International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 01, January-2018

Non linear Analysis of Multistoreyed Building with and without Shear Wall

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Abstract: **A performance - based design is at controlling the structural damage based on precise estimation of proper response parameter. In performance based seismic analysis evaluates how building is likely to perform. It is an iterative process with selection of performance objective followed by development of preliminary design, an assessment whether or not the design meets the performance objective; In the present study pushover analysis has been done an two multistoried R.C. frame building; In which plan of 2 buildings was taken symmetrical 10 storey and it consist of 5 bays in x direction & 5 bays in y direction and second building having 15 storey. The shear wall is providing for studying their resisting lateral forces. In this paper highlight the effect of shear wall on R.C frame building when shear wall providing along the longer and shorter side of the building. The base shear and displacement will decreases of building. The comparative study has been done for base shear, storey drift, spectral acceleration, spectral displacement, story displacement.**

Keywords: Pushover Analysis, Capacity Spectrum Method, Shear Wall

I. INTRODUCTION

The Concept of seismic design is to provide building structure with sufficient strength and deformation capacity to sustain seismic demands imposed by ground motion with adequate margin of safety. Even if the probability of occurrence of earthquake within the life span of structures is very less, strong ground motion would generally cause greater damage to the structure. For designing the structures for this combination having less probability and extreme loading, a criterion is adopted in such a way that a major earthquake, with a relatively low probability of occurrence is expected to cause significant damage which may not be repairable but not associated with loss of life Performance based seismic design is gaining popularity from last decades. Many countries are separate document over this method such as FEMA, ATC etc. Recently formulated Euro codes EC2 and EC8 [Euro code 2, Euro code 8] are also based on performance based design philosophy. But Indian codes are still silent over this method. Even the IS 1893(part I): 2007 draft doesn't talk about performance based seismic design .E-TABS software was used for the design of building.

II. OBJECTIVES

1) To study the effect of providing shear walls, in RC framed building, using pushover analysis.
2) To compare the seismic response of building in terms of base shear, storey drift, spectral acceleration, spectral displacement and storey displacements.
3) Determination of performance point of building to suggest rectrofitting techniques.
4) To determine the best possible combination of reinforcement that would be both economical and effective.
5) To study the effect of shearwalls as a method of rectrofitting.

literature Review

Monavari et al. (2008) used nonlinear static analysis and five locals and overall yields and failure criteria to estimate seismic demands of buildings. The failure is directed towards losing structure's performance during the earthquake or subsequent effects. Because of the consequent excitations of an earthquake or lateral imposed loads on a structure, the stiffness of some elements of structure reduced and the structure started to fail and lose its performance; although failure happened either in small parts of structure or at the whole. In this study thirteen reinforced concrete (RC) frame buildings with 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 16 and 20 stories, having 3 and 4 bays were designed using seismic force levels obtained from the Iranian Seismic Code 2005 and proportioned using the ACI 318-99 building code and then were modeled by IDARC. Pushover analysis with increasing triangular loading was used.

Merter and Ucar (2010) compared pushover analysis and time history analysis. In this study, pushover analyses of six- and ten-story frames are performed and capacity curves of these frames are obtained. For six-story frame, base shear forces obtained from nonlinear time history analyses are smaller than those obtained from pushover analysis; expect Duzce and Erzincan earthquakes which give bigger base shear forces than base shear forces obtained from pushover analysis. The same conclusions can be made for ten-story RC frame. While inter story drift ratios obtained from different analysis methods are compared with each others, nonlinear time history analyses performed by using Duzce, Kocaeli and Erzincan records give larger values. For other earthquakes, inter story drift ratios obtained from pushover analyses are larger. Expect the nonlinear time history results of Duzce, Kocaeli and Erzincan earthquakes, pushover analysis results are on the safe side. It may be concluded that, in case nonlinear time history analyses are not performed, pushover analysis methods give valuable information about nonlinear behavior of structures and they are more practical.

Chattopadhyaya and Sengupta (2011) studied on a 4-storyed regular RC building was considered for comparative study of the options of modeling a shear wall for pushover analysis. The modeling of shear wall was studied for seismic loads along one direction. He concluded that modeling of tall and solid shear wall using column element is adequate for pushover analysis, provided the hinge properties are defined properly. Modeling a shear wall using fiber-based wall element is rigorous. Since it is computationally intensive, it need not be used for pushover analysis of a building with a solid shear walls.

Chopra and Goel (2012) conducted on “Capacity and earthquake response analysis of RC-shear walls”. In this work, nonlinear pushover analysis was carried out for low-rise, reinforced, concrete shear walls with openings. The model showed that well reinforced shearwalls distributed the cracks over a greater area than the poorly reinforced walls, and these cracks are generally more closed, especially when the steel is below the yield point. The analysis also indicated that the capacity of the shear wall is highly affected by the reinforcement around the openings.

Satpute and Kulkarni (2013) studied on “Comparative study of reinforced concrete shear wall analysis in multi storied building with openings by nonlinear methods”. In this work, by performing of RC shear walls building with openings ten storey building was carried out to compare the different sizes of the opening analysis by nonlinear static and nonlinear dynamic method. The analysis of RC shear walls with openings building was carried out using theSAP2000 nonlinear software tool. They concluded that the values of base shear, storey displacement and storey drift for the both methods are found to be increasing order for model 1, 2, 3, 4, and 5.The variation in the height-wise distribution of top displacement increase by 84.97%, 85.91%, 87.09%, 90.05% in time history analysis and 71.14%, 78.32%, 81.21%, and 82.63% in pushover analysis for model 2, 3, 4, 5, respectively as compared to valueof model 1.

III. DESCRIPTION OF PUSHOVER ANALYSIS

The non-linear static pushover procedure was originally formulated and suggested by two agencies namely, federal emergency management agency (FEMA) and applied technical council (ATC), under their seismic rehabilitation programs and guidelines. This is included in the documents FEMA-273 [4], FEMA-356 [2] and ATC-40 [32].

3.1 Introduction to FEMA-273

The primary purpose of FEMA-273 [4] document is to provide technically sound and nationally acceptable guidelines for the seismic rehabilitation of buildings. The Guidelines for the Seismic Rehabilitation of Buildings are intended to serve as a ready tool for design professionals for carrying out the design and analysis of buildings, a reference document for building regulatory officials, and a foundation for the future development and implementation of building code provisions and standards.

3.2 Introduction to ATC-40

Seismic Evaluation and Retrofit of Concrete Buildings commonly referred to as ATC-40 [32] was developed by the Applied Technology Council (ATC) with funding from the California Safety Commission. Although the procedures recommended in this document are for concrete buildings, they are applicable to most building types.

3.3 Pushover guideline as per ATC-40

In Nonlinear Static Procedure, the basic demand and capacity parameter for the analysis is the lateral displacement of the building. The generation of a capacity curve (base shear v/s roof displacement) defines the capacity of the building uniquely for an assumed force distribution and displacement pattern. It is independent of any specific seismic shaking demand and replaces the base shear capacity of conventional design procedures. If the building displaces laterally, its response must lie on this capacity curve. A point on the curve defines a specific damage state for the structure, since the deformation for all components can be related to the global displacement of the structure. By correlating this capacity curve to the seismic demand generated by a specific earthquake or ground shaking intensity, a point can be found on the capacity curve that estimates the maximum displacement of the building the earthquake will cause. This defines the performance point or target displacement. The location of this performance point relative to the performance levels defined by the capacity curve indicates whether or not the performance objective is met.

Thus, for the Nonlinear Static Procedure, a static pushover analysis is performed using a nonlinear analysis program for an increasing monotonic lateral load pattern. An alternative is to perform a step by step analysis using a linear program. The base shear at each step is plotted again roof displacement. The performance point is found using the Capacity Spectrum Procedure. The individual structural components are checked against acceptability limits that depend on the global performance goals. The nature of the acceptability limits depends on specific components. Inelastic rotation is typically one of acceptability parameters for beam and column hinges. The limits on inelastic rotation are based on observation from tests and the collective judgment of the development team.

IV. METHODOLOGY

The methods of pushover analysis used here capacity spectrum method and time history method Equation

4.1 Inelastic component behavior

The key step for the entire analysis is identification of the primary structural elements, which should be completely modeled in the non-linear analysis. Secondary elements, which do not significantly contribute to the building‘s lateral force resisting system, do not need to be included in the analysis. In concrete buildings, the effects of earthquake shaking are resisted by vertical frame elements or wall elements that are connected to horizontal elements (diaphragms) at the roof and floor levels. The structural elements may themselves comprise of an assembly of elements such as columns, beam, wall piers, wall spandrels etc. It is important to identify the failure mechanism for these primary structural elements and define their non-linear properties accordingly. The properties of

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 01, January-2018

interest of such elements are relationships between the forces (axial, bending and shear) and the corresponding inelastic displacements (displacements, rotations, drifts). Earthquakes usually load these elements in a cyclic manner as shown in Fig. 2. For modeling and analysis purposes, these relationships can be idealized as shown in Fig. 3 using a combination of empirical data, theoretical strength and strain compatibility.

4.2 Capacity spectrum method

One of the methods used to determine the performance point is the Capacity Spectrum Method, also known as the Acceleration-Displacement Response Spectra method (ADRS). The Capacity Spectrum method requires that both the capacity curve and the demand curve be represented in response spectral ordinates. It characterizes the seismic demand initially using a 5% damped linear-elastic response spectrum and reduces the spectrum to reflect the effects of energy dissipation to estimate the inelastic displacement demand. The point at which the Capacity curve intersects the reduced demand curve represents the performance point at which capacity and demand are equal.

4.3 Time history method

Time-History Analysis shall be performed with no fewer than three data sets (two horizontal components or, if vertical motion is to be considered, two horizontal components and one vertical component) of appropriate ground motion time histories that shall be selected and scaled from no fewer than three recorded events. Appropriate time histories shall have magnitude, fault distances, and source mechanisms that are consistent with those that control the design earthquake ground motion. Where three appropriate recorded ground motion time history data sets are not available, appropriate simulated time history data sets may be used to make up the total number required. For each data set, the square root of the sum of the squares (SRSS) of the 5%-damped site-specific spectrum of the scaled horizontal components shall be constructed. The data sets shall be scaled such that the average value of the SRSS spectra does not fall below 1.4 times the 5%-damped spectrum for the design earthquake for periods between 0.2T seconds and 1.5T seconds (where T is the fundamental period of the building). Where three time history data sets are used in the analysis of a structure, the maximum value of each response parameter (e.g., force in a member, displacement at a specific level) shall be used to determine design acceptability. Where seven or more time history data sets are employed, the average value of each response parameter may be used to determine design acceptability

V. ANALYSIS AND RESULT

5.1 Description of building

In the present work, a 10 storied and 15 storied reinforced concrete frame building situated in zone V, is taken for the purpose of study. The plan area of building is 20 x 20m with 2m as plinth level and 3m as height of each typical storey. It consists of 5 bays in X-direction and 5 bays in Y-direction. The total heights of the buildings were 32m and 47m. The building is considered as a Special Moment resisting frame.

5.2 Symmetrical building with shear wall

Shear wall is modeled as shell element. Thickness of shear wall is taken equal to 150mm for 10storey building and 200mm for 15storey building. As the building is symmetric shear wall is provided in one bay of building frame.

5.3 Base force

The base force observed from that the hinges for 15 storey the structure were in the elastic region up to a displacement of 32mm and further increase in the displacement leads to formation of 2 hinges with this the structure enters in to the nonlinear stage.The number of hinge formation for the structure remains in this “Immediate Occupancy”level till the displacement reached 32mm with base shear of 3912.91kN. The structure enters the performance level “life safety” with the formation of hinges of 2 hinges at the displacement of about 82mm the building remained in the life safety level. The structure enters in the collapse prevention level after further increases in displacement till 314mm itwas with the help of 111 additional hinges.

The base force for the 10-storey building with different combination of element reinforcement at various floor levels. It is observed that with increase in reinforcement of beams only, there is a very minimal percentage change in the base force varying from 1.28% to -3.27%, which the structure can carry. However, with the increase in reinforcement of storey columns, there is quite an appreciable change in the base force carrying capacity of the structure. Further there is a decline of 4.63% in the base force capacity, when shear wall is provided in one bay of building frame. The combination of change of reinforcement in beams and columns both show a small increase in base force capacity.

Base shear decreases by 7.55% when shear wall is provided in one bay of structure..

5.4 Roof Displacement

The Roof displacement for the ten-storey building with different combination of element reinforcement at various floor level. It is observed that by increasing the reinforcement of beams only, there is a decrease in the roof displacement up to 9th storey and after 9th storey there is no change. The percentage change varies from 1.89% to 13.59%. However, the trends shown by increasing the reinforcement of columns only is a substantial decrease in the roof displacement which varies from 0.6% to 21.08%. The combination of increase of reinforcement of beams and columns both, show a little increase in the roof displacement up to 8th storey and after 8th storey it slightly decreases up to 10th storey.

There is a predominant decrease (63.36%) in roof displacement when shear wall is provided in building.

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ISSN: 2278-0181
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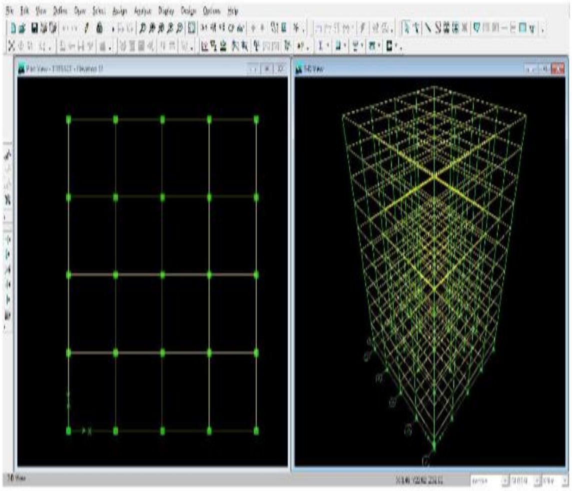

Geometry of Symmetrical Building without Shear Wall.

used to The capacity spectrum curves obtained are shown by which the magnitude of the earthquake and the new capacity spectrum plot can be obtained immediately. The performancpoint for a given set of values is defined by the intersection of the capacity curve the single demand spectrum curve. Also, a table was generated which shows the coordinates of the capacity curve and the demand curve as well as other information convert the pushover curve to acceleration-displacement Response spectrum format (also known as ADRS format).

Storey level	Displacements without Shear wall	Displacements with Shear wall
Terrace	1610295	34093
Storey 9	156.054	30.995
Storey 8	146.856	26.935
Storey 7	134.102	2.808
Storey 6	118.537	18.684
Storey 5	100.861	14.661
Storey 4	81.691	10.852
Storey 3	61.549	7.385
Storey 2	40.983	4.397
Storey 1	21.859	2.047
Ground level	0.4930	0.484

The displacements for 10 & 15 Storey Building shows a decrease in 78% and 74% respectively which are mentioned in the tables.

Storey level	Displacements without Shear wall	Displacements with Shear wall
Storey 14	271.576	72.586
Storey 13	251.881	67.106
Storey 12	233.966	55.862
Storey 11	211.593	50.099
Storey 10	191.289	44.289
Storey 9	170.145	38.488
Storey 8	149.788	32.761
Storey 7	129.767	27.185
Storey 6	110.167	21.846
Storey 5	90.068	16.835
Storey 4	70.251	12.254
Storey 3	51.659	8.209
Storey 2	33.668	4.817
Storey 1	16.774	0.208
Ground level	3.532	0.0514

Table 1 Base and displacement decreases after providing shear wall

Element	Symmetrical building	Unsymmetrical building	
		Shear wall larger side	Shear wall Smaller side
Base shear	7.55%	7.97%	4.3%
Roof displacement	63.36%	55.4%	58.15%

VI. CONCLUSION

1) When a 10 and 15 storied buildings are pushed to 1% transient drift (0.32m,0.47m), the performance of the building lies between Immediate Occupancy and Life Safety levels even with increase in the storey height. In the present case study, both the buildings have moderate resistance.
2) The drift index of 10 and 15 storied buildings are 0.00406 and 0.00415 which is below the permissible index value of 0.005(for no damage as per ATC-40). It infers that the lateral displacement of the structure is well within permissible limits and no damage occurs as a whole.
3) When a 10 and 15 storied buildings are pushed to 2% transient drift(0.64m,0.94m),the performance of the building lies between Life Safety and Collapse Prevention levels even with increase in the storey height. In the present case study, both the buildings have poor resistance.
4) The drift index of 10 and 15 storied buildings are 0.00445 and 0.00459 which is below the permissible index value of 0.005(for no damage as per ATC-40). It infers that the lateral displacement of the structure is well within permissible limits and no damage occurs as a whole.
5) The observed displacements at terrace level for a 10 storied building without shear wall were 161mm. When shear wall was introduced to the structure displacement was drastically reduced to 34.9mm. It infers that the structure is well within permissible limits and no damage occurs as a whole.
6) The observed displacements at terrace level for a 15 storied building without shear wall were 271mm. When shear wall was introduced to the structure displacement was drastically reduced to 72.5mm. It infers that the structure is well within permissible limits and no damage occurs as a whole.
7) Provision of shear wall results in a huge decrease in base shear and roof displacement both symmetrical building and un-symmetrical building.
8) The performance based seismic design obtained by above procedure satisfies the acceptance criteria for immediate occupancy and life safety limit states for various intensities of earthquakes.
9) Performance based seismic design obtained leads to a small reduction in steel reinforcement when compared to code based seismic design (IS 1893:2002) obtained by STAAD.Pro.

SCOPE FOR FUTURE STUDY

The study can be extended to a non-linear time history analysis of the building. modeling of shear walls with openings, coupled shear walls, flanged walls and core walls can also be studied.

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