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Strengthening of Commercial G+2 storey building through Section Enlargement.

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Abstract: The many structure get damaged due to earthquake, ageing of structure, and change in loading condition and change in serviceability of structure. This thesis presents a case study on existing RCC G+2 story building located in Thane city, it's a commercial building G+2 structure, and building is 30 years old. It should be checked that weather it has strength of existence or not. The structure should be audited time to time for human safety. Structural audit is carried out. In this structural audit, structure should be check for various method such as rebound hammer, ultrasonic pulse velocity method. From the results of NDT test it was found the building was observed to heavily distress also it was reaching its design life. Strengthening of concrete structure is required for increasing their capacity to sustain additional loads. Building is re-designed for G+3 storey. As per previous studies concrete jacketing is the one of the most popular retrofitting technique that's why we have used RC Jacketing technique. In this study experimental work and analytical work was carried out. Comparing two model for displacement of structure, bending moment and shear force of with jacketing and without jacketing by using ETABS software. The grade of concrete is M15 for existing building and M25 is adopted for retrofitting of building. The grade of steel is 415 N/mm2.

Keywords: RC jacketing, Retrofitting, Strengthening, Structural repair

I.INTRODUCTION

Structural strengthening is the process of upgrading structures to improve performance of existing loads or to increase the strength of structural members to carry additional loads. When the residential building is being converted into commercial building which results in increase of live load in existing structure, from the physical and experimental investigations it had been concluded that the structure either should be demolished or retrofitted with suitable method to increase its service life. Global retrofitting technique for strengthening which result obtain a better overall behaviour of the entire structure. Some of the examples of global retrofitting are addition of shear walls, addition of steel braces, addition of infill wall, mass reduction etc. The local retrofitting techniques stand for those techniques which are applied on individual members such as beams or columns of the structure which need intervention and aim to improve the performance characteristics of these members. Local retrofit methods include the addition of concrete, steel, and composite. In India, codes and guidelines for design and execution of retrofitting are not well-established. The main codal provision providing general guidelines for design of retrofit in India is IS 15988:2013. This code is formulated to provide guidelines for evaluation of existing structures, and criteria for the design of a few important retrofit techniques. Different materials can be used as matrix, but epoxy based material is the most commonly used. It was then decided to implement RCC column jacketing technique due to its feasibility and ease for execution. All the footing, columns are now suitably jacketed, the loose pockets of concrete that were investigated during the test are re-concreted, and therefore the rusted reinforcement is replaced with new reinforcement as per the planning requirement. Retrofitting utilizes the concept of confinement by strengthening an existing beam or column with external lateral pressure.

II.METHODOLOGY

2.1 Case Study

The current investigation is carried out on RCC building in thane. It's a commercial building G+2 structure, and building is 30 years old. This building was proposed in 1990. The building during its life span at the end in 2019 found completely detoriated and was not capable to sustain further loads. In the existing building the overall compressive strength of 15 MPA was used. This project was redesigned to accommodate additional floor for the existing building and accordingly was re-designed for G + 3 storey. The structural audit of the building is carried out. And also NDT test are carried out on structural element and it is observed that the load carrying capacity of the building is low and hence to strengthen the existing building with the help of RCC jacketing method.

2.1.1 Structural Audit

Structural Audit is the most important tool for knowing the real status of the old buildings. The Audit should highlight & investigate all the risk areas, critical areas and whether the structure needs immediate attention

2.1.2 Recommended NDT Test

The following NDT tests are required to be carried out on structural elements. However, it is important that the testing scheme is prepared based on preliminary survey of the building/structure:

a. Ultrasonic pulse velocity test (UPV)

b. Rebound hammer test

a. Ultrasonic Pulse Velocity

UPV test was carried out at various points of beams and columns to assess the quality of concrete, integrity of concrete and honey combing. Test was carry out the surface of the selected column were marked with grid lines. The transit time of the ultrasonic pulse velocity was read from the digital indicator.

Figure 1: Ultrasonic Pulse Velocity Conducted on Column

b. Rebound Hammer Test

Schmidt rebound hammer test is carried out, it help to measure the quality of near surface concrete. The hammer was used for to compare the quality of concrete in different surface of a concrete member. The rebound hammer test was carried out on all the surface where the UPV test was conducted and also at the additional points in between for the selected location of the column, beams. All the surface were prepared and cleaned to ensure complete removal of laitance and loose particles.

Figure 2: Rebound Hammer Test before jacketing Figure 3: Rebound Hammer Test after jacketing

2.2 Observations from NDT

1. During visual examination, it was observed that the concrete cover portions has spalled very badly and also cracks were noticed in the same area where the treatment was already carried out.
2. Corrosion crack observed in column.
3. Discolorations of foundation, crack observed in foundation of cooling tower.
4. Corrosion noted on roof.

Figure 6: Bldg. shows Exposed Reinforcement. Figure 7: Spalling-Off Concrete Observed on Ceiling

2.3 Foundations Repair and Strengthening of Foundations

The strengthening of the existing footings was done by section enlargement. Existing grade of footing was 15 N/mm2 and use 30 N/mm2 for retrofitting and Steel grade was use 415 N/mm2 for retrofitting. Increasing the size of footing by 300 mm at that time of retrofitting. The construction started by excavating the area around the footing to the required dimensions, Small holes were drilled with epoxy grout at the surface and sides of the footing. Then dowel bars was inserted in the drilled holes. Plain concrete was casted in the extended area of the footing before arranging the reinforcement bars surrounding the footing. Fresh concrete was casted with proper compaction to cover the enlarged area of the footing. Expanding agents must be added to the concrete mixture to ensure gap fillings. To insure bonding of fresh concrete with old one, a polymer bonding agent was applied over the exposed surface of the footing. After a curing period, backfilling of footing with selected material took place to the ground level

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Figure 8: Plain Concrete in the Extended Area and the Reinforcement Bars Arranged Surrounding the Footing.

2.3.1 Schedule of RCC Footing for Jacketing

Table 1 Footing Jacketing

	Old Size			New Size		Pu	Steel	
Column No	L	B	Depth	L	B	1.5(Dl+LL)	Along XX	Along YY
C20,24	1350	1650	550	1650	1950	1060	19-10T	18-10T
C1,8,10,11,14,42,43	1350	1650	550	1650	1950	860	16-10T	14-10T
C2,3,5,7,13,32,35,37	1750	2000	700	2050	2300	1300	24-10T	21-10T
C4,6,12,36,38	1250	1300	550	1550	1600	820	14-10T	9-10T
C9,14,41	1900	2200	850	2200	2500	1770	29-10T	27-10T
C15,26	2300	2300	800	2600	2600	2200	27-12T	27-12T
C16,17,18,27,28,29	2600	2600	950	2900	2900	2600	30-12T	30-12T
C19,21,25	1500	1750	550	1800	2050	960	20-10T	17-10T
C23,33,34	1950	2250	850	2250	2550	1260	21-10T	19-10T
C30,31	2100	2400	900	2400	2700	1200	19-10T	17-10T
C3,5	1750	2000	700	2350	3000	1650	24-10T	21-10T
C26	2300	2300	800	2900	2900	2500	27-12T	27-12T
C27	2600	2600	950	3200	3200	2900	30-12T	30-12T

2.4 Jacketing of Columns

It consists of added concrete with longitudinal and transverse reinforcement around the existing columns. This type of strengthening increase the axial and shear strength of columns while the flexural strength of column and strength of the beam-column joints remain the same. It is also observed that the jacketing of columns is not sufficient for improving the ductility of column. A major advantage of column jacketing is to increase the lateral load carrying capacity of the building. The jacketing of columns is generally carried out by two methods:

(i) Reinforced concrete jacketing
(ii) Steel jacketing.

2.4.1 Reinforced Concrete Jacketing

Reinforced concrete jacketing can be employed as a repair or strengthening scheme. Damaged regions of the existing members should be repaired prior to their jacketing. There are two main purposes of jacketing of columns:

A. Improving shear capacity of columns in order to accomplish a strong column-weak beam design.
B. To increase the column's flexural strength by the longitudinal steel of the jacket made continuous through the slab system are anchored with the foundation.

Figure 9: Construction Technique for Column Jacketing

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2.4.2 Schedule of RCC Column for Jacketing

Table 2: Column Jacketing

Col No	Old size	New Size	Old R/F	New R/F
C15,C26,C16,C17,C18,C27,C28,C29				
GROUND	500x500	700x700	$4-20_{\varphi},4-16_{\varphi}$	$10-16_{\varphi}$
1	500x500	700x700	$4-20_{\varphi},4-16_{\varphi}$	$10-16_{\varphi}$
2	500x500	700x700	$4-20_{\varphi},4-16_{\varphi}$	$10-16_{\varphi}$
3	500x500	700x700	$4-20_{\varphi},4-16_{\varphi}$	$10-16_{\varphi}$
ROOF	500x500	700x700	$4-20_{\varphi},4-16_{\varphi}$	$10-16_{\varphi}$
C44,C45,C46,C47				
GROUND	230x300	330x400	$12-6_{\varphi}$	$10-16_{\varphi}$
1	230x300	330x400	$12-6_{\varphi}$	$10-16_{\varphi}$
C2,C3,C5,C7,C13,C32,C35,C37,C39,C4,C6,C12,C36,C38,C14,C19,C21,C25,C22,C30,C33,C34,C31, 23,C11,C43,C1,C20,C24,C8,C10,C40,C42,C9				
GROUND	300X550	450X700	$4-20_{\varphi},4-16_{\varphi}$	$4-20_{\varphi},12-12_{\varphi}$
1	300X550	450X700	$4-20_{\varphi},4-16_{\varphi}$	$16-12_{\varphi}$
2	300X550	450X700	$4-20_{\varphi},4-16_{\varphi}$	$16-12_{\varphi}$
3	300X550	450X700	$4-20_{\varphi},4-16_{\varphi}$	$16-12_{\varphi}$
ROOF	300X550	450X700	$4-20_{\varphi},4-16_{\varphi}$	$16-12_{\varphi}$

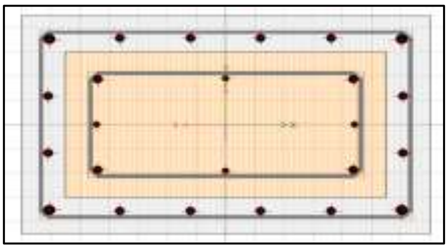

Figure 10: Reinforcement detailing of Column Jacketing in ETABS

2.5 Software Analysis

2.5.1 Introduction- As per the objective defined, the analysis of building was carried out using the ETABS software, and the comparison of without Jacketing and with jacketing model is done.

2.5.2 Building Parameters

Table 3: Structural Details of Existing Building

PLAN AREA	495000000 mm^2
BEAM SIZE	200mm X 600mm
	230mm X 400mm
	230mm X 500mm
	230mm X 600mm
	230mm X 750mm
	300mm X 750mm
COLUMN SIZE	300mm X 550mm
	330mm X 400mm
	450mm X 700mm
	550mm X 550mm
	700mm X 700mm
SLAB THICKNESS	125mm
	130mm
	150mm
	80mm
	120mm

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EXT. WALL THICKNESS	230mm
INT. WALL THICKNESS	150mm
HEIGHT OF BUILDING	18000mm

2.5.3 Preliminary Data
Type of structure = RCC Building
Zone = III
Number of stories = G+3

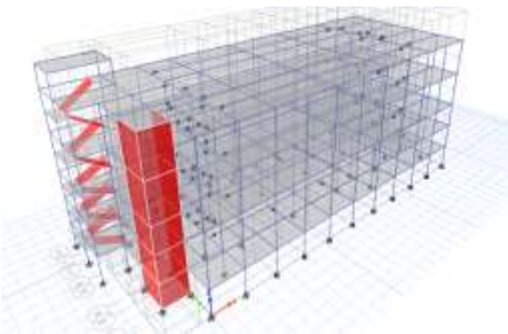

Figure 11: Without jacketing Model

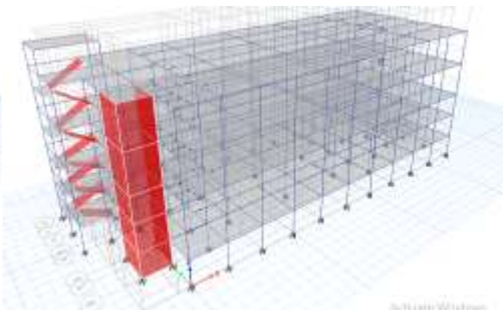

Figure 12: With Jacketing Model

III.RESULT AND DISCUSSION

3.1 Experimental Results
The NDT test results discussed below mainly consist of comparison between with jacketing and without jacketing model.
3.1.1 Ultrasonic Pulse Velocity
Table 4: Ultrasonic Pulse Velocity

Sr no	Location	Element	Distance mm	UPV (m/sec)		Method of testing
				Before Jacketing	After Jacketing	
1	Gr. floor	Col no.4	360	1804	3383	Indirect
2	Gr. floor	Col no.5	300	2199	3936	Indirect
3	Gr. floor	Col no.6	330	1838	3253	Indirect
4	Gr. floor	Col no.10	510	1958	3798	direct
6	Gr. floor	Col no12	300	2015	3408	Direct
7	Gr. floor	Col no.45	250	1763	3314	Direct
8	Gr. floor	Col C4 and C12	380	2070	3788	Direct
9	Gr. floor	Col C4 and C12	380	1923	3190	Direct
10	1st floor	Col no.11	340	2362	4582	Indirect
11	1st floor	Col no.14	560	2149	4061	Direct
12	1st floor	Col no.19	300	2451	4388	Direct
13	1st floor	Col no.42	300	2508	4614	Indirect
14	1st floor	Col no.45	250	2798	4612	Indirect

Table 5: Velocity Criteria for Concrete Quality Grading as per IS 13311(Part1):1992

1	Velocity by cross probing (m/sec)	Above 4500	4500-3500	3500-3000	Below 3000
2	Concrete quality rating as per IS 13311(part1)1992	Excellent	Good	Medium	Doubtful

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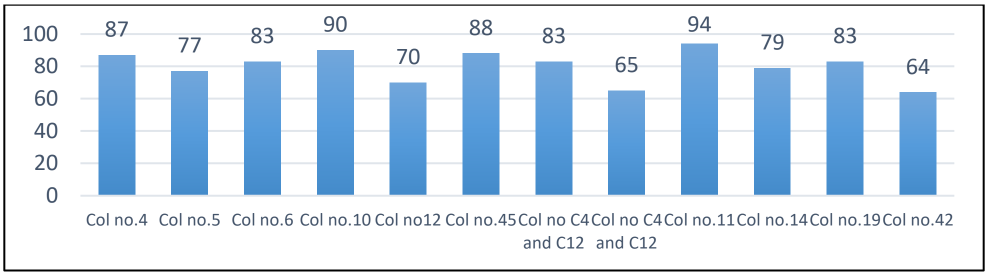

Figure 13: Percentage increase UPV of concrete after Jacketing of structure

From the table 4, it was observed that minimum increment in UPV was observed by 1393at ground floor col no 1 and maximum increment in UPV was observed by 2220 at first floor column no 11. From the above fig 13, it was concluded that the Percentage increase UPV of concrete after Jacketing of structure was observed by 94% in column no 11 and minimum increment was observed by 64 in column no 42 at first floor.

3.1.2 Rebound Hammer Test

Table 6: Rebound Hammer Test Result

Sr no	Location	Element	Rebound No		Concrete Strength MPA	
			Before Jacketing	After Jacketing	Before	After
1	Gr. floor	Col no.5	23	30	13.72	25.49
2	Gr. floor	Col no.6	23	28	13.72	22
3	Gr. floor	Col no.10	27	30	18.63	25.49
4	Gr. floor	Col no.16	24	30	14.71	25.49
5	Gr. floor	Col no.51	28	34	20.69	30.4
6	Gr. floor	Col no.40	25	29	15.7	23.53
7	Gr floor	Col no.28	26	33	17.65	31.38
8	Gr floor	Beam no C4, C12	22	31	11.77	27.45
9	1st. floor	Col no.12	23	30	13.72	25.49
10	1st. floor	Col no.16	22	28	11.77	22
11	1st. floor	Col no.11	26	28	17.65	22
12	1st. floor	Col no.31	27	29	18.63	23.53
13	1st. floor	Col no.42	25	30	15.7	25.49
15	1st. floor	Beam no C17,C26	23	30	13.73	25.49

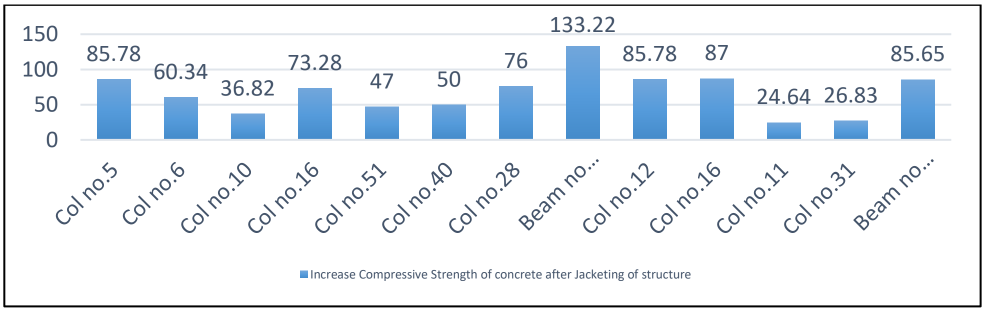

Figure 14: Increase Compressive Strength of concrete after Jacketing of structure

Rebound Hammer Test was carried out on all the members before repair, from table no 6, it was observed that compressive strength of the members varied between M13 to M20 in correlation with carbonation effect on rebound number. Hence, members with lesser compressive strength have been jacketed or repaired after repair again this test was carried out and it was observed that compressive strength varied from 22 to 29. From the above fig 14, it was concluded that the maximum percentage increased in compressive strength of concrete after jacketing was observed by 133.22% in column no 4,12 and minimum increment was observed by 24.64% in column no 11.

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3.2 Analytical Result

The analysis of building was carried out using the ETABS software. The results discussed below mainly consist of comparison between with jacketing and without jacketing model.

3.2.1 Storey Displacement

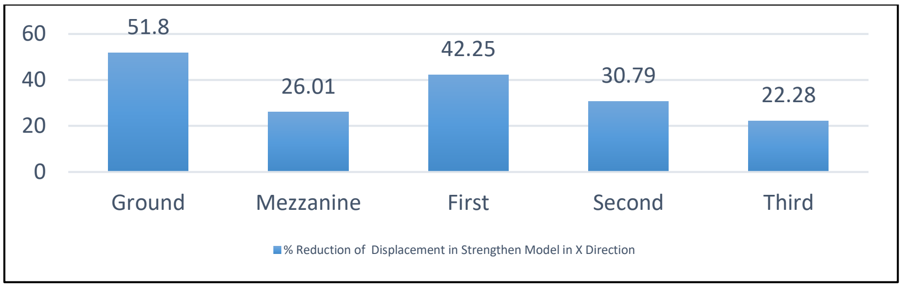

Figure 15: Percentage Reduction of Displacement in Strengthen Model in X Direction

The analysis of the structure Without Jacketing (Fig No 4.4) and With Jacketing (Fig No 4.5) was done in Etabs Software. In the above table No 5.1 the maximum storey displacement at ground floor in X Direction with load combination 1.2(DL+SDL+LL+EQX) and it was reduced by 51.8% as compare to Without Jacketing. Similarly reduction occurs at Mezzanine Storey in X direction is 26.01% reduce as compare to without jacketing with loading combination is 1.2(DL+SDL+LL+EQX). Reduction at first floor is 42.25% with load combination 1.5(DL+SDL+EQX). reduction occurs at Second Floor in X direction is 30.79% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQY). reduction occurs at Second Floor in X direction is 22.28% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQY). Fig No 5.1 represents Percentage reduction of Displacement in Strengthen Model in X Direction.

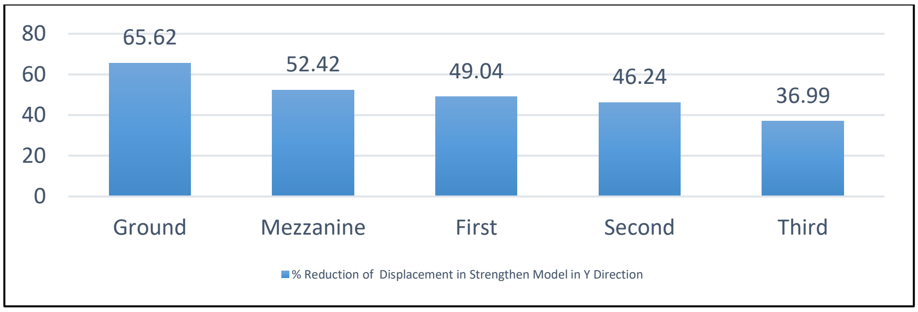

Fig 16: Percentage Reduction of Displacement in Strengthen Model in Y Direction

The above table No 5.1 gives the comparison between Storey Displacement of model Without Jacketing and With Jacketing with same loading condition in Y direction. In the above table No 5.1 the maximum storey displacement at ground floor in Y Direction with load combination 1.2(DL+SDL+LL+EQX) and it was reduced by 65.62% as compare to Without Jacketing. Similarly reduction occurs at Mezzanine Storey in Y direction is 52.42% reduce as compare to without jacketing with loading combination 1.5(DL+SDL+EQY). Reduction at first floor is 49.04% with load combination 1.5(DL+SDL+EQY). reduction occurs at Second Floor in Y direction is 46.24% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQY). reduction occurs at Second Floor in Y direction is 36.99% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQY). Fig No 5.2 represents Percentage reduction of Displacement in Strengthen Model in Y Direction.

3.2.2 Shear Force

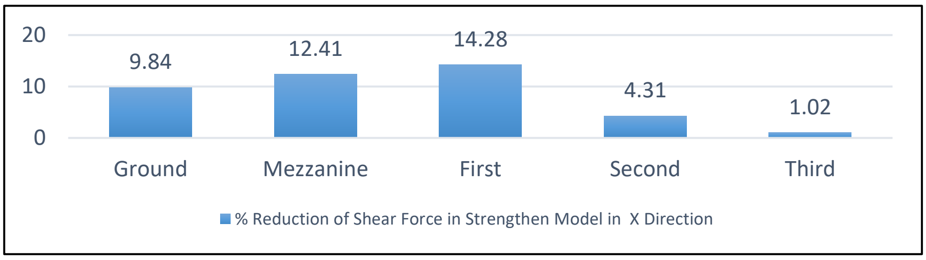

Fig 17: Percentage Reduction of Shear Force in Strengthen Model in X Direction

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The above table No 5.2 gives the comparison between Shear Forces of model Without Jacketing and With Jacketing with same loading condition. In the above table No 5.2 the maximum Shear Force at ground floor in X Direction with load combination 1.5(DL+SDL+EQX) and it was reduced by 9.84% as compare to Without Jacketing. Similarly reduction occurs at Mezzanine Storey in X direction is 12.41% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQX). Reduction at first floor is 14.28% with load combination 1.5(DL+SDL+EQX). reduction occurs at Second Floor in X direction is 4.31% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQX). Reduction occurs at Second Floor in X direction is 1.02% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQX). Fig No 5.3 represents Percentage reduction of Shear Forces in Strengthen Model in X Direction.

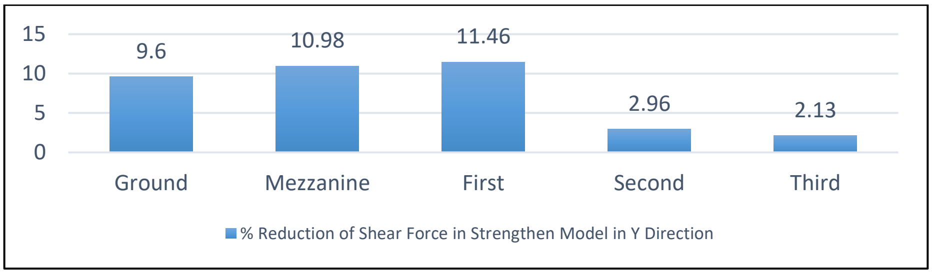

Fig 18: Percentage Reduction of Shear Force in Strengthen Model in Y Direction

In the above table No 5.2 the maximum Shear Forces at ground floor in Y Direction with load combination 1.5(DL+SDL+EQY)and it was reduced by 9.6% as compare to Without Jacketing. Similarly reduction occurs at Mezzanine Storey in Y direction is 10.98% reduce as compare to without jacketing with loading combination 1.5(DL+SDL+EQY). Reduction at first floor is 11.46% with load combination 1.5(DL+SDL+EQY).Reduction occurs at Second Floor in Y direction is 2.97% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQY).. reduction occurs at Second Floor in Y direction is 2.13% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQY). Fig No 5.4 represents Percentage reduction of Shear Forces in Strengthen Model in Y Direction.

5.2.3 Bending Moment

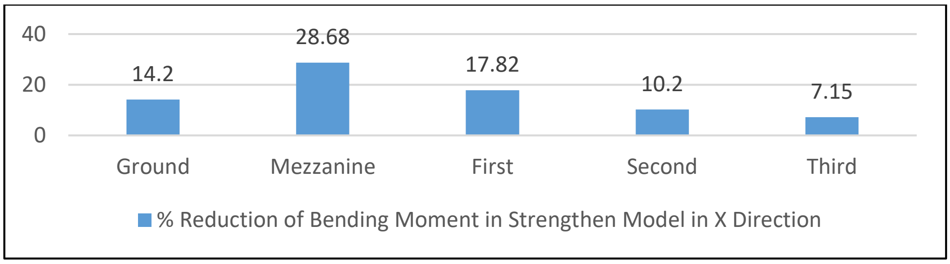

Fig 19: Percentage Reduction of Bending Moment in Strengthen Model in X Direction

The above table No 5.3 gives the comparison between Bending Moment of Structure without Jacketing and With Jacketing with same loading condition. In the above table No 5.3 the maximum storey displacement at ground floor in X Direction with load combination 1.5(DL+SDL+EQX) and it was reduced by 14.2% as compare to Without Jacketing. Similarly reduction occurs at Mezzanine Storey in X direction is 28.67% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQX). Reduction at first floor is 17.82% with load combination 1.5(DL+SDL+EQX). reduction occurs at Second Floor in X direction is 10.2% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQX). reduction occurs at Second Floor in X direction is 7.15% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQX). Fig No 5.5 represents Percentage reduction of Displacement in Strengthen Model in X Direction.

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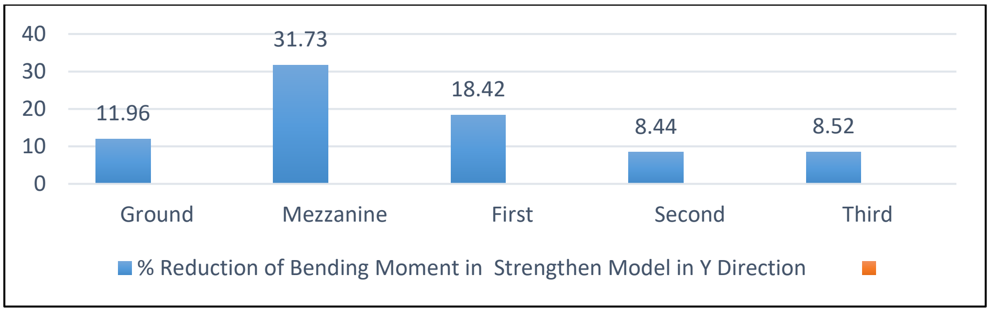

Fig 20: Percentage Reduction of Bending Moment in Strengthen Model in Y Direction

In the above table No 5.3 the maximum Bending Moment at ground floor in Y Direction with load combination 1.5(DL+SDL+EQY)and it was reduced by 11.96% as compare to Without Jacketing. Similarly reduction occurs at Mezzanine Storey in Y direction is 31.73% reduce as compare to without jacketing with loading combination 1.5(DL+SDL+EQY). Reduction at first floor is 18.42% with load combination 1.5(DL+SDL+EQY). reduction occurs at Second Floor in Y direction is 8.44% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQY). reduction occurs at Second Floor in Y direction is 8.52% reduce as compare to without jacketing with loading combination is 1.5(DL+SDL+EQY). Fig No 5.6 represents Percentage reduction of Bending Moment in Strengthen Model in Y Direction.

IV.CONCLUSION

The following conclusions occurs from this study

1. Compressive strength of concrete is increase by 73%- 113% in column after jacketing of structure.
2. Results shows that the R.C.C. retrofitting technique are significant improvement in Moment resisting capacity is 8.5% -31.73% and 7.15% - 28.68% in Y direction and X direction respectively.
3. Shear strength capacity in Beam is increase by 1.02% - 14.28% and 2.13% - 11.46% in X direction and Y direction respectively.
4. R.C.C. retrofitting technique are significantly reduced in storey displacement by 22.8% - 51.8% and 36.99% - 65.62% in X direction and Y direction respectively.
5. Increase axial load carrying capacity in column and Increase in the total stiffness of the column.
6. The durability of deteriorated columns shows a better improvement.
7. Providing a shear connector will make a slight improvement in the overall structural behaviour of column.
8. Results show that the foundation after strengthening is capable to carry extra load from additional storey.

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