A Review Paper on Seismic Retrofitting of Reinforced Concrete Structure by Traditional and Innovative Techniques

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Abstract: *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 every 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.*

Keywords: Pushover Analyses, Seismic Vulnerability, Seismic Retrofitting, Base Isolation

Introduction: Earthquake creates great devastation in terms of life, money and failures of structures. Retrofitting proves to be a better economic consideration and immediate shelter to problems rather than replacement of the whole building. It is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. The retrofit techniques are also applicable for other natural hazards such as tropical cyclones, tornadoes, and severe winds from thunderstorms. In this review paper we will put some light on the progress of earthquake retrofitting techniques and their effectiveness and advantages in aspect of construction like material, cost, durability and process accessibility etc. Over the years different kind of new techniques takes over the place of traditional methods of retrofitting and proven to be effective in the respective conditions. Here we will discuss the traditional and innovative retrofitting techniques that were applied in different places where earthquake took place. Various kinds of traditional retrofitting methods like mass reduction technique of retrofitting, surface treatment, reinforced plaster, Ferrocement, grout and epoxy injection base isolation technique by using different isolating material like elastomeric rubber bearing, roller and ball bearing, spring, sliding bearing etc. are discussed and in the other hand to compare those with the new innovative techniques Stiffness reduction

• Ductility increase

• Damage controlled structures

• Composite materials

• Any suitable combination of the above methods

• Active control

These were discussed. With this review paper our moto will be to let people have a wide idea about new innovative techniques to install in comparison with traditional techniques.

SESMIC RETROFITTING USING TRADITIONAL RETROFITTING TECHNIQUES:

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.

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 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 corresponding to zone – IV has higher probability of extreme damage.

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.

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.

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, post-tensioning, confinement technique, central core technique, grout and epoxy injection. They have also made a comparative study of these aforesaid retrofitting methods.

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.

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.

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.

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.

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 increases with addition of steel strips.

INNOVATIVE APPROACHES TO SEISMIC RETROFITTING*:*

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.

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.

Mahmoud M. Reda Taha and Nigel G. Shrive(2003) studied a new wedge-type concrete anchor for post-tensioning 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.

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 non-engineered damaged building. In case of the non-engineered 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.

Archana T. Kandy, Gul Jokhio, and Abid Abu-Tair(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 Scheme-04 (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.

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 structuralelements. (4) Selective weakening retrofit. This is an intuitive approach to change the inelastic mechanism of the structure.

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.

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.

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.

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.

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.

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.

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.

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.

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.

Summary and conclusion: The paper 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 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 paper will be useful in increasing the understanding of the earthquake engineering problem and of seismic retrofitting.

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