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# Pounding Effect Control in Existing Building by Adding Shear Wall

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***ABSTRACT:*** *Nepal is located in high seismic zone but in Nepal before the Gorkha earthquake 2015 most of the buildings were not designs with proper seismic guidelines. Hence the Existing structures in Nepal are required to be designed for controlling pounding effect between two adjacent buildings and constructed to resist earthquake. In this project at first a site visit of two existing Hospital Building was done, with the help of non-destructive test (NDT) the number of reinforcements and quality of the structure was identified, after that they are modelled and designed by adding shear wall in existing building and its pounding effect is checked as per IS1893:2002/16. The seismic analysis is performed by a Response spectrum method using an FEM software ETABS. After introducing curtailed shear wall the deflection and reinforcements are compared with the existing building model.The results indicated that shear wall method reduces the deflection and reinforcement requirement of Existing Building.*
***KEYWORDS:*** *Pounding Effect and shear wall, ETABS, Response Spectrum Methodand NDT Test.*
*Abbreviations: FEM, Finite Element Method;m, Meter; mm, Millimeter; 3D-ThreeDimensional; 2D, Two Dimensional; NBC Code:IS, Indian Standard; kN, Kilo Newton.*

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## I. INTRODUCTION

Shear walls are used to transfer the vertical loads produced by both, dead and live loads to substructure. Shear walls also enhances ductility and controls lateral drift that prevent the undesirable brittle failure against the strong lateral loads, especially during an earthquake. The thickness of shear wall varies from 140 to 500mm. shear wall has dual role resisting i.e on the both lateral and gravity load. It should be provided in parallel way in plan of the structure.

According to IS 1893:2016 if there are two adjacent building with same height then they should be separated by proper separation joint. The separation join t between them should be multiply by R time with sum of calculated storey displacement but if the height of two adjacent building is different then the value of R should be replaced by R/2.

*1.1. Objectives*

i. To assess the structural deficiencies in the existing buildings.
ii. To examine the seismic performance of the existing building by Response Spectrum analysis.
iii. Application of curtailed shear wall retrofitting techniques to overcome the deficiency (pounding effect as well as lateral storey drift) of existing building.

## II. LITERATURE REVIEW

Here a review of the previous works was carried out to know the structural behavior of RCC buildings with the presence of shear walls. The literature review focuses on areas related to pushover analysis of shear wall structures.

*2.1. Shear Wall Structure*

Smith and Coull (1991) expressed that the shear divider structure is viewed as one whose protection from even stacking is given totally by shear dividers. They may go about as a vertical cantilever as discrete organizer dividers and as non-organizer collects of associated dividers around lift, step and administration shaft. Shear dividers have been the most widely recognized basic components utilized for balancing out the structure structures against horizontal powers. Their high in-plane firmness and quality makes them obviously appropriate for supporting tall structures. The convenience of shear dividers in confining of structures has for quite some time been perceived. Dividers arranged in invaluable situations in a structure can frame a productive horizontal power opposing framework, at the same time satisfying other utilitarian necessities. At the point when a perpetual and comparable region of floor territories in all accounts is required as on account of lodgings or high rises, various shear dividers can be used for horizontal power opposition as well as to convey gravity loads. In such case, the floor by floor monotonous arranging permits the dividers to be vertically consistent which may serve at the same time as great acoustic and fire protectors between the condos. Shear dividers might be planar yet are regularly of L-, T-, I-, or U-molded segment to all the more likely suit the arranging and to build their flexural firmness.

Paulay and Priestley (1992) stated that in the building the shear wall position was dictated by functional requirements .The motivation behind a structure and resulting distribution of floor space may direct required courses of action of dividers that can frequently be promptly used for parallel power obstruction. Building destinations, design interests or customer's longing may lead the places of dividers that are unfortunate from a basic perspective.

Md. Samdani Azad et al. (2016) have performed a comparative study of seismic analysis of multi-storey buildings with shear walls and bracing systems. This paper contained a numerical approach to show dissimilarity between the shear wall system and steel bracing system. The new approach of this research was strengthening lateral force resisting system by using steel bracing. A gradual process has been done step by step to show comprehensible contrasts between the systems. For implicit results, East Malaysia has considered as the corresponding region. The overall analysis has been carried out using the ETABS9.7 software. Six models have prepared for the comparative study. The First model was having a shear wall at a middle portion, second model was having a shear wall at a side portion, third model was having bracing at a centre, fourth model was having bracing at a side, the fifth model was having floor bracing at middle and sixth model was having floor bracing at a side. It has been concluded from the results that model one was the safest among the six models.

## III. METHODOLOGY

The report provides a case study of an existing Hospital Building (Nepal Medical College) located at Kathmandu (Fig. 6.1), Nepal built in 1993. The hospital building is an irregular (X, Y and also Z directions) with six-storey, having three blocks with one basement located in Zone V of Nepal. The adjacent block is located very close to the building with distance between the blocks not as per the seismic requirement of ponding effect during earthquake. It was suggested to retrofit the Hospital building to resist pounding effect as well as lateral storey drift.

Hence, the concept of curtailed shear wall is used to retrofit the building. Response Spectrum analysis was used to examine the seismic performance of the existing building.

### *3.1. Building Description*

The building detailsis shown in Table 1.

**Table 1: Details of Model**

| | |
|---|---|
| **Architectural Features** | |
| Type of Building | Hospital Building |
| Location | Jorpati, Kathmandu |
| Plinth Area | About 1705.60Sqm |
| Floor Area | About 1705.60 sqm First Floor, Second Up to Top |
| Height of Storey | 3.6 m |
| Total Height of the Building :- | 27.4m(block A),28.8(block B& block D),25.2(block C) |
| Wall and Partition :- | Masonry Walls |
| **Structural Features:** | |
| Structural System :- | RCC Frame Structure |
| Foundation Type :- | Raft Foundation |
| Columns :- | Refer to the Structural Drawings |
| Beams :- | Main Beam: Rectangular 400mmX550mm |
| Slab | 140 mm |
| **Geotechnical Features: as per NBC 105:1994** | |
| Type of soil | Loose Soil (Soil type – III) |
| Seismic zone | V (as per IS 1893:2002, part-1) |
| Allowable bearing capacity | 117KN/m2 (Minimum considered as per the Geotechnical report) |
| Subgrade Modulus | 90000KN/m3 (For 50mm Settlement) |
| Mat Thickness | 900mm |

| | |
|---|---|
| **Material Properties:** | |
| Grade of concrete | M-20 Grade of Concrete for all the Structural Members |
| Grade of steel | Fe-500 (elongation >14.5%) |
| Unit weight of concrete | 25 kN/m3 |
| Young's Modulus of Elasticity, Ec | 5000 √fck |
| Modulus of elasticity for Steel, Es | 200 KN/mm2 |
| Poisson's Ratio | 0.20 for concrete and 0.3 for rebar |
| **Cover to Reinforcement:** | |
| Footings (Bottom, and Top) | 50mm |
| Footing (Sides) | 75mm |
| Columns | 40mm |
| Beams | 25mm or bar diameter whichever is greater |
| Slabs | 20mm or bar diameter whichever is greater |
| Stairs (Waist Slab/Folded) | 20mm |
| Water Tank walls and Slab | 30mm |

The front view of Existing six storey Hospital Buildingis shown in Figure 1. The floor plan of the building is shown in Figure 2. Figure 3 shows the Structural Plan of Building with Beam-Column Layout. Figure 4 shows the building sectional elevation.

**Fig.1**.Front View of Existing Six Storey Hospital Building

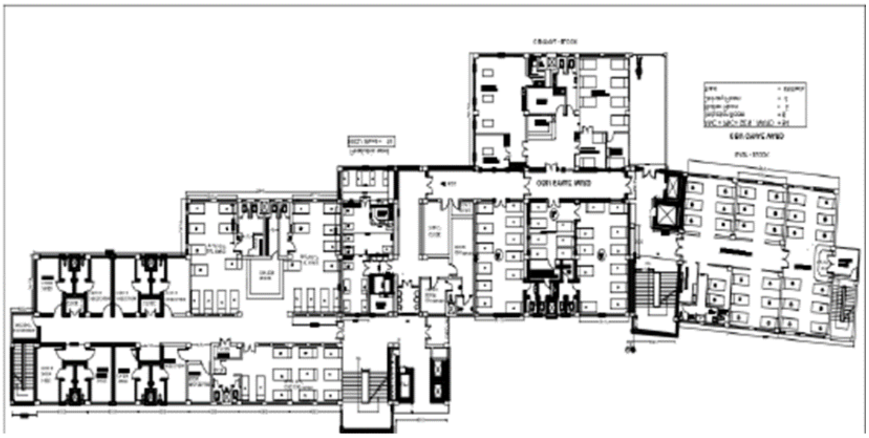
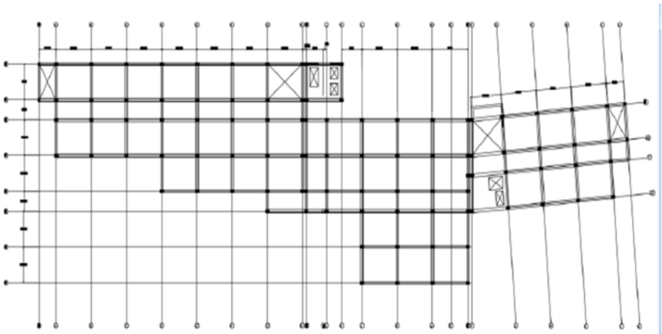


**Fig.2.**Architecture Plan of Building



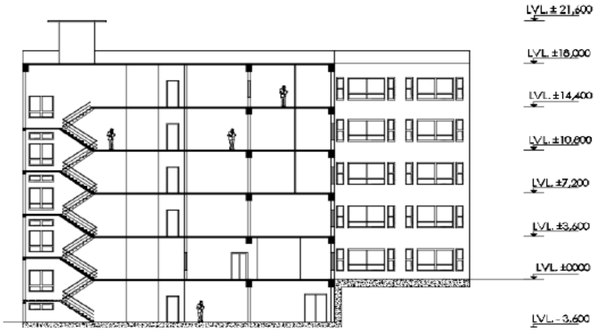
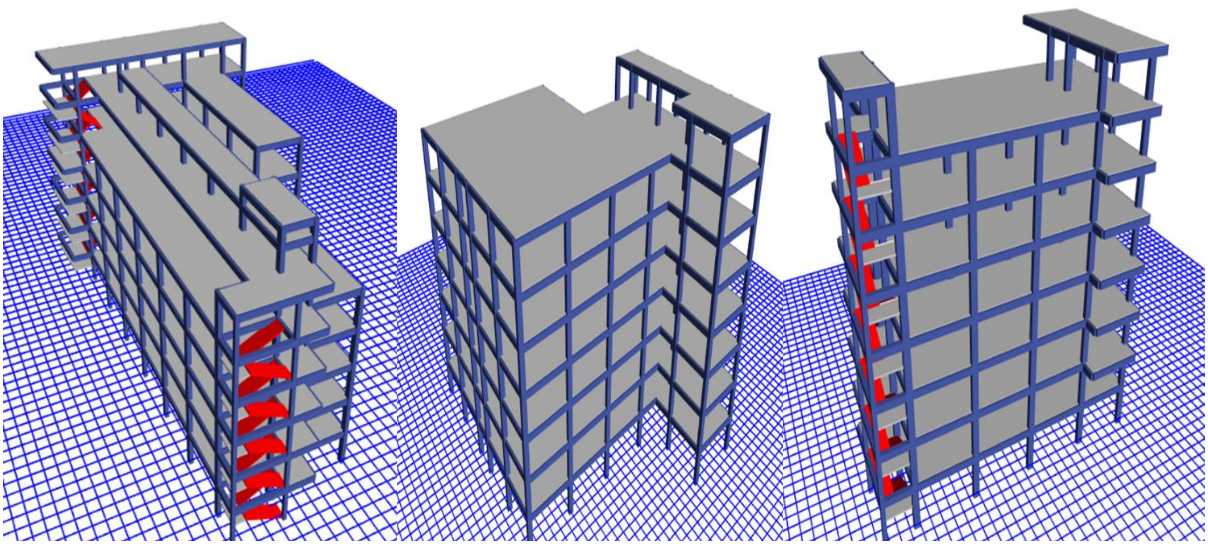



**Fig 3**: Structural Plan of Building with Beam-Column Layout **Fig 4**: Building Section Elevation

*3.2. Modeling and Analysis*

The original drawings of Building and the adjacent buildings were collected from the Trust Office. Multiple site visits were made to observe exposed conditions of the building configuration, building components, site and foundation, position of adjacent structures etc., to verify that the as-built information was representative of the existing conditions. Since no original material compliance certificates were available for this building, a comprehensive material testing program was performed.

With used of ETABS (CSI 2016), a three-dimensional mathematical model of the existing building, as shown in figure 6 was prepared. Response Spectrum Analysis method was adopted to analyze building. Structural 3-D Modelling of Existing building without Shear wall is shown in figure 5.



Block A. Block B. Block C.

**Fig.5.** Structural 3-D Modelling of Existing building without Shear wall

*3.3. Loading*

For the analysis of the building, all the loadings (dead loads and live loads) are calculated based on different parts of IS 875:1987 (NBC has been used wherever applicable).

**Dead Load (DL)** - These are the permanent load which is not supposed to change during the structure's design life. The unit weight of materials are as follows:
Steel: 76.97 $KN/m^3$(7849 $Kg/m^3$)

**Live Load (LL)** - These are the loads that may vary its intensity and/or position during design life. Scale factor for Live load greater than 3$kn/m^2$ is taken as 0.5 and live load less than 3 $kN/m^2$ is taken as 0.25.

**Earthquake Loads (EL)** - Earthquake load has been calculated based on IS 1893 2016(Part 1). Basically, horizontal seismic forces shall be considered for the structures that depend on different parameters.

*3.4. Load Combination*

Different load combinations are generated as per IS 1893 - 2016 (Part 1). Total nine load combinations are used for stress analysis of the structure as follows:
Static Load Combination: 1.5(DL+LL)
Seismic Load Combination:
1.2(DL + LL +EQX / EQY)
1.2(DL + LL - EQX / EQY)
1.5(DL + EQX / EQY)
1.5(DL - EQX/ EQY)
0.9 DL + 1.5(EQX /EQY)
0.9 DL - 1.5(EQX /EQY)

Serviceability Load Combination for displacement check:
(DL + LL + EQX / EQY)
(DL + LL - EQX / EQY)

*3.5. General Evaluation and Retrofit Procedure*

The seismic behavior of building was improved using traditional retrofitting as per the standard procedure. However, corners of the buildings were damaged due to pounding effect. The performance of the building was required to be assessed and remedial measure was required to be provided to prevent further damage during earthquake to enhance the safety requirement of the structure at least for next twenty years. The gap between adjacent blocks was 75 mm only. Various alternatives were thought off as retrofitting procedure, one such being a Prescriptive Code Design approach - a conventional simplified methodology. Subsequently, introduction of shear walls at appropriate location was also tried and compared. Shear wall has provided for optimal result.

Around 50 trials were carried out to decide the positions and size of shear walls which gives minimum eccentricity controlling torsional effect on the building. The main objective of providing Curtailed shear walls is to optimize the cost towards shear wall and also to enhance the efficiency of seismic performance of the structure without compromise in any of the structural and functional requirements, thereby reducing the pounding effect. Location of Shear wall in the Hospital Building Plan is shown in figure 6.

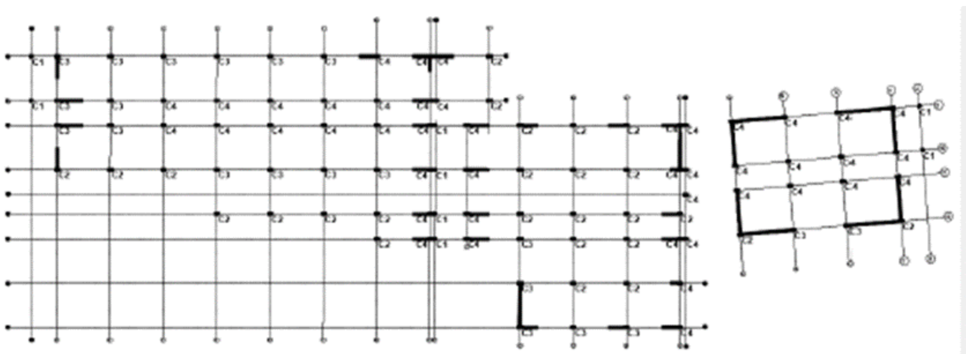
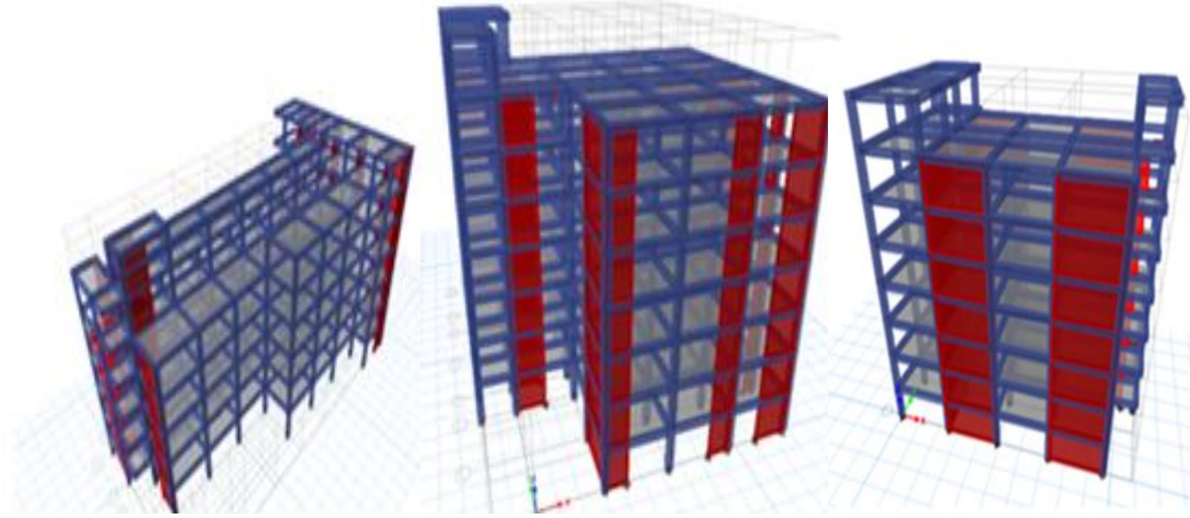


**Fig.6**. Plan of Position of Shear wall in the Hospital Building

The behavior of building before retrofit and after retrofit were analyzed and the results of building were compared to study the seismic performance of the structure with and without of shear walls.Structural 3-D Modelling of Existing building with Shear wall is shown in figure 7.



Block A. Block B. Block C.

**Fig.7**.Structural 3-D Modelling of Existing building with Shear wall

## IV. RESULTS AND DISCUSSION

*4.1. Evaluation and Retrofit*

The deflection and reinforcement demand of the building were assessed in comparison with that of existing structure. A typical result of joint displacement of top floor is shown in the table 2.Representation of displacement before and after retrofitting at the top floor level is NDT Test and Structural Design Comparison Sheet of Column for Hospital Building is shown in table 3.

**Table 2. Joint Displacement Check**

| **BEFORE RETROFIT** | | | |
|---|---|---|---|
| | **BLOCK-A** | **BLOCK-B** | **GAP REQUIRED** |
| The Maximum Displacement in X-Direction | 47.34 mm | 46.882 mm | 236.7mm |
| The 75 mm Seismic Gap has been provided between the Blocks-A & B to Prevent the Seismic Pounding Effect at the time of Earthquake. | | | |
| Required Seismic Gap < Provided Seismic Gap Between the adjacent Blocks, Hence NOT SAFE | | | |
| | | | |
| **AFTER RETROFIT** | | | |
| | **BLOCK-A** | **BLOCK-B** | **GAP REQUIRED** |
| The Maximum Displacement in X-Direction | 13.12 mm | 13.53 mm | 67.65mm |
| The 75 mm Seismic Gap has been Provided between the Blocks-A & B to Prevent the Seismic Pounding Effect at the time of Earthquake. | | | |
| Required Seismic Gap < Provided Seismic Gap Between the adjacent Blocks, Hence SAFE | | | |

**Table 3. NDT Test and Structural Design Comparison Sheet of Column for Hospital Building**

| | | **NDT RESULT** | | | | | **From Structural Drawing** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Column** | **Grid** | **Cross Section (mm)** | | **Rebar Detail** | **Diameter of Stirrup** | **Spacing of Stirrup** | **Rebar Detail** | | | | **Diameter of Stirrup** | **Spacing of Stirrup** | **Area of steel Required** | **Area of steel Provided** | **Condition Check** |
| | | **B** | **D** | **n-Ø mm** | **d** | **s** | **n** | **Ø mm** | **n** | **Ø mm** | **d** | **s** | **mm²** | **mm²** | |
| C1 | H"3 | 400 | 400 | 4-36+ 4-34 | 8 | 106(T&B) and 154(MID) | 4 | 28 | 4 | 25 | 8 | 100(T&B) and 150(MID) | 3605 | 4424.26 | Reinforcement is sufficient |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C4 | G2 | 400 | 600 | 8-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 8 | 28 | 8 | 25 | 8 | 100(T&B) and 150(MID) | 3333 | 8848.52 | |
| C3 | G3 | 400 | 600 | 6-40+ 8-34 | 8 | 106(T&B) and 154(MID) | 6 | 28 | 8 | 25 | 8 | 100(T&B) and 150(MID) | 3140 | 7617.64 | |
| C4 | H3 | 400 | 600 | 8-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 8 | 28 | 8 | 25 | 8 | 100(T&B) and 150(MID) | 2301 | 8848.52 | |
| C4 | H2 | 400 | 600 | 8-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 8 | 28 | 8 | 25 | 8 | 100(T&B) and 150(MID) | 3652 | 8848.52 | |
| C3 | B3 | 400 | 600 | 6-40+ 8-34 | 8 | 106(T&B) and 154(MID) | 6 | 28 | 8 | 25 | 8 | 100(T&B) and 150(MID) | 2148 | 7617.64 | |
| C4 | C3 | 400 | 600 | 8-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 8 | 28 | 8 | 25 | 8 | 100(T&B) and 150(MID) | 2170 | 8848.52 | Reinforcement is sufficient |
| C2 | C4 | 400 | 600 | 4-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 12 | 25 | 0 | 0 | 8 | 100(T&B) and 150(MID) | 3950 | 5887.50 | |
| C2 | D5 | 400 | 600 | 4-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 12 | 25 | 0 | 0 | 8 | 100(T&B) and 150(MID) | 4104 | 5887.50 | |
| C2 | F5 | 400 | 600 | 4-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 12 | 25 | 0 | 0 | 8 | 100(T&B) and 150(MID) | 3616 | 5887.50 | |
| C4 | H4 | 400 | 600 | 8-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 8 | 28 | 8 | 25 | 8 | 100(T&B) and 150(MID) | 2917 | 8848.52 | |
| C3 | G6 | 400 | 600 | 6-40+ 8-34 | 8 | 106(T&B) and 154(MID) | 6 | 28 | 8 | 25 | 8 | 100(T&B) and 150(MID) | 2026 | 7617.64 | |
| C2 | G5 | 400 | 600 | 4-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 12 | 25 | 0 | 0 | 8 | 100(T&B) and 150(MID) | 3486 | 5887.50 | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C4 | H2 | 400 | 600 | 8-36+ 8-34 | 8 | 106(T&B) and 154(MID) | 8 | 28 | 8 | 25 | 8 | 100(T&B) and 150(MID) | 3652 | 8848.52 | |

## V. CONCLUSION

The deflection and reinforcement demand of the building got reduced considerably. This method of seismic retrofitting improves the performance of structure during earthquake. Hence it can be named as an efficient and cost effective strengthening technique for enhancement of seismic performance of the building.

**FUTURE SCOPE**

To control the pounding effect, this present study may not be sufficient .Therefore; there is a need of further investigation on non-linear analysis like pushover analysis and time history analysis in order to control it. Bracing system and friction damper can also be used to control pounding effect.

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**Conflict of Interest:**No conflict of interest as the study is based on the extensive literature review and expert opinion were taken for the analysis.

## REFERENCES

[1]. IS 1893:2002 [Criteria for earthquake resistant design of structure]

[2]. IS 875-1987 (Part 1) Code of practice for design loads (other than earthquake) for buildings and structures-Dead Load, Bureau of Indian Standards, New Delhi.

[3]. IS 875-1987 (Part 2) Code of practice for design loads (other than earthquake) for buildings and structures-Live Load, Bureau of Indian Standards, New Delhi.

[4]. IS 13920-1993 Ductile Detailing of Criteria Reinforced Concrete Structures subjected to Seismic Force.

[5]. Bhatt, A., Titiksh, G., and Rajepandhare, P., (2017). Curtailment of Shear Walls for Medium Rise Structure, International Journal of Control Theory and Applications, 10(6).

[6]. ATC 40(1996). Seismic Evaluation and Retrofit of Concrete Buildings, Applied Technology Council, Redwood City California.

[7]. Keerthi, G.B.S.,Shivananda, S.M., and Shiva K.K., (2014). A Study of Seismic Pounding Effect between adjacent buildings, Proceedings of ACIDIC-2014, 1

Javid Ahmad Bhat, et. al. “Pounding Effect Control in Existing Building by Adding Shear Wall." *International Journal of Engineering Research And Development*, vol. 16(11), 2020, pp 01-08.