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Case Study: Retrofitting of an Existing Residential Building by Using Shear Wall

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Abstract—*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. In this paper, an effort has been made to retrofit an existing residential G+III storied building using exterior shear wall. Shear wall are installed in parallel to the building's exterior sides. This paper deals with the step by step retrofitting of the building by using shear walls with the aid of STAAD ProV8i. This paper incorporates the equivalent static as well as the dynamic method provided in the Indian Standard codes for evaluating the buildings strength and its performance. Applying shear wall to the building has not only strengthened the building but also improved its seismic capacity and stiffness.*

1. INTRODUCTION

In Jammu, most of the residential buildings have been designed only for dead and live loads. Since Jammu (J&K) lies in zone IV, the buildings located in this state needs to be seismic resistant. In this paper, an existing building is considered for the purpose of retrofitting. It is a framed structure with total three stories above ground level. The ground level is an open storey which is utilized as parking. It can be a soft storey. On the roof, there is a water tank too. 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.

2. CASE STUDY

In this paper, an effort has been made to retrofit a G+III storey existing residential building located in Jammu. It is an Ordinary moment resisting Frame structure with masonry infill walls. It has an open ground storey referred to as soft storey. The roof consists of an overhead water tank with a capacity of 2700 LTS. The details of the building are as follows:

The total area of the land = 150.037 m^2

The ground coverage = 73.458 m^2

Total covered area = 293.832 m^2

Parking are =1 NO

Stair head room area= 13.44 m^2

Height of the building= 12.3 m

Main infill walls surrounding the building are 9" thick. These include the external walls and the parapet walls. However, the internal walls are 4.5" thick. Other details are as follows:

Grade of concrete = M20

Grade of steel = Fe415

Height of the Water tank = 1.2 m

2.1 Building Plan

The floor beam, slab, column layout plan has been shown in Fig. 1. The sections at A-A and B-B of the building are shown in Fig. 2 and Fig. 3. Reinforcement detailing of columns has been indicated in table 1.

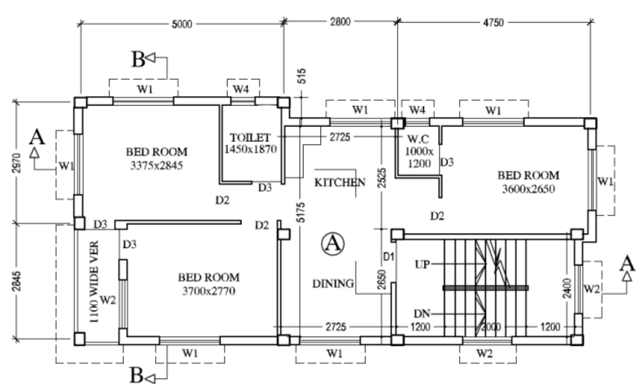

Fig. 1: Floor Beam, Slab, Column Layout Plan

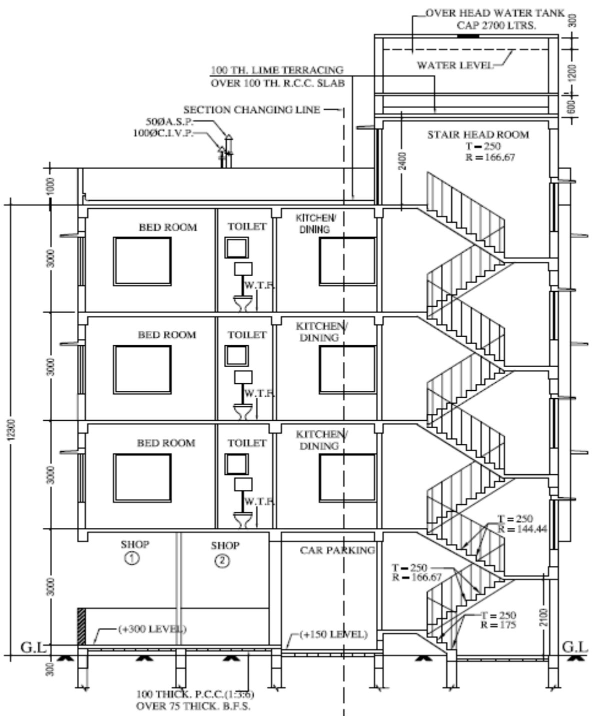

Fig. 2: Section A-A of the Building

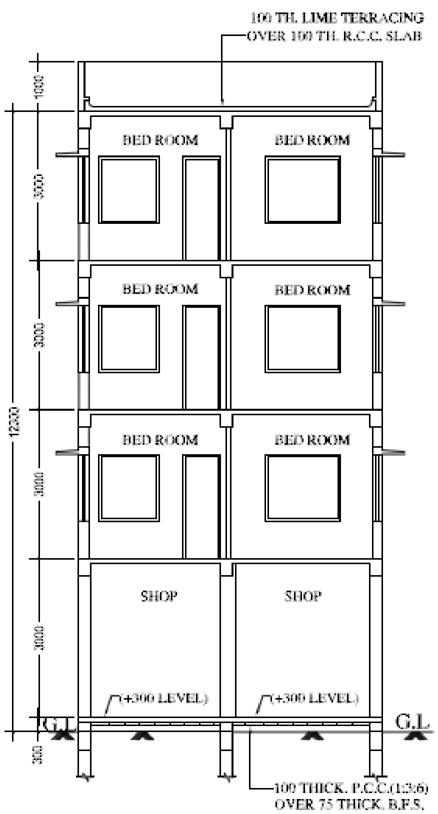

Fig. 3: Section B-B of the Building

Table 1: Cross Section and Reinforcement Detailing of Columns

Column no	Foundation to 1st level		1st to 3rd fl level		Above 3rd fl lvl	
	Size	Reinforce-ment	Size	reinforcement	Size	Reinforce-ment
C1,C4,C9	250X 300	4-16ø + 4-12ø 8ø @150 c/c	250X300	4-16ø 8 ø @ 150 c/c	250X 300	4-16ø 8ø@ 150 c/c
C2,C3,C5,C8,C10,C11,C12	250X350	8-16ø 8ø @ 150 c/c	250X350	8-12ø 8 ø @ 150 c/c	250X350	8-12ø 8ø @ 150 c/c
C6,C7	250X400	8-16ø 8ø@ 150 c/c	250X400	8-12ø 8 ø @150 c/c	250X400	8-12ø 8ø @150 c/c

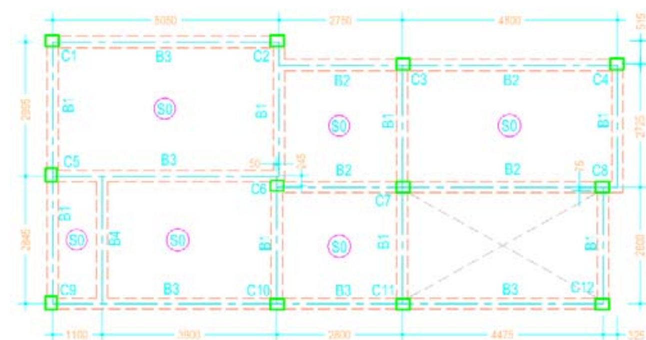

Fig. 4: Floor Beam, Slab, Column Layout Plan indicating column number

3. STRUCTURAL MODELLING AND DESIGN

In this paper, the building is analyzed using STAAD PRO V8i software. Both the static and the dynamic analysis have been done for the existing building. Firstly, Dead and the live loads are found out separately. The unit weights of the material are taken from IS 875: Part 1. The live loads of residential building, accessible and inaccessible roof is taken from IS 875 Part 2. Then, the wind loads are calculated taking the wind speed of Jammu as 39 meter per second and the constants of wind proportionality as unity. Also, the seismic loads are taken out using IS 1893:2002. Analysis and the design of the concrete building are then carried out. The building has been designed for the following load combinations:

Table 2: Load Combinations

Type	L/C	Name
Primary	1	Seismic load in X DIR
Primary	2	Seismic load in Z DIR
Primary	3	
Primary	4	

Primary	5	
Primary	6	
Primary	7	DL
Primary	8	LL
Combination	9	D.L + L.L
Combination	10	D.L + L.L +EQL +VE X-DIR
Combination	11	D.L + L.L +EQL -VE X-DIR
Combination	12	D.L + L.L +EQL +VE Z-DIR
Combination	13	D.L + L.L +EQL +VE Z-DIR
Combination	14	D.L + L.L +W.LOAD IN +X-DIR
Combination	15	D.L + L.L +W.LOAD IN -X-DIR
Combination	16	D.L + L.L +W.LOAD IN +Z-DIR
Combination	17	D.L + L.L +W.LOAD IN -Z-DIR
Combination	18	D.L + L.L
Combination	19	D.L +EQL +VE X-DIR
Combination	20	D.L +EQL -VE X-DIR
Combination	21	D.L +EQL +VE Z-DIR
Combination	22	D.L +EQL -VE Z-DIR
Combination	23	D.L +W.LOAD IN +X-DIR
Combination	24	D.L +W.LOAD IN -X-DIR
Combination	25	D.L +W.LOAD IN +Z-DIR
Combination	26	D.L +W.LOAD IN -Z-DIR
Combination	27	D.L +EQL +VE X-DIR
Combination	28	D.L +EQL -VE X-DIR
Combination	29	D.L +EQL +VE Z-DIR
Combination	30	D.L +EQL -VE Z-DIR
Combination	31	D.L +W.LOAD IN +X-DIR
Combination	32	D.L +W.LOAD IN -X-DIR
Combination	33	D.L +W.LOAD IN +Z-DIR
Combination	34	D.L +W.LOAD IN -Z-DIR

3.1 Problems identified after the analysis

The provided and the required reinforcements are compared for each of the structural member. That is for the columns, beams, slab, and the foundation.

3.1.1 Column

Many columns were identified in which the required reinforcement was more than the provided reinforcement. For example: column number 2001(Fig. 5) in the 1st floor level, the required reinforcement came out to be 1308.27 $mm^{2.}$ However, the provided was 1256 $mm^{2.}$ So there was a shortfall of reinforcement in this column. Likewise if we talk about column number 2007, the required reinforcement was 2326.61mm^2 and the provided one was 1608mm^2. A comparison of required and provided reinforcements is tabulated for each storey level columns. Table 2 shows the shortfall of reinforcements of columns from foundation to ground level. Table 3 shows the difference of required and provided area of steel from Ground to first level.

Table 2: Comparison of Ast required and provided from foundation to ground level.

Foundation to ground level Reinforcements			
Col. No	**Column size**	**Area of reinforcement**	
		Required (mm2)	**Provided (mm2)**
1007	250.0X400.0	2000	1608
1008	250.0X350.0	2100	1608
1011	250.0X350.0	1928.30	1608
1012	250.0X350.0	1820	1608

Table 3: Comparison of Ast required and provided from ground to first level.

Ground to first level Reinforcements			
S.NO	**Column size**	**Area of reinforcement**	
		Required (mm2)	**Provided (mm2)**
2007	250.0X400.0	2326	1608
2008	250.0X350.0	1820/1996	1608
2011	250.0X350.0	1960.00	1608
2012	250.0X350.0	2030/1481	1608

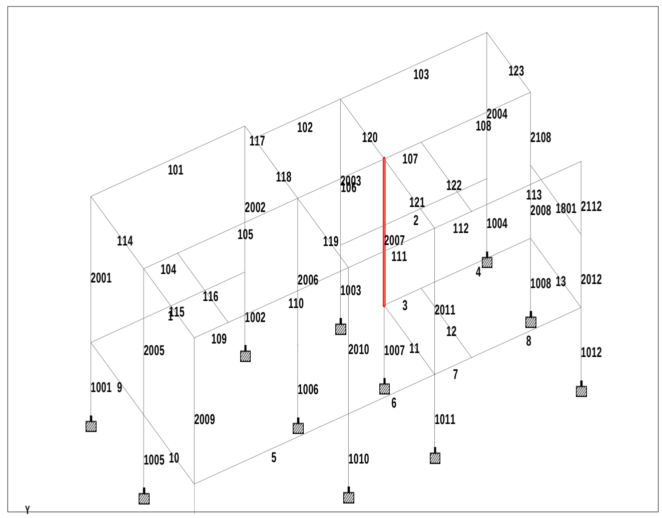

Fig. 5: First floor column no 2007 (shortage of reinforcement)

4. RETROFITTING USING SHEAR WALL

Seismic Retrofitting can be done by adding shear wall, adding infill wall, base isolation etc. 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 are 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.

4.1 Best location of adding shear wall

Using STAAD Pro v8i, shear walls were added in the different bays of the building. For example, it was added in the 2.8m bay on both the sides of the building. However, it did not improve Earthquake resistance of the building. Then the shear wall was added in the 5m and 4.75m bay simultaneously in order to maintain symmetry and for uniform distribution of forces. Fig. 6 and 7 shows the location of shear wall in the building. The blue lines highlighted in Fig. 6 shows the location of shear wall.

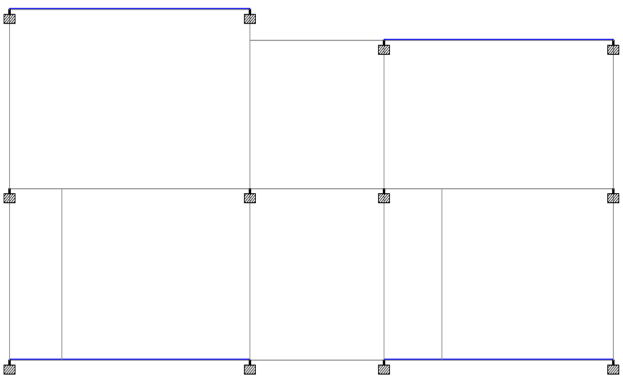

Fig. 6: Plan of the building showing location of shear wall

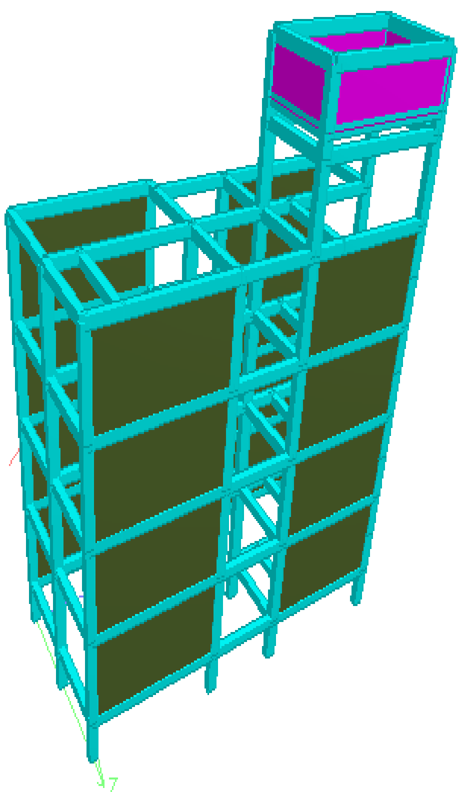

Fig. 7: Location of Shear Wall in the Building

4.2 Shear Wall Design

Shear wall is added to the building as a surface plate. It is added on all the four sides of the building. The provided reinforcements of the existing columns came out to be more than the required reinforcements. Hence, now the design is safe for all the columns and beams of the building. Table 4 shows the required and provided reinforcements of the building columns from foundation to ground level. Table 5 shows the required and provided reinforcements of the building from Ground to first level. Thus, all the beams and columns were checked after applying shear wall. The building was now found to be safe. The shear wall is designed with the help of Indian Standard Codes, IS 1893(Part 1): 2002 Indian Standard Criteria For Earthquake Resistant Design Of Structures, IS 13920:1993 Indian Standard Ductile Detailing Of Reinforced Concrete Structures Subjected To Seismic Forces, IS 15988:2013, Seismic Evaluation And Strengthening Of Existing Reinforced Concrete Buildings –Guidelines.

Table 4: Comparison of Ast required and provided from foundation to ground level after adding shear wall

Foundation to ground level Reinforcements			
Col. No	Column size	Area of reinforcement	
		Required	Provided
1007	250.0X400.0	1418.90	1608
1008	250.0X350.0	1471.49	1608
1011	250.0X350.0	1400.00	1608
1012	250.0X350.0	1606.00	1608

Table 5: Comparison of Ast required and provided from ground to first level after adding shear wall.

Ground to first level Reinforcements			
S. NO	Column size	Area of reinforcement	
		Required (mm2)	Provided (mm2)
2007	250.0X400.0	1600	1608
2008	250.0X350.0	1150.92/1349.65	1608
2011	250.0X350.0	440.48	1608
2012	250.0X350.0	767.29/310.58	1608

5. CONCLUSIONS

Adding shear wall significantly increases the lateral load carrying capacity of the building as well as the ductility. The building before adding shear wall was not designed as earthquake resistant. But after adding shear wall, significant improvement is seen in seismic performance of the building. The columns which were failing before addition of shear wall became safe after addition of shear wall. Also, the problem of soft present was solved. As addition of shear wall imposes very less disturbance to the existing structure so it is still very viable option in improving the earthquake resistance of the existing buildings. Foundations for newly added shear wall need significant attention of structural engineers.

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