Study and Analysis of Seismic Retrofitting Technique in Earthquake Prone Area

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ABSTRACT- Earthquake is one of major natural disaster in which many structures damage and collapse due to unacceptable or improper design against seismic motion. Earthquake also affects the economy of the nation and growth rate of the country, so essential proper measures of prevention must be developed for the betterment of the citizens and nation. This deals with a few case studies in which the applications of the most common retrofitting schemes are employed to improve the efficiency and proficiency of either the seismically earthquake damaged buildings. In view of the mixed and complex seismic responses of retrofitted structures, heterogeneous nature of different constructions along with the strain dependent elastic properties of various materials hamper to bring a complete justification of the application of analytical studies. The need of retrofitting of existing earthquake vulnerable buildings may arise due to one or more than one of the following reasons i.e. The buildings have been designed according to a seismic code, but the code has been upgraded in later years. Buildings designed to meet the modern seismic codes, but deficiencies exist in the design and /or construction. Essential buildings must be strengthened like hospitals, historical monuments and architectural buildings. Important buildings whose service is assumed to be essential even just after an earthquake. Buildings, the use of which has changed through the years.

KEYWORDS – Seismic analysis, retrofitting techniques, strengthening intervention, ETABS.

1. Introduction

Earthquakes are a crucial problem worldwide since it leads to disastrous damages such as failure and collapse of buildings, loss of human lives and loss of homes. In addition, earthquakes lead to a massive economy including loss of built structures and recovery costs of damaged buildings and infrastructure.

Throughout the years, investigations have been made regarding the capacity of the buildings against seismic effects; which demonstrated that damages occur to buildings that do not fulfil the requirements of sustainable structures regarding seismic resistant design. Therefore, regulations and standards have been developed to improve the behavior of buildings regarding ductility and stiffness, to resist seismic actions. Therefore, the seismic design has been applied to design and construction of buildings and civil engineering works in seismic regions. Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. Retrofitting is necessary today since most of the buildings have been designed in the past with different regulations according to each country have. The old methods of designing buildings against earthquakes might not be completely efficient since the technology is developing; new types of structures and applications are arising as well as the regulations are being updated. Moreover, since the morphology of the ground and the climate is changing throughout the years, this can influence the level of earthquakes. Thus, this can lead to differentiation of the information a country has for earthquakes and engineers need to make structures more efficient to fulfill the requirements of the current regulations.

2. Need

i. To increase the lateral strength and stiffness of the building
ii. To increase the ductility in the behaviour of the building, this aims to avoid the brittle modes of failure.
iii. To increase the integral action and continuity of the members in a building
iv. To eliminate or reduce the effects of irregularities
v. To enhance redundancy in the lateral load resisting system, this aims to eliminate the possibility of progressive collapse.
vi. To ensure adequate stability against overturning and sliding

3. Problem Statement

The main reason for this particular study is increasing proficiency and knowledge in earthquake resistant design plus seismic retrofitting of existing buildings and also in order to increase familiarity with modeling & analyzing buildings against seismic loads by utilizing computer software. As lack of standards for retrofitting methods – Effectiveness of each methods varies a lot depending upon parameters like type of structures, material condition, amount of damage etc.,

4. Objectives

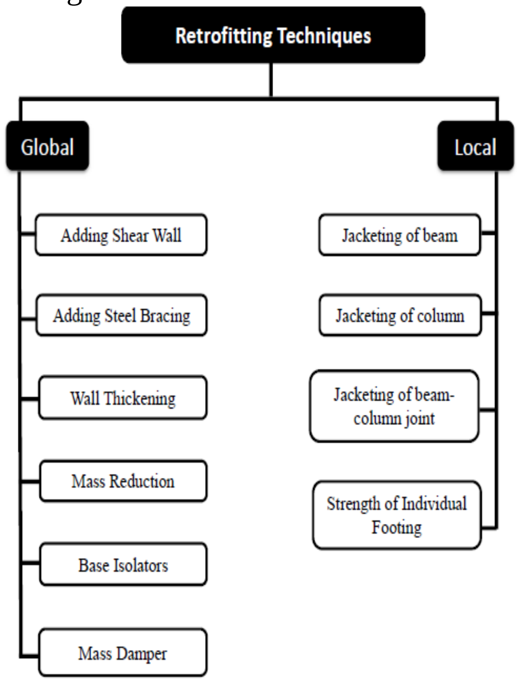
- To study different methods of seismic retrofitting.
- To analyze the respond of building after introducing retrofitting in ETABS.
- To compare different parameters among different retrofitting techniques with each other.

5. Scope of the project

- To ensure the safety and security of a building, employees, structure functionality, machinery and inventory.
- Essential to reduce hazard and losses from structural elements.
- Feasibility is increased by analyzing the structure in ETABS software before actual construction starts.
- Important buildings must be strengthened whose services are assumed to be essential just after an earthquake like hospitals.

6. Methods of Seismic Retrofitting

Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. Different method of seismic retrofitting are classified as –



Global Retrofitting Techniques

Global retrofitting methods are adopted to provide increased lateral stiffness and strength to building as a whole. And, to ensure that a total collapse of the building do not occur. The methods of global retrofitting are –

1. Adding Shear Wall

One of the most common methods to increase the lateral strength of the reinforced concrete buildings is to make a provision for additional shear walls. The technique of adding new shear walls is often taken as the best and simple solution for improving seismic performance. Therefore, it is frequently used for retrofitting of non-ductile reinforced concrete frame buildings. The added elements can be either cast in place or pre-cast concrete elements. New elements preferably be placed at the exterior of the building, however it may cause alteration in the appearance and window layouts. Placing of shear walls in the interior of the structure is not preferred in order to avoid interior mouldings. Shear walls are generally used in high-rise buildings subject to lateral wind and seismic forces. In reinforced concrete framed structures the effects of wind forces increase in significance as the structure increases in height. The shear wall is a concrete wall constructed from the foundation level to the top of the building. The thickness and the length of the walls are determined as per the design requirements. Typically, shear walls are constructed as lift core walls and around the staircases. Generally shear walls are either plane or flanged in section, while core walls consists of channel sections.

In many cases, the wall is pierced by openings. These are called coupled shear walls because they behave as individual continuous wall sections coupled by the connecting beams or slabs. Normally the walls are connected directly to the foundations. However, in a few cases where the lateral loads are relatively small and there no appreciable dynamic effects, then they can be supported on columns connected by a transfer beam to provide clear space.

The shear wall can provide resistance for lateral loads about 35 stories. When the number of floors is increasing shear walls cannot resist the loads along. Further, the length and width of the shear walls also cannot be increased due to the limitations in the floor area. In these situations, we consider the interaction of the shear wall with the frame; it reduces the lateral deflections/drift considerably. Further, it reduces the flexural moment in the wall considerably. Therefore, consideration of the wall frame interactions improves the performance of the structure and it reduces the cost of the construction.

2. Addition of Steel Bracing

Another method of strengthening having similar advantages is the use of steel bracing. The structural details of connection between bracing and column . The use of steel bracing systems for strengthening or retrofitting seismically inadequate reinforced concrete frames is a viable solution for enhancing earthquake resistance. Bracing system reduces bending moments and shear forces in the columns. The bracing system improves not only the lateral stiffness and strength capacity but also the displacement capacity of the structure. The lateral load is transferred to the foundation through axial action. Total weight of the existing structure will not change significantly after the application of the bracings. The installation of steel bracing members can be an effective solution when large openings are required. This scheme of the use of steel bracing has a potential advantage over other schemes for the following reasons;

a. Higher strength and stiffness can be proved.
b. Opening for natural light can be made easily.
c. Amount of work is less since foundation cost may be minimized.
d. The bracing system adds much less weight to the existing structure.
e. Most of the retrofitting work can be performed with prefabricated elements and disturbance to the occupants may be minimized.

Types of steel bracing system:-

a. Diagonal bracing
b. V type bracing
c. Inverted V type bracing
d. Combined V type bracing
e. X type bracing

3. Base Isolation

A base isolation system is a method of seismic protection where the structure (superstructure) is separated from the base (foundation or substructure). By separating the structure from its base the amount of energy that is transferred to the superstructure during an earthquake is reduced significantly. The concept of base isolation is quite easy to grasp. It can be explained as a bird flying during an earthquake is not affected. In simple words if structure is floating on its base, the movement of ground will have no effect on the structure.

Types of base isolation system:-

i. **Elastomeric Rubber Bearings**
ii. **Springs**

iii. **Sliding Bearing**
iv. **Friction Pendulum Bearing**

4. Seismic Dampers

A Seismic Damper can be defined as a mechanical device that dissipates the kinetic energy of seismic waves passing through the building or other structures. The seismic damper is an innovation that greatly reduces the vibrations in the structures that are induced during the occurrence of the earthquake.

Types of seismic dampers:-

i. **Viscous Damper**
ii. **Friction dampers**
iii. **Viscoelastic Dampers**
iv. **Yielding Dampers**
v. **Vibration Dampers (Tuned Mass Dampers)**

Local Retrofitting Techniques

Local retrofit strategies include local strengthening of beams, columns, slabs, beam-to-column or slab to column joints, walls and foundations. Local strengthening allows one or more under-strength elements or connections to resist the strength demands predicted by the analysis, without affecting the overall response of the structure. This scheme tends to be the most economical alternative when only a few of the building's elements are deficient.

1. Jacketing of Beam

Jacketing is a technique used to increase the strength of existing structural members (e.g. Columns, Beams etc.) by providing a "Jacket" of additional material around the existing member. This additional material can be of several types e.g. concrete, steel or FRP etc.

i. Reinforced Concrete Jacketing

Concrete jacketing is probably the mostly used technique for the strengthening of RC members. It is constructed either with cast-in-place concrete or, more often, with shotcrete. The method involves the addition of a layer of reinforced concrete in the form of the jacket using longitudinal steel reinforcement and transverse steel ties outside the perimeter of the existing member. The jacketing with cast-in-place concrete demands the installation of formwork around the existing column, on which the formwork is tied so that to withstand the poured concrete. The thickness of the jacket usually exceeds 10 cm, in order to allow the casting of the concrete without voids and gaps. On the contrary, shotcrete allows for jackets of thickness as low as 5cm, although typically the jackets are 7.5 cm thick or more, in order to allow for a cover of adequate thickness, the positioning of the longitudinal and transverse reinforcements, and some space between the new rebar's and the existing member.

ii. Steel Jacketing

The steel jacketing reinforcement method is a reinforcement method in which section steel (usually angle steel) is wrapped around the four corners (or two corners) of a member to enhance its force-bearing performance. The steel jacketing method can greatly increase the bearing capacity, increase the ductility and rigidity of the component without basically increasing the size of the component, and the force is more reliable. It is applicable to the reinforcement of the structure that does not allow to increase the cross-sectional size of the original member, but requires a large increase in the load-bearing capacity of the cross-section, and increased ductility and rigidity. After steel jacketing reinforcement, the cross-sectional area of the steel under tension and compression is greatly increased, so the front section bearing capacity and section stiffness are also greatly improved.

iii. FRP Jacketing

One of the most commonly used methods for retrofitting is Fiber Reinforced Polymer (FRP) jacketing. FRP is widely used for its properties such as high strength to weight ratio, stiffness, good impact properties, high resistance to corrosion in harsh environmental and chemical condition, and also it causes only a minimum alteration to the geometry of structural elements than other methods. FRP is used to strengthen the corroded rectangular columns considering different levels of corrosion and various volumetric ratios and the test results indicate that shear resistance of FRP and column increases with the increase in volumetric ratio and decreases with increase in different levels of corrosion. Shrinkage is one of the factors responsible for the formation of cracks in structural elements like beams and slab. To reduce the shrinkage hybrid fiber-reinforced polymer (FRP) reinforced shrinkage compensating concrete is used.

- **a. Glass Fibre Reinforced Polymer Jacketing**
- **b. Near-Surface Mounted (NSM) Fiber-Reinforced Polymer (FRP) Jacketing**
- **c. Shape Memory Alloy (SMA) Wire Jacketing**

2. Jacketing of Beam

Reinforced concrete beams need strengthening when the existing steel bars in the beam are unsafe or insufficient, or when the loads applied to the beam are increased. In such cases, there are different solutions that could be followed

i. Adding Steel plates to the Beam

When it is required to strengthen the beam's resistance against the applied moment or shear stress, steel plates are designed with the appropriate size and thickness. Then those plates are attached to the beam as follows:

a. Roughing and cleaning the concrete surfaces where the plates will be attached.
b. Coating the concrete surfaces with a bonding epoxy material.
c. Making holes in the concrete surfaces and plates.
d. Putting a layer of epoxy mortar on top of the plates with a 5mm thickness. Attaching the steel plates to the concrete using bolts.

In some cases, it is needed to reduce the load on the beam that needs strengthening before implementing the previous steps, either partial or complete unloading. This is made by putting steel beams on top or below the concrete beams.

ii. Jacketing of Concrete

There are some disadvantages in this traditional retrofit strategy. First, addition of concrete increases the size and weight of the beam. Second, the new concrete requires proper bonding to the existing concrete. Third, the effects of drying shrinkage must be considered as it induces tensile stresses in the new concrete. Instead of regular concrete, fibre reinforced concrete can be used for retrofit.

iii. FRP Wrapping

Like steel plates, FRP laminates are attached to beams to increase their flexural and shear capacities. The amount of FRP attached to the soffit should be limited to retain the ductile flexural failure mode.

3. Slab Column Connection

In RCC buildings the portion of column which is common to the beams at their intersection are called beam-column joints. The constituent materials of joints have limited force carrying capacity and limited strength. Beam column joints being the lateral and vertical load resisting members which are severely damaged during earthquake, when the forces that applied are larger than the resisting capacity of joints. Beam – Column joints are the weakest link in RC moment resisting frame. The prime reason behind it failure is the inadequate shear strength of the joints, and this is occurred due to the insufficient and inadequate detailed reinforcement in the joint region. Damage must be avoided by using different techniques during construction stages because repairing of damaged joints is very difficult after it appears. Generally column should be stronger then beam in earthquake resisting frame. The behavior of beam column joints are influenced by two major factors like exposure conditions such as exterior and interior and the nature of load coming over the structure – i.e. intensity of earthquake.

i. **Concrete Jacketing**

The joint can be strengthened by placing ties through drilled holes in the beam. But the placement of such ties is difficult.

ii. Steel Jacketing

Steel jacketing helps in transferring moments and acquiring ductility through confinement of the concrete. Steel plating is simpler as compared to steel jacketing, where plates in the form of brackets are attached to the soffits of beams and sides of the column.

iii. FRP Jacketing

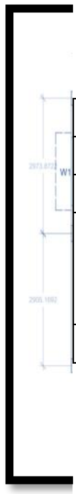
Fibre materials are used to strengthen a variety of reinforced concrete elements to enhance the flexural, shear and axial load carrying capacity of elements. Fibre Reinforced polymer composite (FRPC) materials have been successfully used in the construction of new structures and in rehabilitation of existing structures. FRPCs are non-metallic. Therefore, they are resistant to corrosion. They have high strength to weight ratio. The major constituents of FRP are the fibre and the resin. The commonly used types of FRP are: i) Carbon Fibre Reinforced Polymer (CFRP), ii) Glass Fibre Reinforced Polymer (GFRP)

7. Case Study

An existing G+4 building in Jammu, lies in seismic zone 4 is considered for the purpose of retrofitting. It is a framed structure with total four stories above ground level. The ground level is an open storey which is utilized as parking. It can be a soft storey. This building is designed for the dead and the live loads only. Thus, two main problems are identified in this building with respect to the seismicity of the building. First, the Earthquake load was not considered for the design. Secondly, no provisions have been made up for the existing soft storey. So, ground storey needs to be given special attention.

Details of Building

Grade of concrete	: M20
Grade of reinforcing steel	: HYSD Fe415
Thickness of slab	: 150mm
Thickness of External Wall	: 230mm
Height of bottom story	: 3m
Height of remaining story	: 3m
Live load	: 3KN/m^2
Density of concrete	: 25 KN/m^2
Seismic zone	: Zone 4
Seismic Coefficient	: 0.24
Basic wind speed	: 39 m/s



Member	Size	Position
Beam	350mmX300mm	Throughout
Column	300mmX250mm	C1, C4, C9
Column	350mmX250mm	C2, C3, C5, C8, C10, C11, C12
Column	400mmX250mm	C6, C7

7. Result and Discussion

Analysis of different methods of retrofitting

In this chapter different method of seismic retrofitting is analysed on G+4 building. The method choosen for this study of seismic retrofitting were the – Bracing system, Shear wall, Concrete jacketing and Fluid Viscous Dampers. These methods were then analyzed on the basis of storey displacement and storey drift against the seismic condition of the building. And later, all these methods were then altogether analyzed by comparing it with each other to know which method stands best for displacement and drift.

A. Storey Displacement

Story displacement is defined as total displacement of any storey with respect to ground.

i. Steel Bracing

Graph below (Fig.1) shows storey v/s displacement for building with steel bracing and without building without retrofit; it was observed that the building with bracing system shows less displacement with respect to without retrofitted building.

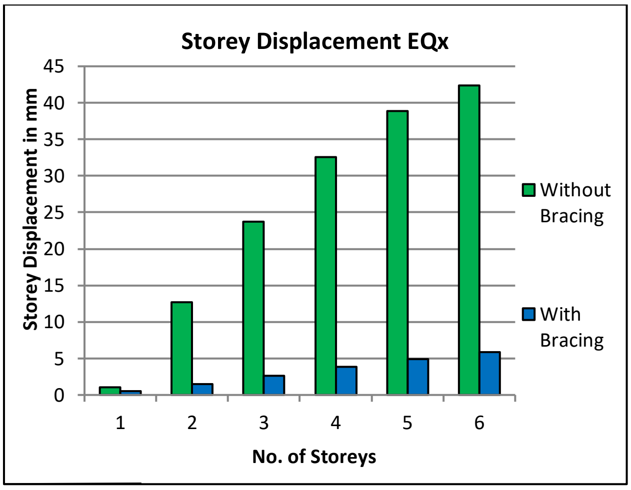


Fig.1 No. of Storey v/s Storey displacement for Steel Bracing

ii. Shear wall

Graph below (Fig.2) shows storey v/s displacement for building with shear wall and building without retrofit, it was observed that the building with shear wall shows less displacement with respect to without retrofitted building.

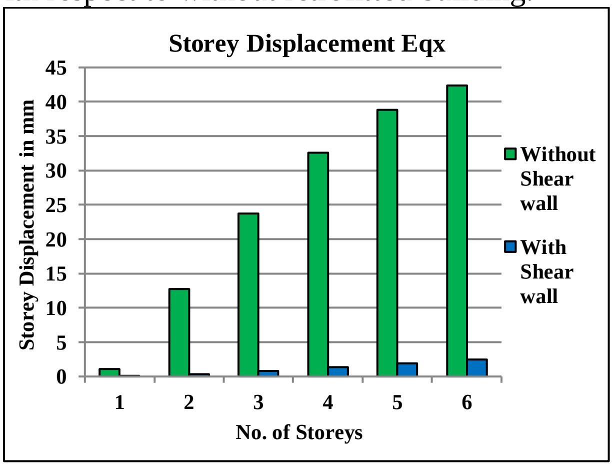


Fig.2 No. of Storey v/s Storey displacement for Concrete Shear wall

iii. Jacketing

Graph below (Fig.4.3) shows storey v/s displacement for building with concrete jacketing and building without retrofit, it was observed that the building with concrete jacketing shows less displacement with respect to without retrofitted building.

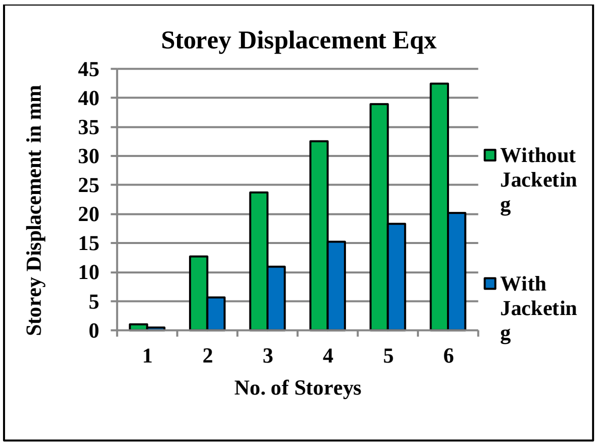


Fig.4.3 No. of Storey v/s Storey displacement for Concrete Jacketing

iv. Dampers

Graph below (Fig.4) shows storey v/s displacement for building with fluid viscous dampers and building without retrofit, it was observed that the building with fluid viscous dampers shows less displacement with respect to without retrofitted building.

Fig.4 No. of storey v/s Storey Displacement for Fluid viscous dampers

B. Storey Drift

It is defined as ratio of displacement of two consecutive floors to height of that floor.

i. Steel bracing

Graph below (Fig.5) shows storey v/s d for building with steel bracing and without building without retrofit; it was observed that the building with bracing system shows less drift with respect to without retrofitted building.

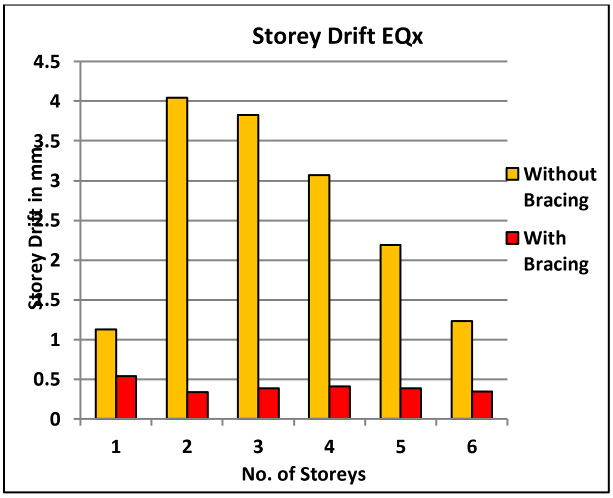


Fig.5 No. of Storey v/s Storey Drift for Steel Bracing

ii. Shear wall

Graph below (Fig.6) shows storey v/s drift for building with shear wall and building without retrofit, it was observed that the building with shear wall shows less drift with respect to without retrofitted building.

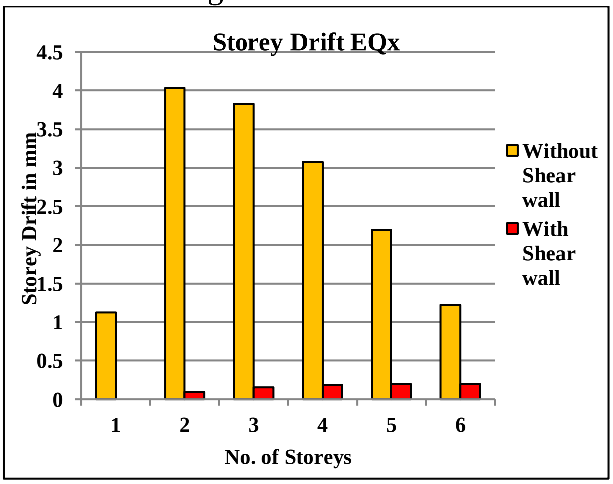


Fig.6 No. of Storey v/s Storey Drift for Concrete Shear Wall

iii. Jacketing

Graph below (Fig.7) shows storey v/s drift for building with concrete jacketing and building without retrofit, it was observed that the building with jacketing shows less drift with respect to without retrofitted building.

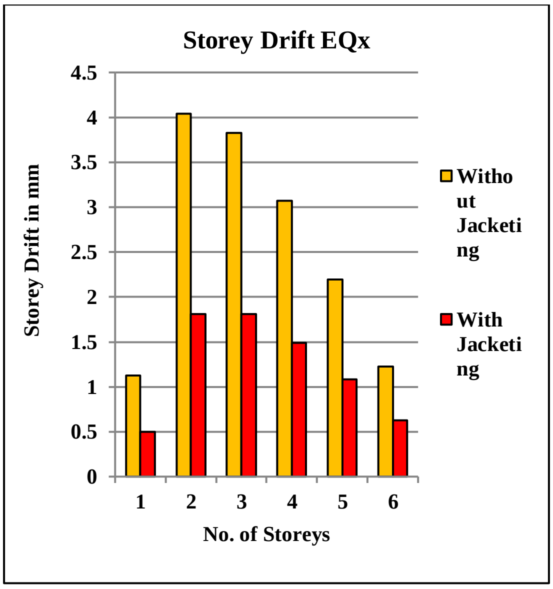


Fig.7 No. of Storey v/s Storey Drift for Concrete Jacketing

iv. Dampers

Graph below (Fig.8) shows storey v/s drift for building with fluid viscous damper and building without retrofit, it was observed that the building with fluid viscous dampers shows less drift with respect to without retrofitted building.

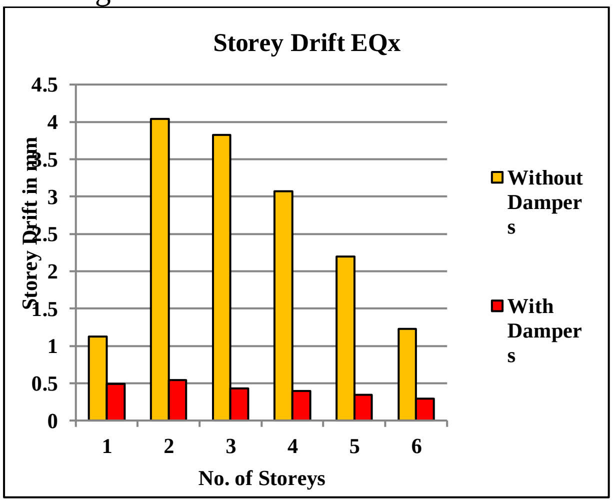


Fig.8 No. of Storey v/s Storey Drift for Fluid Viscous Damper

8. Conclusion

This project work was a small effort towards introducing the different seismic retrofitting methods like steel bracing, shear wall, jacketing etc. in a building that can make the existing building earthquakes resistant which may be made with old codal provision or by jus considering dead load and live load or the members get deteriorated after aging or due to corrosion or other factors. Almost all the buildings in India are RC frame, and earthquake tremors are felt every now a then in some or the other part of the country. 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 building which we considered for retrofication was not designed as earthquake resistant, so by retrofitting it with different seismic retrofitting methods following conclusions were drawn at the end of the study:-

- The structure without retrofit shows more storey displacement and storey drift.
- Different retrofit techniques such as RC column jacketing method, steel bracing and shear wall methods are adopted in this project.
- Adding different method of seismic retrofitting significantly increases the lateral load carrying capacity of the building as well as the ductility.
- After retrofitting storey displacement, storey drifts are reduced.
- Retrofitting technique enhances the axial load and moment carrying capacity in structural members. After retrofitting storey displacement, storey drifts are reduced.
- 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.
- From completing the project, it was concluded that Shear Wall was chosen as the most appropriate technique which enhances the axial load and moment carrying capacity in the structural members.
- From completing the project, it was concluded that seismic retrofitting provides existing structures with more resistance to seismic activity due to earthquakes.

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