REVIEW ON SEISMIC RETROFITTING OF BUILDING USING DIFFERENT TECHNIQUES

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***Abstract*—The present study aims for the Earthquake creates great devastation in terms of life, money and failures of structures. Earthquake mitigation is an important field of study from a long time now. Seismic retrofitting is a collection mitigation techniques for earthquake engineering. It is utmost important for historic monuments, areas prone to severe earthquakes and tall or expensive structures. It is the modification of existing structures to make them more resistant to the seismic activity, ground motions and soil failure due to the earthquake. In the present time various structures made without any adequate detailing and reinforcement for seismic protection. Retrofitting is provided to improve the construction quality and bearing capacity for external load capability. This paper reviews the usefulness of using different retrofitting techniques such as bracing, jacketing, dampers, base isolation and shear wall used in the RCC Building to make it more stiffer. The retrofitting of building mainly results in the increase of stiffness, decreasing story drift and displacement. The review has been carried out on RCC buildings which first analyzed in ETAB's software by static analysis and dynamic analysis and then retrofitted by using different retrofitting techniques. The best suited retrofitted technique is then used in field for retrofitting purpose in the RCC buildings which gives more stiffness, less story drift and less displacement on being analyzed in ETABS's software.**

Keywords: Seismic retrofitting, ETAB's, Jacketing, bracing, dampers, shear wall, base isolation, stiffness, Drift, Displacement.

I. INTRODUCTION

General

Earthquakes are one of the most destructive natural hazards that cause huge amount of loss life and property. Nearly 10,000 people were killed every year because of these hazards. Large strain energy released during an earthquake travels as seismic waves in all directions through the Earth's layers, reflecting and refracting at each interface. These waves are of two types - body waves and surface waves. A number of significant earthquakes occurred in and around India over the past century. Some of these occurred in populated and urbanized areas and hence caused great damage. Many went unnoticed, as they occurred deep under the Earth's surface or in relatively un-inhabited places. The varying geology at different locations in the country implies that the likelihood of damaging earthquakes taking place at different locations is different. Thus, a seismic zone map is required to identify these regions. Based on the levels of intensities sustained during damaging past earthquakes, the 1970 version of the zone map subdivided India into five zones – I, II, III, IV and V. The map has been revised again in 2002 and it now has only four seismic zones – II, III, IV and V.

Earthquake causes shaking of the ground. So a building resting on it will experience motion at its base. From Newton's First Law of Motion, even though the base of the building moves with the ground, the roof has a tendency to stay in its original position. This tendency to continue to remain in the previous position is known as inertia. In the building, since the walls or columns are flexible, the motion of the roof is different from that of the ground. The inertia force experienced by the roof is transferred to the ground via the columns, causing forces in columns. These forces generated in the columns can also be understood in another way. During earthquake shaking, the columns undergo relative movement between their ends. columns would like to come back to the straight vertical position, i.e., columns resist deformations. In the straight vertical position, the columns carry no horizontal earthquake force through them. But, when forced to bend, they develop internal forces. The larger is the relative horizontal displacement between the top and bottom of the column, the larger this internal force in columns. Also, the stiffer the columns are (i.e., bigger is the column size), larger is this force. For this reason, these internal forces in the columns are called stiffness forces. In fact, the stiffness force in a column is the column stiffness times the relative displacement between its ends.

Buildings that are irregular shapes in plan tend to twist under earthquake shaking. Twist in buildings, called torsion by engineers, makes different portions at the same floor level to move horizontally by different amounts. This induces more damage in the frames and walls on the side that moves more. Many buildings have been severely affected by this excessive torsional behavior during past earthquakes. It is best to minimize (if not completely avoid) this twist by ensuring that buildings have symmetry in plan (i.e., uniformly distributed mass and uniformly placed lateral load resisting systems). If this twist cannot be avoided, special calculations need to be done to account for this additional shear forces in the design of buildings; the Indian seismic code (IS 1893, 2016) has provisions for such calculations. But, for sure, buildings with twist will perform poorly during strong earthquake shaking.

Gravity loading on buildings causes RC frames to bend resulting in stretching and shortening at various locations. Tension is generated at surfaces that stretch and compression at those that shorten. Under gravity loads, tension in the beams is at the bottom surface of the beam in the central location and is at the top surface at the ends. On the other hand, earthquake loading causes tension on beam and column faces at locations different from those under gravity loading the relative levels of this tension generated in members. The level of bending moment due to earthquake loading depends on severity of shaking and can exceed that due to gravity loading. Thus, under strong earthquake shaking, the beam ends can develop tension on either of the top and bottom faces. Since concrete cannot carry this tension, steel bars are required on both faces of beams to resist reversals of bending moment. Similarly, steel bars are required on all faces of columns too. For a building to remain safe during earthquake shaking, columns should be stronger than beams, and foundations should be stronger than columns. Further, connections between beams & columns and columns & foundations should not fail so that beams can safely transfer forces to columns and columns to foundations. When this strategy is adopted in design, damage is likely to occur first in beams. When beams are detailed properly to have large ductility, the building as a whole can deform by large amounts despite progressive damage caused due to consequent yielding of beams. In contrast, if columns are made weaker, they suffer severe local damage, at the top and bottom of a particular storey. This localized damage can lead to collapse of a building, although columns at storey above remain almost undamaged.

Earthquake design philosophy

Severity of ground shaking at a given location during an earthquake can be minor, moderate and strong. The engineering intention is to make buildings earthquake resistant such buildings resist the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake as the engineers cannot make a building full earthquake proof because it is rare and also it costs too much. So that, safety of human lives and building is assured in earthquake-resistant buildings. The earthquake design philosophy is as follows:

a) Under the minor but frequent shaking, the main members of the building that carry vertical and horizontal forces should not be damaged, however building parts that do not carry load may sustain repairable damage.
b) Under moderate but occasional shaking, the main member may sustain repairable damage, while the other parts of the building may be damaged such that they may even have to be replaced after the earthquake.
c) Under strong but rare shaking, the main member may sustain severe damage, but the building should not collapse.

Seismic Retrofitting

Seismic retrofitting is defined as the modification of existing structures to make them more resistant to the seismic activity, ground motions and soil failure due to the earthquake. With better understanding of seismic demand on structures. Retrofitting of existing structures with insufficient seismic resistance accounts for a major portion of the total cost of hazard mitigation. Retrofitting is needed in the buildings due to earthquake, insufficient concrete production, bad execution process, design error before & after construction, due to lack of detailing. The basic concept of seismic retrofitting is upgradation of lateral strength of structure, Increase in ductility of structure, Increase in strength and ductility. The initial basics provisions of evaluating existing buildings were based on the thought that buildings resisted earthquakes by strength alone. Retrofit strategy refers to options of increasing the strength, stiffness, and ductility of the elements or the building as a whole. A retrofit strategy is a technical option for improving the strength and other attributes of resistance of a building or a member to seismic forces. The retrofit strategies can be classified under global and local strategies. The grouping of the retrofit strategies into local and global are generally not be mutually exclusive. The global retrofitting and local retrofitting which are discussed below as follows:

a) Global retrofitting techniques: This strategy of retrofitting is used to provide increased lateral stiffness and strength to the building as a whole. And, to ensure that a total collapse of the building does not occur. There are several methods of global retrofitting like addition of infill walls, addition of shear walls, addition of steel braces, Mass Dampers, base isolation etc.

b) Local retrofitting techniques: Local retrofit strategies are used to avoid failure of the components, and also thereby enhance the overall performance of the structure. There are several methods of local retrofitting like jacketing of beams, jacketing of columns, jacketing of beam column joint, strengthening of individual foundations.

Code basics for seismic retrofitting

Recent code provisions also evolved performance based seismic design to focus on better building behavior and performance to reduce and limit economic losses. While the main focus has been on improving seismic provisions for new buildings, seismic provisions for evaluation of existing buildings are limited. Existing buildings are already constructed, the materials are defined and details of construction are in place. The current seismic evaluation and rehabilitation philosophy were based on

a) ASCE 31-03: Seismic Evaluation of Existing Buildings (2003), has been the first nationally applicable seismic evaluation standard has improved the previous seismic evaluation documents including ATC-14: Evaluating the seismic resistance of existing building (1987), FEMA 178: NEHRP handbook for the seismic evaluation of existing buildings (1992).
b) FEMA 310: Handbook for the seismic evaluation of buildings (1998) and ASCE 41-06: Seismic Rehabilitation of Buildings (2006) serves to provide a standard for nationally applicable provisions in seismic rehabilitation of existing buildings and supersedes the previous standards; FEMA 273: NEHPR Guidelines For The Seismic Rehabilitation Of Buildings (1997) and Pre standard and Commentary For Seismic Rehabilitation of Buildings (2000).

Objective

The objective of the seismic retrofitting is as follows:

a) Structure unaffected: By retrofitting we can minimize the loss and damage of house.
b) Structure survivability: The goal is that the structure, while remaining safe for exit, may require extensive repair (but not replacement) before it is generally useful or considered safe for occupation.
c) Structure functionality: Primary structures undamaged and the structure is undiminished in utility for its primary application. A high level of retrofit, this ensures that any required repairs are cosmetic.
d) Public safety only: The goal is to protect human life ensuring that structure will not collapse upon its occupants or passersby and the structure can safely exited. Under severe seismic conditions the structure may be total economic write off, requiring tear down and replacement.

The objective of the paper review is as follows:

a) To model a RCC structure with a structural analysis software program i.e. Etabs and check out the earthquake results with various analysis methods given in standards and codes & use different retrofitting techniques in terminology of the overall performance.
b) To analyze the response of building after introducing retrofitting.
c) To compare the different parameters among different retrofit techniques.
d) To compute the best method of retrofitting among the used techniques.

II. LITERATURE REVIEW

A. Malhotra, D. Carson, P. Gopal, et.al. (2004)(1) In this study, St. Vincent Hospital comprises of five blocks of 5-storey RCC structure was retrofitted by using non - linear time history dynamic analyses in ETABS. Retrofitting by concrete shear walls or rigid steel bracing were not considered suitable for this hospital as upgrades with these methods would have required expensive and time consuming. Pall Friction dampers with appropriate stiffness were used as they were economical. It was concluded that dampers dissipate a significant portion of the seismic energy in friction and structure experiences reduced displacements and member forces.

P. Nawrotzki, T. Popp et.al. (2012)(2) In this study, building Palatul Victoria in Bucharest, Romania was retrofitted by use of Tuned Mass Dampers (TCM). A model analysis and numerical investigation was also performed. It was concluded that TMCS causes a significant seismic response reduction in terms of induced acceleration and displacement levels as well as of internal stresses and support reactions.

Theint Theint Thu Soe, San Yu Khaing (2014)(3) In this study, twelve storey RCC building was upgraded from zone 2 to zone 3 due to higher seismic risks. The superstructure was designed by using ETABS and the retrofitting of weak columns and beams in shear, flexural and confinement respectively by using externally bonded FRP reinforcement the on ‘‘Sika Curbodur Composite Strengthening Systems of FRP Analysis Software’’. Strengthening of beams in shear and columns in confinement was done by using Sika warp Hex 230C (carbon fiber type) & strengthening of beams in flexural using Carbodur S512 and Carbodur S1012. Here minimum thickness of FRP with the less number of layers was used as increasing stiffness, it is easier for debonding to occur.

Eben .C. Thomas (2015)(4) In this study, a soft storey structure is analyzed by using dynamic analysis was carried out by considering various time history analysis by using ETABS software. Seismic response of soft storey structures fitted with Viscoelastic dampers (VED) having various damper configurations viz. single diagonal bracing, chevron bracing and double diagonal bracing considering varying damping coefficients has been studied. It was concluded that use of dampers reduces the displacement upto 70% & also reduce reduction in displacement by provided with damper configuration on both inner and outer bays. VED are easy to install and maintenance free. Hence can be used as retrofitted technique.

S. Shamshad Begum, G. Vani (2016)(5) In this study, 20 floors building was analyzed in Zone 2 and Zone 3 on different soil condition with columns, columns with viscous dampers. The result has been compared using tables & graph to find out the most optimized solution. It was concluded that deflection was reduced by providing Viscous dampers. The stiffness of structure was also improved by providing dampers. By using Viscoelastic Dampers 50% of displacement can be reduced.

Ganesh Kumbhar, Anirudhha Banhatti (2016)(6) In this study, open ground storey and floating columns was analysed in ETABS using Equivalent Static Analysis and Response Spectrum Analysis. Retrofitted was done by using lateral bracings, shear walls, increasing the column size in the soft ground storey and their combinations which reduces reduce the stiffness irregularity and discontinuity in the load path. Shear wall retrofit is the best method of retrofit the soft story which also reduce the displacement of the whole structure.

K. Senthil, SK. Gupta et.al. (2017)(7) In this study, six storey reinforced concrete frames was analysed in ETABS by finite element analysis. Retrofitting was required due to inadequate reinforcements when seismic zone shifting from zone 3 to 5. Techniques used were shear wall, X bracing and jacketing. It was concluded that the lateral displacement, storey drift of the frame without shear wall increase upto 65% as compared to the frame with shear wall. Also, lateral displacement and storey drift of the frame without bracing increase upto 90% as compare to with bracing. Shear wall was found to be 46% and 91% costlier compared to X steel bracing and jacketing.

Valeti Immanial, R. Sai Teja (2018)(8) In this study, G+10 storey is analyzed using Response spectrum method in ETABS. Building was shifted from zone 2 to zone 3 due to which increase in moments and axial forces were observed so the size of existing columns is not sufficient to take the loads which requires retrofitting of columns by FRP, Steel, Concrete jacketing. It was observed that there is increase in moments and axial forces were in structure which is upgraded to Zone 3 so we can say that size of existing columns is not sufficient to take the loads, hence column sizes are increased to make the structure safe. It was also concluded that the least time period was found in FRP due to which FRP jacketing model is more stiffer than other two. The displacements and drifts ratio graphs were also obtained which shows that, the displacement and drifts ratio is drastically reduced in FRP Jacketing and Steel Jacketing when compared to RCC structure. Hence their comes a conclusion that, FRP jacketing is more effective in increasing both strength and deformation capacity of the retrofitted columns

B M Varsha1, Dr. M D Vijayananda (2018)(9) In this study, residential four storey building in Zone II and soil Type-II was converted to commercial building which results in increase of live load in existing building & analysis is carried out with additional live loads on slab under linear static analysis method using ETABS 2016 software. Due to increase of load in the existing four storey structure, the beams and columns of the building got weaken. RC retrofitting technique was used to enhance the axial load and moment carrying capacity in beams and column and also the shear deformation of the joint panel will be reduced significantly after retrofitting.

B.Naresh, J.Omprakash (2018)(10) In this study, it is taken into account that effect of lateral loads increases with increase in height of building due to these lateral loads, moments on steel components will be very high. Here residential building with 20 floors is analyzed with columns, columns with viscous dampers to reduce this increased moment. It was concluded that at top storey 50% displacement is reduced when the dampers are provided at each elevation. By providing the dampers the stiffness of the structure is increased and storey shear is decreased with increase in height of structure.

E. Roy, P. Ghose et.al. (2018)(11) In this study, two analytical models have been generated i.e. existing building in ETABS 2015 & SMA retrofitted building in SeismoStruct 2018. Nitinol (Nickel titanium) is used as SMA material for retrofitting of columns. DCR values of the retrofitted columns were less than 1.0 which means that those columns can withstand the existing loads. It was concluded that responses of RC columns are significantly reduced after retrofitting it by SMA material.

A. K. Kadu, Pawar Tanishk Shantanu et.al. (2019)(12) In this study, the Raja Dinkar Kelkar Museum in Pune was analysed using ETABS and retrofitted by using Base isolation. The building framing is comprised of unreinforced masonry (URM) bearing wall system with stone masonry foundations. It was concluded that base isolation resist the reduced seismic forces without the need for upgrade. From Cost Benefit Ratio it was also concluded that base isolation for an older structure saves additional cost, damages, deaths and injuries during an earthquake & base isolated structures faces slight to no damage during earthquake.

Anant Vats, Ankit Kumar Singh et.al. (2019)(13) The main aim of this study, is to project new as well as old buildings by retrofitting by base isolation methods, here isolator used was lead rubber base isolator and the structure was analysed in ETABS using Time History analysis. It was concluded that by using base isolation storey shear, base shear, storey drift was reduced which makes structure stable and safe against seismic forces. Also, displacement and mode periods were increased which makes structure flexible and stable against earthquake.

Fauzan, F A Ismail et.al. (2019)(14) In this study, due to damage of the structural elements of Andalas University Dental Hospital building retrofitting was required. Here considered shear wall and concrete jacketing method for analysis in ETABS. It was concluded that shear wall was more effective to reduce the internal forces and displacement of the building & is more economical.

Suman Verma, Manish Sakhlecha et.al. (2020)(15) In this study, a hypothetical case study was analysed using ETABS by Linear analysis using Time History Analysis having (G+8) storied MRF building in Zone V. It was concluded that base isolated structure exhibited a much lower fundamental frequency than fixed base structure & also high energy in ground motion at the higher frequencies does not get transmitted to the building as this reduced frequency is much lower than frequency of ground motion. It was also concluded that structures whose period lies around 1.0s require additional lateral resistance, which can be provided using other passive and semi active control like dampers and bracings so base isolation technique is suitable for low and medium rise structures.

Geetha M, Chaitra D M (2021)(16) In this study, G+6 storey in Zone II is analyzed using linear static method in ETABS on different soil condition & the retrofitting techniques adopted were steel jacketing method, column jacketing method, steel bracings. The load on the structure is taken as dead load (from IS 875 Part 1), Live load (from IS 875 Part II), Seismic load (from IS 1893:2002). Column failure was observed when additional floors were added and it is observed that greater number of columns failed in case of soft soil as compare to medium and hard soil condition. The design of RC column jacketing is done by using IS 15988:201 to retrofit the failed columns. The storey displacement, storey drift and storey shear were maximum for the building at soft soil compared to other two conditions. Retrofitting technique enhances the axial load and moment carrying capacity in structural members as a result of which storey displacement, storey drifts are reduced. It has been observed that structure with bracings shows lesser deflection, lesser drift, lesser story shear when compared to structure with RC column jacketing method and steel retrofitting method on soft, medium and hard soil conditions. It was concluded that Bracing technique was chosen as most appropriate technique. The analysis of the structure before and after retrofitting evidently showed that the retrofitting technique complimented in strengthening of the structure. It showed that retrofitting aims in strengthening a structure to satisfy the requirements of the current codes for seismic design

Yaman Hoodaa, Pradeep K. Goyalb (2021)(17) In this study a hospital building located in the North – Eastern Region Zone IV was analysed in ETABS 19 using Pushover Analysis & Retrofitted for weak structural members by using bracing of different sections of varying dimensions i.e. circular rod sections, angle sections and channel sections. It was concluded that, from all the varying sections considered, circular rod sections of 10 mm dia shows the best result. Also, for same section considered ISA 150 x 100 x 10 mm shows the maximum reduction in the displacement – storey relationship.

Amjad Al-Mudhafer (2021)(18) In this study, inter-frame walls of deficient two-story structure was designed using ETABS and retrofitting of columns of half inter-frame was done by brick wall, concrete and FRP jacketing using nonlinear elastic analysis by ABAQUS Software. It was concluded that presence of retrofitting of short shafts using steel jacket and FRP leads to a 3-40% increase in concrete bending framework in the section of shear strength and earthquake resistance. It was also noticed that presence of the brick wall contributes to the strength of the column as it absorbs and damps part of the loads imposed on the columns as a result of which brick walls reduces the risks of damages to the columns due to sudden loads on them.

Kafeel Hussain Ganaie, Birendra Kumar Bohara et.al. (2021)(19) In this study, 4-story soft-story irregularity buildings which is located in Zone V is analyzed using Response Spectrum & Pushover analysis in ETABS software. The steel bracing is provided at the 4 corners of the models. In the analysis p-delta effect is also considered and the required plastic hinges are defined in the beam, columns and bracings. It was concluded that steel bracings in RC buildings increase the strength increase the axial forces in the bottom columns and decrease the column's moments. By adding the bracing there is nearly 50% reduction of maximum top story displacements is obtained. Hence by adding bracing there is decrease in the maximum lateral displacements and inter story drift of the structures. Adding bracing decrease the fundamental time period and bracing increases seismic weight due to which base shear of structure also increases, increase the stiffness, increases the ductility that comes out to be 4. Bracing helps to avoid soft story failures because in the failure mechanism, the bracings fail first, which means the steel bracings are the weakest members in this system.

Nima Sthapit, Nisha Sthapit (2021)(20) In this study, a residence located at Purano-Nikap-13, Kathmandu was analyzed in ETABS using pushover analysis which shows that some columns got weaken & retrofitted by concrete and steel jacketing using epoxy resins. It was concluded that after retrofitting the drift reduced by 61% and 53%, displacement reduced by 62% and 52% in x and y direction. By pushover analysis, it was found out that the capacity of building was improved to 86% and total drift of building was 2%.

III. SUMMARY AND CONCLUSION

This paper review work was a small effort towards perceiving the how introducing different seismic retrofitting techniques such as bracing, jacketing, dampers, base isolation and shear wall in a building can make building to resist earthquake damages. Hence through this project it was tried to appreciate the effectiveness and role of this small extra structural elements that can save both life and property, at least for most of the earthquakes.

The following conclusions were drawn at the end of the study:

a) Seismic retrofitting is a suitable technology for protection of a variety of structures.
b) It has matured in the recent years to a highly reliable technology but the expertise needed is not available in the basic level.
c) The main challenge is to achieve a desired performance level at a minimum cost, which can be achieved through a detailed non-linear analysis.
d) Optimization techniques are needed to know the most efficient retrofit for a particular structure.
e) Proper design codes are needed to be published as a code of practice for professionals related to this field.
f) Retrofitting technique like jacketing, shear wall & bracing enhances the axial load and moment carrying capacity in structural members as a result of which storey displacement, storey drifts are reduced.
g) Dampers are easy to install and maintenance free & also they provide appropriate stiffness to structure.
h) By using base isolation we can make structure which face slight to no damage during earthquake.

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