Strengthening Demand of Columns in A RCC Structure Due To Construction of An Additional Storey

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.*Abstract* - Generally the people construct the structure to fulfill their current needs but with the passage of time they realize that their demands have increased and there is a need for the addition/alteration of the current structure. This demand can be fulfilled by constructing a new storey. However, provision for additional load due to the new construction over existing structure was not made in the structural design of the old structure. Therefore, the construction of new storey requires the strengthening of the old structure. The present study investigates the structural behaviour of an RC frame under the additional load in the form of a new storey. The analysis of existing structure (two storey) and proposed structure (one additional storey constructed over existing two storey structure) is performed by using structural analysis software i.e. STAAD Pro. The analysis results of existing and proposed structure are compared to evaluate the increase in structural forces due to the construction of a new storey. The results indicates that the significant increase is found in the axial force and bending moment in columns. The weak and deficient columns are identified and strengthened for the additional loads and additional moments. The strengthening of columns is done by jacketing of the columns using four steel angles at corners, confined with the help of batten plates placed at equal spacing along the length of the column.

Keywords- Concrete; Steel; Jacketing; Strengthening.

I. INTRODUCTION

Jacketing is one of the most commonly& popularly used practices to strengthen reinforced concrete columns. With this method, axial strength, bending strength, and stiffness of the column are modified. It should be noted that the success of this method depends on the monolithic behaviour of the composite element. The common practice consists of increasing the roughness of the interface surface and applying a bonding agent, generally an epoxy resin. Steel connectors are also sometimes applied. These involve expert workmanship, time, and cost. Regarding the added concrete mixture and due to the reduced thickness of the jacket, the option is usually a grout with characteristics of high strength concrete (HSC) and self-compacting concrete (SCC). The common types of jackets are steel jacket, reinforced concrete jacket, FRP composite jacket, jacket with high tension materials like carbon fiber, glass-fiber etc.

Purpose for jacketing:

To increase concrete confinement, to increase shear strength and to increase flexural strength

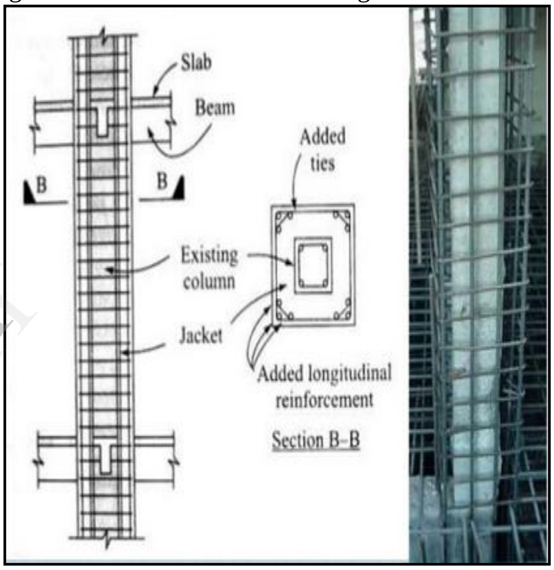

Fig1. Reinforcement mesh for jacketing

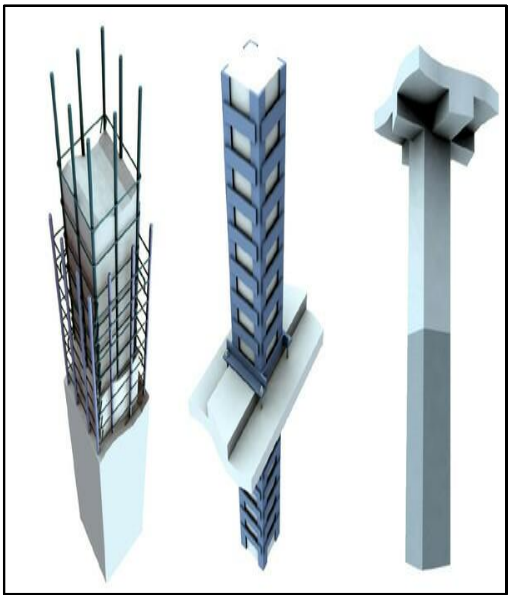

Fig2. 3D view of column jacketing

II. LITERETUREREVIEW

Eduardo N. B. S. Júlio et.al. conducted the study on the monolithic performance of the structure which was strengthened with jacketing. For this experimental investigations were done on seven models casted at the same time. The strength of concrete used was 20MPa and strength of steel was 400MPa .The dimensions of the old column was 0.2 x0.2 m2 and the thickness of reinforced concrete jacketing was 35mm. Three bars of 10mm diameter were used at each face with the reinforcing height of 0.90m for the column of height 1.35m. The transverse reinforcement used was 6mm diameter stirrups with a spacing of 150mm. The result was that all the models showed structural behaviour between the theoretical and experimented models. The stiffness and resistance of the strengthened column were much higher than the original column.

Aboutaha et. al. [1996] conducted the experiment to investigate the large rectangular column performance strengthened with a thin layer of steel jacket. The testing models in actual represented the structural design of 1960s in US. These columns were poor in confinement of concrete and also had a lap splices in reinforcement. Seven models were tested with different configurations of 6.3mm thick steel jacketing under the cyclic loading. The test results showed that there was less change in the stiffness but ductility of the reinforced member was increased significantly. There was also increase in the strength of the member because of the full flexural capacity developed.

Aviles et al. 1996, conducted a similar set of experiments on 18 column models. These models were retrofitted with a 1.2mm thick steel jacket connected with anchor bolts. At foundation level these models were found deficient. There was no increase in the strength and stiffness but there was an increase in the deformation capacity of the model.

III. PROPOSED WORK

The present study investigates the structural behaviour of an RC frame under the additional load in the form of a new storey. The analysis of existing structure (two storey) and proposed structure (one additional storey constructed over existing two storey structure) is performed by using structural analysis software i.e. STAAD Pro. The analysis results of existing and proposed structure are compared to evaluate the increase in structural forces due to the construction of a new storey. The results indicates that the significant increase is found in the axial force and bending moment in columns.

Methodology

The following sequence is adopted for strengthening the structure:

1. Analysis of the existing structure
2. Analysis of the new structure
3. Comparative study to evaluate the increase in column forces and identifying the weak zones
4. Strengthening of weak columns

Pictorial representation of the structure

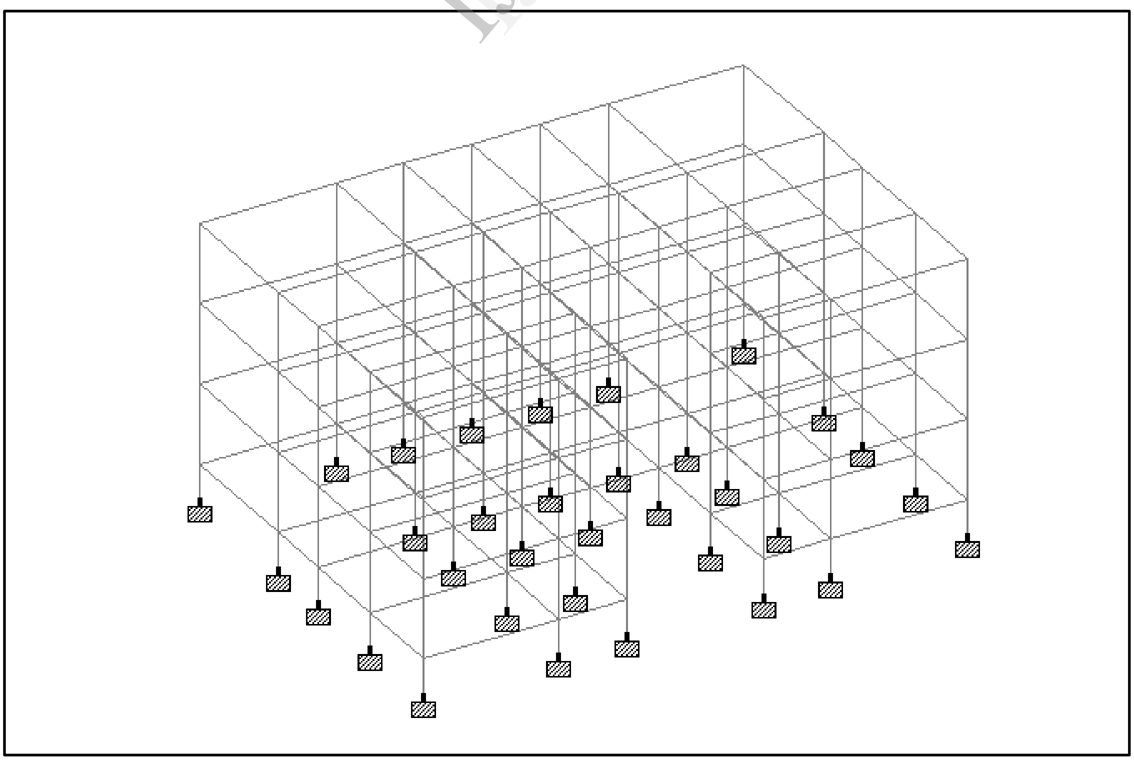

Fig.3Isometric view of the proposed structure

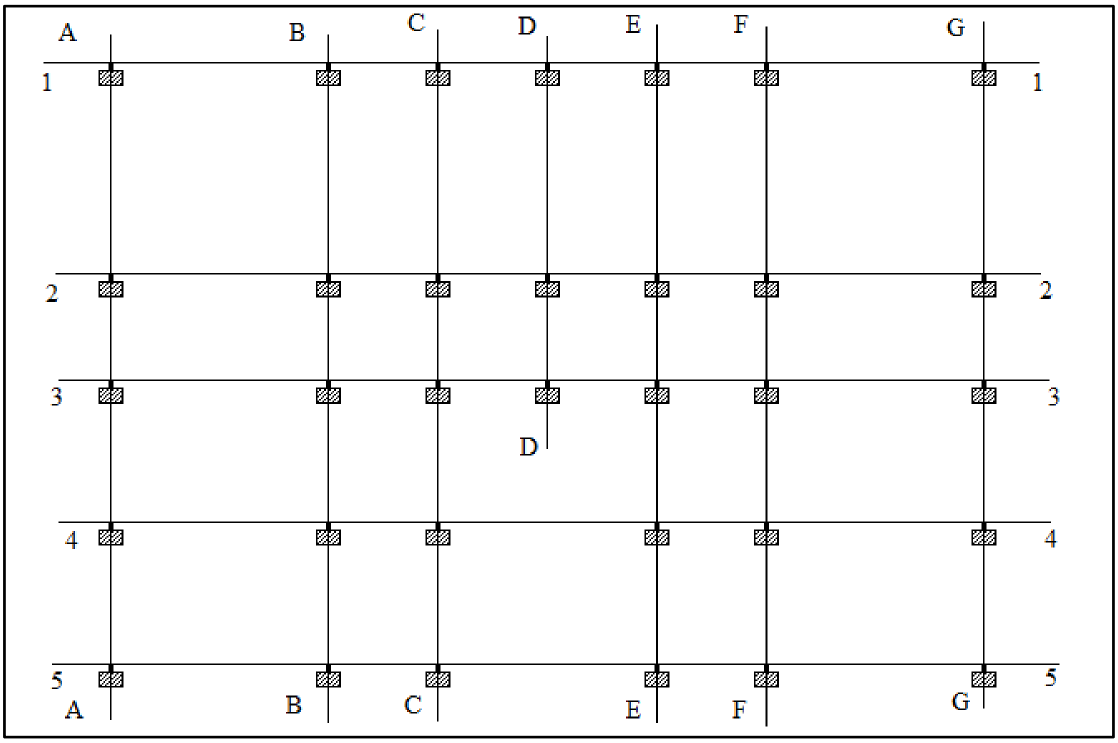

Fig.4Plan of the structure

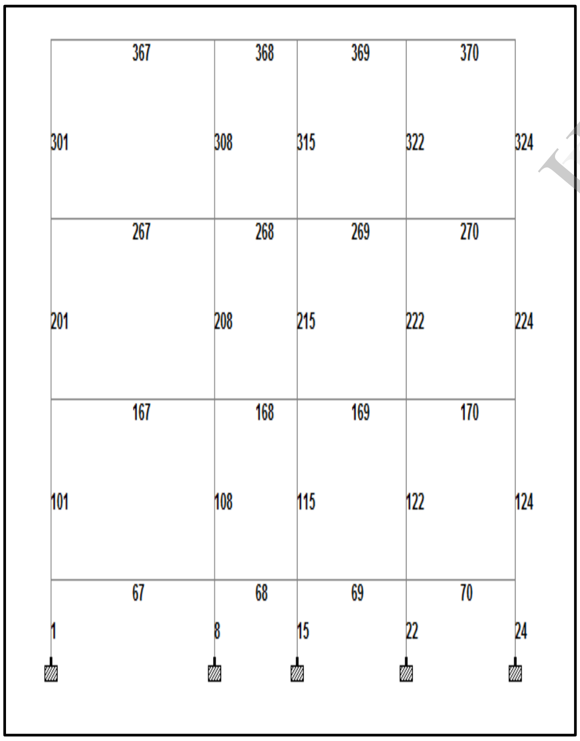

Fig.5 Member numbering at section A-A

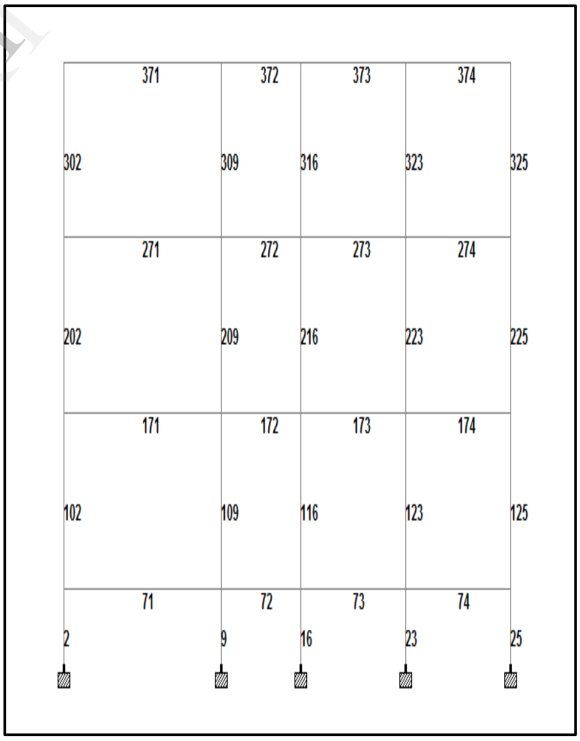

Fig.6 Member numbering at section B-B

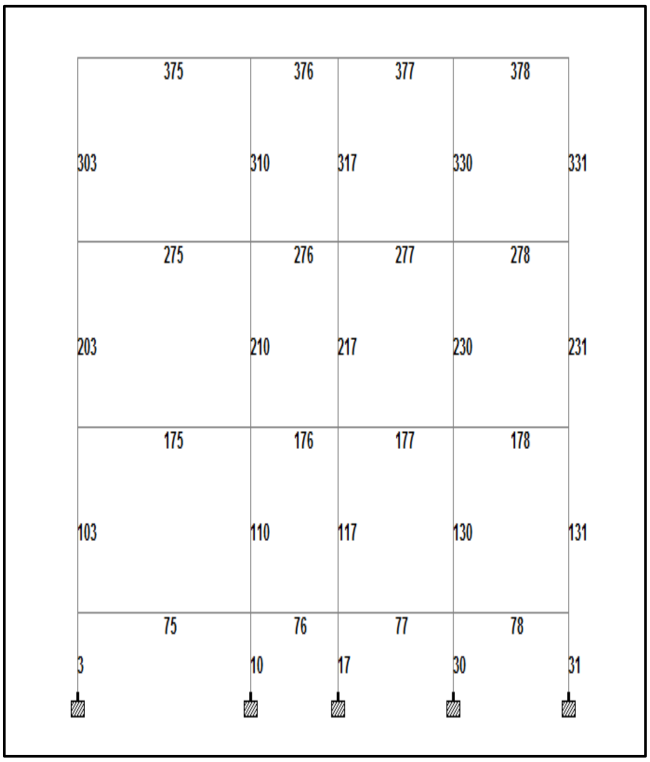

Fig.7 Member numbering at section C-C

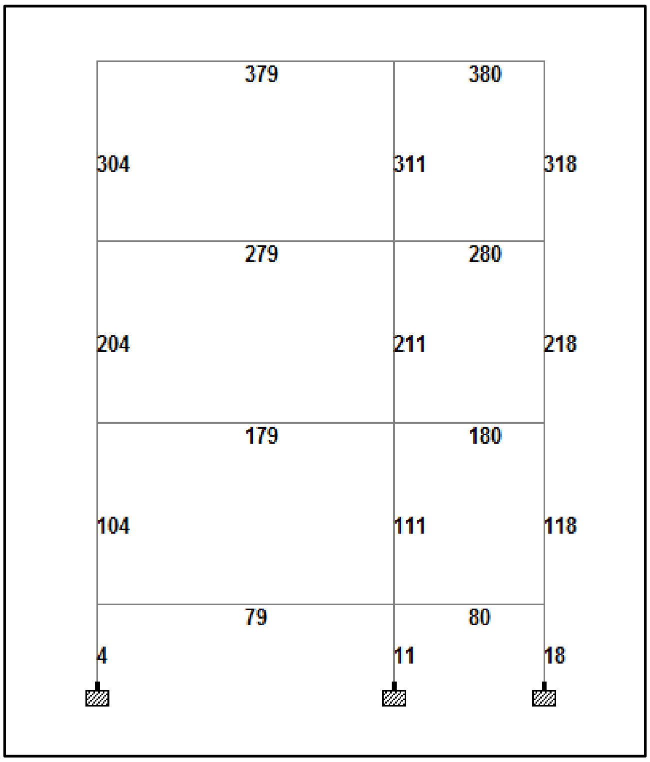

Fig.8 Member numbering at section D-D

IV. DETAILS OF STRUCTURE

This paper presents the analysis and design of an existing structure (two storey) and proposed structure (additional storey constructed over existing two storey structure) RCC framed structure. The details of which are given below.

.TABLE-1: Geometry of the Structure

S. No.	Description	Value
1	Area of building	408 m^2
2	Length	24 m
3	Breadth	17 m
4	Storey height	3.5 m
5	Height of the column below plinth level	1.5 m
6	Size of the column	300 mm x 300 mm
7 (a)	Size of beam for 6m span	200 mm x 500 mm
7 (b)	Size of beam for 4m span	200 mm x 400 mm
8	Thickness of slab	150 mm
9	Thickness of outer walls	200 mm
10	Thickness of inner walls	100 mm
11	Support condition	fixed

Material properties
Grade of concrete = M20
Grade of Steel = Fe415
Elasticity constant = 2.17 X 10^7kN/m^2
Dead load
Unit weight of concrete = 25 kN/m^3
Unit weight of masonry wall = 20 kN/m^3
Dead load of slab = 3.75 kN/m^2
Floor finish = 0.75 kN/m^2
Load of parapet wall = 2.6 kN/m
Load of inner wall = 8.06 kN/m
Load of outer wall = 14.26 kN/m
Live load
Live load on floor = 4 kN/m^2
Live load on roof = 1.5 kN/m^2

Parameters for seismic load

TABLE-2: Parameters for seismic load

S. No.	Parameter	Value
1	Location (ZONE II)	Zone Factor = 0.10
2	Response reduction factor (Ordinary RC Moment Resisting Frame)	RF = 3
3	Importance factor (All General Building)	I = 1
4	Rock and soil site factor (Medium soil)	SS = 2
5	Type of structure (RC Frame Building)	ST = 1
6	Damping ratio	DM = 0.05

V. FORCES IN COLUMNS

Analysis results of axial force Fx, bending moment My and bending moment Mz in columns obtained from Staad pro are presented below.

a) First storey columns

The axial force Fx, bending moment My and bending obtained from analysis of case 1 (existing structure) and case 2 (proposed structure) are presented and compared in Table-3, 4 and 5.

Axial Force Fx in first story columns

The axial force Fx for the columns of first storey which are obtained from analysis of case 1 and case 2 are tabulated and compared in Table 3.

TABLE-3. Comparison of axial force Fx in first storey columns due to additional storey.

Col. No.	Axial force Fx (kN) Case 1 (Existing Structure)	Axial force Fx (kN) Case 2 (Proposed Structure)	Increase in Axial Force Fx (kN)	% Increase
101	328.51	575.62	247.11	75.22
102	400.88	588.21	187.33	46.73
103	254.03	443.36	189.33	74.53
104	276.31	467.53	191.22	69.20
108	365.38	645.90	280.52	76.78
109	478.18	703.01	224.83	47.02
110	292.12	485.21	193.09	66.10
111	351.97	507.00	155.03	44.05
115	215.79	481.69	265.90	123.22
116	350.81	562.40	211.59	60.31
117	80.44	144.34	63.90	79.44
118	85.27	110.61	25.34	29.72
122	302.81	633.75	330.94	109.29
123	472.82	642.92	170.10	35.98
124	243.64	450.00	206.36	84.70
125	307.43	460.49	153.06	49.79
130	68.84	133.35	64.51	93.71
131	15.47	16.17	0.70	4.52

Bending Moment My in first storey columns

The bending moment My for the columns of first storey which are obtained from analysis of case 1 and case 2 are presented and compared in Table-4.

TABLE-4 Comparison of bending moment My in first storey columns due to additional storey

Col. No.	Bending Moment My (kN-m) Case 1 (Existing Structure)	Bending Moment My (kN-m) Case 2 (Proposed Structure)	Increase in Bending Moment My (kN-m)	% Increase
101	35.45	78.28	42.83	120.82
102	30.21	21.98	-8.23	-27.24
103	34.78	30.94	-3.84	-11.04
104	34.77	31.08	-3.69	-10.61
108	64.38	86.61	22.23	34.52
109	62.48	13.71	-48.77	-78.06
110	57.94	77.05	19.11	32.98
111	55.24	76.94	21.70	39.28
115	42.99	61.96	18.97	44.13
116	48.66	5.49	-43.17	-88.72
117	0.21	0.54	0.33	157.14
118	3.37	0.83	-2.54	-75.37
122	39.61	1.94	-37.67	-95.10
123	1.03	0.37	-0.66	-64.08
124	39.92	16.36	-23.56	-59.02
125	16.34	13.05	-3.29	-20.13
130	34.15	51.18	17.03	49.87
131	1.94	2.03	0.09	4.64

Bending Moment Mz in first storey columns

The bending moment Mz for the columns of first storey which are obtained from analysis of case 1 and case 2 are presented and compared in Table-5.

TABLE-5 Comparison of bending moment Mz in first storey columns due to additional storey

Col. No.	Bending Moment Mz (kN-m)		Increase in Bending Moment Mz (kN-m)	% Increase
	Case 1 (Existing Structure)	Case 2 (Proposed Structure)		
101	64.95	36.31	-28.64	-44.10
102	62.06	80.87	18.81	30.31
103	38.92	56.94	18.02	46.30
104	37.04	55.18	18.14	48.97
108	33.93	33.83	-0.10	-0.29
109	22.76	80.77	58.01	254.88
110	2.11	1.89	-0.22	-10.43
111	0.25	0.00	-0.25	-100.00
115	33.37	33.21	-0.16	-0.48
116	24.31	80.33	56.02	230.44
117	36.99	55.62	18.63	50.36
118	36.02	56.16	20.14	55.91
122	34.19	70.35	36.16	105.76
123	63.37	81.65	18.28	28.85
124	34.54	67.24	32.70	94.67
125	61.87	78.27	16.40	26.51
130	1.27	1.89	0.62	48.82
131	22.41	36.01	13.60	60.69

Table 3, 4 and 5 indicates that there is an increase in axial force Fx and bending moment My and Mz in most of the columns.

- Critical value of axial force Fx (703.01 kN) is found in column no 109 of case2 which is 76.78% higher than the critical value of axial force Fx (478.18 kN) in column no109 of case 1.
- Critical value of bending moment My (86.61 kN-m) is found in column no108 of case2 which is 34.52% higher than the critical value of bending moment My (64.38 kN-m) in column no108 of case 1.
- Critical value of bending moment Mz (80.77 kN-m) is found in column no 109 of case2 which is 24.35% higher than the critical value of bending moment Mz (64.95 kN-m) in column no 101 of case 1.

b) Second storey columns

The analysis results of axial force Fx, bending moment My and bending moment Mz for the columns of second storey for case 1 (existing structure) and case 2 (proposed structure) are presented below.

Axial Force Fx in second story columns

The axial force Fx for the columns of second storey which are obtained from analysis of case 1 and case 2 are presented and compared in Table-6.

TABLE-6 Comparison of axial force Fx in second storey columns due to additional storey

Col. No.	Axial force Fx (kN)		Increase in Axial Force Fx (kN)	% Increase
	Case 1 (Existing Structure)	Case 2 (Proposed Structure)		
201	129.53	338.56	209.03	161.14
202	180.35	389.88	209.53	116.18
203	87.73	265.32	177.59	202.43
204	87.61	277.47	189.86	216.71
208	178.86	412.45	234.59	131.78
209	200.41	505.01	304.60	151.99
210	113.55	299.79	186.24	164.02
211	123.43	312.77	189.34	153.40
215	90.92	292.86	201.94	222.11
216	149.46	346.22	196.76	131.65
217	35.63	91.54	55.91	156.92
218	53.26	67.91	14.65	27.51
222	111.97	350.00	238.03	212.58
223	176.98	398.88	221.90	125.38
224	84.74	271.21	186.47	220.05
225	119.64	281.41	161.77	135.21
230	50.00	85.41	35.41	70.82
231	36.45	114.11	77.66	213.06

Bending Moment My in second storey columns

The bending moment My for the columns of second storey which are obtained from analysis of case 1 and case 2 are presented and compared in Table-7.

TABLE-7 Comparison of bending moment My in second storey columns due to additional storey

Colum n No.	Bending Moment My (kN-m)		Increase in Bending Moment My (kN-m)	% Increas e
	Case 1 (Existing Structure)	Case 2 (Proposed Structure)		
201	50.22	81.34	31.12	61.96
202	61.79	42.48	-19.31	-31.25
203	50.64	37.32	-13.32	-26.30
204	42.00	37.43	-4.57	-10.88
208	36.19	76.21	39.31	108.33
209	55.45	71.57	16.12	29.07
210	29.91	79.05	49.14	164.29
211	54.22	79.65	25.43	46.90
215	22.47	58.49	36.02	160.30
216	35.53	6.13	-29.40	-82.75
217	0.09	1.34	1.25	**
218	8.54	2.62	-5.92	-69.32
222	20.92	52.31	31.39	150.05
223	1.63	0.22	-1.41	-86.50
224	25.39	53.02	27.63	108.82
225	20.97	16.25	-4.72	-22.51
230	26.52	45.32	18.80	70.89
231	25.93	37.91	11.98	46.20

Bending Moment Mz in second storey columns

The bending moment Mz for the columns of second storey which are obtained from analysis of case 1 and case 2 are presented and compared in Table-9.

TABLE-8Comparison of bending moment Mz in second storey columns due to additional storey

Col. No.	Bending Moment Mz (kN-m)		Increase in Bending moment Mz (kN-m)	% Increase
	Case 1 (Existing Structure)	Case 2 (Proposed Structure)		
201	52.88	42.19	-10.69	-20.21
202	35.68	70.79	35.11	98.40
203	19.36	52.04	32.68	168.80
204	24.92	50.38	25.46	102.17
208	63.86	53.34	-10.52	-15.80
209	35.01	36.91	1.90	5.43
210	29.01	1.61	-27.40	-94.45
211	0.55	0.00	-0.55	-100.00
215	48.95	40.51	-8.44	-17.24
216	30.17	82.06	51.89	171.99
217	25.29	49.01	23.72	93.79
218	25.64	49.25	23.61	92.08
222	50.34	41.07	-9.27	-18.41
223	59.46	85.91	26.45	44.48
224	37.24	38.15	0.91	2.44
225	51.66	80.28	28.62	55.40
230	6.99	3.75	-3.24	-46.35
231	6.23	6.07	-0.16	-2.57

Table 6, 7 and 8 indicates that there is an increase in axial force Fx and bending moment My and Mz in most of the columns.

- Critical value of axial force Fx (505.01 kN) is found in column no 209 of case2 which is 152% higher than the critical value of axial force Fx (200.41 kN) in column no 209 of case 1.
- Critical value of bending moment My (79.65 kN-m) is found in column no 211 of case2 which is 28.90% higher than the critical value of bending moment My (61.79 kN-m) in column no 202 of case 1.
- Critical value of bending moment Mz (85.91 kN-m) is found in column no 223 of case2which is 34.52% higher than the critical value of bending moment Mz (63.86 kN-m) in column no 208 of case 1.

Comparison of maximum values of axial force Fx at different storey.

The maximum values of axial force Fx is compared for the columns of below plinth level, first storey and second storey due to additional storey.

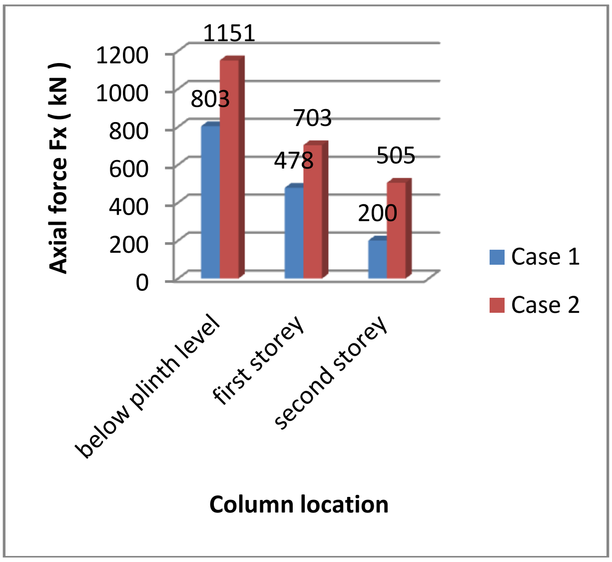

Fig9. Comparison of maximum axial force Fx in columns at different storey

Comparison of maximum values of bending moment My in columns at different storey.

The maximum values of bending moment My is compared for the columns of below plinth level, first storey and second storey due to additional storey.

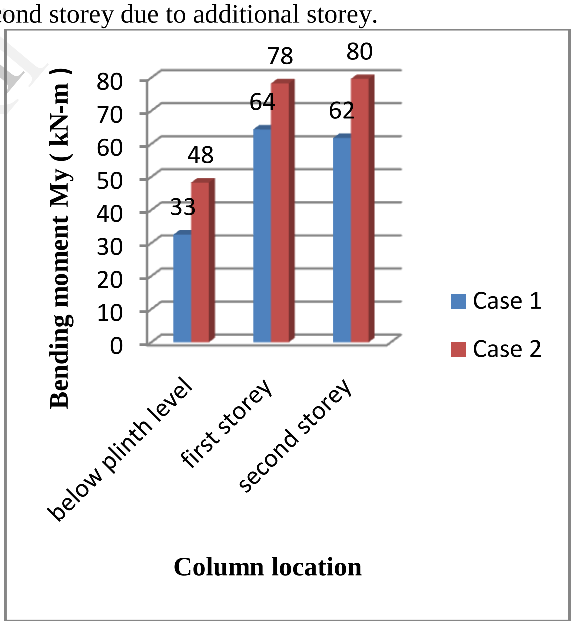

Fig 10. Comparison of maximum bending moment My in columns at different storey

Comparison of maximum values of bending moment Mz in columns at different storey.

The maximum values of bending moment Mz is compared for the columns of below plinth level, first storey and second storey due to additional storey.

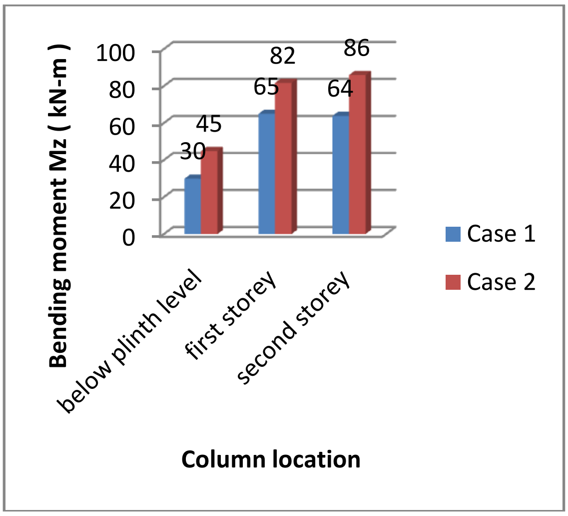

Fig 11. Comparison of maximum bending moment Mz in columns at different storey

VI. STRENGTHENING OF COLUMNS

The columns of first storey and second storey are strengthened for the additional load and moment estimated from theabove tables.

a)Strengthening of first storey columns

The first storey columns are strengthened for critical value of additional axial load and bending moment obtained from Table 3 due to construction of new storey.

Strengthening requirement for additional axial load

Maximum increase in axial load = 330940 N

Permissible stress = 150 N/mm^2

Additional area required for Fe250 grade steel

$= \frac{\text{Load}}{\text{Permissible Stress}} = \frac{330940}{150}$

$M = f \times \frac{I}{y} = 51.89 \times 10^6 = 150 \times \frac{A \times 130^2}{160}$

$\therefore Ast_2 = 3275\ mm^2$

Therefore,

Total area required $(Ast_1 + Ast_2) = 5305\ mm^2$

Area required for each section = 5305/4 = 1326

Angle section provided = ISA 75 x 75 x 10

Total area provided = 4 x 1402 = 5608 mm^2

$\therefore Ast_1 = 2206\ mm^2$

Strengthening requirement for additional moment

Additional moment = 58.01 kN-m

Assuming Cyy = 20 mm and

thickness of angle section = 10 mm

Moment of Inertia = A x 130^2

Extreme fiber distance from CG = y = 160 mm

$M = f \times \frac{I}{y} = 58.01 \times 10^6 = 150 \times \frac{A \times 130^2}{160}$

$\therefore Ast_2 = 3661 mm^2$

Therefore,

Total area required $(Ast_1 + Ast_2) = 5867 mm^2$

Area required for each section = 5867/4 = 1466 mm^2

Angle section provided = ISA 80 x 80 x 10

Total area provided = 4 x 1502 = 6008 mm^2

b) Strengthening of second storey

The second storey columns are strengthened for critical value of additional axial load and bending moment obtained from Table 4 due to construction of new storey.

Strengthening requirement for additional axial load

Maximum increase in axial load = 304600 N

Permissible stress = 150 N/mm^2

Additional area required for Fe250 grade steel

$= \frac{\text{Load}}{\text{Permissible Stress}} = \frac{304600}{150}$

$\therefore Ast_1 = 2030\ mm^2$

Strengthening requirement for additional moment

Maximum increase in bending moment = 51.89 kN-m

Assuming Cyy = 20 mm and

thickness of angle section = 10 mm

Moment of Inertia = A x 130^2

Assuming thickness of the angle section = 10 mm

Extreme fiber distance from CG = y =160 mm

VII. CONCLUSIONS

In present work the effect of additional forces due to construction of new storey on existing structure is studied. The axial force and bending moment in columns are compared to investigate the need of strengthening of columns. Comparison of column forces due to construction of additional storey over existing structure is presented in Table-5.

TABLE-5 Comparison of column forces due to construction of additional storey over existing structure.

Structural component	Variation of forces in existing structure	Variation of forces in structure with additional storey	% Variation in forces due to additional storey
i) Axial force Fx (kN)			
a) Below plinth level (Member no.)	13.16 – 803.32 (31)* - (9)	5.46 – 1150.51 (31) - (9)	−0.58**– 43.21
b) First storey (Member no.)	15.47 – 478.18 (131) - (109)	16.17 – 703.01 (131) - (109)	4.52 – 47.01
c) Second storey (Member no.)	36.45 – 200.41 (231) - (209)	67.91 – 505.01 (218) - (209)	86.31 – 151.98
ii) Bending moment My (kN-m)			
a) Below plinth level (Member no.)	0.04 – 32.57 (16) - (1)	0.18 – 48.31 (30) - (8)	3.50 – 48.32
b) First storey (Member no.)	0.21 – 64.38 (117) - (108)	0.37 – 86.61 (123) - (108)	76.19 – 34.52
c) Second storey (Member no.)	0.09 – 61.79 (217) - (202)	0.22 – 81.34 (223) - (211)	144.44 – 31.63
iii) Bending moment Mz (kN-m)			
a) Below plinth level (Member no.)	0.05 – 29.91 (4) - (24)	0.03 – 43.77 (10) - (2)	-40.00 – 46.33
b) First storey (Member no.)	0.25 – 64.95 (111) - (101)	1.89 – 81.65 (110) - (123)	# - 25.71
c) Second storey (Member no.)	0.55 – 63.86 (211) - (208)	1.61 – 85.91 (210) - (223)	192.72 – 34.52

Note:
* Value within the bracket indicates member no.
** Negative sign indicates decrease in the value.
# Indicates insignificant value.

The main findings of this study are mentioned below:

1. The construction of additional storey causes substantial increase in axial force in all the columns. The increase in critical value of axial force is found to be about 50% in columns below plinth level and first storey and 152% for second storey columns.
2. The construction of additional storey causes substantial increase in bending moment in all the columns. The increase in critical value of bending moment is found to be about 30% in columns below plinth level and first storey and about 50% for second storey columns.

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