ISSN : 2455-9679
Impact Factor : 3.340

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INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"UPGRADING THE SEISMIC RESPONSE OF EXISTING BUILDING FOR ITS STRENGTHENING"

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ABSTRACT

Existing reinforced concrete (RC) frame buildings with non-ductile detailing represent a considerable hazard during earthquakes. This type of buildings suffered severe damages and were responsible for most of the loss of life during the major seismic events. Improving the seismic response of this type of construction can be considered as one of the main concern for structural engineers. Among seismic performance upgrading, there are two techniques are available. They are conventional upgrading techniques and special upgrading techniques. Conventional upgrading techniques do not require special devices or new materials. In special upgrading techniques, a number of recently developed techniques are available which use special devices or new materials, and more are expected to be developed in the future. In this project, existing four storied hostel building consists of G+3 floors with size of 80mx50m were carried out for strengthening purpose. Conventional upgrading techniques are used for retrofitting. Many conventional techniques are recently available; among them are shear walls and steel bracings. Performance of steel bracers and shear walls in the existing building are discussed and suitable retrofitting is suggested for existing R.C. Building.

Keyword: *Reinforced Concrete; earthquake resistant; retrofitting; STAAD Pro; etc.*

I. INTRODUCTION

Many buildings in seismic areas were built before there was an adequate understanding of earthquake resistance. Many of these buildings would be deemed unsafe by current building codes. Also, because code requirements are written for the design of new buildings and not for the evaluation of existing buildings, the cost of upgrading an existing building to the current code can be very large, as well as destructive to its heritage value. A set of alternate procedures for evaluating existing buildings was therefore prepared by NRC and published in the Guidelines for Seismic Evaluation of Existing Buildings.

There are two types of seismic upgrading techniques available. They are

i. Conventional Upgrading Technique.
ii. Special Upgrading Technique.

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Conventional Upgrading Techniques do not require special devices or new materials. Some Basic techniques currently used for seismic upgrading are Adding shear walls, bracings, infill, overlays, strengthening members, strengthening joints, Anchorage/Ties, Chords / Collectors, etc. Special Upgrading Techniques is recently developed techniques are available which use special devices or new materials, and more are expected to be developed in the future. Some Basic techniques currently used for seismic upgrading are Supplementary Damping, Base Isolation, FRP / FRC Overlays or Encasing.

In this project, existing hostel (G+3) building designed and constructed for gravity loadings were taken analyzed for seismic loadings and find the amount of deficiency present in the building and depends upon the deficiency, shear walls and steel bracers are provided in required places then analysis and design were carried out and results are compared and tabulated. Software package used for analysis of models is STADD Pro.

Consequent up on revision of IS:1893 Criteria for earthquake resistant design of structures in year 2002 and introduction of IS:13920 Ductile detailing of reinforced concrete structures subjected to seismic forces in year 1993 a paradigm shift has taken place in the design of structures for earthquake resistance. However, many buildings of medium height, say up to six storeys, are not designed in adherence to these codes. Therefore this project proposes to undertake the evaluation of an existing building for its earthquake resistance as per the current codes.

II. LITERATURE REVIEW

Gaetano Della Corte et al (2008) presented the significant improvement to the seismic response of RC structures equipped with dissipative bracing systems, such as eccentric braces (EBs) and buckling restrained braces (BRBs). In fact, the results of experimental tests carried out on two similar two-storey one-bay RC structures, respectively equipped with EBs and BRBs, are described. Referring to EBs, 3 lateral loading tests have been performed. Each test is characterized by shear links with bolted end-plate connections. Different design criteria have been applied in the design of the connections. In the first test, capacity design criteria have not been considered. In the second test, a capacity design criterion has been applied, with a link shear over-strength factor equal to 1.5. In the third test, a design criterion similar to the one adopted for the second test has been implemented, but with a larger over-strength factor. In case of BRBs, two types of „only-steel‟ braces have been tested: one type was made using two buckling- restraining rectangular tubes that are fully welded together with steel plates; the other type is detachable, being made again with two buckling-restraining rectangular tubes but joined together by means of bolted steel connections. In both cases, the internal yielding core was a rectangular steel plate. The experimental results of both bracing systems are encouraging about the possibility to use these devices for improving the seismic resistance of existing RC structures.

Vishwanath et al (2010) investigated the seismic performance of reinforced concrete buildings rehabilitated using concentric steel bracing. A four storey building is analysed for seismic zone IV as per IS 1893: 2002 using STAAD Pro software. The effectiveness of various types of steel bracing in rehabilitating a four storey building is examined. The effect of the distribution of the steel bracing along the height of the RC frame on the seismic performance of the rehabilitated building is studied. The performance of the building is evaluated in terms of global and story drifts. The study is extended to eight storied, twelve storied and sixteen storied building. The percentage reduction in lateral displacement is found out. It is found that the X type of steel bracing significantly contributes to the structural stiffness and reduces the maximum inter storey drift of frames.

Hasan Kaplan et al (2011) has studied an new strengthening alternative for RC structures, namely exterior shear walls, has been experimentally investigated under reversed cyclic loading. Using the proposed technique, it is possible to strengthen structures without disturbing their users or vacating the building during renovation. In this technique, shear walls are installed in parallel to the building's exterior sides. It has been observed that the usage of exterior shear walls considerably improve the capacity and sway stiffness of RC structures. The experimental results have also been compared and found to be in agreement with the numerical solutions. Post attached exterior shear walls behaved as a monolithic member of the structure. Design considerations for the exterior shear wall- strengthened buildings have also been discussed in the paper.

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Hamdy Abou-Elfath et al. (2016), this study evaluates the seismic upgrading of a 6-story RC-building using single diagonal buckling restrained braces. Seismic evaluation in this study has been carried out by static pushover analysis and time history earthquake analysis. Ten ground motions with different PGA levels are used in the analysis. The mean plus one standard deviation values of the roof-drift ratio, the maximum story drift ratio, the brace ductility factors and the member strain responses are used as the basis for the seismic performance evaluations. The results obtained in this study indicate that strengthening of RC buildings with buckling restrained braces is an efficient technique as it significantly increases the PGA capacity of the RC buildings. The results also indicate the increase in the PGA capacity of the RC building with the increase in the amount of the braces.

III. SEISMIC RETROFITTING

3.1 General:

The configuration of any building, which is adequate enough for resisting gravity loads may nit be suitable for resisting earthquake forces. It is hence important to identify the exact deficiencies in a building before retrofitting it. The deficiencies in any can be broadly classified in two classes:

a) Global deficiency
b) Local deficiency

When a building has deficiencies that have been accounted for in the structural design, it needs retrofit. The different retrofit strategies can be grouped under global retrofit strategies or local strategies. A global retrofit strategy targets the performance of the building as a whole under lateral loads.

3.2. Goals of Retrofitting:

The goals of seismic retrofitting of a building can be summarized as follows:

a) Giving unity to the structure.
b) Eliminating sources of weakness or features that produce concentration of stresses in members.
c) Enhancing the redundancy of the lateral load resisting systems, thereby eliminating the possibility of progressive collapse.
d) Increasing the lateral strength and stiffness of the building.
e) Increasing the ductility (energy absorption) and damping (energy dissipation). Avoiding the possibility of brittle nodes of failure.
f) The retrofit scheme should be cost effective should consistently and reliably the intended performance objective.

- **GLOBAL DEFICIENCIES:**

Global deficiencies are the attributes that degrade the lateral load resisting mechanism of a building subjected to an earthquake. Some of the deficiencies are caused by "irregularities" in the structural configuration. The irregularities are broadly classified as plan irregularities and vertical irregularities.

1. **Plan irregularities**: The various plan irregularities are as follows:

a) Torsional Irregularity
b) Diaphragm Discontinuity
c) Out-of-Plan Offsets
d) Non-Parallel System

2. **Vertical Irregularities:** The various vertical irregularities are as follows-

a) Stiffness Irregularity
b) Mass Irregularities
c) Vertical Geometric Irregularity
d) In-Plane Discontinuity
e) Strength Irregularity

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- LOCAL DEFICIENCIES:

Local deficiencies arise due to improper design, faulty detailing, poor construction and poor quality of materials. These lead to the failure of individual members of the building such as flexural and shear failure of beams, columns and shear walls, crushing or diagonal cracking of masonry walls and failure of beam-column joints or slab-beam or slab-column connections.

3.3 Retrofitting Strategies:

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.

A global retrofit strategy targets the performance of the entire building under lateral loads. A local retrofit strategy targets the resistance of members against seismic forces without affecting the total resistance of the building. The local and global retrofitting strategies should be combined looked for feasibility and economically.

3.4 Global Retrofitting Strategies:

When A Building Is Found To Be Severely Deficient For The Design Seismic Forces, The First Step In Seismic Retrofit Is To Strengthen And Stiffen The Structure By Providing Additional Lateral Load Resisting Elements.

1. Addition Of Infill Walls: The Lateral Stiffness Of A Storey Increases With Infill Walls. Addition Of Infill Walls In The Ground Storey Is A Viable Option To Retrofit Building With Open Ground Storeys.

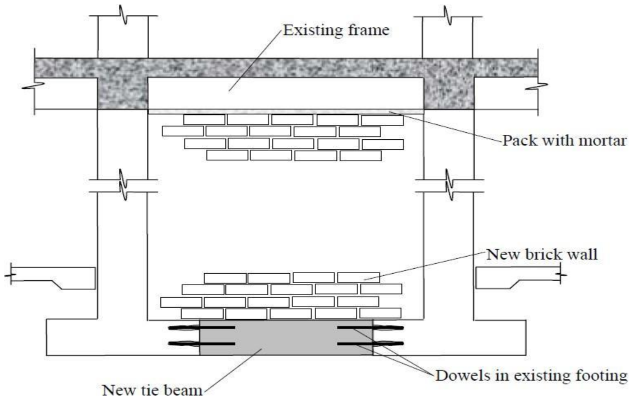

Figure 1: Addition Of Infill Walls

2. Addition Of Shear Walls Or Wing Walls Or Buttress Walls: Shear Walls, Wing Walls Or Buttress Are Added To Increase Lateral Strength And Stiffness Of A Building. The Shear Walls Are Effective In Buildings With Flat Slabs Or Flat Plates. The Shear Walls Are Generally Placed Within Bounding Columns, Adjacent To Columns.

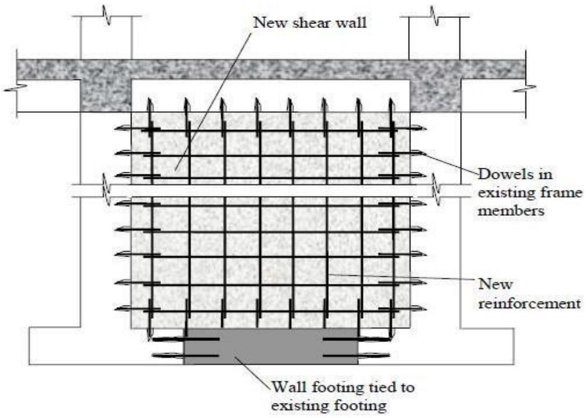

Figure 2: Additions Of Shear Walls

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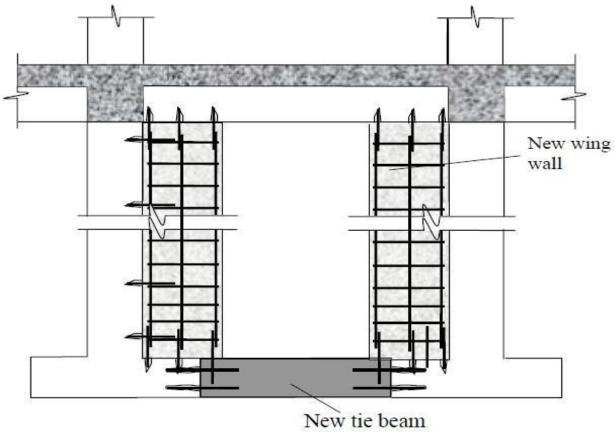

Figure 3: Additions Of Wing Walls

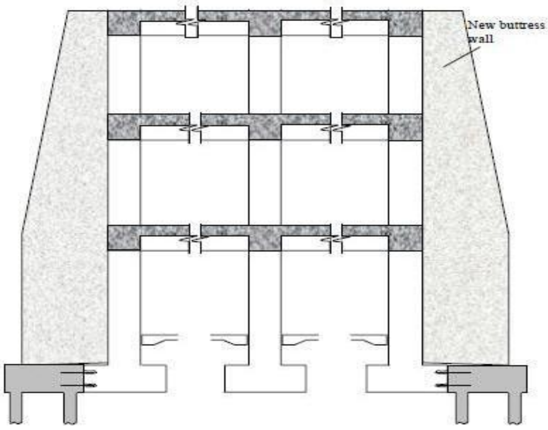

Figure 4: Addition Of Buttress Walls

3. Addition of steel braces: the steel bracing inserted in a frame provides lateral stiffness, strength, ductility, hysteretic energy dissipation, or any combination of these. The braces are effective for relatively more flexible frames, such as those without infill walls.

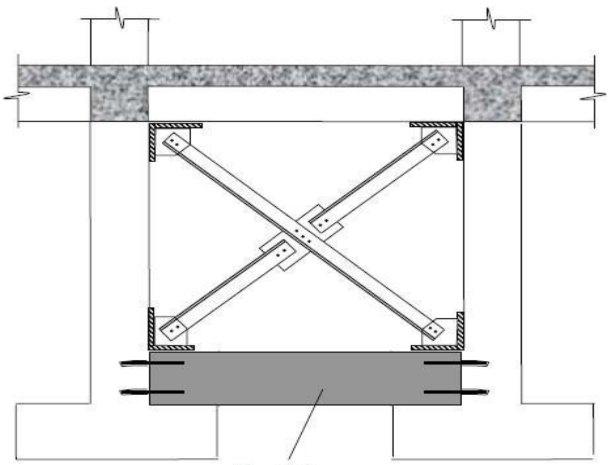

Figure 5: Addition Of Steel Bracers

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3.5 Local Retrofitting Strategies:

Local retrofit strategies pertain to retrofitting of columns, beams, joints, slabs, walls and foundations. The local retrofit strategies are categorized according to the retrofitted elements. The local retrofit strategies fall under two categories:

1. Column retrofitting
2. Beam retrofitting

1. Column retrofitting:

The columns are retrofitted to increase their flexural and shear strengths, to increase the deformation capacity near the beam- column joints and to strengthen the regions of faulty splicing of longitudinal bars. For column strengthening: - concrete jacketing, steel jacketing and fibre reinforced polymer sheet wrapping is carried out.

a) Concrete jacketing:

It involves adding a concrete layer, longitudinal bars and closely spaced ties. The jacket increases the both flexural strength and shear strength of the column.

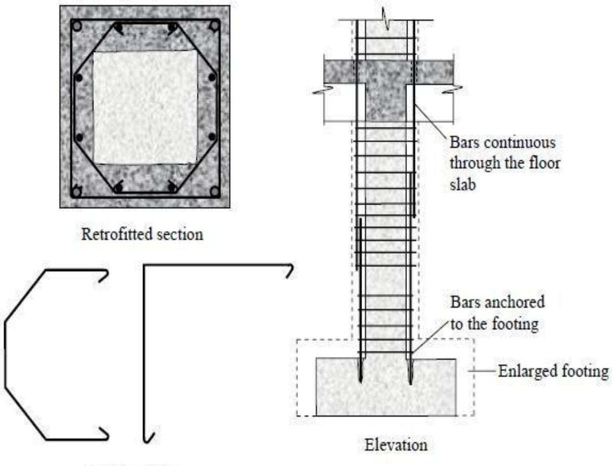

Figure 6: Concrete Jacketing Of Column

b) Steel jacketing:

Steel jacketing includes encasing the columns with steel plates and filling the gap with non-shrink grout. The jacketing is effective to remedy inadequate shear strength and provide passive confinement to the column.

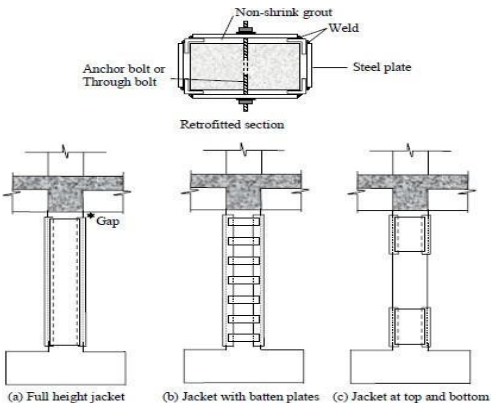

Figure 7: Steel Jacketing Of Column

c) Fiber reinforced polymer sheet wrapping :Fiber reinforced polymer shows all the desirable physical properties such as high tensile strength, strength to weight ratio and corrosion resistance. The FRP sheets are

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very thin, light in weight and flexible such that they can be inserted behind pipes and other service ducts, thus facilitating installation.

The use of FRP sheets in retrofitting of any column increases its ductility due to confinement without noticeable increase in the size. The main drawbacks of FRP are the high cost, brittle behavior and inadequate fire resistance.

2. Beam retrofitting:

The beams are retrofitted to increase their positive flexural strength, shear strength and the deformation capacity near the beam-column joints. The lack of adequate bottom bars and their anchorage at the joints needs to be addressed. For column strengthening: - concrete jacketing, steel jacketing and fiber reinforced polymer sheet wrapping, use of frp bars.

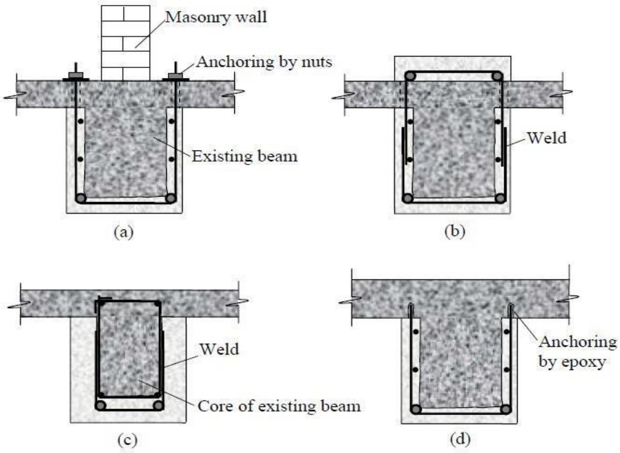

Figure 8: Concrete Jacketing Of Beam

3.6 Analytical Investigation

Existing hostel building with an area of 4000 sq.m having length of 80 m and width of 50 m in Chennai were analyzed and designed for gravity loading.

The materials used in the existing R.C. building are concrete grade used for columns and beams are m25, grade of steel used is fe415, safe bearing capacity taken for soil is 200kn/m2. Column and beams reinforcements are detailed according to is456- 2000.

Load Combinations:

According to the commands of STAAD pro the 1893 loads were defined and as per is1893:2002 from table 8 the percentage of imposed load is considered to be 25%.

Load Combinations Used In Limit State Of Serviceability Are	Load Combinations Used In Limit State Of Collapse Are
➢ COMB 1 = 1.0 (DL+LL) ➢ COMB 2 = 1.0 (DL+EQX) ➢ COMB 3 = 1.0 (DL+EQZ) ➢ COMB 4 = 1.0 (DL-EQX) ➢ COMB 5 = 1.0 (DL-EQZ) ➢ COMB 6 =	➢ COMB 1 = 1.5 (DL+LL) ➢ COMB 2 = 1.5 (DL+EQX) ➢ COMB 3 = 1.5 (DL+EQZ) ➢ COMB 4 = 1.5 (DL-EQX) ➢ COMB 5 = 1.5 (DL-EQZ) ➢ COMB 6 = 1.2

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1.0DL+0.8LL+0.8 EQX ➢ COMB 7 = 1.0DL+0.8LL+0.8 EQZ ➢ COMB 8 = 1.0DL+0.8LL-0.8EQX ➢ COMB 9 = 1.0DL+0.8LL-0.8EQZ ➢ COMB 10 = 1.0 (DL+EQX) ➢ COMB 11 = 1.0 (DL+EQZ) ➢ COMB 12 = 1.0 (DL-EQX) ➢ COMB 13 = 1.0 (DL-EQZ)	(DL+LL+EQX) ➢ COMB 7 = 1.2 (DL+LL+EQZ) ➢ COMB 8 = 1.2 (DL+LL-EQX) ➢ COMB 9 = 1.2 (DL+LL-EQZ) ➢ COMB 10 = 0.9 (DL+1.5EQX) ➢ COMB 11 = 0.9 (DL+1.5EQZ) ➢ COMB 12 = 0.9 (DL-1.5EQX) ➢ COMB 13 = 0.9 (DL-1.5EQZ)

3.7 Building with Steel Braces:

Steel bracers are used in the model of existing building to reduce the deflection and increase the stiffness of the building for seismic loading. Steel bracers are introduced in between columns in required position where the stiffness and stability of the building increases.

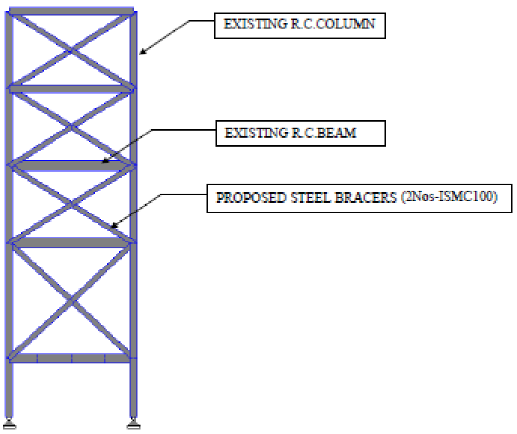

Figure 9: Typical Modelling Of Steel Bracers In R. C. Building

3.7 Building with Shear Walls:

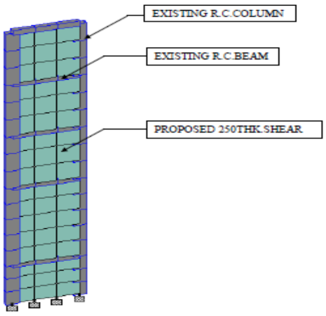

Figure 10: Typical Modelling Of Shear Walls In R. C. Building

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IV. RESEARCH METHODOLOGY

The methodology applied for upgrading of an existing building has been followed as:

- Identification of building which is lacking in the seismic requirements.
- Collection of structural drawings of the building and studying them.
- Learning STAAD Pro software in the context of dynamic analysis.
- 3-D modelling of the existing building and analyzing the model for seismic loading and designing as per IS: 1893-2002, quantifying the amount of deficiency present in the existing building to satisfy IS1893-2002.
- Introducing steel bracers in the separate model and analysis and design are carried out and results are tabulated.
- Introducing the shear walls in the separate model and analysis and design are carried out and results are tabulated.
- Comparing the existing structural provision with required additional provision as per current code and recommending suitable retrofitting techniques.

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V. RESULTS AND DISCUSSION

5.1 Displacement Comparisons:

Table 1: Displacement of Existing Building for Seismic Loading

LOAD CASE	X-Direction (mm)	Y-Direction (mm)	Z-Direction (mm)
1.5(DL+EQX)	141.8	-2.5	44.06
0.9DL+1.5EQZ	31.58	12.7	35.287
1.5(DL-EQZ)	-74.233	-2.077	-105.411

Table 2: Displacement of Existing Building with Steel Bracers

LOAD CASE	X-Direction (mm)	Y-Direction (mm)	Z-Direction (mm)
1.5(DL+EQX)	141.8	-2.5	44.06
0.9DL+1.5EQZ	31.58	12.7	35.287
1.5(DL-EQZ)	-74.233	-2.077	-105.411

Table 3: Displacement of Existing Building with Shear Walls

LOAD CASE	X-Direction (mm)	Y-Direction (mm)	Z-Direction (mm)
1.5(DL+EQX)	60.637	-3.184	14.46
0.9DL+1.5EQZ	4.235	8.089	24.662
1.5(DL-EQZ)	-26.37	-3.346	-25.23

5.2 Base Shear Comparisons:

Table 4: Comparison of Base Shears

Model Type	Base Shear Calculated using Fundamental Natural period	Design base shear from STAAD model
Model-1	11783 kN	11090 kN
Model-2	11783 kN	11762 kN
Model-3	11783 kN	11037 kN

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VI. CONCLUSIONS

The performance of the existing building were analyzed for existing building and the same building were analyzed by introducing steel bracers as well as shear walls. The following are the observations getting, they are:

- Shear walls are attracting more lateral forces when compare to steel bracers.
- The performance of shear walls in irregular buildings are effectively high when compare to the steel bracers.
- In the deflection criteria of the building also the performance of the shear walls are comparatively giving better result when compare to steel bracers.
- In the case of steel bracers 50% of the columns are safe under seismic loading but in the case of shear walls all the columns are safe under seismic loading.

The retrofitting proposal using shear wall is given in figure:

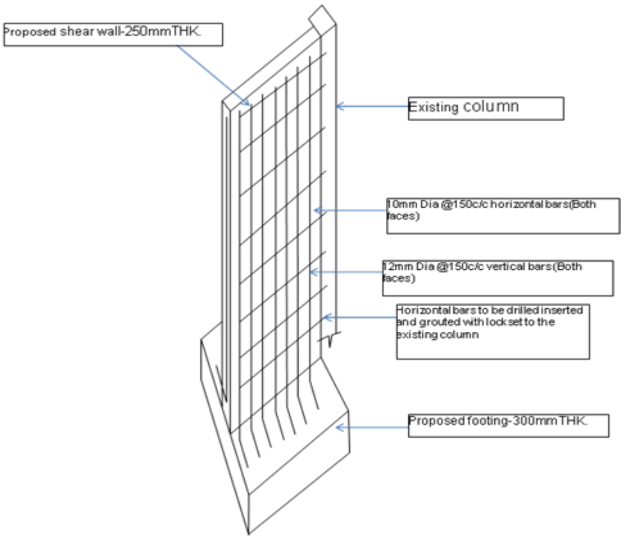

Figure 11: Retrofitting Proposal Using Shear Wall

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