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Feasibility Study for Construction of an Additional Floor on the Existing Building

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ABSTRACT

This project involves the feasibility study on a three storey building upon which an additional floor had to be constructed. Here building is checked whether its structural members can efficiently take up the additional loads coming on it due to the construction of addition floor on it. Hence,Visual inspection was done to see whether there is any visible distress in the building. Building plan was prepared by measuring the dimensions of the building. Non-destructive and semi destructive tests were done to know the present strength of the building.By using the results obtained from investigations carried out, the building is analysed for additional floor load using computer software ETABS and if the structural members are not capable of taking additional loads the structural members are strengthened accordingly.

KEYWORDS

Feasibility study for construction of additional floor, Non Destructive testing, analysis modal in ETABS, strengthening of structural members, column jacketing.

INTRODUCTION

As the city grows, there will be expansion of the civil infrastructure of the city such as residential buildings and public buildings etc. These structures are constructed for certain design periods and for certain anticipated loads. Growing city requires construction of new skyline by densifying the city which leads to storey extensions on the existing building. This will necessitate to determine the present strength of the building by conducting Non-destructive or semi destructive tests.

The behaviour of old existing buildings is affected by their initial structural inadequacies, material strength degradation due to time, and changes carried out during use over the years such as making new openings, addition of new parts inducing dissymmetry in plan and elevation, etc. The strengthening of existing reinforced concrete members is a task that should be carried out by a structural engineer according to data collected and proper analysis.

Concrete construction is expected to give trouble free service throughout its intended design life. However, these expectations are not realized in many constructions because of structural deficiency, material deterioration, unanticipated over loadings or physical damage. Premature material deterioration can arise from a number of causes, the most common being when the construction specifications are violated or when the facility is exposed to harsher service environment than those expected during the planning and design stages. Except in some cases, most of the structures require restoration or strengthening to meet its functional requirements for construction of additional floors.

CAUSES OF DETERIORATION IN A BUILDING

The building may deteriorate due to following reasons;

- Drying Shrinkage.
- Temperature stresses - This may be due to difference in temperatures between the inside of the building with its environment and variation in internal temperature of the building or structure.
- Absorption of moisture by concrete.
- Corrosion of reinforcement - This could be caused by entry of moisture through cracks, pores and Electrolytic action.
- Aggressive chemical action.
- Weathering action.
- Poor design details at re-entrant corners, changes in cross section, rigid joints in precast elements, deflections - this lead to leakage through joints, inadequate drainage, inefficient drainage slopes, unanticipated shear stresses in piers, columns and abutments etc., incompatibility of materials of sections, negligence in design.
- Errors in design.
- Errors in earlier repairs.
- Overloading.
- External influences such as earthquakes, wind, fire calamities and cyclones etc.

SITE INVESIGATIONS

In order to ascertain the structural stability, following investigative tests were resorted to:

1. Dimensional measurements of structural members.
2. Examination of foundation and test on soil at founding level
3. Semi-destructive test to assess the quality / strength of in-situ concrete in r.c. slab.
4. Non-destructive tests to assess the quality / strength of in-situ concrete in r.c members.

a) Ultrasonic Pulse Velocity Test on r.c. columns and beams

b) Rebound Hammer Test on r.c. slabs.

5. Cover meter study to assess the thickness of cover concrete and to map peripheral reinforcement in r c members.
6. Theoretical Analysis and Design Verification.

DIMENSIONAL MEASUREMENTS OF STRUCTURAL MEMBERS.

As all the relevant structural drawings were not made available at the time of inspection and testing, detailed physical measurement was resorted to at site in order to obtain the dimensions of the various members. The dimensions of typical footing (after exposing typical column footing), columns, beams and slab were physically measured and recorded for theoretical verification. Measured dimensions of all three floors are plotted in AutoCAD. Typical floor plan is as shown in figure 1.

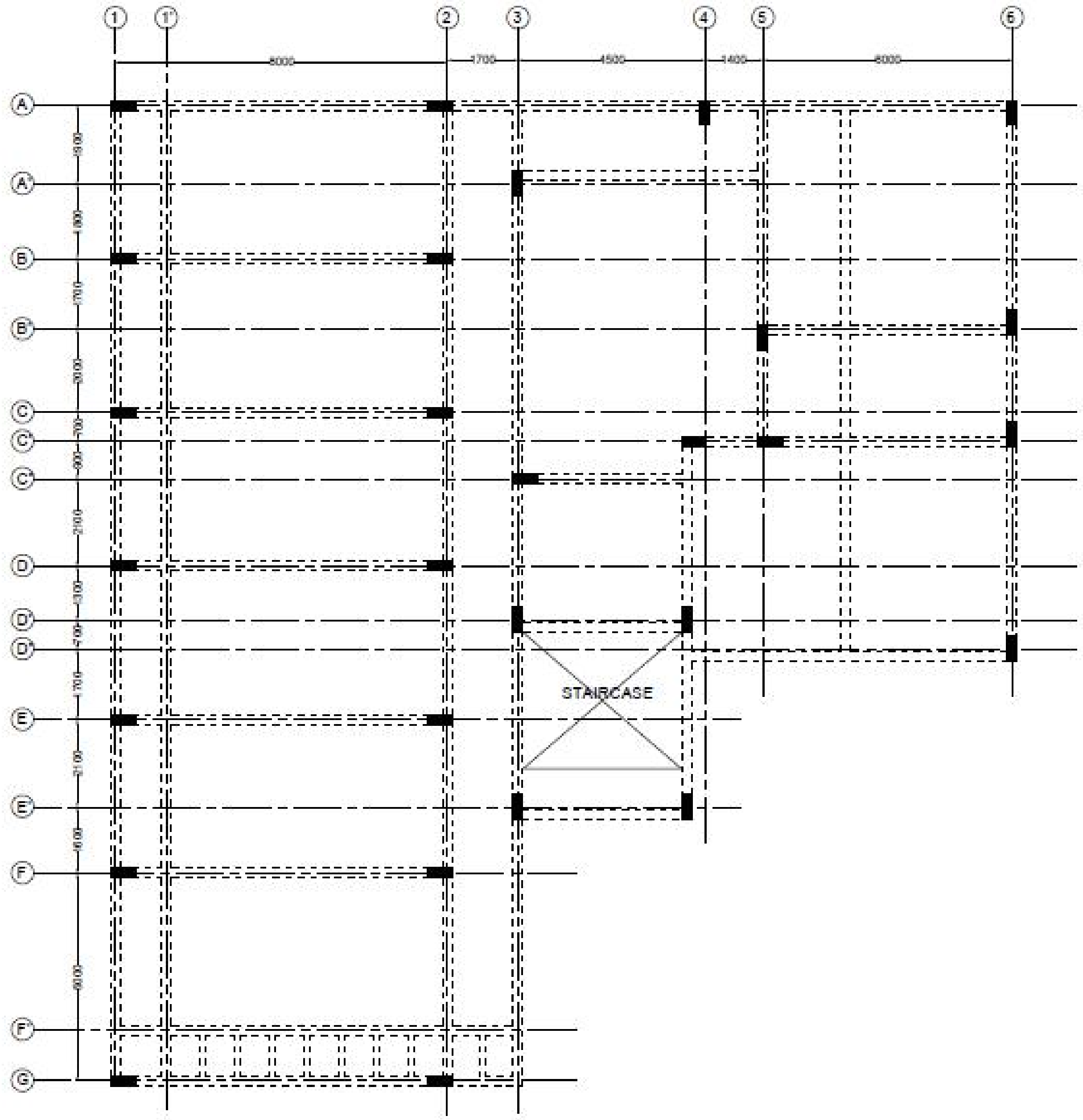

Fig 1: Typical floor plan with grids

EXAMINATION OF FOUNDATION AND TESTS ON SOIL AT FOUNDING LEVEL

To examine the foundation system and to verify the soil characteristics below the foundation, trail pit was excavated up to founding level at two of the column footings. The field investigation was carried out by drilling 2 bore holes of 150mm diameter using manual auger. Standard penetration test was conducted at regular intervals as per IS:2131-1981 and Undisturbed soil sample was collected for laboratory test. The results of the test are tabulated in table 1.Based on the laboratory test results, the safe bearing capacity of soil is considered as **25t/sq.m** at founding level.

Table 1: soil exploration

BH No.	Depth (m)	Bulk Density (g/cc)	Water Content (%)	Grain Size Distribution (%)					Atterberg Limits (%)			Shear Test		
				Gravel	Sand			Silt & Clay	Liquid Limit	Plastic Limit	Plasticity Index	Type	C	Ø
					Coarse	Med	Fine						(kg/cm^2)	(Deg)
BH 1	1.0	1.97	15	1	2	22	32	43	33	20	13	Tri-axial	0.20	24
	1.5			-	3	24	36	38	34	22	12			
	2.5			1	1	27	25	46	34	18	16			
	3.5			-	1	22	28	49	35	21	14			
	4.5			-	-	26	26	48	35	19	16			
	6.0			2	2	35	30	31	30	24	6			
BH 2	1.5			5	9	26	20	34	39	20	19			
	2.5	1.90	16	2	3	37	30	28	33	20	13	Tri-axial	0.23	25
	3.0			2	3	29	30	36	30	22	12			
	4.5			1	1	39	31	28	35	25	10			

SEMI-DESTRUCTIVE TESTS TO ASSESS THE QUALITY / STRENGTH OF IN-SITU CONCRETE IN R.C FOOTING & SLAB.

In order to assess the quality / strength of in-situ concrete in r c footing and slab, semi- destructive test such as core test was resorted. The core sample was extracted from the R.C footing & first floor slab for laboratory tests. The extracted core samples were subjected to compressive strength test after necessary trimming and capping as per the guidelines in IS: 516-1959 Reaffirmed in 1998). The extracted core samples were observed to be homogeneous and free from any voids/pores. The results of concrete core test are tabulated in table 3.2 shown below.

Table 2: core test

Sl. No.	Member and Grid Identification*	Core Length** (l) (mm)	Core Dia (d) (mm)	Core Wt.** (Kg.)	Failure load (kN)	Core Comp. Strength# (N/sq.mm)	l/d Ratio	Correction factor for (l/d) ratio+	Corrected Cyl. Comp Strength (N/sq.mm)	Equivalent Cube Comp. Strength ++ (N/sq.mm)	Type of Failure
1	RC Footing A-1	116	74	1.09	93.12	23.37	1.568	0.953	22.28	27.8	typical compression failure
2	RC Footing F-2	117	74	1.10	106.40	26.71	1.581	0.954	25.49	31.9	
3	2nd floor ceiling slab A-B/1-2	107	74	1.02	62.50	15.69	1.446	0.940	14.74	18.4	
4	2nd floor ceiling slab A-A'/3-4	103	74	0.97	55.20	13.86	1.392	0.934	12.94	16.2	
5	2nd floor ceiling slab D-E/2-3	105	74	1.01	45.40	11.40	1.419	0.937	10.68	13.3	

* As Furnished by the customer.

** Core length and core weight after trimming and capping.

After applying correction factor for diameter of core which is less than 100 mm (i.e., strength of core x 1.08) as per SP:24-1983, clause:16.3.2

+ For l/d ratio, correction factors are as per Figure-1 of IS:516-1959 (Reaffirmed in 2013).

++ Equivalent cube compressive strength = 1.25 x corrected cylinder compressive strength as per IS:516-1959, Cl.5.6.1 (Reaffirmed in 2013).

*Refer Sketch fig1 for Floor /Member/ Grid Identification.

NON-DESTRUCTIVE TESTS TO ASSESS THE QUALITY / STRENGTH OF IN-SITU CONCRETE IN R.C. MEMBERS.

A.ULTRASONIC PULSE VELOCITY TEST ON R. C. COLUMNS AND BEAMS

Ultrasonic Pulse Velocity Test was conducted on r.c. columns and beams at random accessible regions in order to assess the quality/strength of in-situ concrete. The tests was conducted using **"PUNDIT LAB+" (Portable Ultrasonic Non-destructive Digital Indicating Tester)** equipment from **M/s. PROCEQ,Switzerland as per the guidelines in Indian Standards IS: 13311-(Part 1)-1992 (Reaffirmed 2013)**.

The quality of concrete in RC columns and beams falls under the category of **" Medium to Good Concrete"** as per Table-2 of IS: 13311-(Part-1)-1992 Reaffirmed 2013. Further, the estimated compressive strength of concrete in tested columns and beams in fallsin the range of **19.0N/sq.mm** to **26.0 N/sq.mm.**Refer table 3.1 and 3.2 for reference charts of concrete quality and compressive strength respectively.

Table: 3 Ultrasonic pulse velocity test results

Sl No.	Floor / Member Identification*	Grid Identification*	Average PulseVelocity (Km/Sec)	Remarks
1	2	3	4	5
	Ground Floor			Refer Table – 3A for estimated compressive strength range and Quality grading of in-situ Concrete.
1	RC Columns	A4	3.7	
2		C'3	3.4	
3		B'4	3.5	
4		D2	3.7	
5		F2	3.6	
6		E2	3.4	
7		A2	3.8	
8		B1	3.6	
9	RC Beams	A'/3-5	3.4	
10		A-B/4	3.6	
11		C''/3-4	3.8	
12		2/(C-D)	3.4	
13		(D-E)/1	3.7	

	Ground Floor			Refer Table – 3.3A for estimated compressive strength range and Quality grading of in-situ Concrete
14	**RC Beams**	I'/ (E-F)	3.5	
15		(A-B)/I'	3.5	
	First Floor			
16	**RC Columns**	G1	3.5	
17		G2	3.6	
18	**RC Beams**	F'/(1-3)	3.3	
19		2/(F-F')	3.5	
20		3/(F-F')	3.4	
21		D''/(3-5)	3.7	
22		4/(B'-C)	3.6	
23		B'(5-6)	3.3	
24		A/(3-4)	3.3	
	Second Floor			
25	**RC Columns**	D2	3.3	
26		C2	3.4	
27		F2	3.5	
28		E2	3.7	
29		B2	3.3	
30		A2	3.6	
31	**RC Beams**	3/(A'-C'')	3.4	
32		D/(1-2)	3.3	
33		C/(1-2)	3.4	
34		2/(C-D)	3.5	
35		F/(1-2)	3.4	
36		E/(1-2)	3.4	
37		B/(1-2)	3.6	
38		2/(A-B)	3.5	

* Refer sketch fig 01 for Member / Grid Identification.

Table:3.1reference strength chart for ultrasonic pulse velocity test

Pulse Velocity (Km/sec)	Concrete Quality Grading
Below 3.0	Doubtful
3.1 to 3.5	Medium
3.6 to 4.5	Good
Above 4.5	Excellent

Note: Concrete quality grading for different velocity criterion as reproduced from Table-2 of IS:13311-(Part-I)-1992-(Reaffirmed in 2013).

In case of "Doubtful quality", it may be necessary to carry out further testing.

Table: 3.2Compressive Strength reference chart

Pulse Velocity (Km/sec)	Estimated Compressive Strength (0N/Sq.mm)
2.7 to 3.0	14 - 16
3.1 to 3.4	17 – 21
3.5 to 3.8	22 - 26
3.9 to 4.2	27 – 31
4.3 to 4.6	32 – 36
Above 4.7	36 and above

Note: The estimated compressive strength worked out based on the calibration Chart developed for the above test instrument in laboratory.

B.REBOUND HAMMER TEST ON R. C. SLAB

Rebound Hammer Test was carried out on slab at random to assess the surface hardness and strength of in-situ concrete. The test was conducted using **Schmidt Rebound Hammer from M/s Proceq, Switzerland** as per the guidelines in Indian Standards IS: 13311-(Part-2)-1992 (reaffirmed 2013).

Rebound Hammer test results indicate that the estimated strength of in-situ concrete in tested unaffected region of slabs in falls in the range of **14.0N/sq.mm to 22.0N/sq.mm.**

Tests results obtained for respective member with grid labels are tabulated in table 4. Refer table 4.1 for reference charts for estimated compressive strength against rebound number.

Table: 4 Rebound hammer results

Sl No.	Floor / Member Identification*	Grid Identification*	Average Rebound Number++	Remarks
1	2	3	4	5
	Ground Floor			Refer Table – 4A for Estimated compressive strength range of in-situ concrete
1	RC Ceiling Slab	E-D/1-2	31	
2		E-F/1-2	30	
3		A'-C''/3-4	34	
4		A-B/1-2	33	
5		A-B'/3-4'	32	
6		D-E/1-2	31	
7		B-C/1-2	33	
	First Floor			
8	RC Ceiling Slab	F-F'/1-2	28	
9		F-F'/2-3	26	
10		D'-C''/3-4	34	
11		B'-C/4-5	33	
12		B'-C/3-4	30	

1	2	3	4	5
	Second Floor			Refer Table – 4A for Estimated compressive strength range of in-situ concrete
13	**RC Ceiling Slab**	A-B/3-4	26	
14		B-E/1-2	29	
15		C-D/1-2	27	
16		E-G/1-2	28	
17		G-F/2-3	26	
18		E-F/1-2	36	
19		A-B/1-2	28	
20		B-C/1-2	26	

*Refer sketch fig 01 for Member / Grid Identification.
++ After applying necessary correction factor for position of Hammer.

Table: 4.1 Reference chart

REBOUNDNUMBER	ESTIMATED COMPRESSIVE STRENGTH RANGE (N/Sq.mm)
22 to 26	10 to 14
26 to 30	14 to 18
30 to 34	18 to 22
34 to 38	22 to 26
38 to 42	26 to 30
42 to 46	30 to 34

Note: Estimated compressive strength is worked out based on the Calibration Chart developed for the above test instrument in laboratory

C. COVER METER STUDY TO ASSESS THE THICKNESS OF COVER AND TO MAP PERIPHERAL REINFORCEMENT IN R C MEMBERS.

Covermeter studies were carried out on various r c members in order to assess the thickness of cover concrete, disposition and probable dia of peripheral embedded rebars in the RC members. The test was conducted using **Profometer 5⁺** from **M/s. Proceq, Switzerland** as per the guidelines furnished by the manufacturer's manual.

The covermeter study revealed that the cover concrete provided to the rebars in the r c members is adequate in most of the tested r c members and disposition of reinforcement is recorded for theoretical verifications.

Table: 5Covermeter readings

Sl. No.	Floor / Member Identification*	Grid Identification*	Range of Cover Concrete ** (mm)
1	2	3	4
	Ground Floor		
1	**RC Columns**	A4	35-50
2		C'4	30-40
3		D2	35-45
4		A2	30-55
5		B1	30-40
6	**RC Beams**	A'/3-5	25-35
7		A-B'/5	30-40
8		3/(C-D)	30-50
9		(A-B) /1'	30-40
10	**Ceiling Slab**	C-D/1-2	20-30
11		A'-C''/3-5	20-35
12		A-B/1-2	20-35
13		A-B'/5-6	25-35
14		D-E/1-2	25-40
15		B-C/1-2	25-35

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1	2	3	4
	First Floor		
16	Ceiling Slab	F-F'/1-2	25-35
17		E-F/1-2	30-40
18		B'-C/4-5	25-35
19		3-4/B'-C'	20-30
	Second Floor		
20	Ceiling Slab	A-B/3-4	20-30
21		C-D/1-2	20-35
22		F-G	25-35
23		A-B/1-2	20-35
24		B-C/1-2	20-35

* Refer fig1 for Member / GridIdentification.

** Inclusive of plaster.

ANALYSIS IN ETABS

Structural analysis of the building was done in ETABS using the data obtained from site investigations conducted and using material strength data obtained by conducting Non Destructive tests on the building. Analysis was done by applying gravitational loads, wind loads and earthquake loads according to IS codes.Table 6 shows the material properties adopted for the analysis. Figure 4 shows the existing building modelled in ETABS.

Table: 6 Material properties

Name	Type	E (Mpa)	Unit weight KN/m^3	Design strength (Mpa)
Fe415	Steel	200000	78.50	415
M20	Concrete	8944.3	25	20

Table: 7 Section properties

Structural members	Dimension (mm)
Beams Sections	B230x450M25
	B230x600M25
Column Sections	C200x600M25
	C350x750M25(after jacketing)

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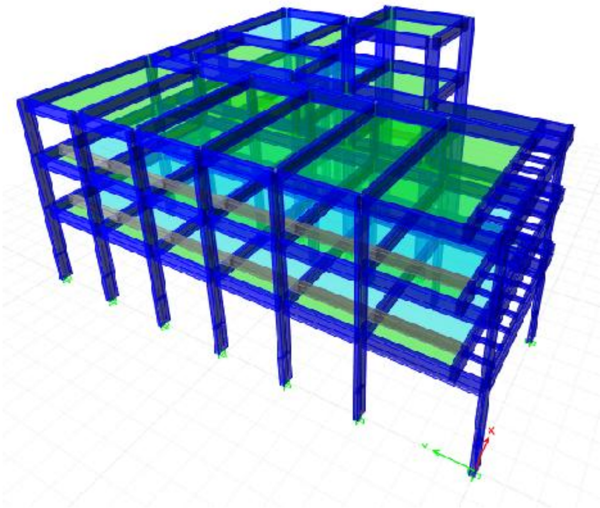

Fig. 2 ETABS model of existing building

Figure 3 shows the design results obtained from ETABS for additional loads but with existing column dimension and for obtained strength results from NDTs. It can be observed that the reinforcement required in the ground floor columns exceeds the reinforcement provided, also it exceeds the minimum allowable reinforcement i.e. 4% (clause26.5.3,IS456)

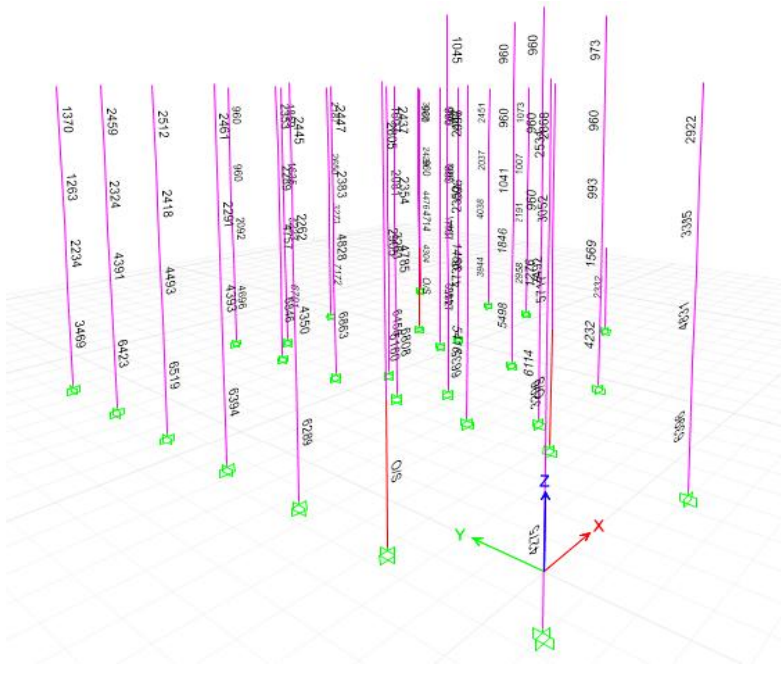

Fig. 3 Design results of ETABS

STRENGTHENING OF STRUCTURAL MEMBERS

Due to the extra load coming on the existing structure because of additional floor load the inefficient structural members are to be strengthened. Additional loads does not cause much affect on the slabs and beams of the existing floors. But the loads on the columns increases and the ground floor columns are not efficient to take up the loads. Hence ground floor columns are proposed for strengthening.

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There are various methods of column strengthening like RCC jacketing, CFRP wrapping, strengthening by steel plates, adding steel profiles etc. here, column jacketing with section enlargement is considered because it is economical, easy to construct and no high skilled labours are required.

Figure 7 shows the rebar percentage after section enlargement is done. Minimum 75mm thick jacket must be provided for the ease of construction and concreting hence the dimensions of the columns will increase by 150mm i.e. 200x600mm columns will become 350x750mm after jacketing. Enlargement in section will increase the column capacity and hence minimum percentage of steel if sufficient i.e. 0.8% of enlarged section as shown in figure7.

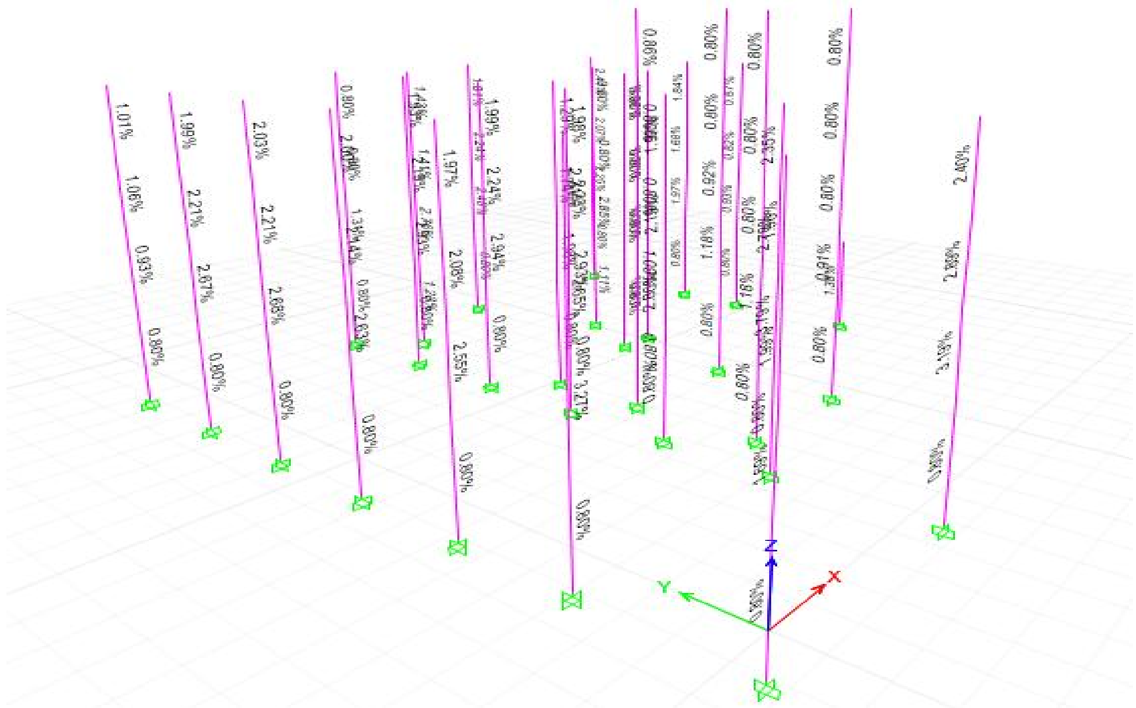

Fig. 4 Design results after jacketing

DESIGN AND DETAILING OF JACKET

There is no different design procedure for jacketing hence design is done as conventional design of columns as per IS456: 2000 by considering enlarged section i.e. 350x750mm. which gives same results as ETABS results (figure4). Reinforcement details of existing column and jacketed portion(hatched) is shown figure 5.

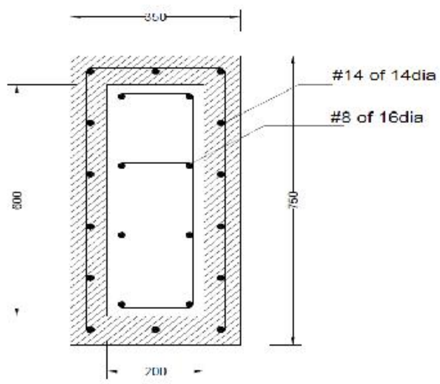

Fig. 5 Cross sectional details showing jacketed portion

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