Seismic Performance Evaluation of In-Plan Irregular R.C. Moment Resisting Frame with Mid-Pier and Multi-layered Shell Element of Shear Wall Modelling

[1]Subham Mittal Rajesh, [2]Prof. A. R. Darji,[3] Dr Y. K. Tandel

[1]P.G Student ,[2] Assitant Professor,[3]Assistant Professor
[1]Applied Mechanics Department,
[1]Government Engineering College, Dahod, India

Abstract: Earthquakes are known to produce one of the most destructive forces on earth. They produces the force and displacement in the structure. Most of forced based seismic design codes are intended to provide design and analysis such that, Structure will resist small earthquakes without damage, moderate earthquake without major structural damage, and severe earthquake without collapse. This current provisions attempt to achieve all three performance objective by specifying only one design earthquake level. We are designing building for the forces obtain from the elastic analysis. But during earthquake excitation structure can undergo inelastic deformations which cannot be obtained from the elastic analysis. To achieve the performance of the building beyond elastic limit non-linear analysis needs to be performed. In this , Two RC Moment Resisting Frame is to be taken, one is of regular building with shear wall and second one is of in-plan irregular building with shear wall are analyzed. Performance evaluation of these frames is carried out using Nonlinear Static Pushover Analysis. To determine structural response beyond yield point, both the types of non-linearity has been considered as Material nonlinearity and Geometrical Non Linearity. Among the various method of Non-linear modelling of shear wall, Walls are modelled as Mid-pier frame element, Multilayer shell element and with simple shear wall. For the Analysis SAP2000 software will be used. For the parametric study, 10-storey, 15-storey and 20-storey frames with shear wall are considered. After the analysis, it can be concluded that Frame with midpier, multilayered and shear wall behaves differently and building with multilayered type of shear wall performs better compare to that of midpier and simple shear wall and it is also observed that shear wall modelled with multilayered take more lateral load than other types of model of shear wall in case of both regular and in plan irregular building.

***IndexTerms* – Midpier Element Modelling Frame, Multilayered shell element Frame, RC Frame with Shear wall, nonlinear static analysis, shear wall participation at performance point and over strength factor.**

I. INTRODUCTION

In late 1970s decade California state government has started evaluating the seismic behavior of the buildings. They have found that buildings built before 1970 are behaving poorly in seismic behavior. Accordingly many more buildings have evaluated and retrofitting designs would have to be made. Here conventional use of the simple equivalent lateral force analysis procedures prescribed in building codes for the design of new buildings leads to costly and overly conservative retrofit where none is needed to meet owners performance objective because since buildings will respond to the earthquake ground motions in an inelastic manner, the linear elastic equivalent lateral force procedures do not provide a direct method to determine the resulting maximum displacements. The inelastic performance evaluation technique was used to evaluate the performance of the structure at late 1970s. At present it is widely used for design verification for new construction, evaluation of existing structures to know the damage states for various amplitudes of the ground motion. The procedure compares the capacity of the structure (in the form of pushover curve) with the demands on the structure (in the form of response spectra). The graphical intersection of two curves approximates the response of the structure. Nowadays pushover analysis is widely used for performance evaluation of new structures and retrofitting of existing structures. Considering the drawbacks of forced base design, the purpose of pushover analysis is to evaluate the expected performance of a structural system by estimating its strength and deformation demand in design earthquake.

Non Linear Shear wall Modelling Techniques

1) Midpier Modelling

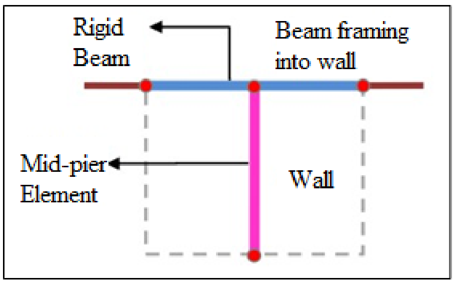

Fig.1 Midpier element modelling

Frame element is given size of S.W. in section designer. P-M and M- property is taken out and hinges are formed. This hinges are assigned at the ends of shear wall as frame element. Connecting beams are made rigid so it will not take moments.

2) **Multi-layered Shell Element Modelling**

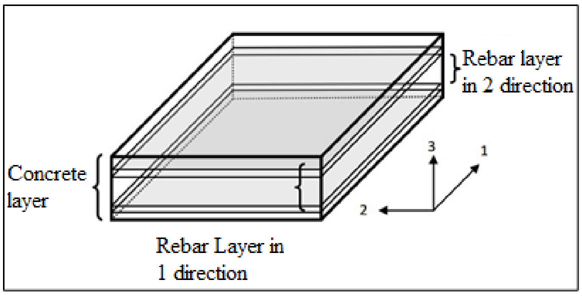

Fig.2 Multi-layer shell element modelling

The shear wall is modelled using a fine mesh of smeared multi-layer shell elements. The multi-layer shell element is based on the principles of composite material mechanics and it can simulate the coupled in-plane/out-plane bending and the coupled in-plane bending-shear nonlinear behaviours of RC shear walls. The shell element is made up of many layers with different thickness. And different material properties are assigned to various layers. This means that the reinforcement rebars are smeared into one layer or more. During the finite element calculation, the axial strain and curvature of the middle layer can be obtained in one element. Then according to the assumption that plane remains plane, the strains and the curvatures of the other layers can be calculated. And then the corresponding stress will be calculated through the constitutive relations of the material assigned to the layer. From the above principles, it is seen that the structural performance of the shear wall can be directly connected with the material constitutive law

II. Description of structural system

2.1 Building Description

Table.1 Data of Regular Building

Type of frame	:G+10 Storey space Frame	G+15 storey space frame	G+20 storey space frame
Zone	: V (0.36)	: V (0.36)	: V (0.36)
Damping Ratio	: 5%	: 5%	: 5%
Response Reduction Factor(R)	: 5	: 5	: 5
Mass source	: DL + 0.25 LL	: DL + 0.25 LL	: DL + 0.25 LL
Importance Factor(I)	: 1	: 1	: 1
Soil type	: II(Medium)	: II(Medium)	: II(Medium)
concrete	M25	M25	M25
Steel	HYSD500	HYSD500	HYSD500
Beam	230 x 500	230 X 550	400 X 600
column	600 x 600	750 X 750	925 X 925
Slab thickness	150	200	200
Wall	5230 x 300	5230 X 450	5230 X 550
Wall load	13.28(kn/m2)	13.28(kn/m2)	13.28(kn/m2)
Live Load	2 kn/m2	2 kn/m2	2 kn/m2
F.F	1 kn/m2	1 kn/m2	1 kn/m2

Table.2 Data of Irregular Building

Type of frame	:G+10 Storey space Frame	G+15 storey space frame	G+20 storey space frame
Zone	: V (0.36)	: V (0.36)	: V (0.36)
Damping Ratio	: 5%	: 5%	: 5%
Response Reduction Factor(R)	: 5	: 5	: 5
Mass source	: DL + 0.25 LL	: DL + 0.25 LL	: DL + 0.25 LL
Importance Factor(I)	: 1	: 1	: 1
Soil type	: II(Medium)	: II(Medium)	: II(Medium)
concrete	M25	M25	M25
Steel	HYSD500	HYSD500	HYSD500
Beam	230 X 500	230 x 500	400 x 600
column	500 X 500	650 x 650	900 x 900
Slab thickness	150	150	150
Wall	5230 X 300	5230 x 450	5230 x 550
Wall load	13.28(kn/m2)	13.28(kn/m2)	13.28(kn/m2)
Live Load	2 kn/m2	2 kn/m2	2 kn/m2
F.F	1 kn/m2	1 kn/m2	1 kn/m2

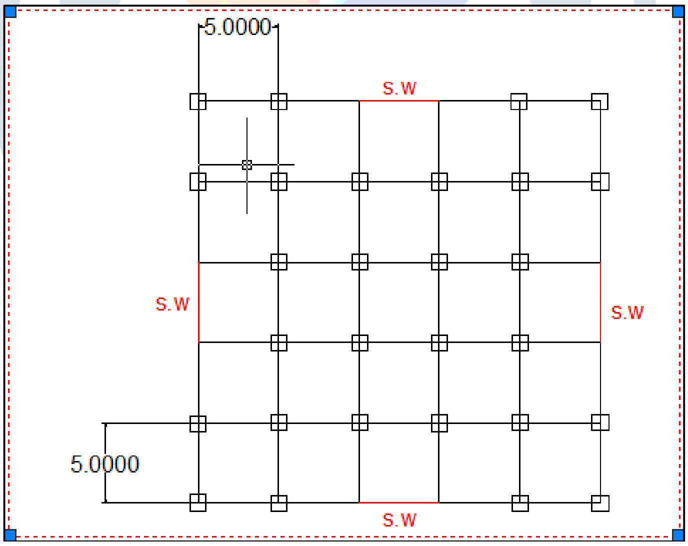

Fig.3 Typical Plan of regular building

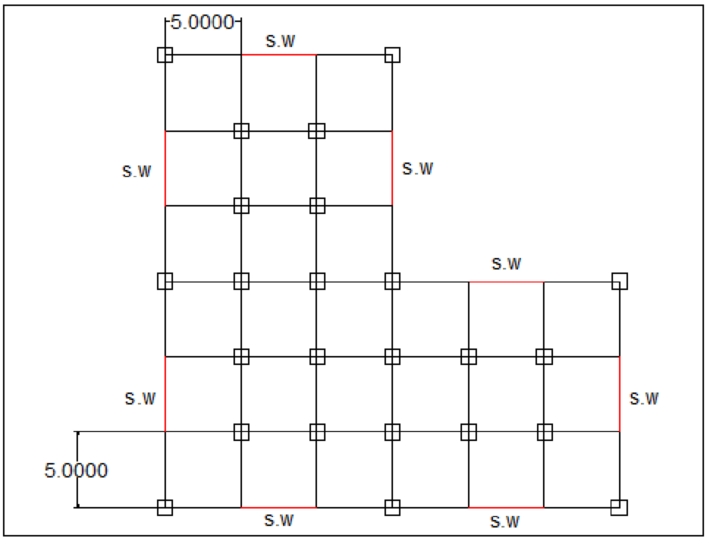

Fig.4 Typical plan for irregular building

2.2 Fundamentals of pushover analysis

In this method of analysis is carried out under permanent vertical loads and gradually increasing lateral loads to estimate deformation and damage pattern of structure.

Demand and capacity

The key elements of a performance-based design procedure are demand and capacity. Demand is a representative of the earthquake ground motion. Capacity is a representation of the structure's ability to resist the seismic demand. The performance is dependent on the manner that the capacity is able to handle the demand.

Determination of three primary elements: capacity, demand (displacement) and performance are required for Nonlinear Static (Pushover) Analysis. Each of these is briefly described below.

Capacity: The overall capacity of a structure depends on the strength and deformation capacities of the individual components of the structure. In order to determine capacities beyond the elastic limits, some form of nonlinear analysis, such as the pushover procedure, is required. This procedure uses a series of sequential elastic analysis, superimposed to approximate a force displacement capacity diagram of the overall structure. The mathematical model of the structure is modified to account for reduced resistance of yielding components. A lateral force distribution is again applied until additional components yield. This process is continued until the structure becomes unstable or until a predetermined limit is reached.

Demand: Ground motion during an earthquake produce complex horizontal displacement patterns in the structures. It is impractical to trace this lateral displacement at each time-step to determine the structural design parameters. The traditional design methods use equivalent lateral forces to represent the design condition. For nonlinear methods it is easier and more direct to use a set of lateral displacements as the design condition. For a given structure and ground motion, the displacement demand is an estimate of the maximum expected response of the building during the ground motion.

Performance: Once, a capacity curve and demand displacement, are defined, a performance check can be done. A performance check verifies that structural and nonstructural components are not damaged beyond the acceptable limits of the performance objective for the forces and displacements implied by the displacement demand.

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III. ANALYSIS RESULTS

The models are analyzed statically and designed in SAP2000. The pushover analysis is carried out on all models and performance point of the structure are determined.

3.1 Performance Point:

As per ATC 40, the buildings are pushed to a controlled displacement of 4% of the height of the structure. The performance point for all the RC models are determined.

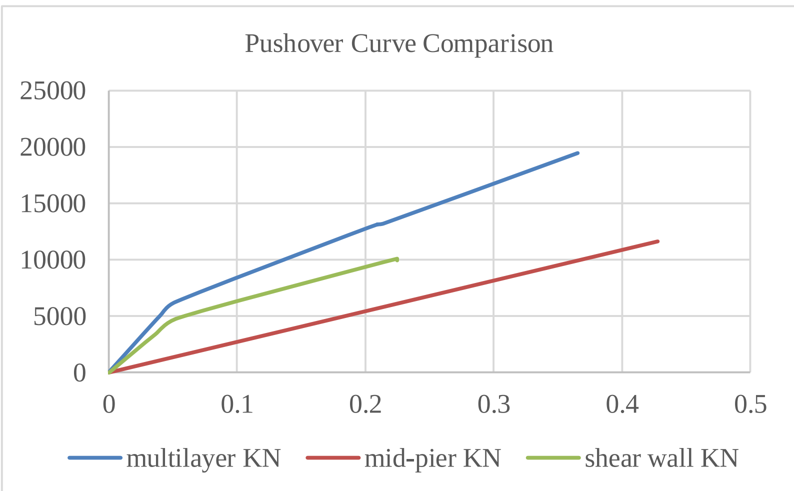

Fig.5 Pushover curve comparison of G+10 regular building

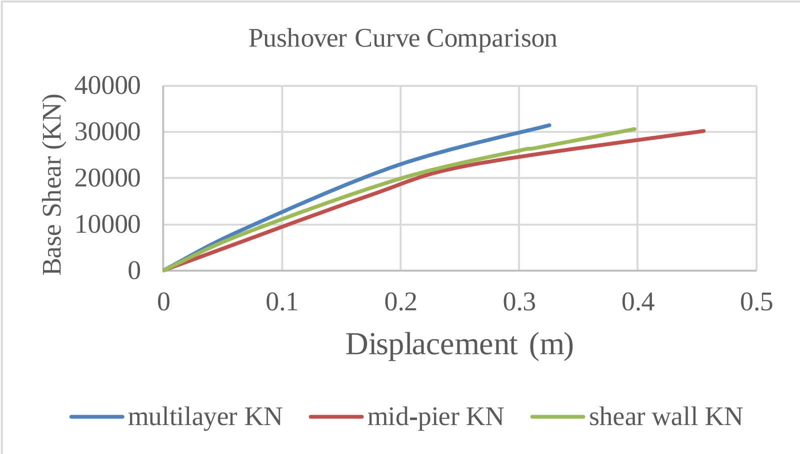

Fig.6 Pushover Curve comparison of G+15 regular building

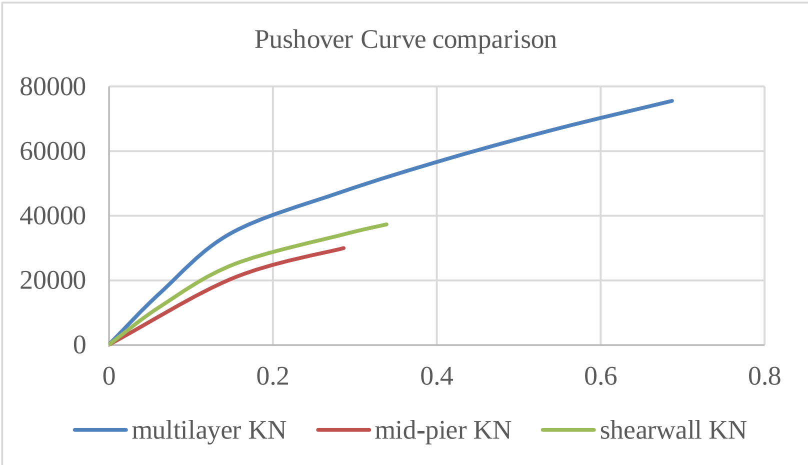

Fig.7 Pushover Curve comparison of G+20 regular building

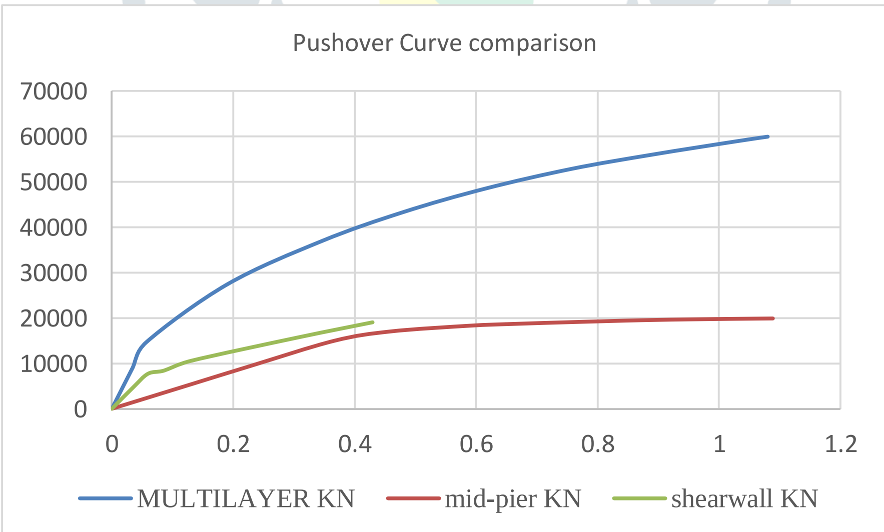

Fig.8 Pushover curve comparison of G+10 irregular building

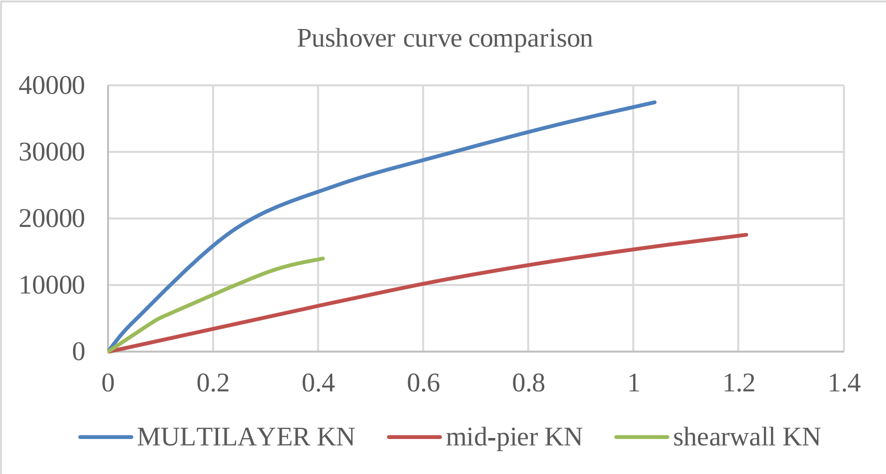

Fig.9 Pushover curve comparison of G+15 irregular building

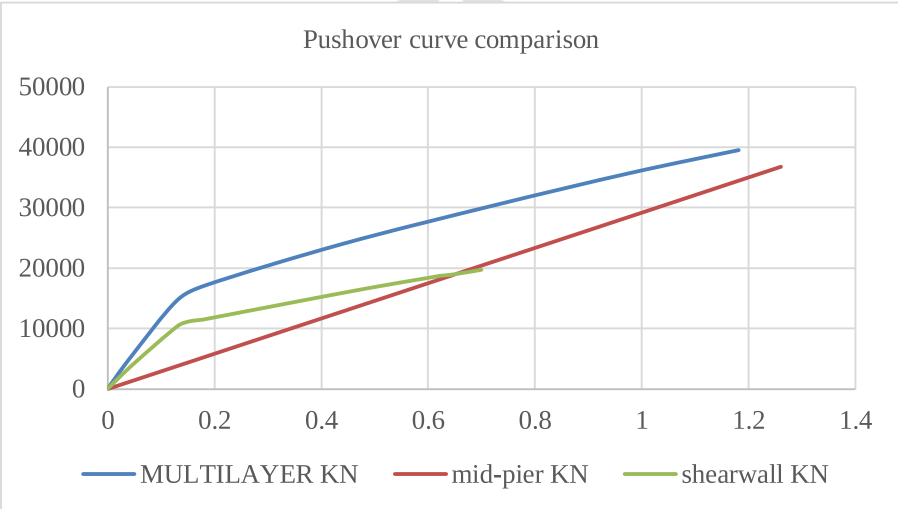

Fig.10 Pushover curve comparison of G+20 irregular building

Table.3 Performance Point Base shear (KN) of regular and irregular building

	Regular Building			Irregular Building		
Performance point	Midpier	Multilayered	shear wall	Midpier	Multilayered	Shear wall
G+10	10555.176	12053.479	9936.656	13799.663	21540.31	12543.204
G+15	22766.418	22806.22	22763.474	10994.476	12165.004	10163.453
G+20	26374.581	34886.702	29058.58	18448.665	22129.797	14264.411

Table.4 Shear wall participation at performance point in percentage of regular and irregular building

	Regular Building			Irregular Building		
Shear wall participation in (%)	Midpier	Multilayered	shear wall	Midpier	Multilayered	Shear wall
G+10	56	69.49	66.71	69.81	78.53	62.73
G+15	28.42	47.86	44.05	64.33	70.17	55.25
G+20	30.94	50.02	44.39	57.87	63.02	42.01

IV. CONCLUSION

The main objective of present study is seismic performance evaluation of in-plan irregular RC moment resisting frame with non-linear modelling techniques of shear wall and to evaluate building shear wall behaviour. For this 10 storey, 15 storey and 20 storey RC moment resisting frame of regular building and in plan irregular building with these shear wall techniques are analysed using SAP2000. Building are assumed to be located in seismic zone V and non-linear static pushover analysis is carried out.

- In case of Regular building, It is observed that over strength factor for Mid-pier, Multilayered & shear wall respectively for 10 storey frame is 1.27, 1.46 and 1.2 & for 15 storey is 1.64, 1.65 and 1.60 & for 20 storey is 1.25, 1.65 and 1.38 respectively.
- In case of Irregular building, It is observed that over strength factor for Mid-pier, Multilayered & shear wall respectively for 10 storey frame is 1.34, 2.09 and 1.22 & for 15 storey is 1.09, 1.09 and 1.01 & for 20 storey is 1.07, 1.28 and 1 respectively.
- It is observed that Pushover curve vary for Mid-pier, Multi-layered and simple shear wall modelling techniques in case of both regular and in plan irregular building.
- Shear wall participation is evaluated for each building with Mid-Pier modelling, Multi-Layer shell modelling and simple shear wall modelling. It is observed that shear wall modelled as Multi-Layer shell modelling takes more lateral load than building modelled with Mid Pier frame element modelling and simple shear wall modelling in case of both regular and irregular building.
- It is observed that storey drift criteria is satisfied in all types of modelling.
- It is observed that failure of building is govern by hinge formation in beam and column not in shear wall from hinge formation at various time-step.

REFERENCES

1. A.K.Mapari (2017),"Seismic Performance Of Multi-storey RC SMRF and OMRF buildings", Journal of Structural Engineering,Vol. 44,No.6,PP:663-672.
2. AbazarAsaghari (2017),"A New study of Seismic Behaviour of Perforated Couple Shear walls",International Journal of Civil Engineering.
3. Achyut S. Naphade, Prof. G. R. Patil ,(2015),"Pushover Analysis of RCC Building with Soft Storey at Different Levels", Journal of Mechanical and Civil Engineering (IOSR-JMCE),PP:100-108.
4. AmanMwafy (2016),"Effect of vertical structural irregularity on seismic design of tall bilding",Strcutural design of tall building(Wiley).
5. Amar Lousai ,(2014)," Evaluation of the seismic behavior factor of reinforced concrete frame structures based on comparative analysis between non-linear static pushover and incremental dynamic analyses", Bull Earthquake Eng.(Springer).
6. Anirudh Gotala and Kintali Sai Nanda Kishore (2015),"Comparitive Study of Static and Dynamic Seismic Analysis Of Multi-storey Building",International Journal of Science Technology and Engineering,Vol.2,PP:173-183
7. AnjuNayas, Minu Antony,(2017),"Pushover Analysis of Plan Irregular RC Buildings with Special Columns", International Journal of Engineering Research & Technology (IJERT), Vol. 6 Issue 05,PP:95-99.
8. Arvindreddy and R.J.Fernandes (2015),"Seismic Analysis Of Regular and Irregular Frame Structure",International Research Journal Of Engineering and Technology,Vol.2,PP:44-47.
9. Ashraf Uddin (2013),"P-Delta effect in Reinforced Concrete Structure in Rigid Joints",Journal of Mechanical and Civil Engineering"ISSN: 2278-1684,PP:42-49.
10. C.Konapure (2015),"Effect Of P-delta Action Multistorey Building",International Journal of Engineering Research and Technology.
11. Fabio Mazza(2014)," Modelling and nonlinear static analysis of reinforced concrete framed buildings irregular in plan", Engineering Structures,PP:98-108.
12. FEMA-356, (2000), Prestandard and Commentary for the Seismic Rehabilitation of Buildings, Building Seismic Safety Council, Federal Emergency Management Agency, Washington, D.C., USA.
13. G. Uva, F. Porco,(2011)," Appraisal of masonry infill walls effect in the seismic response of RC framed buildings: A case study",Engineering Structures (Elsevier),:PP:514-526.
14. Guray Arslan,(2016)," Performance Evaluation of In-Plan Irregular RC Frame Buildings Based on Turkish Seismic Code", Int J civil Eng.(Springer).
15. Hendramawat A Safarizki, S.A. Kristiawan, and A. Basuki, Procedia Engineering 54 (2013) ,"Evaluation of use of steel bracing to improve seismic performance of Reinforced Concrete Building,Procedia Engineering,PP:447-456.
16. IS 1893 (Part1):2002 Indian Standard, "Criteria for earthquake resistant design of structure General provision and buildings", Bureau of Indian Standard, New Delhi.
17. IS-456:2000, "Plain and reinforced concrete-code of practice" by Bureau of Indian Standard, New Delhi.
18. JunwonSeo(2015)," Seismic Performance Evaluation of Multistory Reinforced Concrete Moment Resisting Frame Structure with Shear Walls",Sustainability , 7, 14287-14308;
19. K RAMA RAJU, A CINITHA and NAGESH R IYER,(2011),"Seismic Performanc Evaluation of existing RC buildings designed as per Past codes of Practice",CSIR-Structural Engineering Research Centre,vol.37,PP:281-297.
20. Kai Hu,Yimeng Yang and Ge Qu(2011),"Study on High Rise structure with Oblique Columns by Etabs,Sap2000, Midas, Satwe",International Conference on advances in computational modelling and simulation,Procedia Engineering,PP:474-480.
21. KetanKulkarni (2015),"Comparitive study of RC Structural walls for Non Linear Static Analysis",National Conference on Technological Innovation for sustainable infrastructure".
22. M.F. Huang (2015)," Performance-based design optimization of tall concrete framed structures subject to wind excitations", Journal of Wind Engineering and Industrial Aerodynamics,PP:70-81.
23. M.K.Rahman (2010),"NonLinear Static Pushover Analysis of an Eight Storey RC Frame Shear wall building in Saudi Arabia",15 WCEE.
24. M.K.Rahman (2012)," Non Linear Static Pushover Analysis of an Eight Storey RC Frame Shear wall building in south Arabia"15 WCEE
25. N.M.Nikam,(2016)," Pushover Analysis of Building with Shear Wall", IJESC Vol.6 Issue No.8
26. ParmodiniNaik, (2017),"Performance evaluation of 9 Storey RC building Located in North Goa ",(Elsevier) Procedia Engineering,:PP:1841-1846.
27. Reza Allahvirdizadeh and YaghoubGholipour (2016)," Reliability evaluation of predicted structural performances using nonlinear static analysis", Bull Earthquake Eng.(Springer).
28. Rahul Ghosh (2016),"Sesimic Vulnerability Assessment of soft storeyed structures with plan irregularities and collapse prevention", International Journal of Engineering Research and Technology,ISSN:2278-0181.
29. Shaik Kamal Mohammed Azam (2013),"Seismic Performance Evaluation of MultistoriedRC framed buildings with Shear wall", Research Volume 4, Issue 1, ISSN 2229-5518.
30. T.Mahdi and V.Bahreini (2013)," Seismic Response of Asymmetrical Infilled Concrete Frames", The 2nd International Conference on Rehabilitation and Maintenance in Civil Engineering,Procedia Engineering,PP:341-352.
31. Y.Fahjan (2012)," PUSHOVER ANALYSIS FOR PERFORMANCE BASED-SEISMIC DESIGN OF RC FRAMES WITH SHEAR WALLS",15 WCEE.
32. YousufDinar (2013),"Deflection of Steel High-Rise Structure Due to P-Delta effect considering Global Slenderness Ratio", International Journal Of Engineering Technology and Advanced Engineering,Vol.3,PP:250-256.