and they are brittle by nature. Methods for calculating the stiffness of brick infill walls and modelling them as equivalent diagonal pin-jointed struts, also known as macro modelling of infill walls, may be found in certain international papers. The inplane effect of a masonry infill wall constructed as an analogous diagonal strut on a Reinforced Concrete structure as compared to a bare frame structure will next be examined.

Keywords: Pushover Analysis, Infill Wall, Equivalent Strut, Stiffness

I. Introduction

The need for calculating the seismic capacity of existing concrete buildings is related to several earthquakes, in which concrete structures have been severely damaged and have collapsed, leading to the loss of life and property. Recent earthquakes in various parts of the world have exposed the issues pertaining to the seismic vulnerability of existing buildings. The existing building structures, which have been designed and constructed according to former code provisions, do not fulfill requirements of the current seismic code and design practices. Many reinforced concrete buildings in urban areas with active seismic zones, as well as the majority of India's metro cities, which are in zones III or IV*, may sustain moderate to severe damage during future ground motions. Indian metro cities are exceptionally densely populated cities, and their population has been increasing in recent years. As a result, the demand for multi-story structures is growing. As a result, even a single structural breakdown during an earthquake cannot be tolerated. As a result, the best design, i.e. earthquake resistant design, will serve best in terms of performance during an earthquake.

Pushover analysis is a simplistic method for determining the nonlinear behaviour of buildings or structures. An elastic analysis can determine a structure's elastic capacity and anticipate where the first yielding will occur, but it cannot predict failure mechanisms or account for force redistribution during progressive yielding (ATC-40, 1996). Pushover analysis can be utilised in these situations to anticipate the structure's strength beyond the yield capacity. It can also be used to estimate the structure's ultimate capacity. The elastic analysis method is unable to forecast critical processes that influence a structure's seismic performance. The static pushover analysis is a basic method for estimating the force and displacements on structures induced by significant ground motions. The structure is subjected to monotonically rising lateral forces, which are dependent on the building's height, until the target displacement is reached in pushover analysis. The study is made up of a sequence of consecutive elastic analyses that are stacked to approximate the overall structure's force-displacement curve. The lateral forces are raised (i.e., the structure is pushed) until some structural members yield, resulting in fractures, the production of plastic hinges, and the load at which failure occurs. The structure model is changed to account for the reduced stiffness after the first yield, and the lateral force is raised until the rest of the members yield. The operation is repeated until the desired displacement is achieved or the equilibrium of the building becomes unstable. To construct a pushover curve for the structure, the obtained base shear is plotted against the top/roof displacement.

II. Objectives

1) Using modern structural analysis software SAP2000, create a computer model of the structure, execute a pushover analysis for the modeled structures, and verify the performance of the structures using a pushover curve.
2) The study's major goal is to examine the impacts of changing the RCC frame structure's dimension as well as the effects of inserting infill walls on the seismic response of reinforced concrete frames. Changes in inter-storey drift allocation with the addition of Infill walls are explored in particular.
3) Using SAP2000, calculate the response reduction factor from the non-linear analysis result.
4) The seismic responses and frame drift allotment are calculated and compared.
5) For the adopted building, compare the performance point in two separate zones.

III. DESCRIPTION OF STRUCTURAL MODELLING

The structures are supposed to be regular in plan, with variations in the number of bays, number of storeys, and infill masonry layout. Building descriptions are listed in the tables below:

- Each bay length = 4 m (c/c in both direction)
- Each floor height = 3m

SL No	Frame Title	Seismic Zone	No. of Storey	No. of Bays	Frame Type
1	5B10S-BF-III	III	10	5	BARE
2	5B12S-BF-III	III	12	5	BARE
3	5B14S-BF-III	III	14	5	BARE
4	6B10S-BF-III	III	10	6	BARE
5	6B12S-BF-III	III	12	6	BARE
6	6B14S-BF-III	III	14	6	BARE
7	7B10S-BF-III	III	10	7	BARE
8	7B12S-BF-III	III	12	7	BARE
9	7B14S-BF-III	III	14	7	BARE

Table 1: Details of RCMC Frames without Infill in Zone-III

Sl No	Frame Title	Seismic Zone	No. of Storey	No. of Bays	Frame Type
1	5B10S-IF-III	III	10	5	WITH INFILL
2	5B12S-IF-III	III	12	5	WITH INFILL
3	5B14S-IF-III	III	14	5	WITH INFILL

Table 2: Details of RCMC Frames with Infill in Zone-III

Sl No	Frame Title	Seismic Zone	No. of Storey	No. of Bays	Frame Type
1	5B10S-BF-IV	IV	10	5	BARE
2	5B12S-BF-IV	IV	12	5	BARE
3	5B14S-BF-IV	IV	14	5	BARE
4	6B10S-BF-IV	IV	10	6	BARE
5	6B12S-BF-IV	IV	12	6	BARE
6	6B14S-BF-IV	IV	14	6	BARE
7	7B10S-BF-IV	IV	10	7	BARE
8	7B12S-BF-IV	IV	12	7	BARE
9	7B14S-BF-IV	IV	14	7	BARE

Table 3: Details of RCMC Frames without Infill in Zone-IV

Sl No	Frame Title	Seismic Zone	No. of Storey	No. of Bays	Frame Type
1	5B10S-IF-IV	IV	10	5	WITH INFILL
2	5B12S-IF-IV	IV	12	5	WITH INFILL
3	5B14S-IF-IV	IV	14	5	WITH INFILL

Table 4: Details of RCMC Frames with Infill in Zone-IV

Length Of Bay @Each Direction In Plan(M)	4
Height Of Storey(M)	3
Beam Depth(Mm)	450
Shear Stress(N/Mm2)	0.2
Elastic Modulus Infill(E_{me} , N/Mm^2)	2300
Elastic Modulus Frame Material(E_{fe}, N/Mm^2)	25000
Possions Ratio (M)	0.15
Width Of Infill(T)	0.23
Square Col. Dimension (M)	0.5
I_{col} (In^4)	12513.0
Diagonal Length Of Infill(R)	4.33
Θ (Radians)	0.63
Λ	0.02
Width Of Strut(M)	0.49

Table 5: Details of Equivalent Diagonal Strut

Furthermore, it is a R.C.C. structure with a Special Moment Resisting Frame (SMRF). Other data about the construction and materials used are shown below.

S.no.	Design parameter	Value
1	Floor Height (c/c)	3m
2	Size of Beam	350X 450 mm
3	Size of Column	500 X500mm
4	Unit Weight of Concrete	25 KN/m³
5	Unit Weight of Masonry Infilled Walls	20 KN/m³
6	Characteristic Strength of Concrete (f_{ck})	30 MPa
7	Characteristic Strength of Masonry Infilled Walls	3.89 MPa
8	Modulus of Elasticity of Concrete (E_c)	$5000\sqrt{f_{ck}}$
9	Modulus of Elasticity of Masonry Infilled Walls (E_m)	5500 MPa
10	Poison’s Ratio for Concrete	0.20
11	Poison’s Ratio for Masonry Infilled Walls	0.17
12	Slab Thickness	150 mm
13	Masonry Infilled Walls Thickness	230 mm
14	Angle made by Strut with the Horizontal (θ)	36.07°

Table 6: Building Geometry and Material Property

S.No.	Design Parameter	Values	Values
1	Seismic Zone	III	IV
2	Zone Factor	0.16	0.24
3	Response Reduction Factor (R)	5	5
4	Importance Factor (I)	1	1
5	Soil Type	Medium Soil (type II)	Medium Soil (type II)
6	Damping Ratio	5%	5%
7	Frame Type	SMRF	SMRF

Table 7: Seismic Design Data

A. Gravity Load Considered For Design

1) (DEAD LOAD) (IS875: Part 1)

1) Beams and Columns DL:
   Based on material unit weight and dimensions.
2) DL on floor slab (Flooring Load): 1.5 KN/m2
3) DL on roof slab (flooring load) : 2 KN/m2

4) DL on Periphery Beam (Ext Wall Load, 230mm thick): 11.73KN/m
5) DL on Interior Beam (Int Wall Load, 115 mm thick): 5.865KN/m
6) DL on Periphery Beams of Roof (Parapet Wall load, 1m high): 4.6 KN/m

2) (LIVE LOAD) (IS875: Part 2)

1) LL on Floor Slabs (except roof) : 2 KN/m²
2) LL on Roof Floor Slab : 1.5 KN/m²

The percentage of live load used for seismic load calculation is 25%, according to IS 1893:2002, cl 7.3.1

IV. PUSHOVER ANALYSIS

Pushover analysis is a nonlinear, static process in which the structural force is gradually increased in accordance with a specified pattern. Modeling parameters, acceptability criteria, and methodologies for pushover analysis were created in the ATC-40 and FEMA-356 publications. The procedure for determining the yielding of frame members during the analysis is also described in these documents. Deformation-controlled (ductile action) and force-controlled approaches are employed to guide the inelastic behaviour of the member during the pushover analysis, as shown in Figure (brittle action).

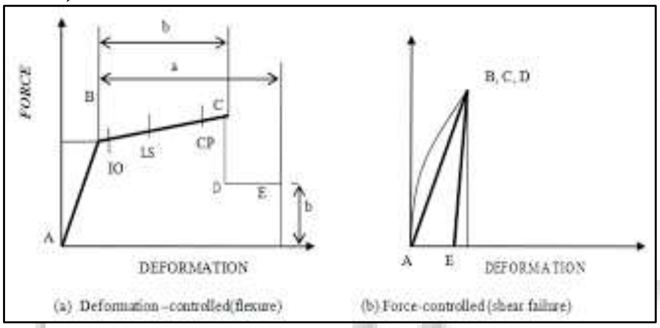

Fig. 1: Force- Deformation Behavior of Hinges

V. PUSHOVER WITH SAP2000

Non-linear static analysis of the structural models is performed using the popular finite element software SAP2000. Pushover analysis is possible on two-dimensional and three-dimensional models. The application has the ability to execute force-controlled and displacement-controlled analyses. The entire load and displacement control options are available in the load application control window, as shown in the diagram above. The pushover analysis normally progresses to the full load value determined by the sum of all loads in the load pattern box in the force-controlled analysis. To do the analysis, the displacement-control option pushes the pushover load case to a desired or goal displacement.

For displacement-control analysis in SAP 2000, there are two options: conjugate displacement and monitored displacement. The conjugate displacement is a weighted average of all displacements in the structure, where each degree of freedom of displacement is weighted by the load acting on it. It's most commonly employed when the analysis is having difficulties convergent. The monitored displacement option is used to keep track of the displacement until it reaches the desired regulated displacement or the target displacement. The required degree of freedom at the joint can be monitored as the displacement. In most cases, the joint is assumed to be near the center of the structures mass.

VI. RESULT AND DISCUSSION

Fig. 2: Storey Drift Comparison for All Fourteen Storey Bare Frames

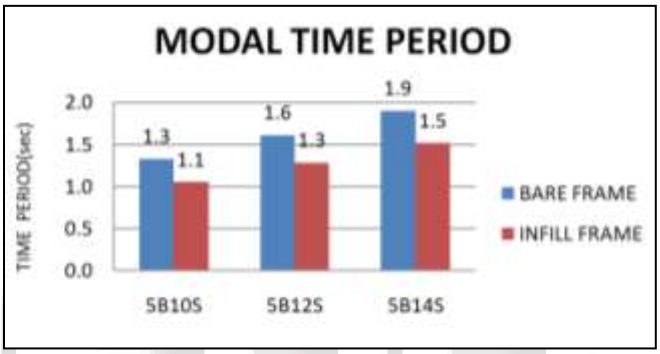

Fig. 3: Comparison of Modal Time Period b/w Bare and Infill Frame

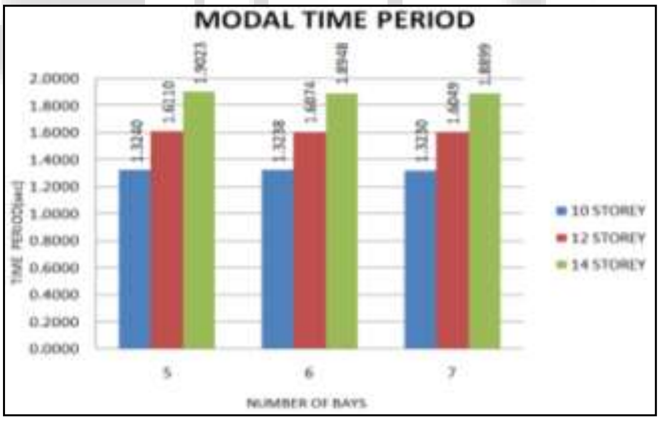

Fig. 4: Comparison of Modal Time Period by Changing Bays and Number of Storeys of Bare Frame

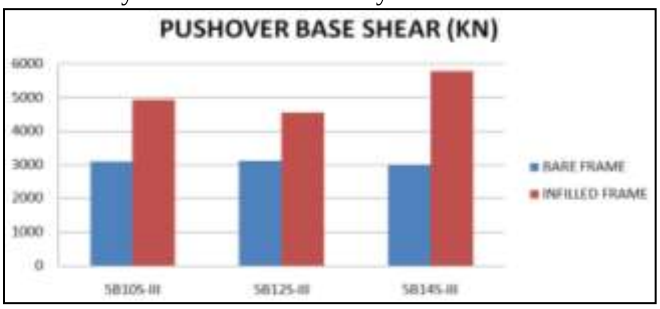

Fig. 5: Comparison of Pushover Base Shear b/w Bare Frame & Infilled Frame in Zone III

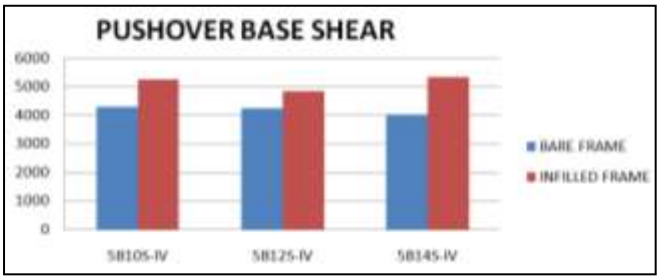

Fig. 6: Comparison of Pushover Base Shear b/w Bare Frame & Infilled Frame in Zone IV

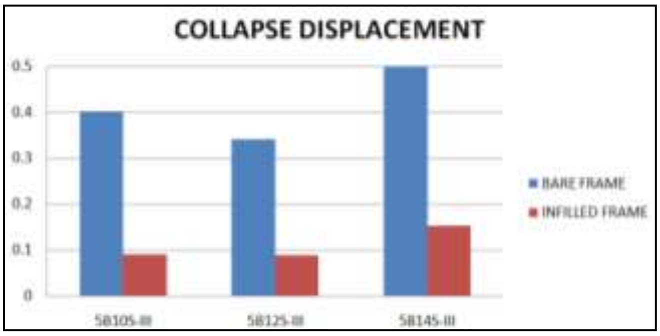

Fig. 7: Comparison of Collapse Displacement b/w Bare Frame & Infilled Frame in Zone III

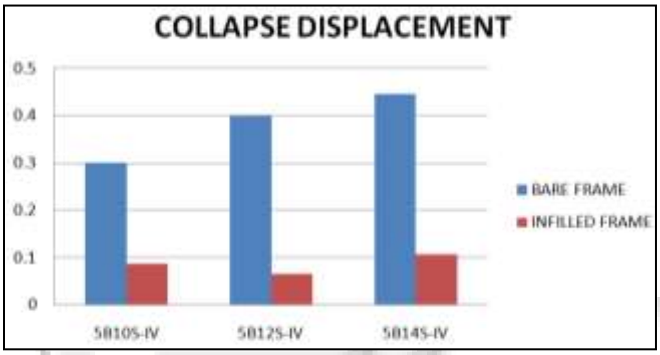

Fig. 8: Comparison of Collapse Displacement b/w Bare Frame & Infilled Frame in Zone IV

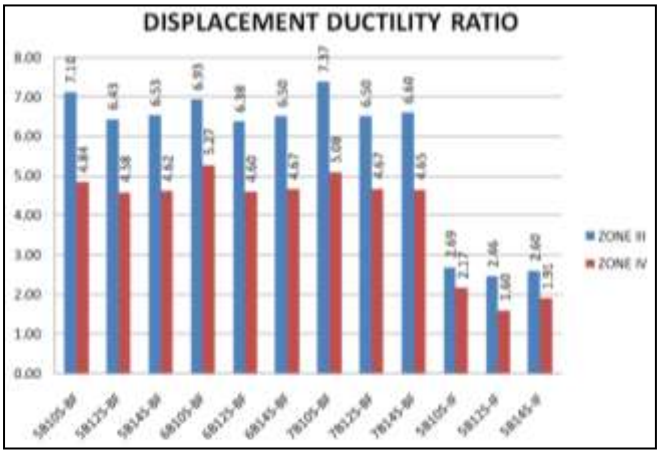

Fig. 9: Comparison of Ductility Ratio Of Frames Due To Change In Seismic Zone.

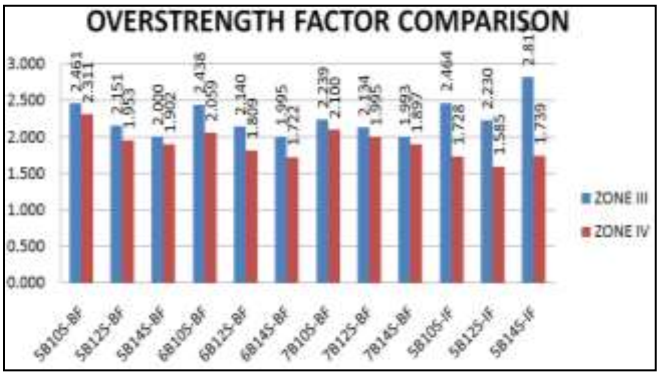

Fig. 10: Effect on Overstrength Factor Due To Change in Seismic Zone

VII. Conclusion

- EFFECT OF BAYS ON STIFFNESS: It is evident that in linear static analysis maximum interstorey drift are found in 5 bays frames. So we can say that 5 bay bare frame has least stiffness compared to other frames with more number of bays.
- EFFECT OF INFILL ON STIFFNESS: On Considering the infill stiffness the maximum drift significantly for the frame without infill.
- EFFECT OF INFILL ON MODEL TIME PERIOD: Inclusion of stiffness of infill wall in analysis shows decrease the modal time period.
- EFFECT OF HEIGHT & BAYS ON MODEL TIME PERIOD: As we increase the height of the structure time period increases but increase in number of bays reduces the modal time period very trivial.
- EFFECT OF INFILL WALL ON FAILURE: it is seen in each case that at collapse condition the infill wall stiffness consideration in analysis shows the frame more global stiffness than the frame analysed without infill wall stiffness consideration. The infilled structure show brittle behaviour at collapse.
- EFFECTS OF INFILL, ZONE, STOREYS ON BASE SHEAR: Inclusion of stiffness of infill wall in analysis results in increase base shear at collapse 1.58, 1.46 ,1.93 times in Zone III and 1.222,1.143 , 1.329 times in Zone IV as we increase the number of storeys but decrease in increment due to change in high design base shear Zone(i.e. Zone III to Zone IV).
- EFFECT OF INFILL ON COLLAPSE DISPLACEMENT: Inclusion of stiffness of infill wall in analysis results in decrease in collapse displacement significantly.
- EFFECT OF ZONE ON BASE SHEAR: At performance point base shear increase on an average 1.3922 in Zone IV with respect to Zone III.
- EFFECT OF INFILL ON DUCTILITY: It is observed that the ductile behaviour of the building is significantly reduced in both zones due to the consideration of Infill wall stiffness in design consideration.
- EFFECT OF ZONE ON DUCTILITY RATIO: As compared to Zone III the ductility ratio is reduces for each Reinforced Concrete frame in Zone IV. It is due to the increment in yield displacement more than the

increment of ultimate displacement from ZONE III to ZONE IV. Because of the increase in the design force level building yields later.

- EFFECT OF ZONE ON OVERSTRENGHT RATIO: It is visible that overstrength factor of Bare frame as compared to Infilled frame is less in Seismic Zone III but more in Seismic Zone IV. It is due to high increase in the design base shear in Seismic Zone IV.
- EFFECT OF BAYS & HEIGHT ON RESERVE STRENGTH: As we increase bay as well as height, over strength factor reduces. That will lead to reduction of reserve strength respectively.
- EFFECT OF ZONE ON BASE SHEAR CAPACITY: All the frame shows increase in base shear capacity in ZONE IV as compare to ZONE III except the last frame(5B14S-IF),it may be the result of of brittle failure of building frame in ZONE IV because of highest design base shear.
- EFFECT OF ZONE, HEIGHT ON OVERSTRENGHT FACTOR: Overstrength factor decreases from Zone III to Zone IV. It is due to thedesign seismic base shear increases more as compared to the increment in maximum base shear capacity in Zone IV as compared to Zone III. It is also seen that in general the overstength factor is decreasing with increase in height of the building.
- Hence we can conclude that using pushover analysis we can get suffice data to analyze the behavior of structure in seismic analysis. It seems to be more rational method for estimating the lateral strength and distribution of inelastic deformations.

References

[1] Modeling the Impact of Infill Walls on concrete Buildings' seismal Performance Abdelmalek Essaâdi University, M'hannech two, Tetouan, Morocco. Sabri Attajkani, Abdellatif Khamlichi, Abdellah Jabbouri Department of Physics, Abdelmalek Essaâdi University, M'hannech two, Tetouan, Morocco.

[2] S. Pujol and D. Fick (2010) 2010: The check of a all-out Three-story RC Structure with Masonry Infill Walls. Pujol, S.; Fick, D. Volume 32, pages. 3112–3121 in Engineering Structures.

[3] Variations in infill wall stiffness have a bearing on the behaviour of concrete frames once subjected to earthquake hundreds. Cemalettin Dönmez2 and Egemen Sönmez1

[4] By yourself, you'll learn Earthquake Engineering: From Engineering geophysical science to Performance-Based Engineering. Vitelmo V. Bertero (Editor), Bozorgnia (Editor) (Editor).

[5] (IIT Roorkee's Department of Earthquake Engineering's Gopen Paul and Pankaj Agarwal) "Experimental Verification Of seismal analysis Of Rc Frame Buildings Designed in line with Previous Is Codes Before And once Steel Bracing Retrofit").

[6] Drain 2ndX – seismal Response and harm Assessment for 2D Structures, Ph.D. Thesis, University of Calif. at Berkeley, California. Allahabadi R., 1987, Drain 2ndX – seismal Response and harm Assessment for 2D Structures, Ph.D. Thesis, University of Calif. at Berkeley, California.

[7] Bureau of Indian Standards, New Delhi, India, IS: 1893-2002, Criteria for Earthquake Resistant style of Structures, Part 1.

[8] M. Holmes, "Steel Frames With masonry and Concrete Infilling," Proceedings of the establishment of Civil Engineers, vol. 19, no. 4, 1961, pp. 473-478.

[9] "A technique of study for infill frames," Proceedings of the establishment of Civil Engineers, vol. 44, pp. 31-48, 1969. B. Stafford Smith and C. Carter, "A technique of study for infill frames," Proceedings of the establishment of Civil Engineers, vol. 44, pp. 31-48, 1969.

[10] FEMA 356 [Prestandard and comment for seismal Rehabilitation of Buildings, FEMA (2000)]. (FEMA 356). ASCE ready this report for the Federal Emergency Management Agency in Washington, D.C.

[11] [A. E. Fiorato, M. A. Sozen, and W. L. Gamble, "Behavior of Five-Storey concrete Frames with Filler Walls," Interim report back to the Department of Defense workplace of the Secretary of the military, workplace of protection, Urbana, Illinois, 1970.]

[12] National Institute of Engineering, Mysore, Ashwini K. C and Dr. Y. M Manjunath "Analysis of pushover in concrete structures: a comparative study"

[13] IS: 13920-1993 IS: 13920-1993 IS: 13920-1993 IS: 13920-1993 IS Code of practise for ductile description of concrete structures subjected to seismal forces.

[14] Department of engineering science, Kannur University, Kerala, Neetu K. N and Saji K. P "Pushover analysis of concrete structures," International Journal of Science and analysis (IJSR), Volume four Issue eight, August 2015, pp. 208-211.

[15] "Indian customary Code of Criteria for seismal style of Structures" (IS-1893 (Part 1): 2002).

[16] Code of practise for style hundreds (other than earthquake) for buildings and structures, "IS-875 (Part three): 1987" (Part 3 Wind Loads).