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SEISMIC RESPONSE STUDY AND PUSH OVER ANALYSIS OF MULTI-STORIED REINFORCED CONCRETE BUILDING

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ABSTRACT

In this study to perceive the capacity of the building and have a preimagination of the lateral load the structure can withstand by using Nonlinear static analysis (Pushover analysis) for sesismic response analysis of reinforced concrete building. To acquire an idea within the structure, which member will collapse first if the failure load is achieved. A newly constructed reinforced concrete G+5 residential building is analyzed and design, and is located in musheerabad, Hyderabad. A series of Equivalent static analysis and response spectrum analysis is also carried out to compare the results for stability. Finally pushover analysis has been done to find out the capacity of the building. A reinforced concrete G+5 residential building is taken and applied with dead and live loads along with earthquake forces in X and Y direction as per zone II to do equivalent static analysis. A response spectrum function of zone II is applied in X and Y direction to do the response spectrum analysis and finding out the similar results as in equistatic method. Pushover analysis results will be compared with equivalent static and response spectrum as the two values i.e., base shear and displacement. Pushover analysis is having two methods to find capacity of building is Displacement method and Capacity spectrum method. We have applied capacity spectrum method to the building as non-linear pushover in both X and Y directions. We have taken auto hinges for concrete beams and columns as for ASCE 41-13. Finally it is compared in the results i.e., displacement, base shear, hinges at what displacement and collapse displacement.

INTRODUCTION

Design of earthquake resistant RCC structure is very much important in these days. In these paper a multi-storied building designed from linear static analysis and then analyzed to resist the equivalent static loading. The response of the building is then observed by comparing the results from response spectrum and push-over analysis. Though over the recent years heavy costs have been paid for accurate recognition of force of an earthquake in the research institutes of the world with the purpose of decreasing its damage, the increasing need for more research studies on the effects resulted from the earthquake is felt in the theoretical and laboratorial scales [1]. Over the last fifty years, the earthquakes are categorized into two groups of near-field earthquakes and far-field earthquakes based on the distance of the place of recording the earthquake from the fault. Later, this definition was modified and other factors also influenced this categorization. Over the recent years, the research studies concentrated on the study of impacts of ground motion in the near-field earthquake on the structural performance. The devastative effects of the recent earthquakes such as Northridge earthquake (1994), Kobe earthquake (1995), and Taiwan earthquake (1999) on the buildings of the cities adjacent to fault, and with regard to the close location of many of the cities of India to the active faults indicate the significance of the research. In last few years, many essential developments in seismic codes are turned up. Utmost of the modification in the seismic design area derive from greater awareness of actual poor buildings performances in contemporary earthquakes. Due to the renewed knowledge of the existing buildings behaviour, retrofit of buildings is a paramount task in reducing seismic risk. New techniques for protecting buildings against earthquake have been developed with the aim of improving their capacity. Seismic isolation and energy dissipation are widely recognized as effective protection techniques for reaching the performance objectives of modern codes. However, many codes include design specifications for seismically isolated buildings, while there is still need of improved rules for energy dissipation protective systems.[2]

LITERATURE REVIEW

Andreas J. Kappos et al., (1989) From the practical application point of view, probably the most important conclusion is that an elastic frame model with full vertical and horizontal rigid offsets was found to be accurate enough to be used for the analysis of unreinforced masonry buildings. Consideration of the effect of diaphragms is relevant in 3D models only, since its action is in the plane normal to the walls, therefore in 2D models it has a negligible effect, while in 3D models its effect is crucial to the overall behavior of the structure. Finally, this study has clearly shown that methods for an effective and reasonably accurate nonlinear analysis of masonry buildings using commercially available software do exist, a conclusion that is significant for the assessment of existing unreinforced masonry URM buildings.

Andrew Whittaker et al., (1990) The objective of seismic design practice in the United States has long been the provision of life safety in a design earthquake. Recent urban earthquakes in the United States and analytical and experimental studies have brought into question the reliability of modern building construction in the United States with respect to likely performance (response) in a design earthquake.

Andrea Lucchini et al., (2009) In this paper the results of nonlinear dynamic analyses carried out on a two-way asymmetric single-story frame structure have been reported. The evolution of the maximum displacement demand in the different resisting elements of the system and of the corresponding global restoring forces has been investigated for earthquakes of increasing intensities characterized by different angles of incidence. The results obtained from the considered case study are found to be consistent with those obtained by the writers in previous investigations on one-way asymmetric-plan structures (Lucchini et al. 2009). Since the presented results have been obtained from the analysis of a single structure subjected to two ground motions only, additional work is still needed for confirming the generality of the reported conclusions. Analyses with more earthquake records considering also structural schemes, more representatives of real buildings, such as multistory systems, are already underway by the writers.

G. P. Cimellaro et al., (2013) Nonlinear static procedures are less time-consuming than nonlinear response history analysis (NRHA); therefore nowadays they are extensively used by practicing engineers for virtually every type of building. However, because the majority of real structures are irregular, pushover methods need to be improved to take into account the torsional effects of buildings and the directivity of the seismic ground motion before being implemented in design codes. In this paper, a modification of the N2 method to overcome the torsional problem in plan and elevation of asymmetric buildings subjected to bidirectional ground motion is proposed.

Ozgur Avsar et al., (2007) A detailed investigation was conducted on the two RC buildings, which were affected by the Simav earthquake, which is considered a moderate event. Although both buildings have many similar structural deficiencies, the one with symmetrically arranged structural walls survived the earthquake without any structural damage, whereas the ground story of the other building collapsed. Based on the site observations of the

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two buildings after the earthquake as well as the analytical results, structural walls were found to be one of the key structural components to improve the earthquake resistance of RC buildings with several structural deficiencies. Therefore, structural walls can be a very effective solution for developing countries in seismic regions where the construction and design inspections cannot be applied properly.

METHODOLOGY

General :

The study in this thesis is based on linear and nonlinear analysis of RC structures with different areas of building and variable cross section of column. This chapter presents a summary of various parameters defining the computational models, the basic assumptions and the RCC frames geometry considered for this is study. Accurate modelling of the nonlinear properties of various structural elements is very important in nonlinear analysis. In the present study column are modelled with inelastic flexural deformations using nonlinear Hinges or auto Hinges The pushover analysis is a method to observe the successive damage states of a building. The method is relatively simple to be implemented, and provides information on strength, deformation and ductility of the structure and distribution of demands which help in identifying the critical members likely to reach limit states during the earthquake and hence proper attention can be given while designing and detailing. This method assumes a set of incremental lateral load over the height of the structure. Local nonlinear effects are modelled and the structure is pushed until a collapse mechanism is developed. With the increase in the magnitude of loads, weak links and failure modes of the buildings are found. At each step, the base shear and the roof displacement can be plotted to generate the pushover curve .This method is relatively simple and provides information on the strength, deformation and ductility of the structure and distribution of demands. This permits to identify the critical members likely to reach limit states during the earthquake by the formation of plastic hinges. On the building frame load/displacement is applied incrementally, the formation of plastic hinges, stiffness degradation, and lateral inelastic force versus displacement response for the structure is analytically computed. Here we consider real structure for applying Pushover analysis. Pushover load case is used to apply gravity load and then lateral pushover load cases are specified to start from the final conditions of the gravity pushover. The present study is to evaluate the behavior of G+5 reinforced concrete frame structure subjected to earthquake forces in zone II. The reinforced concrete structures are analyzed by nonlinear static analysis (Pushover Analysis) using ETABS software. It shows the performance levels, behavior of the components and failure mechanism in a building. It also shows the types of hinge formation, the strength and capacity of the weakest components.

Geometry

The RCC structure is consist of columns, beams and slab as shown in figure 3.2. The overall dimensions of the structure is 21.13 m x 18.93 m. Column dimensions C1 and C2 for G+5 are 230mm x 600mm & 300mm x 600mm, beam dimensions B1 and B2 are 230mm x 450mm & 230 x 600mm and slab thickness is 127mm

Plan of the model

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Material

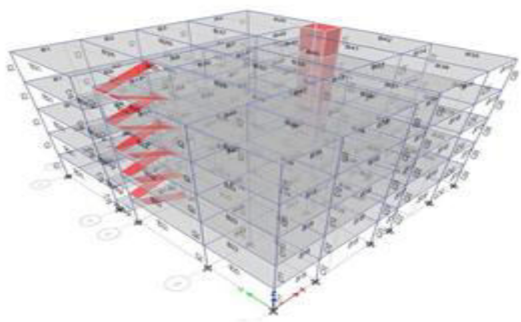
The building considered here is commercial building having G + 5 storied located in seismic zone II and for earthquake loading, the provisions of the IS: 1893(Part1)2002 is considered. The plan of building is shown in fig. the building is planned to facilitate the basic requirements of residential building. The plan dimension of the building is 21.13 x 18.93 m. Height of each storey is 3m. The study is carried out on the newly constructed building plan with same material properties. The basic loading on the structure are kept same, other relevant data is tabulated in table 3.1.

Table 3.1: Section properties

Section properties	21.13m x18.93m
Beam dimensions B1 and B2	230mm x 450mm and 230 x 600mm
Column dimensions C1 and C2	230mmx600mm and 300mmx600mm
Thickness of slab	127mm
Grade of concrete	M25
Grade of reinforcement	Fe415
Live load	2kN/m^2
Wall load	10.925kN/m^2
Floor finishes	2.25 kN/m^2
Seismic zone	II
Importance factor	1
Zone factor	0.10
Density of concrete	25 kN/m^3

Design based on IS456

In this structure dead load, live load are applied. The plan of building is shown in fig. the building is planned to facilitate the basic requirements of residential building. The plan dimension of the building is 21.13 x 18.93 m. Height of each storey is 3m. After the design of building, static nonlinear analysis is performed to determine the pushover curve and performance point. In these we had took live load as 2 kN/m2, wall load as 10.925 kN/m2 and floor finishes as 1.5 kN/m2. Define the pushover load cases. Pushover load case is used to apply gravity load and then lateral pushover load cases are specified to start from the final conditions of the gravity pushover as shown in below figure 3.3.



Plan of the building model in 3D

ANALYSIS OF STRUCTURE

General

Linear static analysis represents the most basic type of analysis. The term “linear” means that the computed response displacement or stress, for example is linearly related to the applied force. The term “static” means that the forces do not vary with time or, that the time variation is insignificant and can therefore be safely ignored. An example of a static force is a building's dead load, which is comprised of the building's weight plus the weight of offices, equipment, and furniture. This dead load is often expressed in terms of lb/ft^2 or N/m^2. Such loads are often defined using a maximum expected load with some factor of safety applied for conservatism.

Shear Force

Shear force is the internal resistance developed at any section to maintain free body equilibrium of either left or right part of the section. It may be horizontal or vertical. Shear force at any section is algebraic sum of all transverse forces either from left or right of that section. Shear force of the building is obtained after doing analyses of gravity loads in ETABS and digrametical representation of shear force is shown in

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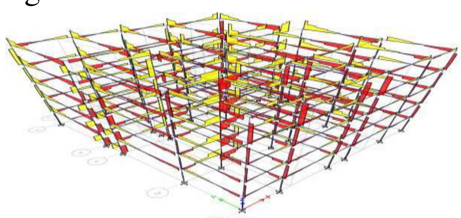
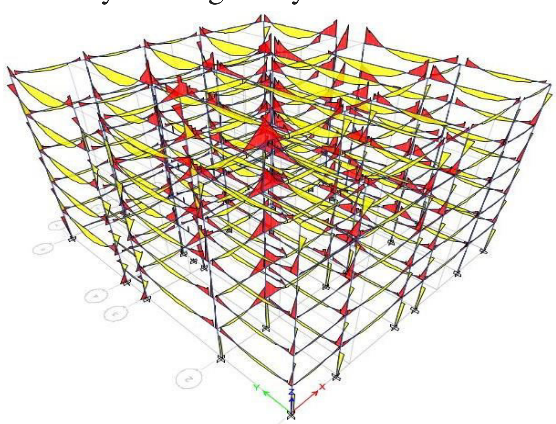
the below figure 4.1



Shear force diagram

Bending Moment

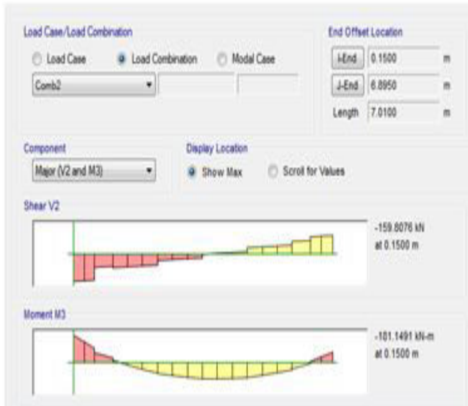
Bending moment at any section is the internal reaction due to all the transverse force either from left side or from right side of that section. It is equal to algebraic sum of moments at that section either from left or from right side of that section. Bending moment is different from twisting moment. The forces and moments on either side of the section must be equal in order to counteract each other and maintain a state of equilibrium so the same bending moment will result from summing the moments, regardless of which side of the section is selected. The simplest type of beam is the cantilever, which is fixed at one end and is free at the other end neither simple or fixed. In reality, beam supports are usually neither absolutely fixed nor absolutely rotating freely.



Bending moment diagram

BMD and SFD of single beam from Equivalent static analysis

The maximum values of bending moment and shear force due to the combination (1.5 D.L.+1.5 L.L.), is taken for a beam and shown in the below figure 4.3.



Bending moment and Shear force diagram of single beam

Design check for the structure

In this we discussed shear force, bending moment and axial force. After these applying forces will go for design check. Will make it run analysis and will go for it and it is seismically safe.The results obtained from the analysis are compared in terms of seismic responses such as base shear, time period, displacement, spectral acceleration and spectral displacement along with the location of plastic hinges at the performance point of all the building structures considered respectively. Pushover analysis showed actual nonlinear behavior of the structure which helps in performance based seismic design of structure. The results obtained from the analysis are compared in terms of seismic responses such as base shear, time period, displacement, spectral acceleration and spectral displacement along with the

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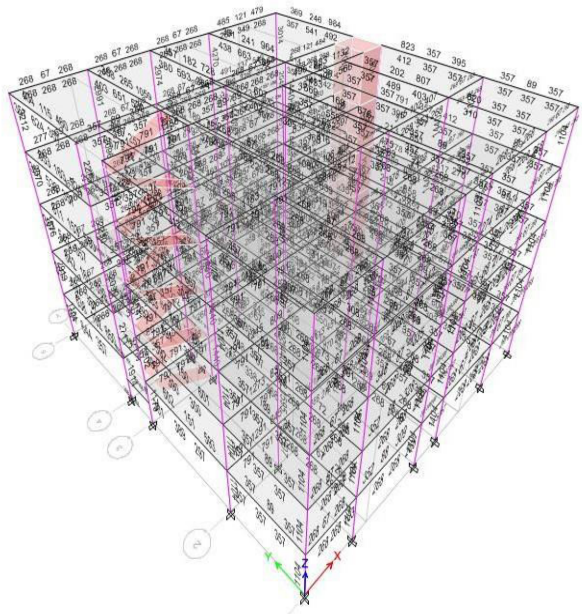
location of plastic hinges at the performance point of all the building structures considered respectively as shown in figure 4.6.



Design check for multi-storied building

RESULTS AND DISCUSSION

In this chapter the analysis carried out on the 2D and 3D structures. Finally the results obtained from the analysis are taken into consideration based on the aim of the research. After getting the results these are compared to draw the final conclusion from it. As it is discussed in the previous chapters that the response spectrum analysis and push over analysis has been carried out, from that the effectiveness of the results on these models is obtained in this chapter. Dynamic analysis may be performed either by the pushover Method or by the Response Spectrum Method.However, in either method, the design base shear (VB) shall be compared with a base shear (VB).

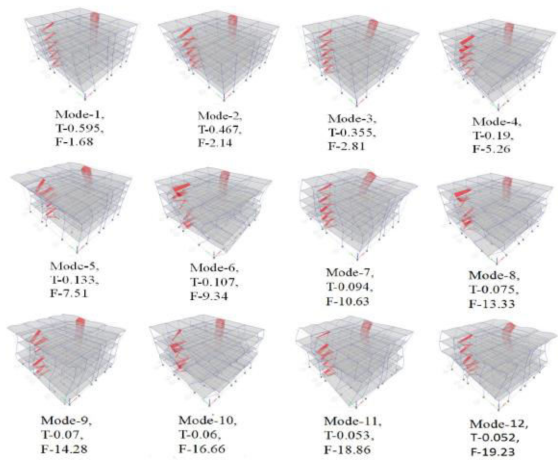
Modal analysis

A modal analysis calculates the frequency modes or natural frequencies of a given system, but not necessarily its full-time history response to a given input. The natural frequency of a system is dependent only on the stiffness of the structure and the mass which participates with the structure (including self-weight). It is not dependent on the load function. It is useful to know the modal frequencies of a structure as it allows you to ensure that the frequency of any applied periodic loading will not coincide with a modal frequency and hence cause resonance, which leads to large oscillations as shown in below
The method is:

1. Find the natural modes (the shape adopted by a structure) and natural frequencies

2. Calculate the response of each mode

3. Optionally superpose the response of each mode to find the full modal response to a given loading .



Mode shapes of Symmetry

Time Period

In any structure the stresses are basically calculated from the net

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displacement of each and every node in various directions. Once we calculated the displacements The building will oscillate back-and-forth horizontally and after some time come back to the original position, these oscillations are periodic. The time taken in seconds for each complete cycle of oscillation (i.e. one complete back-and-forth motion) is the same and is called Fundamental Natural Period T of the building. The below table shows the results of the RC buildingl in different position.in this table the values of the mode shapes are shown. The time period and frequency values are discussed below. Time period and frequency results

Mode Shape No	Time period (sec)	frequency(sec)
1	0.595	1.68
2	0.467	2.14
3	0.355	2.81
4	0.19	5.26
5	0.133	7.51
6	0.107	9.34
7	0.094	10.63
8	0.075	13.33
9	0.07	14.28
10	0.06	16.66
11	0.053	18.86
12	0.052	19.23

This table shows the time period and frequency of the building without shear wall in different positions.maximum time period is 0.595sec and minimum is 0.052sec. where as the maximum frequency is 1.68sec and minimum is 19.23sec. The time period of the structures decreases from mode shape1 to mode shape12.where as the frequency increases for mode shape1 to mode shape12 and it shows time period is inversly proportional to frequency.

Equivalent static analysis

The natural period of the building is calculated by the expression t given in IS 1893:2002 where h is the height and d is the base dimension of the building in the considered direction of vibration.The lateral load calculation and its distribution around the height are done as per IS 1893-2002 the seismic weight is calculated using full dead load + 25% of live load as shown

Base shear due to earthquake loading in X and Y direction

Base shear	Earthquake
X-Direction	787.6247
Y-Direction	496.0738

Story displacement due to EQ X

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	Mm
Story5	15	Top	6.087	1.74
Story4	12	Top	5.002	1.336
Story3	9	Top	3.663	0.908
Story2	6	Top	2.212	0.504
Story1	3	Top	0.847	0.22
Base	0	Top	0	0

Story displacement due to EQ Y

This shows story displacementplot obtained from equivalent static results at specified story due to EQ Y loading as given in table 5.4. The maximum value of displacement is obtained at story 5 in the Y direction as shown in figure.

Story displacement from EQ Y in X and Y direction

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Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	Mm
Story5	15	Top	1.076	6.309
Story4	12	Top	1.146	5.442
Story3	9	Top	1.028	4.167
Story2	6	Top	0.743	2.653
Story1	3	Top	0.355	1.077
Base	0	Top	0	0

Response spectrum analysis

An important aspect of earthquake loads exerted on extended structures, or structures founded on several foundations, is the spatial variability of the seismic motion. Hence, a rigorous earthquake resistant design of lifeline structures should account for the spatial character of the seismic input, at least in an approximate way. Therefore, a procedure for the modification of the design response spectrum is proposed in this paper, which enables addressing the problem of multiply supported structures subjected to imperfectly correlated seismic excitations. For response spectrum analysis G+5 building is considered and located in seismic zone II. For earthquake loading, the provisions of the IS:1893(Part1)2002 is considered. The zone factor value is 0.10 and soil type is medium soil. Response spectrum analysis done in both the directions i.e., x and y. From response spectrum analysis base shear results are taken in table

Base shear due to response spectrum in X and Y direction

Base shear	Response Spectrum
X-Direction	669.4319
Y-Direction	421.628

Pushover analysis

The use of the nonlinear static analysis pushover analysis came into practice in 1970's but the potential of pushover analysis has been recognised for last 10 to 15 years. This procedure is mainly used to estimate the strength and drift capacity of existing structure and the seismic demand for this structure subjected to selected earthquake this procedure can be used for checking the adequacy of new structural design as well pushover analysis is defined as an analysis wearing a mathematical model directly incorporating the normal load deformation characteristics of individual components and elements of the building shall be subjected to monotonically interesting lateral loads representing inertia forces in an earthquake until a target displacement is excised accident exceeded target displacement is the maximum displacement elastic plus in asterisk inelastic of the building address expected under selected earthquake ground motion pushover analysis assesses the structural performance by estimating the force and deformation capacity and seismic demand using a nonlinear static analysis algorithm the seas meet demand parameters are global displacement at roof or any other reference point story dressed story forces component deformation and component forces the analysis accounts for geometrical nonlinearity, material inelasticity and the redistribution of

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internal forces.

. This makes the analysis procedure iterative. Difficulty in the solution is faced near the ultimate load as the stiffness Matrix at this point becomes negative definite due to instability of the structure becoming a mechanism. In these the base shear from pushover analysis in X and Y direction as shown in figure.

Base shear due to pushover analysis in X and Y direction

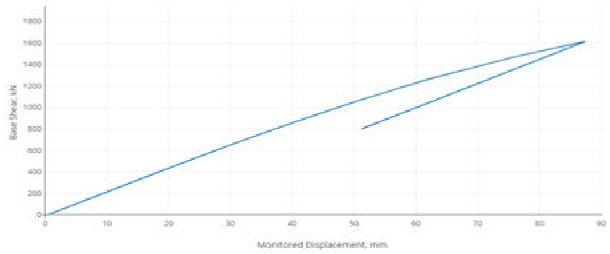
Base shear	Pushover
X-Direction	1553.76
Y-Direction	1330.56

Pushover curve in 3D formation

The capacity curve of a structure can be obtained from the pushover analysis, which is carried out based on the first mode response of the structure assuming that the fundamental mode of vibration is the predominant response of the structure as shown in table 5.21. Pushover capacity curve exhibits the behaviour of structure beyond the elastic limit under seismic loads. This analysis has been established to evaluate the response of structures by applying a predefined pattern of earthquake loads incrementally. For this purpose, the non-linear force-deformation relations of the structural components (material non-linearity) and P- Δ effects (geometric non- linearity) should be considered. At first, the structure is subjected to gravity loads which consists of dead and live loads. Then, Horizontal forces, representing the inertia forces, are applied to the structure (pushover analysis). The lateral loads monotonically increase by control displacement of node until a plastic collapse mechanism is reached as shown in below figure.

Pushover curve in 3D frame at each stage

Step	Monitored Displ	Base Force	A-IO	IO-LS	LS-CP	>CP	Total Hinges
	Mm	kN					
0	-0.425	0	694	0	0	0	694
1	-9.408	200	694	0	0	0	694
2	-10.234	218.3844	694	0	0	0	694
3	-19.755	429.2683	694	0	0	0	694
4	-29.521	640.9398	694	0	0	0	694
5	-40.108	859.1511	693	0	0	1	694
6	-50.514	1060.4915	692	1	0	1	694
7	-62.233	1267.1731	687	6	0	1	694
8	-76.039	1472.7183	679	13	1	1	694
9	-87.423	1615.5743	669	18	3	4	694
10	-51.231	800.1596	668	19	3	4	694



Pushover curve in 3D frame at each stage

Pushover curve in 3D frame at each stage

Discussion

In these the results are compared to draw out some of the conclusions. The base shear, story displacements and story drifts are compared from analyses i.e., equivalent, response spectrum and pushover analysis.

Base shear comparison from Equivalent, response spectrum and pushover analysis

- From equivalent static analysis there is a decrease of 63% in base shear in Y

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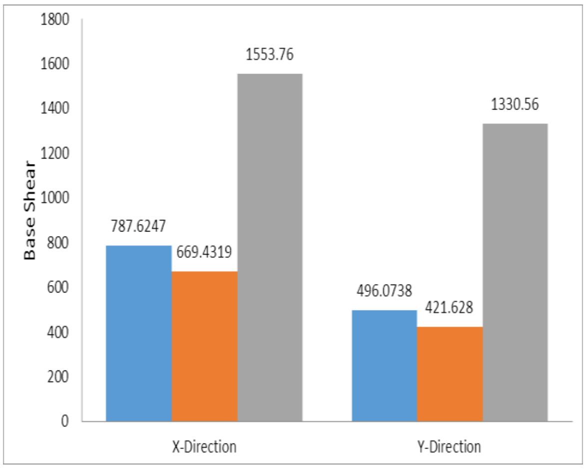
direction.

- From response spectrum analysis there is a decrease of 62% in base shear in Y direction when compared with X direction.
- Then similarly when we check for push X and push Y there is a 86% of variation.



Base shear from equivalent, response spectrum and pushover analysis

Summary:

This chapter dealt with the procedure of analysis within the Etabs 2016 software and obtaining certain results from the analysis. The RC structure have been analysed and comparative results have been developed using response spectrum and pushover analysis. The frame was subjected to design earthquake forces as specified in the IS code for zone II along longer directions. Bare frame pushover curves for the building in X and Y directions as shown.The performance point is obtained at a base shear level of 1553.76 Kn in X direction and 1330.56 kN in Y direction.Using these results in next chapter conclusion on research is obtained by subsequent discussion.

Conclusion

- From above analysis it is observed that at 86% of the base shear in Y direction of the building due to push y the hinges exceeds the collapse prevention level.
- From the hinge results of push-over analysis it is found that hinges in the X direction are in between IO and CP level, whereas in Y direction it exceeds CP.
- From the displacement results there is very high deflection is observed in both the directions which is under the allowable limit H/50.
- From story drifts it is found that the values within the limit in X and Y direction(0.04 is the allowable limit).
- From push-over analysis it is observed that the building capacity is 30907.64 N-m.

Future Scope

As the performance based pushover analysis is very useful method to design the structure at required performance level, it can be applied in different structures.

- This work can be extended by the addition of bracking effect on the structure under both pushover analysis and time history analysis.
- Irregular buildings, unsymmetrical buildings and Tall structures can be an extension to this work.
- Its use in Steel structures can bring much effective solutions.

- Non-linear static analysis can be carried out of various types of RCC structures.

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