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EXPERIMENTAL STUDY ON ANALYSIS OF RCC STRUCTURE WITH OR WITH OUT INFILL DIFFERENT SEISMIC ZONES

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ABSTRACT:

The infills are mostly used as interior partition walls and external walls which are protecting from outside environment to the building. The masonry infill panels are generally not considered in the design process and treated as architectural (non-structural) components. Reinforced concrete (RC) frame buildings with masonry infill walls have been widely constructed for commercial, industrial and multi-story residential uses in seismic regions. This thesis focuses on the intrinsic vulnerability of multistory structures with open (soft storey) ground floors to collapse owing to seismic stresses, yet their constructions are nevertheless common in industrialized countries today. The social and practical demand for underground parking significantly overcomes the warnings of the technical community against such structures.

In this study, 3D analytical model of G+10 multistory building has been generated for different buildings models and analyzed using structural analysis tool 'E-TABS'. In the analytical building model, all of the significant components are included that affect the mass, strength, and stiffness of the structure. As part of the research, seismic analysis using linear dynamic (response spectrum technique) and nonlinear static (pushover) procedures will be used to assess the capacity, demand, and performance level of the model under consideration. The ductility coefficients of structures are assessed using numerical findings for the following seismic demands, which take the inelastic behavior of the building into consideration.

1.0 INTRODUCTION

The capacity of structural members to undergo inelastic deformations governs the structural behavior and damageability of multi-storey buildings during earthquake ground motions. From this point of view, the evaluation and design of buildings should be based on the inelastic deformations demanded by earthquakes, besides the stresses induced by the equivalent static forces as specified in several seismic regulations and codes. Although, the current practice for earthquake-resistant design is mainly governed by the principles of force-based seismic design, there have been significant attempts to incorporate the concepts of deformation-based seismic design and evaluation into the earthquake engineering practice. In general, the study of the inelastic seismic responses of buildings is not only useful to improve the guidelines and code provisions for minimizing the potential damage of buildings, but also important to provide economical design by making use of the reserved strength of the building as it experiences inelastic deformations. In recent seismic guidelines and codes in Europe and USA, the inelastic responses of the building are determined using nonlinear static methods of analysis known as the pushover methods.

Infill Walls

The infill wall is the supported wall that closes the perimeter of a building constructed with a three-dimensional framework structure (generally made of steel or reinforced concrete). Therefore, the structural frame ensures the bearing function, whereas the infill wall serves to separate inner and outer space, filling up the boxes of the outer frames. The infill wall has the unique static function to bear its own weight. The infill wall is an external vertical opaque type of closure. With respect to other categories of wall, the infill wall differs from the partition that serves to separate two interior spaces, yet also non-load bearing, and from the load bearing wall. The latter performs the same functions of the infill wall, hygro-thermically and acoustically, but performs static functions too.

Figure 1 : Test Structure with Infill Walls

The mortar used to build the infill walls were made with QUIKRETE® Mortar Mix (No. 1102); a blend of masonry cement and graded sand meeting ASTM C 270 for Type N Mortar. Its average compressive strength, obtained from tests of 45 50-mm (2-in.) cubes, was 10 MPa (1500 psi) and the corresponding standard deviation was 2.8 MPa (400 psi). Tests of 29 100x200-mm (4x8-in.) cylinders yielded an average strength of 12 MPa

(1700 psi) and a standard deviation of 4.1 MPa (600 psi).

Objectives of study

1. To study the effect of infill walls and without infill walls on structure.
2. To study the performance level of the structure.

The considered objectives are useful to study the overall behavior of the structure under the seismic load, from which the performance level can be determined.

2.0 LITERATURE REVIEW

Various research works and experiments have been carried out since a long time all over the globe to understand or to evaluate the effect of seismic forces on existing RC building in high seismic zones and in hilly terrain. The concept of modeling and analysis techniques used for this purpose has also been getting improved with advancement of engineering and technology as well as with past experience.

Chidananda HR, Raghu [1] studied 4, 8 and 12 storey buildings with their number of bays increasing from 3 to 6 were modelled as bare and infilled frame. Equivalent Static Analysis (ESA), Response Spectrum Analysis (RSA) and non-linear static Pushover analysis were performed on all structures. Base shear capacity for both ESA and RSA were compared for bare and infilled frame

Mohammad H. Jinya [2] investigated the seismic response of reinforced concrete (RC) frame building considering the effect of modelling masonry infill (MI) walls. The seismic behaviour of a residential 6-storey RC frame building, considering and ignoring the effect of masonry, is numerically investigated using response spectrum (RS) analysis. The considered herein building is designed as a moment resisting frame (MRF) system following the Egyptian code (EC) requirements.

Narendra A. Kaple [3] analyzed two models of tall structures with different symmetric and asymmetric plan geometries are analysed by linear static method and designed for the same. The analysis results are shown in terms of storey shear, storey drift and storey displacement in all the two models.

Mircea Bârnaure [4] presents a study about the effect of masonry infill walls on the behaviour of framed buildings, in seismic areas. The study was done for a building that will be built in Bucharest, Romania. In this case, the building will have 6 stories. The bays are narrow, because of the architecture requirements. The structure is composed of concrete frames

Murty, C.V.R et al [5] study, a 3-story R/C frame structure with different amount of masonry infill walls is considered to investigate the effect of infill walls on earthquake response of these type of structures. The diagonal strut approach is adopted for modelling masonry infill walls

3.0 RESEARCH METHODOLOGY

The analysis procedures can be divided into linear procedures (linear static & linear dynamic) and non-linear procedures (nonlinear static and nonlinear dynamic) In linear static procedures the building is modeled as an equivalent single-degree of freedom (SDOF) system with a linear static stiffness and an equivalent viscous damping These linear static procedures are used primarily for design purposes and are incorporated in most codes. Their expenditure is rather small. However, their applicability is restricted to regular buildings for which the first mode of vibration is prominent.

Linear Dynamic Analysis

As a result of recent developments in desktop computing capabilities and seismic analysis software, there has been a shift among practicing engineers toward the routine application of linear dynamic analysis rather than linear static analysis for multistoried buildings. The application of linear dynamic analysis is favored due to its ability to explicitly account for the effects of multiple modes of vibration. Furthermore, the results of linear dynamic analysis can be used to determine whether significant inelastic behavior is likely to occur and thus can be used to determine whether more complex static or dynamic nonlinear analysis is warranted.

Pushover Analysis

The pushover analysis can be considered as a series of incremental static analyses carried out to examine the non-linear behavior of structure, including the deformation and damage pattern. The procedure consists of two parts. First, a target displacement for the structure is established Pushover analysis, also known as collapse analysis, is a nonlinear static monotonic lateral force–displacement analysis in which the mathematical model of the multi degree- of-freedom structure is subjected to a distribution of incrementally increasing lateral forces until the stability limit of the structure is reached. The pushover analysis can establish the capacity curve (pushover curve) of the structure, i.e. the path taken to reach the strength and ductility capacities of the structure, including the sequence of cracking, yielding and failure of components.

Displacement-based seismic analysis generally begins with a psedu-static multi-degree-of-freedom (MDOF) pushover analysis of the building to establish the pushover curve which is, in turn, transformed to a capacity curve that characterizes the structure response in its fundamental mode of vibration (see Figure 3.2). Note that the terminology for displacement-based analysis is still evolving and thus the terms used above are not necessarily consistent with those found in other related documents.

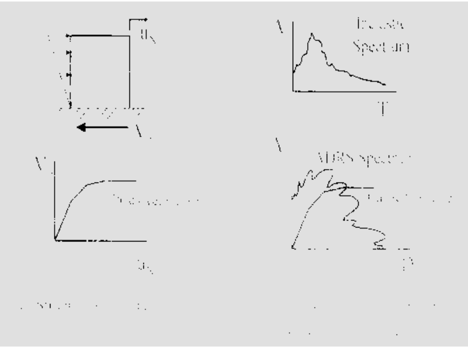

Figure 2: Graphical depiction of displacement based Seismic Analysis

The pushover analysis requires the selection of a lateral force distribution (often being proportional to the fundamental mode shape) and a control node. The force distribution is applied to the structure in an incremental fashion while monitoring the occurrence of nonlinear behavior and plotting the base shear (Vb) versus control node displacement (Un). Note that gravity loads should be applied to the structure prior to the application of lateral loads. The pushover analysis is stopped when the structure reaches either a pre-defined displacement limit or the ultimate capacity is reached.

Target Displacement

The fundamental question in the execution of the pushover analysis is the magnitude of the target displacement at which seismic performance evaluation of the structure is to be performed. The target displacement serves as an estimate of the global displacement of the structure is expected to experience in a design earthquake.

Use of Pushover Results

Pushover analysis has been the preferred method for seismic performance evaluation of structures by the major rehabilitation guidelines and codes because it is conceptually and computationally simple. Pushover analysis allows tracing the sequence of yielding and failure on member and structural level as well as the progress of overall capacity curve of the structure. The expectation from pushover analysis is to estimate critical response parameters imposed on structural system and its components as close as possible to those predicted by nonlinear dynamic analysis. Pushover analysis provides information on many response characteristics that cannot be obtained from an elastic static or elastic dynamic analysis. These are [30];

- Estimates of inter story drifts and its distribution along the height.
- Determination of force demands on brittle members, such as axial force demands on columns, moment demands on beam-column connections.
- Determination of deformation demands for ductile members.
- identification of location of weak points in the structure (or potential failure modes).

Pushover analysis also exposes design weaknesses that may remain hidden in an elastic analysis. These are story mechanisms, excessive deformation demands, strength irregularities and overloads on potentially brittle members.

Limitations of Pushover Analysis

Although pushover analysis has advantages over elastic analysis procedures, underlying assumptions, the accuracy of pushover predictions and limitations of current pushover procedures must be identified.

There are many unsolved issues that need to be addressed through more research and development. Examples of the important issues that need to be investigated are:

- Incorporation of torsional effects (due to mass, stiffness and strength irregularities).
- 3-D problems (orthogonality effects, direction of loading, semi-rigid diaphragms, etc)
- Use of site-specific spectra.
- Cumulative damage issues.
- Most importantly, the consideration of higher mode effects once a local mechanism has formed.

Safety Evaluation of Reinforced Concrete Buildings

Safety against collapse of reinforced concrete is usually defined in terms of its ductility ratios. The design of reinforced concrete structures is performed by using resistance smaller than the one required for the system to remain elastic under intense ground shaking. Then, the seismic codes implicitly cause structural damages during strong earthquake motions and the design relies on the capacity of the structures to undergo large inelastic deformations and to dissipate energy without collapse.

Seismic Vulnerability

The vulnerability of a building subjected to an earthquake is dependent on seismic deficiency of that building relative to a required performance objective. The seismic deficiency is defined as a condition that will prevent a building from meeting the required performance objective. Thus, a building evaluated to provide full occupancy immediately after an event may have significantly more deficiencies than the same building evaluated to prevent collapse.

Stiffness:

A building is made up of both rigid and flexible elements. For example, beams and columns may be more flexible than stiff concrete walls or panels. Less rigid building elements have a greater capacity to absorb several cycles of ground motion before failure, in contrast to stiff elements, which may fail abruptly and shatter suddenly during an earthquake. Earthquake forces automatically focus on the stiffer, rigid elements of a building.

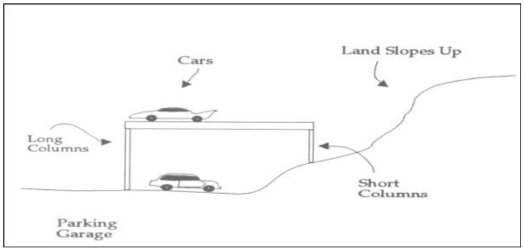

Figure 3: showing long and short columns

Effect of Infill

The presence of the infill walls increases the lateral stiffness considerably. Due to the change in stiffness and mass of the structural system, the dynamic characteristics change as well. Infill walls have an important effect on the resistance and stiffness of buildings. However, the effects of the infill walls on the building response under seismic loading are very complex and math intensive.

Exterior masonry walls and/or interior partitions built as an infill between a reinforced concrete frame’s beams and columns are usually considered to be non-structural elements in design. The interaction between the frame and infill is often ignored. However, the actual behavior of such structures observed during past earthquakes shows that their response is often wrongly predicted during the design stage. Infill-frames have been used in many parts of the world over a long time.

Soft Storey:

RECENT trend of urbanization of cities of the developing countries, especially in South Asia region, is witnessing construction of multistoried buildings with open ground floor reserved for car parking or other utility services. Though multistoried buildings with open (soft) ground floor are inherently vulnerable to collapse due to earthquake load, their construction is still widespread in the developing nations. Social and functional need to provide car parking space at ground level far out-weighs the warning against such buildings from engineering community. These buildings are generally designed as RC framed structures without regards to the structural action of the masonry infill (MI) walls present in the upper floors.

ANALYTICAL MODELLING

Most building codes prescribe the method of analysis based on whether the building is regular or irregular. Almost all the codes suggest the use of static analysis for symmetric and selected class of regular buildings. For buildings with irregular configurations, the codes suggest the use of dynamic analysis procedures such as response spectrum method or time history analysis.

In the present study lateral load analysis as per the seismic code for the following type of structures, bare frame, full infill, base soft storey, central core wall, shear wall in x & y direction and along with central core wall, shear wall in corners & along with central core wall is carried out and an effort is made to study the effect of seismic loads on them and thus assess their seismic vulnerability by performing pushover analysis. The analysis is carried out using ETABS analysis package.

Description of the Sample Building

The plan layout for all the building models are shown in figures

Symmetric Building Models:

Model 1: Tenstoried Building with full infill masonry wall (230 mm thick) in all storeys and without ground soft storey.

Model 2: Ten storied Building with ground soft story and infill masonry wall(230 mm thick) in all storeys.

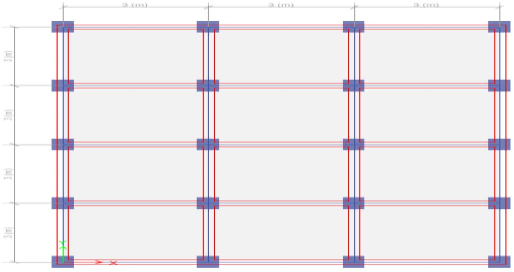

Figure:4 Plan Layout of Structures

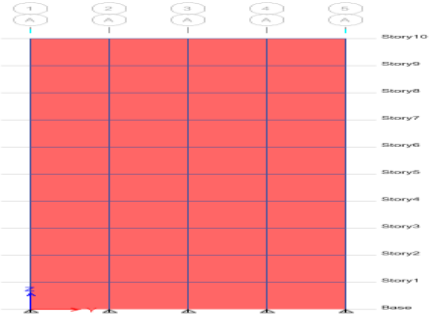

Figure 5: Elevation of building with infills and without soft storey

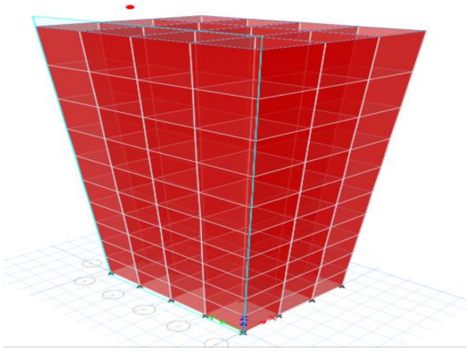

Figure 6: 3-D view of building with infills and without soft storey

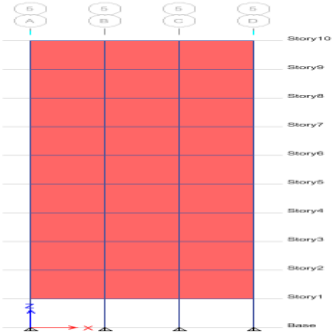

Figure 7: Elevation of building with infills and with soft storey

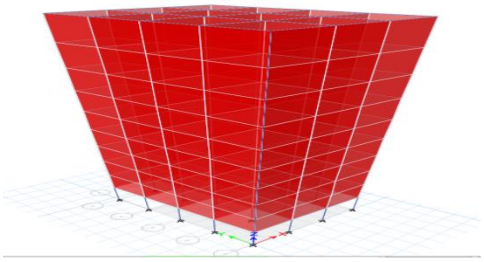

Figure 8: 3-D view of building with infills and with soft storey

Example Buildings Studied

The plan layout, elevation and 3D view of the reinforced concrete moment resisting frame building of ten storeyed building for different models is shown in Figures 4.1 to 4.5. In this study, the plan layout is deliberately kept similar for all the buildings for the study. Each storey height is kept 3 m for all the different buildings models

Design Data:

Material Properties:

Young's modulus of (M25) concrete, E = 25.000x10⁶kN/m²
Young's modulus of (M20) concrete, E = 22.360x10⁶kN/m²
Density of Reinforced Concrete = 25kN/m³
Modulus of elasticity of brick masonry = 3500x10³kN/m²
Density of brick masonry = 19.2 kN/m³
Assumed Dead load intensities
Floor finishes = 1.5kN/m²
Live load = 4 KN/ m²

Member properties

Thickness of Slab= 0.125m
Column size= (0.6mx0.45m)
Beam size= (0.3m x 0.6m)
Thickness of infill wall= 0.230m

IS: 1893-2002 Response Spectrum Method: Spectrum is applied from fig.2 of the code corresponding to medium soil sites. The spectrum is applied in the longitudinal and transverse directions.

Pushover Analysis:

ETABS is a general-purpose finite element analysis program for static and dynamic analysis of two and three-dimensional linear and nonlinear structures with a particular emphasis on dynamic loading and earthquake loading. The particular program used for this study, ETABS Nonlinear, is capable of performing pseudo-static nonlinear pushover analysis and nonlinear time-history analysis.

4.0 RESULTS AND DISCUSSIONS

Most of the past studies on different buildings and unsymmetrical buildings have adopted idealized structural systems without considering the effect of masonry infill and concrete shear walls. Although these systems are sufficient to understand the general behaviour and dynamic characteristics of unsymmetrical buildings, it would be interesting to know how real buildings will respond to earthquake forces. In this chapter, the results of the ten storeyed buildings are presented and discussed in detail. The results are including of all different building models and the response results are computed using the response spectrum and pushover analysis. The analysis and design of the different building models is performed by using ETABS analysis package.

Analysis Results of G+10 Building with Infill Walls and Soft Storey Response Spectrum method

Table 1: Storey displacements of building with infill walls and soft storey using RSM

Storey	Elevation m	Location	For EQ X		For EQ Y	
			X-Dir (mm)	Y-Dir (mm)	X-Dir (mm)	Y-Dir (mm)
Story10	30	Top	0.1	8.419E-05	4.778E-05	0.1
Story9	27	Top	0.1	2.596E-05	1.238E-05	4.954E-02
Story8	24	Top	0.1	2.801E-05	2.533E-05	4.404E-02

Story7	21	Top	0.1	6.858E-05	4.251E-05	3.852E-02
Story6	18	Top	4.902E-02	1.473E-04	7.525E-05	3.31E-02
Story5	15	Top	4.033E-02	2.678E-04	1.266E-04	2.787E-02
Story4	12	Top	3.211E-02	4.517E-04	2.102E-04	2.295E-02
Story3	9	Top	2.446E-02	6.71E-04	3.702E-04	1.844E-02
Story2	6	Top	1.749E-02	7.121E-04	4.987E-04	1.441E-02
Story1	3	Top	1.061E-02	7.877E-04	5.081E-04	1.059E-02
Base	0	Top	0	0	0	0

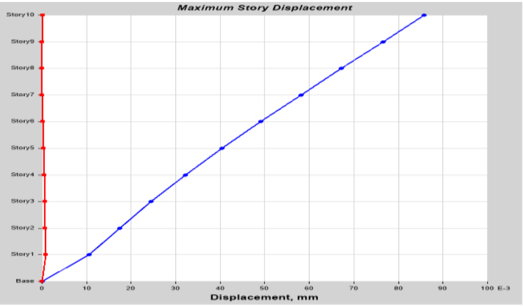

Figure 9: Storey displacements of structure with infill walls and soft storey for EQ X using RSM

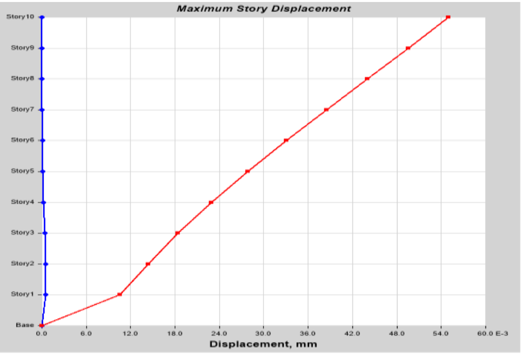

Figure 10: Storey displacements of structure with infill walls and soft storey for EQ Y using RSM

Table 2: Storey drifts of building with infill walls and soft storey using RSM

Storey	Elevation m	Location	For EQ X		For EQ Y	
			X-Dir	Y-Dir	X-Dir	Y-Dir
Story10	30	Top	0.000003	1.941E-08	1.196E-08	0.000002
Story9	27	Top	0.000003	1.382E-08	6.748E-09	0.000002
Story8	24	Top	0.000003	1.769E-08	9.462E-09	0.000002
Story7	21	Top	0.000003	2.623E-08	1.284E-08	0.000002
Story6	18	Top	0.000003	4.017E-08	1.711E-08	0.000002
Story5	15	Top	0.000003	6.131E-08	2.786E-08	0.000002
Story4	12	Top	0.000003	7.31E-08	5.333E-08	0.000002
Story3	9	Top	0.000003	4.663E-08	5.335E-08	0.000002
Story2	6	Top	0.000002	5E-07	3.356E-07	0.000002
Story1	3	Top	0.000004	2.626E-07	1.694E-07	0.000004
Base	0	Top	0	0	0	0

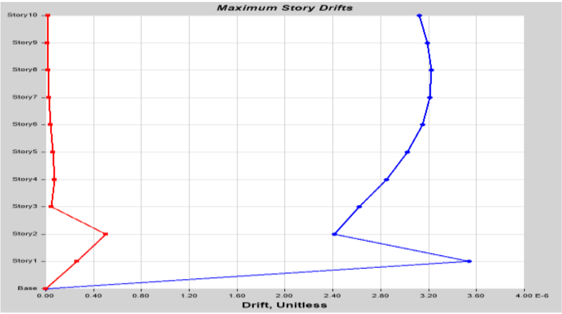

Figure 11: Storey drifts of structure with infill walls and soft storey for EQ X using RSM

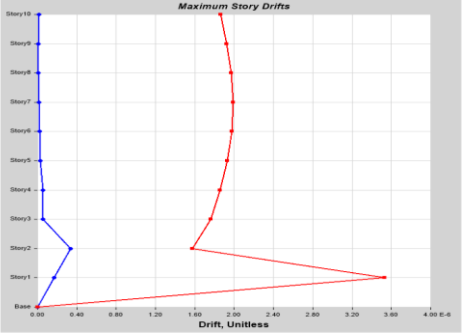

Figure 12: Storey drifts of structure with infill walls and soft storey for EQ Y using RSM

Analysis Results of G+10 Building with Infill Walls and without Soft Storey

Response Spectrum method

Table 3: Storey displacements of building with infill walls and without soft storey using RSM

Story	Elevation m	Location	For EQ X		For EQ Y	
			X-Dir (mm)	Y-Dir (mm)	X-Dir (mm)	Y-Dir (mm)
Story10	30	Top	4.414E-02	3.09E-05	1.498E-05	2.925E-02
Story9	27	Top	3.873E-02	4.346E-05	2.224E-05	2.587E-02
Story8	24	Top	3.318E-02	8.062E-05	4.494E-05	2.236E-02
Story7	21	Top	2.758E-02	1.374E-04	7.998E-05	1.876E-02
Story6	18	Top	2.207E-02	2.094E-04	1.242E-04	1.518E-02
Story5	15	Top	1.679E-02	2.935E-04	1.752E-04	1.172E-02
Story4	12	Top	1.194E-02	3.861E-04	2.319E-04	8.492E-03
Story3	9	Top	7.667E-03	4.793E-04	2.955E-04	5.608E-03
Story2	6	Top	4.168E-03	5.394E-04	3.527E-04	3.182E-03
Story1	3	Top	1.637E-03	5.098E-04	3.663E-04	1.341E-03
Base	0	Top	0	0	0	0

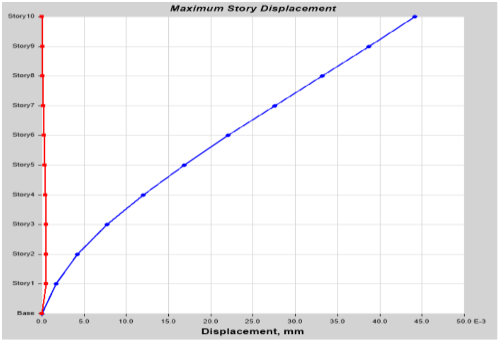

Figure 13: Storey displacements of structure with infill walls and without soft storey for EQ X using RSM

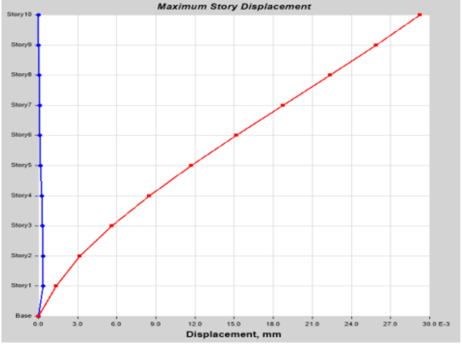

Figure 14: Storey displacements of structure with infill walls and without soft storey for EQ Y using RSM

Pushover Analysis

Table 5.17 Storey displacements of building with infill walls and without soft storey using pushover analysis

Story	Elevation m	Location	For Push X		For Push Y	
			X-Dir (mm)	Y-Dir (mm)	X-Dir (mm)	Y-Dir (mm)
Story10	30	Top	16.7	1.092E-02	6.7E-03	13
Story9	27	Top	14.8	1.273E-02	7.425E-03	11.7
Story8	24	Top	12.8	2.238E-02	1.41E-02	10.2
Story7	21	Top	10.9	3.889E-02	2.567E-02	8.8
Story6	18	Top	8.9	0.1	4.185E-02	7.3
Stor	15	Top	7	0.1	0.1	5.8

y5						
Story4	12	Top	5.2	0.1	0.1	4.4
Story3	9	Top	3.5	0.2	0.1	3.1
Story2	6	Top	2	0.2	0.2	1.9
Story1	3	Top	0.9	0.2	0.2	0.8
Base	0	Top	0	0	0	0

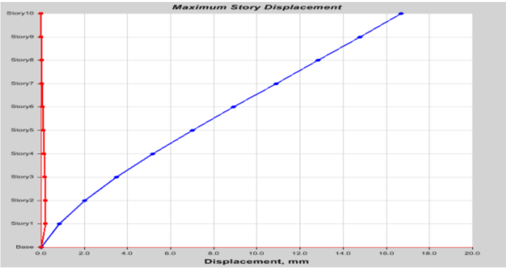

Figure 15: Storey displacements of structure with infill walls and without soft storey for Push X using pushover analysis

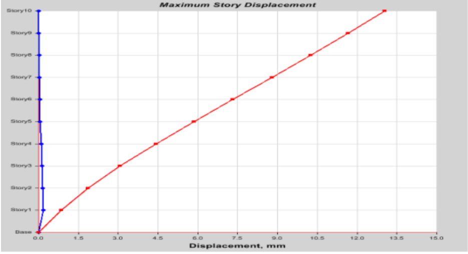

Figure 16: Storey displacements of structure with infill walls and without soft storey for Push Y using pushover analysis

DISCUSSIONS:

Response Spectrum Method:

As compared to Model 2, Model 1 has 60% less displacement than Model 2.

As compared to Model 2, Model 1 has 35% less drifts than Model 2.

As compared to Model 1, Model 2 has 0.07% less shears than Model 1.

As compared to Model 1, Model 2 has 20% less overturning moments than Model 1.

Push Over Analysis:

In Pushover Analysis different building Models have pushed to its failure and correspondingly displacement is noted.

As compared to Model 2, Model 1 has 61% of more displacement than Model 2.

As compared to Model 1, Model 2 has 80% of more drifts than Model 1.

As compared to Model 2, Model 1 has 30% of more shears than Model 2.

As compared to Model 2, Model 1 has 60% of more overturning moments than Model 2.

CONCLUSIONS

In this project finally concluded that the inelastic pushover analysis for demand prediction, since in many cases it will provide much more relevant information that an elastic static or dynamic analysis, but it would be counterproductive to advocate this method as a general solution technique for all cases. The pushover analysis is a useful, but not infallible till for assessing inelastic strength and deformation demands and for exposing design weaknesses. Its foremost advantage is that it encourages the design engineer to recognize important seismic response quantities and to use sound judgment concerning the force and deformation demands ands and capacities that control the seismic response close to failure, but it needs to be recognized that in some cases it may provide a false feeling of security if its short comings and pitfalls are not recognized. As the push was incrementally applied on a control node plastic hinge corresponding to various levels (I.O,L.S and C.P) the vulnerability of different beam and column members can be recognized. Depending on the degree of importance of a particular structure the retrofitting of the structure may be taken up. Based on the results from the linear and nonlinear static pushover analysis performed on the tens Torey building following observations are made

- Since neither national building code nor any of earthquake related codes in India illustrate the categorization of the building for structural retrofitting, no generalized retrofitting procedure may be defined. The introduction of bracings in the ground storey was done based on the proposed car parking plan and incorporated them rationally without affecting the functionality of the open ground storey.
- The bracings proved to eliminate the soft storey failure mechanism and also brought down the global response of the structure and are recommended for preventing much damage or collapse of the building in an earthquake of higher magnitude.
- It may be concluded from the pushover analysis that there is an increase in initial stiffness and strength of the infilled frame, compared to the bare frame, despite the wall's brittle failure modes. However, it fails at a relatively lower drift level than the bare frame (at around one third of the roof displacement).

- For the considered earthquake the existing building can survive collapse but may suffer little damage in the ground storey columns which show soft storey mechanism of failure.
- No retrofitting is required if design level earthquake for Zone II is considered, as the structures performance is in immediate occupancy level i.e., no structural damage is expected. Only nominal repair works may be carried out.
- The building without soft storey has more displacements, drifts, shears and moments than the building with soft storey.

SCOPE FOR FUTURE STUDY

Further studies can be conducted on high rise buildings (sky-scrapers) by providing more thickness of shear walls.

- For better ductility beam-column junction study can also be made. And further study an existing building can be considered for evaluation. Where, a preliminary investigation using FEMA-273 can be done before evaluation of the existing building using mathematical modeling with the help of FEA package and further it can be evaluated using Non-Linear Dynamic Analysis and other software's like sap & staadpro.
- This investigation can also be done on Sloping RCC buildings constructed on hills in hill stations were land is at high cost and it will also attracts the tourists. Various damping mechanisms and its applications on structures can also be studied. Studies can also be conducted by modeling the structures having base isolation system.

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