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A Review on "Seismic Performance Evaluation and Retrofitting of L-shaped RC building"

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ABSTRACT: The maintenance work is done periodically to avoid the building from degrading and hence preventing it from non-functioning or ill functioning. The Reinforced cement concrete components are mainly responsible for taking the load and hence are vital elements in any building structure. Retrofitting is the process of repairing existing structures, such as buildings, commercial building structures, bridges, and historic buildings, to make them resistant to seismic forces such as earthquakes, volcanic eruptions, and other natural disasters such as landslides, tsunamis, floods, and thunderstorms. The main objective of retrofitting RCC structural elements is to recover the strength of the deteriorated concrete element structure. It also helps to prevent further damage in concrete elements. The deficiency in the strength of the concrete element could be because of design errors flaws or poor construction workmanship. There could be another reason too for the damage such as the aggression of harmful and hazardous agents.The purpose of this project was to assess the seismic vulnerability of an existing RC structure and to provide for retrofit in case the members fail. The plan and reinforcement details of the building were provided. I modeled the building in STAAD Pro software and applied seismic load combinations to it. Equivalent static procedure as per Indian Standard IS 1893:2002 (Part 1) was used to compute the seismic forces. The members' adequacy was assessed by computation of their dcr (demand to capacity ratio) values. The demand of individual members was obtained after analysis from STAAD Pro software and the capacity for the corresponding members was calculated, the ratio of the two gave the dcr values. The simple concept that if the dcr of any member is greater than one would result in the failure of that member under the applied loads was used to find out the status of the members under flexure and shear.

KEYWORDS: STAAD PRO, RETROFITTING, EARTHQUAKE, SEISMIC ANALYSIS, DCR VALUES

I. INTRODUCTION

The maintenance work is done periodically to avoid the building from degrading and hence preventing it from non-functioning or ill functioning. The Reinforced cement concrete components are mainly responsible for taking the load and hence are vital elements in any building structure. Retrofitting is the process of repairing existing structures, such as buildings, commercial building structures, bridges, and historic buildings, to make them resistant to seismic forces such as earthquakes, volcanic eruptions, and other natural disasters such as landslides, tsunamis, floods, and thunderstorms. The main objective of retrofitting RCC structural elements is to recover the strength of the deteriorated concrete element structure. It also helps to prevent further damage in concrete elements. The deficiency in the strength of the concrete element could be because of design errors flaws or poor construction workmanship. There could be another reason too for the damage such as the aggression of harmful and hazardous agents.

Several existing reinforced concrete (RC) buildings fail to conform to current seismic codes, increasing its susceptibility to damage and collapse during earthquakes. A concern for building upgrading and rehabilitation has grown considerably in the last decades. However, there is limited information related to the seismic performance of RC buildings retrofitted with steel jacketing. Once the right methodology of retrofitting is implemented and specified, the required ability to the structure could

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be returned and it completely depends on the type and seriousness of the damage caused. There are numerous techniques that are utilized in the process of retrofitting such as outside plate bonding, grouting, outer post-tensioning, section extension, and fiber built reinforced polymer materials. The need for rebuilding and restoration of buildings and engineering construction may arise once they are damaged to a point that they are not qualified for general use purpose. The building cannot withstand, with good reliability, a further sequence of the same action or unintended accidental actions and consequently, the chance of lives and thus the raising of any structural and content damage would be not justifiable. An appropriate strengthening replacement that can bring back an adequate magnitude of wellbeing and assurance against such moves is described as retrofitting.

Retrofitting of structures implies making changes to a present day building to provide protection from various hazards in future such as high wind flows, flooding and earthquakes.

Every building structure is built to serve some particular function service, after this service life is completed; the structure is subjected to repairs. In order to keep the structure in fair condition such that it fulfils all desire purpose, time to time maintenance and repair work are necessary. The maintaining work of structure is done time to time and properly to avoid the building from degrading and thereby preventing any future repairing works. For different types of construction of structures mostly reinforced concrete is used a construction material. Distress and deterioration are main cause of major failure of rock structures. With the help of various repair techniques, the minor defects in structures such as cracks and leakages are removed. Restoration is really necessary if the damage extend to a considerable damage. The building should be kept in such a condition such that it provides its main purpose of construction to improve the strength of the building and service of a constructed building structure.

Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. With better understanding of seismic demand on structures and with our recent experiences with large earthquakes near urban centers, the need of seismic retrofitting is well acknowledged. Prior to the introduction of modern seismic codes in the late 1960s for developed countries (US, Japan etc.) and late 1970s for many other parts of the world (Turkey, China etc.), many structures were designed without adequate detailing and reinforcement for seismic protection. The retrofit techniques outlined here are also applicable for other natural hazards such as tropical cyclones, tornadoes, and severe winds from thunderstorms. Whilst current practice of seismic retrofitting is predominantly concerned with structural improvements to reduce the seismic hazard of using the structures, it is similarly essential to reduce the hazards and losses from non-structural elements. It is also important to keep in mind that there is no such thing as an earthquake-proof structure, although seismic performance can be greatly enhanced through proper initial design or subsequent modifications.The performance based seismic design (PBSD), evaluates how the buildings are likely to perform under a design earthquake. As compared to force-based approach, PBSD provides a methodology for assessing the seismic performance of a building, ensuring life safety and minimum economic losses.

Retrofitting is the process of addition of new features to older buildings, heritage structures, bridges etc. Retrofitting reduces the vulnerability of damage of an existing structure during a near future seismic activity. Retrofit in structures is done to increase the survivability functionality. In India, there exists a number of old and existing buildings that are either constructed without taking into account the effects of earthquake forces or that are previously damaged or are likely to be damaged in the near future during the shaking of the ground. There are various ways of retrofitting these buildings so as to mitigate the effect of future earthquake. The technique of infilling/adding new shear walls is often regarded as the best and simple solution for improving seismic performance.

Most earthquakes occur through the sudden movement of earth crust in faults zones. The sudden movement releases strain energy and causes seismic waves through the crust around the fault. These seismic waves cause the ground surface to shake and this ground shaking is the principal concern of structural engineering to resist earthquakes among many other effects. Historical records and geological records of the earthquakes are the main data sources in estimating the possibility of ground shaking or seismicity at a certain location. Both data sets have been taken into account to develop the seismic hazard maps.

The initial difference of structural response to an earthquake compared to most other loadings is that the earthquake response is dynamic, not static. With the ground shaking, the portion of the structure above ground is not subjected to any applied force. The earthquake forces are generated by the inertia of buildings as they respond to earthquake induced ground shaking. In design, the response of a structure to an earthquake is predicted from a design spectrum such as specified in ASCE-7. To create a design response spectrum, the first step is to determine the maximum response of the structure to a specific ground motion.

This is generally prepared by seismologists and geotechnical engineers by presenting a response function (acceleration, velocity or displacement) against response period. The theory behind is based on the response of a single degree of freedom system such one story frame with mass concentrated at the roof. By recalculating the record response by time to a specific ground motion for a wide range of frequencies and a common amount of damping, the response spectra for one ground motion may be determined.

The principles of dynamic modal analysis, on the other hand, allow a reasonable approximation of the maximum response of multi degree system. The procedure involves determining the maximum response of each mode from a single degree of freedom response spectrum and then estimating the maximum total response by summing the responses of the individual modes. Due to the contribution of the higher modes to total response is relatively minor; it is not required to consider all possible modes of vibration.

The primary objective of earthquake resistant design is to prevent building collapse during earthquakes to minimize the risk of death or injury to people. Severe earthquakes have extremely low probability of occurrence during the life time of a structure. In the traditional structural design against most type of loads, stresses and strains are not permitted to approach the elastic limit. However in earthquake design, structures are permitted to strain beyond elastic limit in response to ground motion. If a structure has to resist such earthquakes elastically, it would require an expensive lateral load resisting system. During a severe earthquake, the structure is likely to undergo inelastic deformation and has to rely on its ductility and hysteric energy dissipation capacity to avoid collapse. Modern buildings can be designed to be safe under severe ground shaking by avoiding collapse. An effective earthquake engineering design requires that the designer controls the building's response. This can be achieved by selecting a preferred response mode, adopting inelastic deformations to acceptable zones by providing necessary detailing and preventing the development of the undesirable response modes which could lead to building collapse.
Many existing structures that were built according to past design codes & standards are often found vulnerable to earthquake damage due to inadequate detailing, underestimated earthquake loads or material deterioration by time, etc.

The high cost of new construction and historical importance of older buildings has led building owners to renovate rather than replace the existing structures. This has caused governmental institutions to implement mandatory seismic strengthening regulations. In this way, seismic rehabilitation techniques for buildings need to include both the evaluation of the existing lateral-force-resisting elements of the building and the addition of new elements where necessary.

Most retrofitting techniques will result an increase in stiffness and slightly increase in mass which causes in return a shorter period. Shortening in period of vibration often results an increase in strength and ductility of retrofitted structure. Thus, a proposed retrofit scheme can be said to be successful if it results an increase in strength and ductility capacity of the structure which is greater than the demands imposed by earthquakes.

II. LITERATURE REVIEW

The literature survey has been pioneered effort in this regard. Various seismic design concepts, mechanics, material behavioural properties and STAAD PRO concepts form literatures help to establish comparative study between existing and new experimentation.

2.1 REVIEW/ RESEARCH ARTICLE

[1] Analysis of Seismic Retrofitting on RC Building (2019)

- Many existing reinforced concrete structure in present world are inadequate for earthquakes. Recent earthquakes which occurred during last decade have indicated that major damage occurred was not directly due to actions of earthquakes but due to poor performance of structure during earthquake.

- The existing building structure, which were design and constructed according to early codal provisions, do not satisfy requirements of current seismic code and design practices. It is recognized that the most effective method of reducing the risk of damaging structure is seismic retrofitting. In recent years, there is a significant improvement of retrofitting techniques. This study highlights the principles of assessing and retrofitting of structure against seismic events.
- A three-dimensional R.C. frame designed with linear elastic dynamic analysis using response spectrum method. The computer software package STAAD Pro is used for dynamics analysis technique is used to assess the performance of a reinforced concrete building. The different retrofitting methods such as steel and concrete jacketing and application of fibre reinforced polymer (FRP) composites which were used to improve the load bearing capacity of individual structure elements are highlighted and methods such as shear walls and shear cores which can be used to improve overall stability of buildings.
- Most retrofitting techniques will result an increase in stiffness and slightly increase in mass which causes in return a shorter period. Shortening in period of vibration often results an increase in strength and ductility of retrofitted structure.
- Thus, a proposed retrofit scheme can be said to be successful if it results an increase in strength and ductility capacity of the structure which is greater than the demands imposed by earthquakes.
- The lateral displacement of the building is reduced by 40.56% by the use of X Type steel bracing system and 46.81% by the use of shear wall as compare to the bare frame, so shear wall reduces the maximum displacement.

[2] Seismic Performance Evaluation of Residential Building in Dhaka City (2022)

- Bangladesh is situated in a moderate earthquake-prone region. Major metropolitan cities of our country are under serious threat because of faulty design and construction of structures. So, structural engineers nowadays are more concerned about different procedures.
- According to Bangladesh National Building Code, the buildings are designed according to the equivalent static force method, response spectrum method, and time history analysis. But these methods can hardly find the actual performance of a structure. The nonlinear analysis provides a better understanding of the actual behaviour of the systems during earthquakes. The nonlinear elastic analysis has a wide range of applications in the seismic evaluation and retrofitting of structures.
- This research mainly follows the procedures of ETABS 9.5.0 software in evaluating the seismic performance of residential buildings in Dhaka, Bangladesh. The present study investigates as well as compares the performances of bare, full-infilled, and soft ground story buildings. For different loading conditions resembling the practical situation of Dhaka city, the performance of this structure is analyzed with the help of a deflection, drift, and base shear.
- The performance of an infilled frame is found to be much better than a bare frame structure. It is seen that consideration of the effect of the infilled leads to a significant change in the capacity. Investigation of buildings with soft stories shows that the soft story mechanism reduces the performance of the structure significantly and makes them the most vulnerable type of construction in earthquake-prone areas. There are some desired levels of seismic performance when the building is subjected to specified levels of seismic ground motion. Acceptable performance is measured by the level of structural and non-structural damage expected from the earthquake shaking.
- The main goal of the study was to analyze the deflection, drift, and base shear characteristics of bare frames, infilled frames, and different infilled frames and compare them with each other.

[3] A Review Paper on Seismic Retrofitting of Reinforced Concrete Structure by Traditional and Innovative Techniques (2021)

- Due to the devastating effect of earthquake repairing or retrofitting has taken an important chapter in the field of earthquake resistant structure construction. To retrofit and preserve very important Reinforced concrete structures various kinds of methods and techniques adopted over the decades. But by time the techniques are renovated and applied to the earthquake effected structures.
- Each and all methods have their pros and cons in the structures to be applied. In this paper we will discuss over different kinds of traditional methods and comparing them to the innovative methods of retrofitting.

- Modern methods and philosophies of seismic retrofitting, including base isolation and energy dissipation devices, are reviewed. The presentation is illustrated by case studies of actual buildings where traditional and innovative retrofitting methods have been applied.

[4] Performance Based Evaluation of Existing RC Building in Chiplun, Maharashtra (2022)

- Civil engineers deal with earthquakes in seismically active areas. Earthquakes cause building collapses and deaths in cities. Older buildings designed with outdated laws and architectural norms may not meet seismic design standards. Outdated rules and codes. This study analysed an older structure's seismic load to evaluate retrofitting needs. The building met Eurocode 8's seismic norms after retrofitting. 1970 concrete structure in Chiplun, Maharashtra, India. India's Maharashtra.
- ETAB software evaluates seismicity. Building seismic reactivity is determined by two analyses. Before and after retrofitting, modal analysis is undertaken. This analysis measures torsional strength. Pushover analysis compares construction deformation to target displacement. The building's target displacement. This displacement must not be exceeded for structural integrity. If the projected displacement is greater, the structure's weaknesses must be recognised and retrofitted. If goal displacement is lower, the comparison is useless.
- Analyzing pushover before and after retrofitting. Eigenvalue and pushover analyses indicated the building's torsional sensitivity and shear failures. Both were found after inspection. The structure is weak.
- The desired displacement did not exceed the structure's displacement when the building's initial member reached a limit condition. True. The building didn't collapse. Many beams sheared when X-shaped steel bracing were installed. This increased stiffness and torsional resistance. Some steel-braced columns collapsed.
- Wrapping the structure's problematic members in fiber reinforced plastic prevented shear and compression failures. Possible shear failures. Reduced seismic risk. After retrofitting, the building met India's current seismic design regulations. This project thesis could lead to greater earthquake damage prevention and seismic retrofitting research.

[5] Performance Evaluation of Retrofitting of Reinforced Concrete Structures (2022)

- Every building is built is to serve for some particular purpose, even after its service life is completed. The structure is required to get repaired in order to keep the structure in serviceable condition so that it fulfills its desire purpose, for which time to time maintenance and repair work are necessary. Every structure is constructed to serve a particular service, after the service structure is subjected to repairs. In order to keep the structure in good condition such that it fulfills its desire purpose, the maintenance and repairs are necessary.
- The maintenance of structure is done properly and periodically to prevent the structure from defects and hence prevent any repair works. Reinforced concrete is widely used for the construction material for different types of construction of structures. The major failure of rock structures is due to distress and deterioration. Generally, the minor defects in structures such as cracks and leakages are removed with the help of various repair techniques.
- However, if the defects extend to a considerable damage, rehabilitation is necessary. To keep the building in such a condition so that it provides it intended purpose of construction to improve the strength of the building and service of a building. The purpose of this project is economical structure rather than the reconstruction of the structure and to avoid various types of repairs, cracks, distress and deterioration in the structure. In this project a building taken for study which was 19 years before constructed, but due to poor construction it requires retrofitting.
- Columns, beams, slabs and walls need to retrofit; it requires increasing strength of the section. Finally, section-enlarging method is used for retrofitting of columns and jacketing method is used for retrofitting of beams. A proposed estimate is calculated with is about Rs. 7,26,827.00/-. Extended life of the building is about 45 years. Annual worth of the extended life period of building is about Rs. 600000/- per year. The experimental results of rebound hammer indicated that the strength of an existing building can be increased by retrofitting the building.
- Also, quality of concrete is in between Fair to Good for the building. The percentage increase in strength of the building before and after retrofitting is 57.75%. This project has reported on a structural experiment conducted to verify the effectiveness of a retrofitting method for reinforced concrete buildings that uses jacketing method and section- enlarging reinforcing method. Valuation of market is increased by 75% with retrofitting. The life cycle cost of Market is 41,58,563/- Rs.

2.2 SESMIC RETROFITTING USING TRADITIONAL RETROFITTING TECHNIQUES

[1] Giuseppe Oliveto and Massimo Marletta (2005) studied the procedures of several traditional techniques of retrofitting and also presented the weak points of those techniques. Their presentation is illustrated by case studies of actual buildings where traditional retrofitting techniques were applied. They have categorised these techniques into two parts, one based on the classical principles of structural design which requires an increase of strength and stiffness and the other one is based on mass reduction. They have concluded that both of these aforesaid criteria of traditional methods of seismic retrofitting are effective but not cost-effective.

[2] G. Navya and Pankaj Agarwal (2015) studied and performed ‘ Pushover analysis ‘ of a frame structure as per IS 1893 (part 1):2002 on the basis of confined plastic hinge regions performs much satisfactorily as compared to un-confined condition. They have also determined ‘Fragility curves’ which indicate that corresponding to zone – IV has higher probability of extreme damage.

[3] Hendramawat . A. Safarizki, S.A. Kristiawan and A.Basuki(2013) aimed to evaluate possible improvement of seismic performance of existing reinforced concrete building by the use of steel bracing.
Steel bracing could be utilized for seismic retrofitting and both non-linear static pushover analysis based on FEMA 356 and FEMA 440 and dynamic time history analysis confirm this aspect. Their study does not clearly show the effect of steel bracing in improving seismic performance of structure under consideration.

[4] M.Elgawady, P.Lestuzzi and M.Badoux(2004) reviews common conventional techniques used in retrofitting of existing un-reinforced masonry buildings. They have also studied common causes and failure of URM buildings and State-of-the-art retrofitting techniques are also vividly presented. They have also presented with traditional retrofitting methods which are ‘surface treatment ‘which incorporates techniques such as ‘ferrocement’,’reinforced plaster ‘and ‘shortcrete’. They have also studied other conventional techniques like ’grout and epoxy injection’, ‘external reinforcement’, ’confining un-reinforced masonry with reinforced concrete tie columns’etc.

[5] Reza Amiraslanzadeh , Toshikazu Ikemotoand Masakatzumiyajima (2012) In this paper, they have studied the seismic retrofitting methods of masonry brick walls with their advantages, drawbacks and limitations. They have introduced surface treatment technique with ‘Bamboo-Band retrofitting technique, shortcrete, fiber reinforced polymer laminates, posttensioning, confinement technique, central core technique, grout and epoxy injection. They have also made a comparative study of these aforesaid retrofitting methods.

[6] Michael P. Schuller, Richard H .Atkinson and Jeffrey T. borgsmiller (2004) studied to strengthen existing masonry buildings which often contain voids, cracks and other weaknesses which can be minimized by applying injection of grout to restore the structure into its original structural conditions. This study also indicates that by injecting grout into voids in the collar joint and enhancing the masonry structure by increasing the composite action between adjacent wythes.

[7] VasantA.Matsagar and R.S.Jangid (2008) studied in their paper the analytical response of structures retrofitted using base isolation . It has specific objectives to study the usefulness of base isolation in seismic retrofitting of historical buildings, a bridge and liquid storage tank and to substantiate the efficacy of different isolation devices in seismic retrofitting works and also to study the various aspects influencing the retrofitting works using seismic isolation technique. Conventionally designed building is more vulnerable as compared to building designed with seismic provisions related to confinement at the possible location of plastic hinges. They have pointed out the fragility analysis indicates that conventionally designed buildings.

[8] L Di Sarno and A.S.Elnasai (On steel and composite structure retrofitting) studied traditional rehabilitation methods and provides a detailed discussion of the design issues along with advantages and disadvantages of retrofitting of steel and composite structures. It also depicts the viability and cost-effectiveness of base isolation and supplemental damping devices on the basis of multiple limit states within the framework of performance based design. A number of parameters which govern the selection and choice of intervention devices are thoroughly investigated.

[9] L Di Sarno and A.S Elnasai (On application of special metals in retrofitting) briefly studied about special metals such as aluminium alloys, stainless steel and shape memory alloys which can be implemented in retrofitting of steel buildings.

Furthermore, it compares their mechanical characteristics in order to assess a) relative merits and b) the cost-effectiveness in the practical execution of these special metal in case of strengthening of existing structures.

[10] Mustafa Taghdi, Michael Bruneau and Murat Saatcioglu (2015) reported the results of tests on several full-scale, low-rise masonry and concrete wall specimens with intention to retrofit low-rise masonry and concrete walls using steel strips. The following results showcase that the in-plane strength, ductility and energy dissipation capacity significantly increase with addition of steel strips.

2.3 INNOVATIVE APPROACHES TO SEISMIC RETROFITTING

[1] S. Saibabu; N. Lakshmanan; A. Rama Chandra Murthy; S. ChitraGanapathi;R. Jayaraman; and R. Senthil (2009) studied that an innovative external prestressing technique for strengthening of prestressed concrete (PSC) girders has been described. This technique is very much useful when the ends of the PSC girders are inaccessible. The developed method relies on anchoring the external prestressing to the sides of the end block. The transfer of an external force is in shear mode and the required transversal prestressing force is smaller compared to conventional techniques.
From the analysis they have observed that the computed slope of the steel bracket is in good agreement with the corresponding experimental observations whereas slip is in reasonable agreement with the corresponding experimental values.

[2] Debric. J. Oehlers, Ninh T. Nhuyen and Mark A.Bradford (2000) studied a design procedure that has been developed for adhesive bonding steel plates to the sides of reinforced concrete beams that ensures that the plate-ends do not debond prematurely. The procedure has been developed from mathematical models and from 39 additional beam tests.

[3] Mahmoud M. Reda Taha and Nigel G. Shrive (2003) studied a new wedge-type concrete anchor for posttensioning applications using CFRP tendons. The anchor provides the potential of a completely metal-free, and thus corrosion-free, post-tensioning system. The idea of the new anchor is to hold the tendon through mechanical gripping. The anchor consists of a barrel with a conical housing and four wedges. A 0.1 degree angle differential angle between the slope of the conical housing and the wedges tightens the wedges on the tendon. There is no sleeve on the tendon. The new anchor is made of specially developed UHPC. The barrel was wrapped with CFRP sheets to provide the necessary increase in the load-carrying capacity of the anchor system.

[4] Rakesh Dumaru, Hugo Rodrigues, Humberto Varum (2018) studied the increase in stiffness for the non-engineered non-damaged building ranges from 4 to 7 times and increase in maximum strength by 2–3 times in both directions relatively compared to as built nonengineered damaged building. In case of the nonengineered damaged building, the increase in stiffness was 1.5–2.5 times and maximum strength increased by 2–3.5 times in both directions. For the pre-engineered non-damaged building, the increase in stiffness and maximum strength capacity were almost 3.5–7 and 4–10 times, respectively. Furthermore, in case of the pre-engineered damaged building, the increase in stiffness was 1.5–3 times and maximum strength increased by 1.5–3 times compared to as-built building.

[5] Archana T. Kandy, Gul Jokhio, and Abid AbuTair (2020) conducted seismic retrofitting scheme on Structure-01 under Scheme-01 (addition of steel bracings) and Scheme-02 (addition of ductile reinforced shear walls) which substantiated the time period under Scheme-01 is less than that for Scheme-02. Larger the time period in the Structure, higher the flexibility to the Structure and.
Whereas similar comparison of Structure-02 under Scheme-03 (addition of ductile reinforced shear walls) and Scheme04 (addition of steel bracings) indicated the time periods of Scheme-03 to be less than that in Scheme-04 and compared the results for base shear.

[6] Ervin Paci and Altin Bidaj (2015) examined the flexural strength of the beams and out of plane work of some masonry panels by approaching four different methods (1) Increasing the global capacity (strengthening).(2) Reduction of the seismic demand by means of supplementary damping and/or use of base isolation systems; (3) Increasing the local capacity of structural elements. (4) Selective weakening retrofit. This is an intuitive approach to change the inelastic mechanism of the structure.

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[7] Bharat Diliprao Daspute and L. G. Kalurkar (2020) showed the responses of the bare frame model and the changes in the responses after using bracings and shear wall. The results include changes in base shear, inter-storey drifts and top-storey deflections for ground motions along X and Z direction considered individually. The results of, base shear, inter-storey drifts and top- storey deflection for bare frame, braced frame and shear wall frame were then compared with each other and a conclusion was then drawn.

[8] Jovan Tatar and H. R. Hamilton (2015) presented a comparison of a proposed bond durability factor (BDF) based on the results of notched-beam three-point bending tests with a database of bond durability data from the literature. The purpose of the comparison was to confirm both the validity of the proposed BDF and the appropriateness of the ACI 440.9R-15 test method for evaluation of bond durability.

[9] Amritha Ranganadhan and Anju Paul (2015) discussed the analysis and designing of an existing old structure which was actually designed for seismic zone II as per the previous code IS 1893: 1984 and redesigning the structure as per the revised code IS 1893: 2002 for seismic zone III. Columns were found to be the deficient member and are to be retrofitted so as to achieve ductile performance. The most suitable retrofitting technique is use of FRP wrapping which is suggested for the retrofitting of the deficient columns.

[10] P.D. Gkournelos, T.C. Triantafillou,D.A. Bournas (2021) outlined the seismic upgrading methods that have been developed for application in RC buildings, emphasizing on novel approaches. Both local and global techniques were discussed and assessed in terms of their strengths and weaknesses.

[11] Karan Singh and Atul Uniyal (2019) investigated the effects of earthquake forces on buildings and literature search on earthquake resistant design evaluate the feasibility of seismic evaluation of buildings and advantages of applying the retrofit measures developed for strengthening. They analysed performance-based design and compare different seismic analysis method and modeled a real building with a structural analysis software and investigate the earthquake effects with different analysis methods prescribed in codes & standards and propose appropriate rehabilitation methods in terms of the performance.

[12] Kyong Min Ro, Min Sook Kim and Young HakLee (2020) analysed a seismic retrofitting method using a WCFST(welded concrete filled steel tubes) system was proposed in order to improve the seismic performance of an RC moment-resisting frame without seismic details. One non-seismically designed reinforced concrete frame specimen and one specimen retrofitted with the WCFST system were subjected to cyclic lateral loading tests. Crack patterns, failure modes, maximum load, effectiveness, and energy dissipation were evaluated.

[13] Anant Vats, Ankit Kumar Singh and Mr. Ashuvendra Singh (2019) analysed that after LRB(lead rubber bearing) is provided as base isolation system, it increases the structural stability against earthquake and also reduces reinforcement hence make structure economical. Base shear reduced up to 3258.02 KN in case of base isolated structure as compared to that of the 5764.79 KN in case of fixed base supported structure.

[14] Gkournelos, D. P., Bournas, D. A., Triantafillou, T. C. (2019) performed the TRM strengthening technique after testing in a close to real-world situation. Furthermore, the efficacy of the integrated seismic and energy retrofitting scheme is evaluated based on the results of the case studies.

[15] Marı´a-Victoria Requena-Garcı´a-Cruz, Antonio Morales-Esteban, Percy Durand-Neyra, João M. C. Estêvão (2019) studied nonlinear static analyses that is just adding retrofitting elements in the most vulnerable direction of the building can lead to higher values of efficiency than including fewer elements but in both directions. The addition of bracings, jackets and single braces in only one direction did not improve the behaviour of the other direction. Contrariwise, the implementation of walls produced improvements in both directions.

III. SUMMARY

The above article then considers the retrofitting of buildings vulnerable to earthquakes and briefly describes the main traditional and innovative methods of seismic retrofitting. Examples drawn from the professional, editorial and research

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activity of the senior author are used to illustrate the problems in a simple way. Among all the methods of seismic retrofitting, particular attention is devoted to the method which is based on stiffness reduction. This method is carried out in practice by application of the concept of springs in series, leading in fact to base isolation. One of the two springs in series represents the structure and the other represents the base isolation system. Though the other methods like shear wall, Jacketing and base isolation itself have their own popularity in their respective areas. Also being the most effective method stiffness reduction cannot be applicable in every vulnerable condition of the building. The enhanced resistance of the buildings to the design earthquake clearly shows the effectiveness of the method, while a generally improved seismic performance also emerges from the application. In conclusion it is hoped that the material presented in this article will be useful in increasing the understanding of the earthquake engineering problem and of seismic retrofitting.

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