Study of seismic performance and retrofitting engineering essay

Engineering

SHAIK KABEER AHMEDAssistant Professor, Department of Civil EngineeringNMAM Institute of Technology, Nitte, INDIAEmail: Kabeer092@gmail. comAbstract—In current scenario very little knowledge about seismic evaluation of structures are available in the way of guidelines for use in the existing concrete buildings. An improved Pushover analysis using ETABS based on structural dynamic theory, ATC-40 and FEMA273 is developed and an attempt has been made to study the seismic performance of existing RC structure subjected to earthquakes forces. For this purpose, behavior of 8 storey 3-D R. C structure is studied under various seismic zones as per IS-1893: 2002 and ATC-40. Pushover analysis is carried out and performance level of the structure under continuous lateral earthquake forces is studied. The adequacies of design are checked and if the building is below expected performance level, retrofits at proper positions are suggested. Keywords-Seismic Performance, Retrofit, Pushover, Non-linear Seismic Hinges, Storey Drift, Storey Shear.

Introduction

Earthquake is a manifestation of rapid release of stress waves during a brittle rupture of rock. The complexity of earthquake ground motion is primarily due to factors such as source effect, path effect and local site effect. The intensity of the quake is measured in terms of the energy release at the location of the ground fault. Earthquake causes ground to vibrate and structures supported on ground are subjected to this motion. Thus the dynamic loading on the structure during an earthquake is not external loading, but due to motion of support. The various factors contributing to the structural damage during earthquake are vertical irregularities, irregularity in

strength and stiffness, mass irregularity, shape irregularity etc. which needs to be analyzed if required and retrofitted accordingly. The purposes in earthquake-resistant design are: (a) to prevent non-structural damage during minor earthquakes, which may occur frequently in life time, (b) to prevent structural damage and minimize non-structural damage during moderate earthquakes which may occur occasionally, (c) to prevent sudden collapsing or serious damage during major earthquakes which may occur rarely. Designs are explicitly done only under the third condition.

Statement of Problem

The seismic performance of newly constructed structure at NMAM Institute of Technology, Nitte (which comes under zone III) is considered for study, in which all structural design aspects are provided as per the specifications given by IS 456-2000 and IS 1892-2002. The structure is pushed both along X and Y direction [Refer Fig. 1] and performance of the structure for various seismic forces are studied. The study is based on the comparison of pushover curve, performance point, seismic-hinge formation, storey drift and storey shear; after analyzing the structure proper retrofit is suggested if required. ETABS, finite element software for structural analysis is used to carry out nonlinear pushover analysis. C: UsersSHIVAMDesktophhh. jpg

Fig. 1. Showing 3D ETAB Model

Objective of Study

The following are major objectives of present study: To perform nonlinear pushover analysis on 3D reinforced concrete structure using ETABS. To study the seismic performance of the structure under various seismic zones. To

understand the vulnerability of various stories under different intensity of earthquake. To study the effect of shape of the structure on overall seismic performance. To study the possibilities of retrofitting at various portions of the structure if required.

Literature Review

Earthquake engineering in recent years have emphasized the need for performance-based seismic analysis. An essential element in many seismic evaluations is the determination of ultimate inelastic response of the structure. Performance-based methods require reasonable estimates of inelastic deformation or damage in structures which are better quantities to assess damage than stress or forces. The performance based analysis is based on quantifying the deformation of the members and the building as a whole, under the lateral forces of an earthquake of a certain level of seismic hazard. Pushover analysis is a simplified, static, nonlinear procedure in which a predefined pattern of earthquake loads is applied incrementally to frameworks until a collapse mechanism is reached. FEMA-273 (1997), ATC-40(1996), are the codaldocument which provides a comprehensive, technically sound recommended methodology for the seismic evaluation and retrofit design of existing concrete buildings. Acceptable performance is measured by the level of structural and/or non-structural damage expected from the earthquake shaking. Damage is expressed in terms of post yield, inelastic deformation limits for various structural components and elements found in concrete buildings. The analytical procedure incorporated in the methodology accounts for post elastic deformations of the structure by using simplified nonlinear static analysis methods. Ashraf et al., (1998) presented

a study on the steps used in performing a pushover analysis of a simple three-dimensional building. SAP2000, a state-of-the-art, general-purpose, three-dimensional structural analysis program, is used as a tool for performing the pushover analysis. The SAP2000 static pushover analysis capabilities, which are fully integrated into the program, allow quick and easy implementation of the pushover procedures prescribed in the ATC-40 and FEMA-273 documents for both two and three-dimensional buildings. Dhileep. M et al., (2011) explained the practical difficulties associated with the non-linear direct numerical integration of the equations of motion leads to the use of non-linear static pushover analysis of structures. Pushover analysis is getting popular due to its simplicity. High frequency modes and non-linear effects may play an important role in stiff and irregular structures. Nonlinear static pushover analysis used as an approximation to nonlinear time history analysis is becoming a standard tool among the engineers, researches and professionals worldwide. High frequency modes may contribute significantly in the seismic analysis of irregular and stiff structures. In order to take the contribution of higher modes, structural engineers may include high frequency modes in the nonlinear static pushover analysis. The behaviour of high frequency modes in nonlinear static pushover analysis of irregular structures is studied. Bracci et al (1997) presented a static pushover analysis procedure for evaluating the seismic performance and retrofit options for low-to-medium rise RC buildings. The technique is based on the capacity spectrum method and was illustrated by application to the 1/3-scale 3-storey RC frame model that had been previously tested on the shaking table at Buffalo. Three retrofit examples

were considered. These were (1) prestressed concrete jacketing of internal columns, (2) RC fillets around beam-column joints, and (3) post tensioning of additional column longitudinal reinforcement. Retrofit increased the frame's base shear strength by 66% (from 0. 15W to 0. 25W) and the maximum drift from 1% to 2%. Giuseppe Oliveto et al., (2004) studied the seismic retrofitting of two reinforced concrete buildings in Eastern Sicily not originally designed to withstand the seismic action. Some special characteristics of the two buildings suggested the choice of a base isolation retrofitting system. Tests performed on the original building materials and also structural analyses performed on the original and on the retrofitted buildings suggested that some stiffening of the superstructure was required. The reasons that led to the retrofitting and to the choice of the retrofitting system are presented in some detail. The analyses conducted for the evaluation of the seismic resistance and vulnerability of the existing buildings and of the seismic resistance of the retrofitted buildings are also presented.

Pushover Analysis

Pushover Analysis in the recent years is becoming a popular method of predicting seismic forces and deformation demands for the purpose of performance evaluation of existing and new structures. Pushover analysis is a partial and relatively simple intermediate solution to the complex problem of predicting force and deformation demands imposed on structures and their elements by severe ground motion. Pushover analysis is one of the analysis methods recommended by ATC 40 and FEMA 273. Steps Involve in Pushover analysis:-Building is pushed in horizontal direction. Proportion of

applied force on each floor is constant, only its magnitude is increased gradually. Material nonlinearity is modeled by inserting plastic hinge at potential location. Lateral load is increased in step and sequence of cracking, yielding, and failure of component is recorded.

Performance Levels

A performance level describes a limiting damage condition which may be considered satisfactory for a given building and given ground motion. The limiting condition is described by the physical damage within the building, the threat to life safety of the buildings occupants created by the damage, and the post-earthquake serviceability of the building. Target performance levels for structural and nonstructural systems are specified independently. Structural performance levels are given names and number designations, while nonstructural performance levels are given names and letter designations. Which are mentioned below:-Structural Performance Level: Immediate Occupancy(SP-1); Damage Control(SP-2); Life Safety(SP-3); Limited Safety(SP-4); Structural Stability(SP-5); Not Considered(SP-6)Non-structural performance level: Operational (NP-A); Immediate Occupancy (NP-B); Life Safety (NP-C); Reduced Hazard (NP-D); Not Considered (NP-E). C: UsersAMITDesktopCapture. PNG

Fig. 2 Combination of structural and non-structural performance level as per ATC-40

Fig. 3. Performance level and corresponding structural failure

Retrofitting

A number of reasons may necessitate the need to retrofit existing structures. It may be the rehabilitation of a structure damaged by an earthquake or other causes, or the strengthening of an undamaged structure made necessary by revisions in structural design or loading codes of practice. Earthquakes are by far the most common cause of damage to structures in earthquake-prone areas. Here, the collective term, retrofit, which implies the addition of structural components after initial construction, is applied to both rehabilitation and strengthening processes. Seismic retrofit becomes necessary if it is shown that, through a seismic performance evaluation, the building does not meet minimum requirements up to the current building code and may suffer severe damage or even collapse during a seismic event. Multi-storied buildings are often constructed with provision for vertical extension in future. Before carrying out vertical extension in future, it is sometimes noticed that the existing structures may not be adequate to take the additional vertical and lateral loads on account to the additional stories. Under such situation one has to conduct a cost-benefit analysis to decide the two obvious options: strengthening the existing structure to enable it to take the load of additional stories. Seismic strengthening is a specialized job and is for obvious reasons more difficult than construction of a new facility. Each building poses a unique set of constraints and problems requiring due care in

design and detailing. Ultimately, the success of any upgrading exercise depends on the quality of work at the site. During execution of the work, many difficulties arise which may not have been anticipated during the design stage. At present, India lacks adequate experience in strengthening of seismically-deficient low and medium-rise RC framed buildings. This is partly due to the lack of awareness regarding the importance of the problem. The problem of seismic strengthening is being recognized as a major challenge to civil engineering profession in many countries of the world. In recent years, there has been a tremendous increase in the research and publication activities in this area in many countries. However, since a suitable strengthening technique depends on many factors such as the type of construction and the professional environment; what is suitable for one country may not be suitable for another country. Thus, while we can draw benefit from the experiences of many other countries, we must evolve methodologies suitable to our own conditions. Considering the severe seismic risk that many parts of our country are prone to, experience on seismic strengthening needs to be accumulated by carefully documenting individual case histories. Since cost is a very important consideration, we also need to study cost aspects of different strengthening schemes for such buildings. Professional engineers involved in design and constructions in the country need to accept the challenge that is posed by seismically deficient buildings. Seismic Strengthening Procedures

Jacketing of elements:

The strength and ductility of existing beams, columns, and/or beam-column joints can be enhanced by jacketing shown in fig. 5. 2 and 5. 3. This requires

puncturing the slab to pass new reinforcement. This technique is very effective for strengthening an individual element, including for gravity loads. However, as a means to provide the overall strengthening to a building, it is somewhat uneconomical and even impractical since it involves work in most areas of building. C: UsersSHIVAMDesktopUntitled2. jpg

Fig 4(a). Jacketing of a beam

Fig 4(b). Jacketing of a column

Providing steel bracing inside the RC frame:

Steel braced frame can be provided inside the RC frames along the perimeter of the building. For this technique to be effective, it is necessary to have good connecting between the bracing and concrete structures because bracing causes the stress concentration at the frame corners. This technique may be considerably expensive in India in view of high steel costs.

Providing RC shear panels in the frame:

Reinforced concrete shear wall panels can be provided as infill to existing frames. The bays to be provided with shear panel have to be carefully chosen. The new concrete should be connected with existing construction. This may be done by drilling holes in the existing beams and columns and by providing reinforcement dowels and fixing with these with epoxy mortar. The frame with this panel becomes much stiffer than the rest of the frames and therefore attracts most of the seismic forces. This means that the foundation with new panel should be able to transfer a significantly higher load to soil; hence, foundation has to be strengthened in many cases. Also, sometimes

the columns may also have to be strengthened to account for increased axial force in columns as a result of the increased stiffness.

Methodology

Analysis is done with the help of ETABS 9. 06, which is a integrated design and analysis software for building system. It is a finite element based powerful structural engineering software, used to carry out the pushover analysis which does the pushover analysis as per guidance given by ATC-40 and FEMA-273.[Refer Fig. 4]F: Project pushoverREPORTpushover flow chart. jpg

Fig 5. Flow chart representing methodology of Pushover analysis

Results

Following graphs are obtained after analyzing the structure and they are concluded as:

Capacity Curve vs. Demand Curve:

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Fig 6(a). capacity curve along X-direction for Zone III

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Fig 6(b). capacity curve along Y-direction for Zone III

Along X-direction Performance point is fitting properly whereas along Y-direction Performance point is just fitting and only one Non-linear hinge is crossing the capacity curve by the Demand curve. Again this shows the lack of stiffness and ductile characteristics of structure along Y-direction. Similarly

because of increase in spectral acceleration (Sa) and spectral displacement (Sd), the performance point shifts in a linear way rather than shifting in a non-linear way.

Seismic Hinge Curve:

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Fig 7(a). Seismic hinges graphs along X-direction for Zone III

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Fig 7(b). Seismic hinges graphs along Y-direction for Zone III

From Non-linear Hinge horizontal bar chart we are getting approximately 2850 Non-linear hinges at various performance levels along X-direction in zone-III. We are getting similar amount of non-linear hinges but performance levels are much lesser along Y-direction. The structure is collapsing under Immediate Occupancy level because we are getting maximum number of Non-linear hinges in Immediate Occupancy level. This shows that we cannot predict the failure of structure along Y-direction. The failure may be brittle.

Storey Shear Vs. Storey Drift:

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Fig 8(a). Storey Shear Vs. Storey Drift Curve along X-direction for zone III

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Fig 8(b). Storey Shear Vs. Storey Drift Curve along Y-direction for zone III

The maximum Storey shear obtained is 7031kN and the maximum Storey drift is 0. 0212m. The maximum storey drift is obtained for 2nd floor level and respective base shear is 6128kN. We can conclude that second floor is much more vulnerable compared to other floors when we move towards higher zone levels. In zone-IV and zone-V, the base shear is more compared to zone-II and zone-III and we are getting approximately same amount of storey drift at both 1st and 2nd floor level along X-direction. Similarly along Y-direction we are getting same amount of storey shear and storey drift at 2nd floor level when structure is in zone-II and zone-III condition but when the structure is in zone-IV and zone-V condition we are getting higher value of storey shear; but the drift at 1st and 2nd floor levels are similar.

Conclusions

Shape effect weakens the structure along Y-direction. Safety and ductility are the main criteria should be considered for earthquake design; however in this case the structure does not satisfy these requirements. The structure fails in immediate occupancy level without the formation of other performance levels; hence retrofitting can't be done for major part of structure. Limited portions of the structure can be repaired when the intensity of earthquake is mild, whereas for moderate and severe earthquake the retrofitting is not possible. The structure is designed considering both static and dynamic load cases but ductile detailing is not done properly which causes pre-matured failure. Retrofitting can done either by jacketing of the element or byproviding steel bracing inside the RC frame. IS 1893-

2002, doesn't gives failure and retrofitting criteria of seismically affected

structure; hence there is a need to implement performance based analysis

for design of structures.