PERFORMANCE EVALUATION OF AN EXISTING RC BUILDING USING SAP

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Abstract:
Earthquakes are very common in every part of the wo rld. Geographical statics of India show that almost 54% of the land is vulnerable to earthquakes. Due to these earthquakes large destruction is caused to the infrastructure and the buildings. The buildings, which appeared to be strong enough, may cru mble like houses of cards during earthquake and deficiencies may be exposed. Experience gained fro m the recent earthquake of Indonesia, 2013 demonstrates that the most of build ings collapsed were found deficient to meet out the requirements of the present day codes. It has raised the questions about the adequacy of framed structures to resist strong motions, since many buildings suffered great damage or co llapsed. Pushover analysis is a method to evaluate the performance o f a building under earthquakes. In the proposed study a four-story residential existing rein forced concrete building in the city of Port Blair, Andaman and Nicobar Islands, subjected to seismic hazard, was analyzed. Plastic hinge is used to represent the failure mode in the beams and colu mns when the member y ields. The pushover analysis was performed on the building using SAP2000 ver.14 software both in X and Y d irection. The equivalent lateral force (ELF) procedure is used to compute design forces and distributed over the height of the structure. The main object ive of the study reported in this paper is to check the performance level of the reinforced concrete structures during the seismic events.

Keywords: Pushover analysis, Reinforced concrete structures, Seismic performance, Unsymmetrical structures, soft storey .

1. INTRODUCTION

1.1 General

A large number of existing build ings in India are severely deficient against earthquake forces and the number of such buildings is growing very rap idly. Th is has been highlighted in the history of earthquake. So it has become very important to assess the performance level of an existing building under seismic loads and if it’s not safe further retrofit of the existing build ing to meet up the recent performance levels. The behaviour of the buildings during earthquake depends not only on the size of the members and amount of reinforcement, but to a great extent on the placing and detailing of the reinforcement. There are three sources of deficiencies in a building, which have to be accounted for by the retrofitting engineer:

(i) Inadequate design and detailing

(ii) Degradation of material with time and use

(iii) Damage due to earthquake or other catastrophe

The purpose of pushover analysis is to evaluate the expected performance of structural systems by estimat ing its strength and deformat ion demands in design earthquakes means of static inelastic analysis, and co mparing these demands to available capacities at the performance levels of interest. The equivalent static lateral loads approximately represent earthquake induced forces. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The paper deals with non -linear analysis of unsymmetrical structures constructed on plain ground subjected to various kinds of loads. The analysis has been carried out using SAP2000 ver. 14 software . A Pushover Analysis has been carried out of a 4 Storey's Reinforced Concrete Build ing aiming to evaluate the zone-V selected.

reinforced concrete building to conduct non -linear static analysis (pushover analysis) using SAP 2000.The study showed that hinges have developed in the beams and columns showing the three stages immediate occupancy, life safety and collapse prevention. Utilizing the results from the analysis, some modifications were made to the original code-based design so that the design objective of Life Safety performance is expected to be ach ieved under design earthqua.

1.2 Seismic Design

RC frame building would beco me massive if they were to be designed to behave elastically without incurring damage, and hence the project may become economically unviable . On the contrary, the building must undergo damage necessarily to be able to dissipate the energy input to it during the earthquake. Thus, as per the seis mic design philosophy, (a) under occasional strong shaking, structural damage is acceptable. Therefore, structures are designed to damage, but collapse is not, and (b) under semi occasional moderate shaking, structural damage is limited oven though non - structural damage is not acceptable

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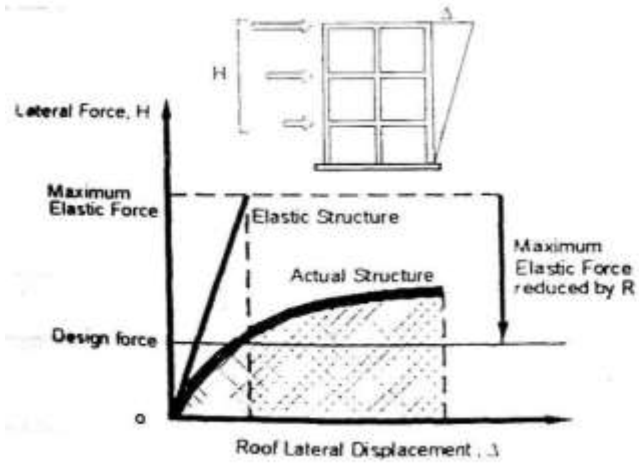

Fig. 1.1 Basic Strategy of Earthquake Design

. Therefore, structures are designed only for a fraction of the force that they would experience if they were designed to remain elastic during the expected strong ground shaking and thereby permitting damage under minor shaking refer Thus, seismic design balances reduced cost and acceptable damage, thereby making the project viab le.

1.2 Seismic Retrofitting

All buildings those are constructed, before the modern regulations came up for the design of buildings in seismic areas, those which are constructed before thirty years or those constructed recently but not properly designed, constructed or maintained can be considered as possible sources for retrofitting.

2. PUSHOVER ANALYSIS

Pushover Analysis is the simp lest among the different nonlinear analysis procedures. Pushover analysis is a static nonlinear procedure in which the magnitude of lateral load is incrementally increased, maintain ing a predefined distribution pattern along the height of the building. Weak lin ks and failure modes of the build ing are found with the increase in the magnitude of the load. Ult imate load, maximu m inelastic deflection and related behaviour of the building can be determined fro m the pushover analysis. The structure is pushed until a collapse mechanis m is developed. Pushover curve is generated by plotting the base shear vs roof displacement for each step of load increment (Fig -2.1). The maximu m base shear capacity and maximu m roof displacement of the structure is determined fro m the pushover analysis. Approximate value of the global stiffness of the build ing can also be determined. The nonlinear behaviour occurs in discrete user-defined locations identified as hinges. Currently, h inges can be introduced into frame objects only and assigned at any location along the frame object. Uncoupled mo ment, torsion, axia l force and shear hinges are availab le. There is also a coupled P-M 2-M 3 h inge that yields based on the interaction of axial fo rce and bending mo ments at the hinge location. More than one type of hinge can exist at the same location; for examp le, both an M3 (mo ment) and a V2 (shear) hinge may be assigned to the same end of a frame object. Pushover analysis is used to evaluate the real strength of the structure and it pro mises to be a useful and effective tool for performance based seismic design.

Base shear versus displacement at a specified control joint can be plotted in the ADRS fo rmat where the vertical axis is spectral acceleration and the horizontal axis is spectral displacement. The demand spectra can be superimposed on that plot and the performance point is evaluated. The sequence of hinge formation and the colour -coded state of each hinge can be viewed graphically, on a step -by-step basis, for each step of the pushover.

The following general sequence of steps is involved in a nonlinear static pushover analysis. The three dimensional reinforced concrete frame model is created. Static load patterns are defined for pushover analysis. Pushover load cases are defined for the model reinforced concrete frame. Suitable hinge properties are assigned to frame elements of the model reinforced concrete frame. Static nonlinear load case is selected to run the pushover analysis. Pushover results are rev iewed. Pushover analysis provides a good idea of how various retrofit strategies will impact the buildin g's response to seismic demands.

Two key elements of a performance-based design procedure are demand and capacity. Demand is a representation 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 how the capacity is able to handle the demand.

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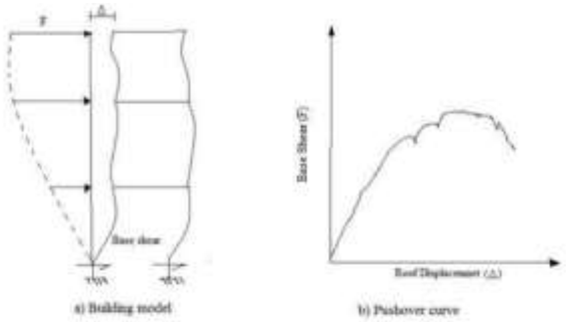

Fig-2.1 Pushover analysis

A performance check is done after the capacity curve and demand curve are defined and verified that structural components are not damaged beyond the acceptable limits of the performance objective for the forces and displacements implied by the displacement demand. The ‘performance point’ is the point where the capacity curve crosses the demand curves (Fig. 2.2). If the performance point exists and the damage state at this point is acceptable, the structure satisfies the target performance level.

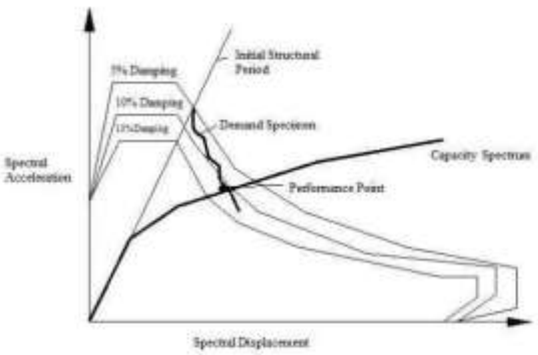

Fig- 2.2 Demand and Capacity S pectra in ADRS format 2.1 Advantages of Pushover Analysis

- It allo ws us to evaluate overall structural behavior and performance characteristics.
- It enables us to investigate the sequential formation of plastic hinges in the individual structural elements constituting the entire structure.
- When a structure is to be strengthened through a rehabilitation process, it allows us to selectively reinforce only the required members maximizing the cost efficiency.
- The pushover analysis provides good estimate of global and local inelastic deformation demands for structures that vibrate primarily in the fundamental mode.

2.2 Limitations of Pushover Analysis

- Deformat ion estimates obtained fro m a pushover analysis may be grossly inaccurate for structures where higher mode effects are significant.
- In most cases it will be necessary to perform the analysis with displacement rather than force control, since the target displacement may be associated with very small positive or even a negative lateral stiffness because of the development of mechanis ms and P-delta effects.
- Pushover analysis imp licitly gives assurance that damage is a function only of the lateral deformation of the structure, neglecting duration effects, number of stress reversals and cumulative energy dissipation demand.
- The procedure does not take into account the progressive changes in modal propert ies that take place in a structure as it experiences cyclic non -linear yielding during earthquake.

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- Most critical is the concern that the pushover analysis may detect only the first local mechanism that will form in an earthquake mechanism that will form in an earthquake and may not expose other weakness that will be generated when the structures dynamic characteristics change after format ion of first local mechanis m.

3. MODELLING AND ANALYS IS OF BUILDING 3.1 Introduction to SAP 2000

The software used for the present study is SAP 2000. It is product of Co mputers and Structures, Berkeley, USA. SAP 2000 is used for analyzing general structures including bridges, stadiums, towers, industrial p lants, offshore structures, buildings, dam, silos, etc. It is a fully integrated program that allows model creat ion, modification, execution of analysis, design optimization, and results review fro m within a single interface. SAP 2000 is a standalone finite element based structural program analysis and design of civil structures. It offers an intuitive, yet powerful user interface with many tools to aid in quick and accurate construction of models, along with sophisticated techniques needed to do most comp lex projects.

SAP 2000 is object based, mean ing that the models are created with members that represent physical reality. Results for analysis and design are reported for the overall ob ject, providing informat ion that is both easier to interprets and consistent with physical nature.

The SAP 2000 structural analysis programme offers following features -

- Static and Dynamic Analysis
- Linear and Nonlinear Analysis
- Dynamic seis mic analysis and Static push over analysis
- Geo metric Nonlinearity including P- effect
- Frame and shell structural elements
- 2-D and 3-D plane and solid elements

3.2 Modelling and Analysis of Building

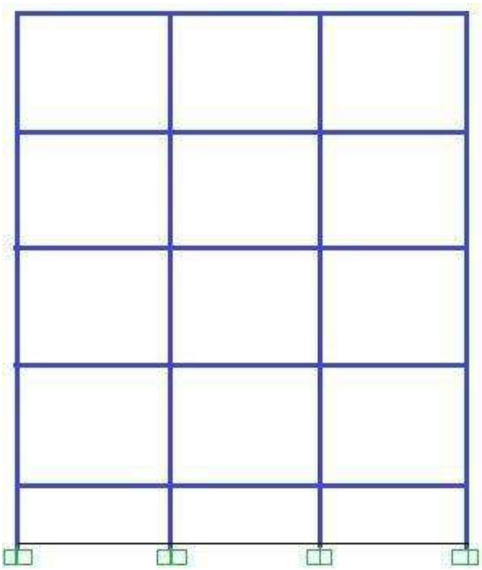

Fig 3.1 Elevation of building

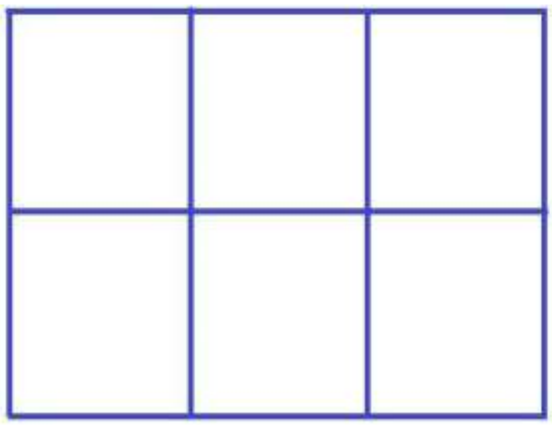

Fig 3.2 Plan of building

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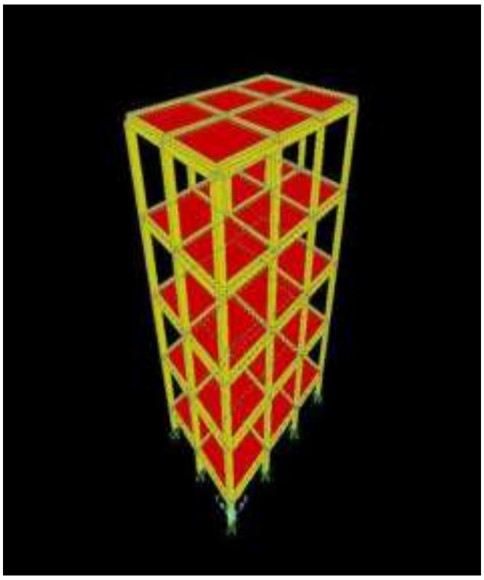

Fig 3.3 3D Model of building

Building description

i)	Zone	V
ii)	Zone factor	0.36
iii)	Response reduction factor	3
iv)	Important factor	1
v)	Soil condition	Medium
vi)	Height of building	14 m
vii)	Wall thickness	230 mm
viii)	Weight density of Brick masonry	20 kN/m^3
ix)	Weight density of RC material	25 kN/m^3
x)	Thickness of slab	150 mm
xi)	Floor to floor height	3.5 m
xii)	Size of columns	230 mm x 450 mm
xiii)	Size of beams	230 mm x 400 mm
xiv)	Size of brace	50 X 50 X 6 mm
xv)	Grade of steel	Fe-415
xvi)	Grade of concrete	M20
xvii)	Floor finish	1.0 kN/m^2
xviii)	Imposed load	3.0 kN/m^2

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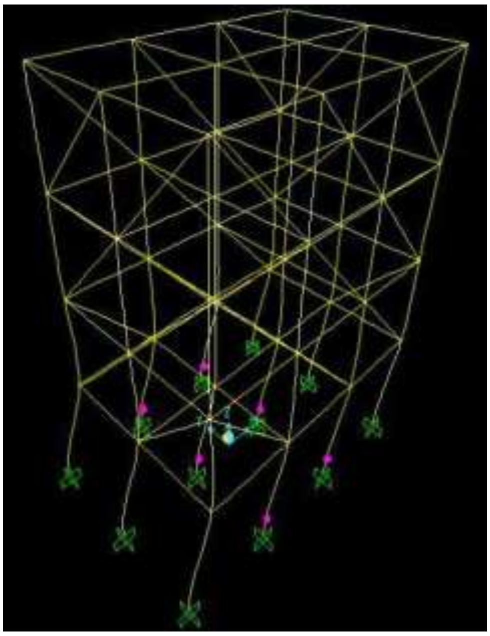

Fig. 3.4 Hinge pattern for the model in x-direction

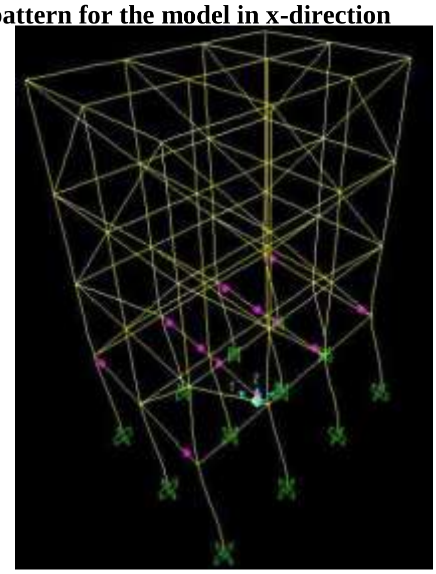

Fig.3.5 Hinge pattern for the model in y-direction

Fig. 3.4 and fig. 3.5 shows the hinge patterns for the models in both x and y direction. After the analysis of the model in x-direction, the hinges were observed on the columns of the open ground storey which shows that the structure performs poorly under seismic excitation and the model analysed in y - direction, the hinges were observed on beams which also shows that the structure performs poorly under seismic excitation.

4. RESULTS AND DISCUSSIONS

In the present study, non-linear response of existing RC frame building using SAP 2000 under the loading has been carried out. The ob jective of this study is to check the performance level of the structure in both x and y direct ion under seismic excitation.

After running the analysis, the pushover curve is obtained as shown in figures 4.1 to 4.4.

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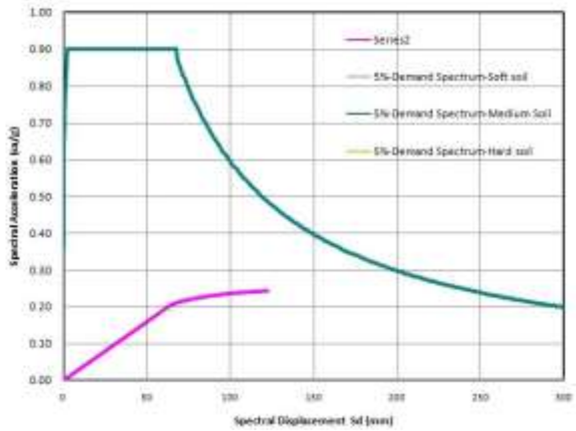

Fig. 4.1 Demand and capacity s pectra for the model without bracings in x- direction

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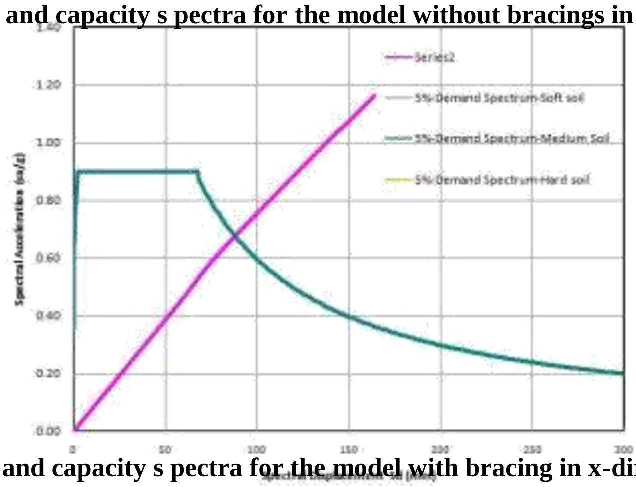
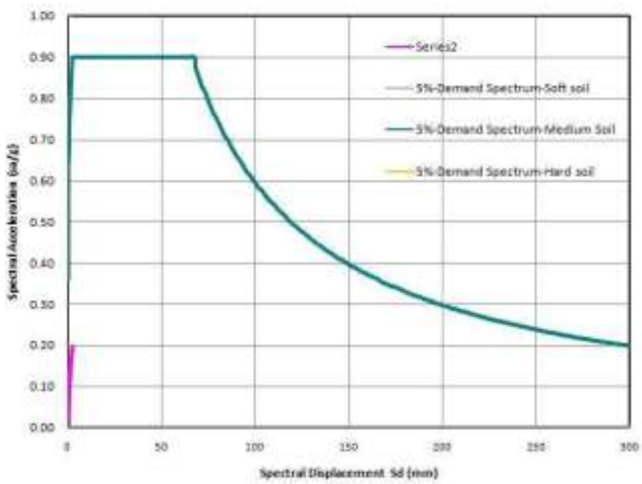


Fig 4.2 Demand and capacity s pectra for the model with bracing in x-direction



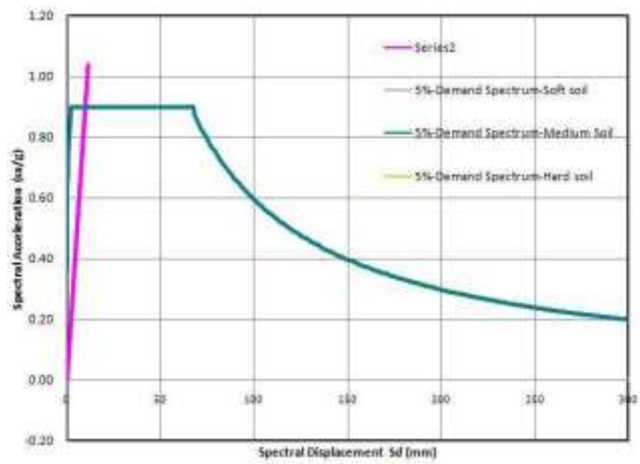


Fig. 4.3 Demand and capacity s pectra for the model without bracings in y- direction

Fig 4.4 Demand and capacity s pectra for the model with bracing in y-direction

Table 4.1 Frequencies of the structure Frequency (Hz)

Model Name	X-direction	Y-direction
M od el with b ra cin gs	1.19 3	1.25
M od el with ou t		
bracin gs	0.71 4	0.40

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Figures 4.1 to 4.4 gives the demand and capacity spectrum for models in both x and y d irection considered in this study. Fro m the above figures it can be observed that, due to the provision of bracings in the open ground storey, the performance of the structure has improved. The frequency of the models analysed in this study is given in the table 4.1. The provision of the bracings increases the frequency of the model due to increase in stiffness as shown in the table 4.1.

5. CONCLUS ION

The performance of rein forced concrete building was investigated using the Push Over Analysis from wh ich the following conclusions can be drawn:

The main output of a pushover analysis is in terms of response demand versus capacity. If the demand curve intersects the capacity envelope near the elastic range, then the structure has a good resistance. If the demand curve intersects the capacity curve with little reserve of strength and deformat ion capacity, then it can be concluded that the structure will behave poorly during the imposed seismic excitation and need to be ret rofitted to avoid future major damage or co llapse.
In this study, after the pushover analysis the hinges were found on column which shows the structure is seismically unsafe. The provision of bracings in the ground storey increases the stiffness of the structure and reduces the displacement is proved in the pushover analysis. The performance of the infilled reinforced concrete frame has enhanced due to the provision of bracings in the open g round storey.

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