Systematic Evaluation and Assessment of Existing Building for Storey Extension: A Case Study

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Abstract

Urbanization is a need of this developing era but rapid growth has led to the problems of urban sprawl, ribbon development, unregulated development, high cost for urban infrastructure and pollution due to the inadequate disposal of urban and industrial waste. As we know that, India is a second largest population country in the world and population required land to fulfil their basic need as a shelter. To minimize the problem of land, there is a need to explore/developed a vertical extension of buildings. Vertical growth is capitalizing the remaining buildable space which can be utilized from many older buildings. At the same time, engineer can focus on the refurbishes the housing block and improves standards of energy efficiency, safety, and accessibility of the existing building as per the revised codal provisions. The literature has shown various measures/techniques for strengthening/retrofitting of existing structure for the floor expansion. Before going for vertical extension to any structure, there is a need to check the strength and stability of existing structure through structural audit (physical verification and NDT- correlating strength). After structural auditing, engineers/designers will have the reference data about desired strength to available strength and load carrying capacity of existing building. The main aim of this paper is present a case study regarding how the task of ascertain the decision making for storey extension over existing building located in Amravati (Seismic Zone II), Maharashtra, India was conducted. The findings are presented in this paper can be taken as an idea/methodology to perform an evaluation of existing structure by performing NDT procedures which would be useful to make decisions on the basis of available limited data and constraints of projects, rather than demoralizing the potential of project in spite of having sufficient available strength of the building to withstand the storey extension.

Keywords: Storey extension, Non-Destructive Test, Foundation, Retrofitting/Strengthening of members, Structural Audit.

1.Introduction

Real estate sector is one of the most globally recognized sectors. It comprises of four sub sectors - housing, retail, hospitality, and commercial. The growth of this sector is well complemented by the growth in the corporate environment and the demand for office space as well as urban and semi-urban accommodations. The Indian commercial real estate sector is fair in relation to the city's overall financial health and provides plenty of opportunities. During Covid-19 period, the market value of real estate has become higher as most of the existing facilities have to renovated or changed for emergency situations. Considering this change most of the owners have an option to extend existing building to fulfill their present requirement. When any one goes for vertical extension of existing building then there is a need to study, asses strength and stability of existing building, consequently strengthen the structure as per revised code [1][5]. The present structure is situated in seismic zone II (Amravati, M.S., India) with height less than 15 m, due to consideration of seismic forces on a structure has not been considered limited to static analysis and designed as per IS-456-2000 [2]. As per load transfer mechanism of a structure is concern, if we increase extra floors on the existing structure then the columns as well as foundations will have to carry extra load coming from the building,

Consequently, before going for any extension, there is need of systematic evaluation and assessment of existing building (Structural Audit, physical verification and NDT) [3]. If the columns are not strong enough to carry the load of extra floors, the need arises to decide the extension depending on various aspects such as reducing dead load via using AAC blocks, apply various strengthening measures that increase structural element strength using the different retrofitting/strengthening techniques. Hence, present work addresses an methodology to introspect the internal capacity of the structure and make an attempt to decide to opt for extension of floor or terminate the further development on respective project.

2. Literature Review

A literature review on the stability of structures is a comprehensive survey of the research and developments in the field of structural stability. This topic is crucial in civil engineering as it deals with the ability of a structure to maintain its equilibrium under various loading conditions. Here is a brief overview of key concepts and findings from the literature:

Table 1 Literature review on structural stability and its technique

Sr. No	Author	Technique	Remark
1	Sahar Hasani (2023)	NDT on different structure	Systematic review of NDT technique sensor based
2	Tian, L (2022)	Crack detection	Crack detection using different NDT Techniques
3	Yuan, F (2021)	Crack detection in metals	An approach to quantify cracks in structure
4	Ghosh, A (2020)	Concrete beam members	offered a cost-effective 'Industry 4.0'solution for real-time SHM.
5	Rathod, H.; Gupta, R (2019)	Ultrasonic pulse velocity (UPV) technique Reinforced concrete Debonding	Check strength of existing building using UPV

6	Zumrawi M. M. E (2018)	Stability check using NDT	Strengthening of Building foundation for Storey Extension
7	Anu Soikkelia. (2016)	Additional Floors in Old Apartment Blocks	Systematic evaluation of old apartment
8	Song, Y.; Wu, F (2015)	Acoustic emission of Railway Cracks	Crack analysis after studying the failure patterns

After carried out a literature survey it was observed that the field of structural stability is continuously evolving with new research, materials, and technologies. Each structure have there own strength and weakness and hence development of systematic evaluation technique for individual structure is important.

3. Methodology

In this paper, a case study of an existing building located in Amravati, Maharashtra, India is presented. The aim of this work is to decide, whether the existing building is in position of extension or not. It will be ascertained if new floor above existing building can be constructed or not possible to extend storey using existing strength of structure. After assessment, it has been observed that storey extension can be done over existing building can take loads of floors form extension after additional floor are considered and subsequently any proper strengthening measures can be adopted.

a. Structural Audit Report:

The four-storey reinforced concrete building consist of an office and computer lab at the ground floor and 6 flats at the 1st, 2nd and 3rd floor (2 flats at each floor on either side of the staircase). The floor system is a reinforced concrete slab supported on columns that have a rectangular cross section. Floor to floor height a building is 3m. The provided thickness of exterior walls is 0.23m and interior walls is 0.115m. The footing is an isolated footing (no drawings and details of footing, columns, beam and slab are provided by the owners of the building).

Figure 1 Photo of existing Structure

Type of structure: RCC building (Framed structure)
Address: Amravati, Maharashtra
No of stories: G+3 stories
No of Lifts: None.
No & type of apartments: 6 flats
Description of building: Office at ground floor and flats at 1st, 2nd and 3rd floor.
Year of construction: 2012
Age: 8 years
Previous Structural Audit: This is first Structural Audit
Area inspected: External building faces, terrace etc.
Seismic zone: II as per IS 1893:2016

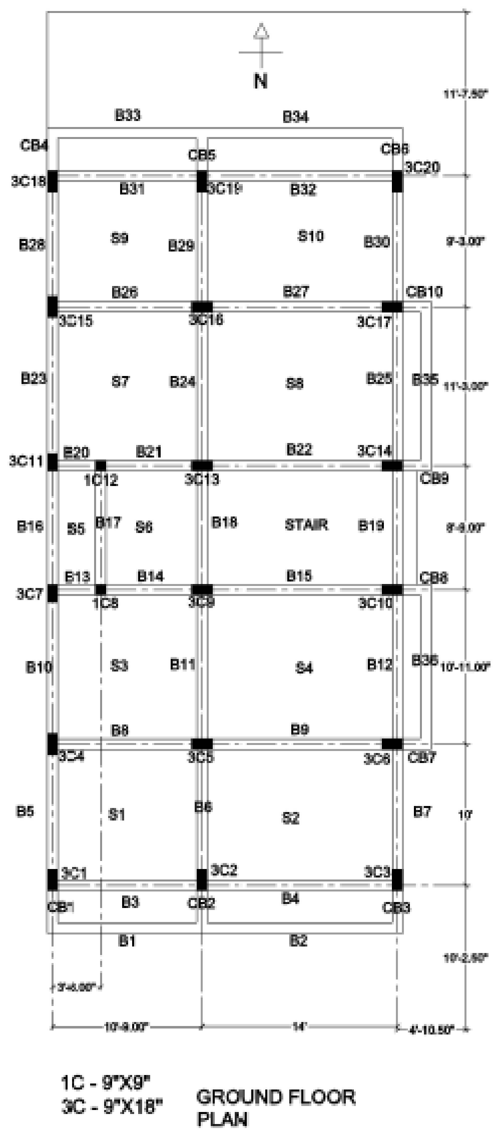

Figure 2 Plan of Ground Floor of Building/parent model

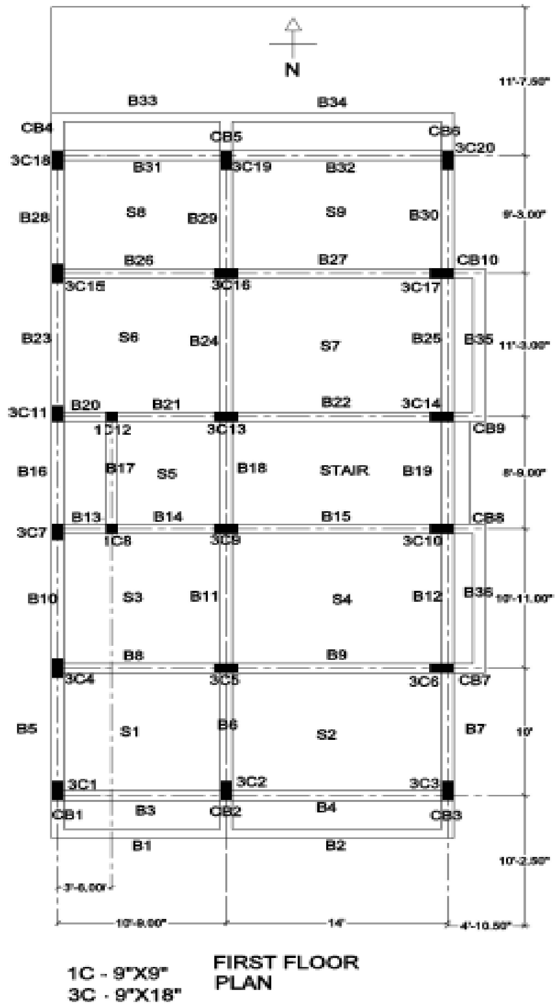

Figure 3 Plan of First Floor of Building/parent building

Non-destructive Rebound hammer test is carried out to identify grade of concrete in existing building. The results of the rebound hammer are correlated with the strength of column/beam using calibrated rebound hammer at institute, which are displayed below for easy reference:

4. Results of Rebound Hammer Test and correlated compressive strength shown in Table 1 ,

Table 2 Results of Rebound Hammer Test

Sr no	Beams	Rebound Hammer no.	Compressive Strength(N/mm^2)	Columns	Rebound Hammer no.	Compressive Strength(N/mm^2)
1	B1	24	10	3C1	32	23
2	B2	26	12	3C2	31	22
3	B3	23.25	10	3C3	34	26

4	B4	26.9	14	3C4	32	23
5	B5	25	11	3C5	29	19
6	B6	27	14	3C6	35	27
7	B7	24.4	11	3C7	34	26
8	B8	24	10	1C8	38	32
9	B9	25	11	3C9	29	19
10	B10	28	15	3C10	32	23
11	B11	26.2	12	3C11	36	29
12	B12	25.6	12	1C12	31	22
13	B13	26	12	3C13	32	23
14	B14	25.3	11	3C14	33	24
15	B15	27.6	15	3C15	31	22
16	B16	27	14	3C16	29	19
17	B17	25	11	3C17	30	20
18	B18	24	10	3C18	32	23
19	B19	26.2	13	3C19	34	26
20	B20	24.2	10	3C20	31	22
21	B21	25.3	12	NA	NA	NA
22	B22	24.6	11	CB1	24	10
23	B23	25	11	CB2	26	12
24	B24	25	11	CB3	25	11
25	B25	26	12	CB4	24	10
26	B26	24.2	10	CB5	24	10
27	B27	26	12	CB6	26	12
28	B28	25	11	CB7	25	11
29	B29	27	14	CB8	25	11
30	B30	24.3	10	CB9	24	10
31	B31	25	11	CB10	26	12
32	B32	27	14	NA	NA	NA
33	B33	26	12	S1	38	30
34	B34	26.3	13	S2	39	32
35	B35	25.2	11	S3	32	20
36	B36	26	12	NA	NA	NA

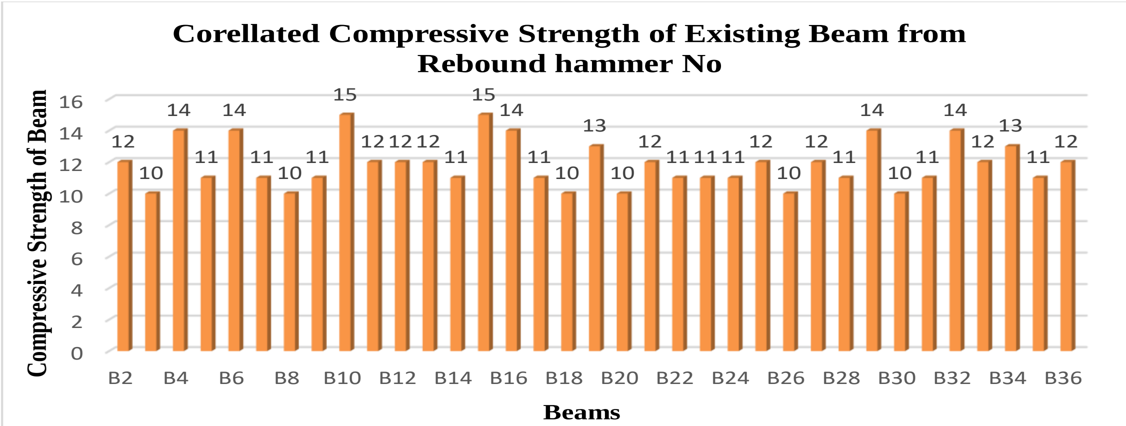

Figure 4 Correlated Compressive Strength of Existing Beam from Rebound hammer No

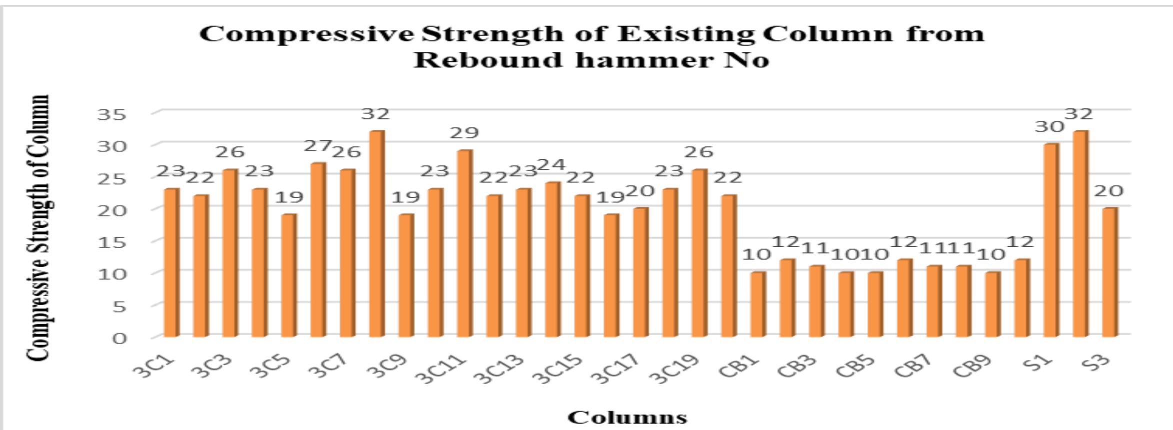

Figure 5 Correlated Compressive Strength of Existing Column from Rebound hammer No

2.2. Parent Frame Analysis

Using the data collected after structural audit, we have correlated and estimated that the building was constructed using the M20 grade of concrete and Fe415 grade of steel. The load calculation is done using the unit density of reinforced cement concrete as 25 KN/m3and unit density of brick work with cement mortar as 20 KN/m3, given in IS 875 (part I) also the live load intensity is referred form IS 875 (part II) as 2 KN/m2for living area and 3KN/m^2 for stair and balcony area. Access was provided on roof slab so the live load intensity was 1.5 KN/m2. The load was calculated using the load combination 1.5(Dead load + Live load) as per IS 456:2000.

After evaluation of existing building and understanding structural auditing results an analytical model of a structure using STAAD PRO software is made, using static analysis required calculations and required results are generated. On the basis of support reactions, the footing dimensions of existing building were ascertained. The load carrying capacity of columns and associated column reinforcement was also ascertained from the parent model. The column size was sufficient and at par same as that verified from site. Which satisfy minimum steel reinforcement required as per clause no. 26.5.3.1 of IS 456-2000, that is 0.8% of gross cross-sectional area of column

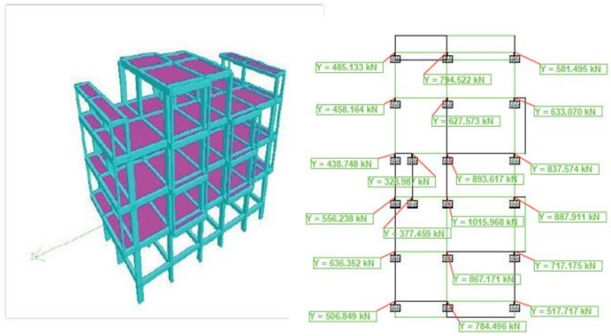

Figure 6 Analytical Model of existing structure/parent model developed in STAAD Pro software and support reactions of the same

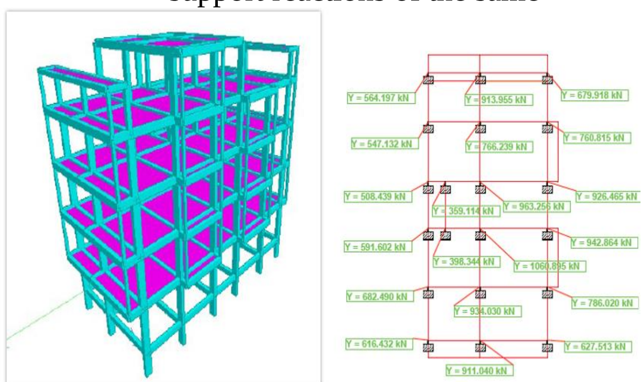

Figure 7 Analytical Model of existing structure + 1 floor extension developed in STAAD Pro software and support reactions of the same

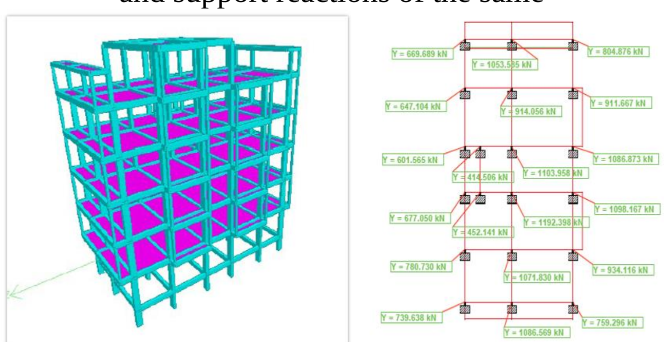

Figure 8 Analytical Model of existing structure + 2 floor extension developed in STAAD Pro software and support reactions of the same

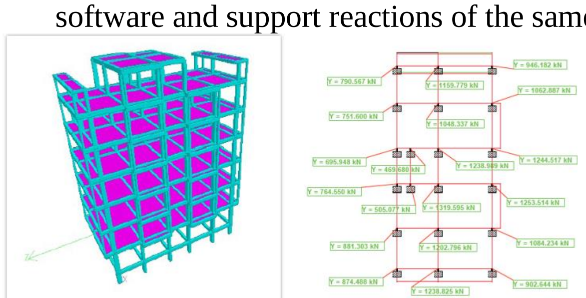

Figure 9 Analytical Model of existing structure + 3 floor extension developed in STAAD Pro software and support reactions of the same

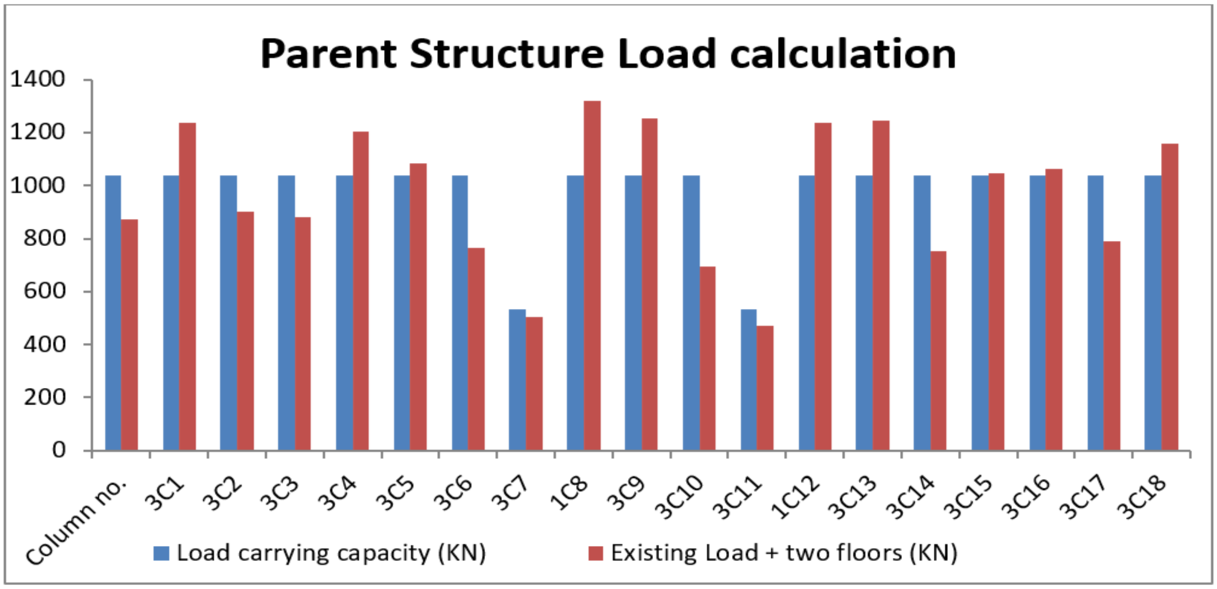

Figure 10 Parent Structure model and Graph of Load calculation

After calculating load carrying capacity of existing column, study on reinforcement present in structure was conducted. Details of footing designed on the basis of support reactions generated in existing structure/ parent model, parent model + 1 storey extension (purposely not incorporated due to length of paper limitation) , parent model + 2 storey extension and parent model +3 storey extension were calculated and checked presented in table 2.

2.3 Parent Frame with extra one storey Analysis

The load of extra storey must be as minimum as possible. To decrease the loading of the extended floor following measures can be adopted:

1) Using light weight material: To decrease the load of extra storey the material used must be light weight. So, we use the light weight AAC block with unit weight 8 KN/m2 for the interior as well as exterior walls also for parapet walls. Also, light weight flooring is considered with 0.5 KN/m2.

2) Reduction in size of columns: If we can reduce the size of the members without affecting its strength, then the dead load can be effectively decreased. So, we decrease the size of all columns in the new construction from 230mm X 450mm to new size 230mm X 380mm.

3) Removing the access to roof: By removing the access to roof, the live load can be decreased from 1.5 KN/m2 to 1 KN/m2.

4) Effect of consolidation of soil: By the time the soil below the footing gets consolidated due the overburden pressure of the structure. Due to this consolidation, there is increase in the bearing capacity of soil. So, we assume that there may be 10% increase in the Safe Bearing Capacity of soil, then it becomes 220 KN/m2 (5).

Above considerations are adopted for developing analytical model for two floors extension and three floor extension. By using the above loading conditions, the new columns are designed for the adopted size. Using the above values and measured dimensions, the present loads on structure were calculated with the help of Staad Pro model. The footing is designed with extension of storey above, Hence, we designed the columns taking the load calculated with factor of safety applicable to SBC.

Following is the bar chart and table showing the columns with their load carrying capacity and (existing load + load due to extra one floor) at the bottom of ground floor column:

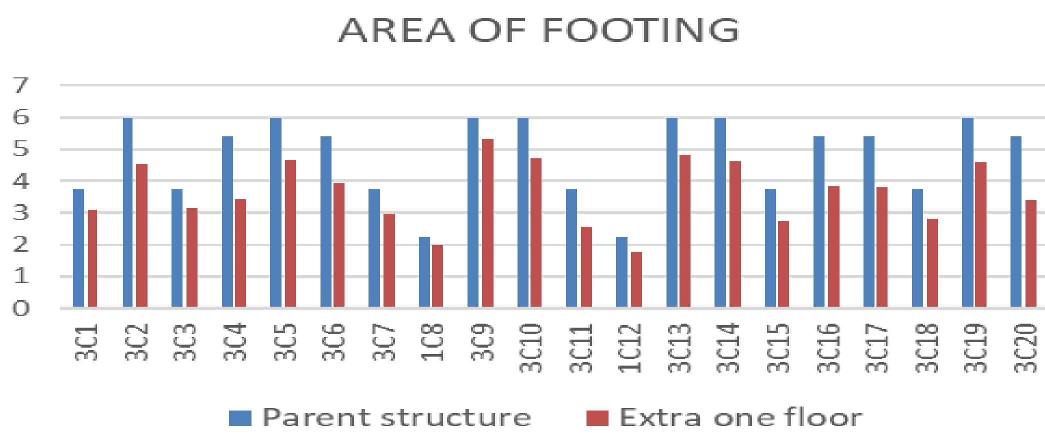

Figure 11 Loads of Footing for parent model + 1 storey extension

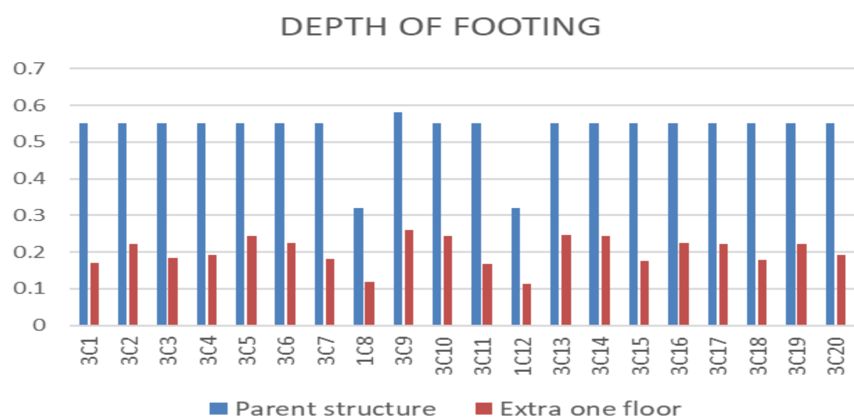

Figure 12 Areas of Footing for parent model + 1 storey extension

Table 3. Details of Footing for parent model

					Spacing in x direction		Spacing in y direction	
Colum n no.	**L**	**B**	**Depth of Foundation on**	**Depth of footing**	**Dia. ofbar**	**Provid ed Spacing**	**Dia. of bar**	**Provid ed Spacing**
-	m	m	m	d (m)	mm	mm	mm	mm

3C1, 3C3, 3C7, 3C11, 3C15, 3C18	2.5	1.5	1.5	0.55	16	120	12	180
3C2, 3C5, 3C9, 3C10, 3C13, 3C14, 3C19	3	2	1.5	0.55	20	140	12	150
3C4, 3C6, 3C16, 3C17, 3C20	3	1.8	1.5	0.55	20	150	12	170
1C8, 1C12	1.5	1.5	1.5	0.32	16	180	12	100

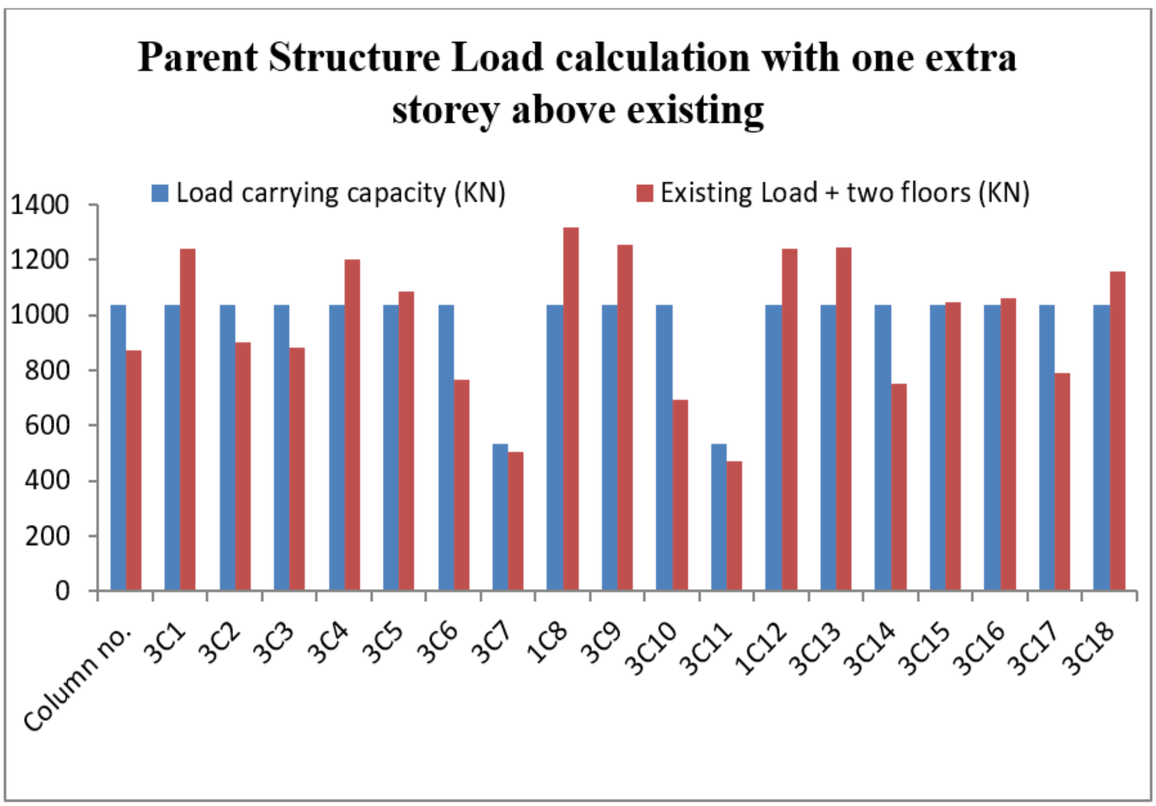

Figure 13 Graph of Parent structure load calculation with one extra storey above existing

Design of building shows that existing column size is sufficient to carry the load with minimum steel reinforcement as per IS 456-2000. Assuming that the columns are provided with minimum steel required as per clause no. 26.5.3.1 of IS 456-2000, that is 0.8% of gross cross-sectional area of column. As the reinforcement was calculated with reference to parent model, the column was designed for the present loading to get the reinforcement details.

Table 3. Loading Details of one extra Floor

	Existing + Extra one floor			
Column no.	**Area Required (mm^2)**	**Depth Required (m)**	**One way SF (KN)**	**Two-way SF (KN)**
3C1	3.08	0.169	259.928	537.033
3C2	4.55	0.221	413.384	871.865
3C3	3.13	0.185	264.600	546.686
3C4	3.41	0.191	344.093	642.308
3C5	4.67	0.243	593.342	893.866
3C6	3.93	0.223	554.799	739.732
3C7	2.95	0.181	249.458	515.401
1C8	1.99	0.119	118.307	379.263
3C9	5.30	0.259	673.936	1004.72
3C10	4.71	0.245	598.951	902.317
3C11	2.54	0.168	214.392	442.952
1C12	1.79	0.113	106.655	341.912
3C13	4.81	0.247	611.910	921.839
3C14	4.63	0.242	588.654	886.804
3C15	2.73	0.174	230.706	476.659
3C16	3.83	0.223	540.837	721.117
3C17	3.80	0.222	536.800	715.733
3C18	2.82	0.177	237.904	491.531
3C19	4.5698	0.222139	414.7094	874.6597
3C20	3.3996	0.192654	342.793	639.8803

2.4 Parent Frame with extra two stories Analysis:

Similar to the Part (B) analysis, the load of extended floors is calculated using the light weight material and to decrease the dead load the access to roof is avoided. All the data used for load calculations is similar to Part (B) Analysis. During design we get that the column size was sufficient enough to carry the load with minimum steel reinforcement. So we assume that the columns are provided with their minimum steel required as per clause no. 26.5.3.1 of IS 456-2000, that is 0.8% of gross cross sectional area of column. Following is the bar chart and table showing the columns with their load carrying capacity and (existing load + load due to extra two floors) at the bottom of ground floor column:

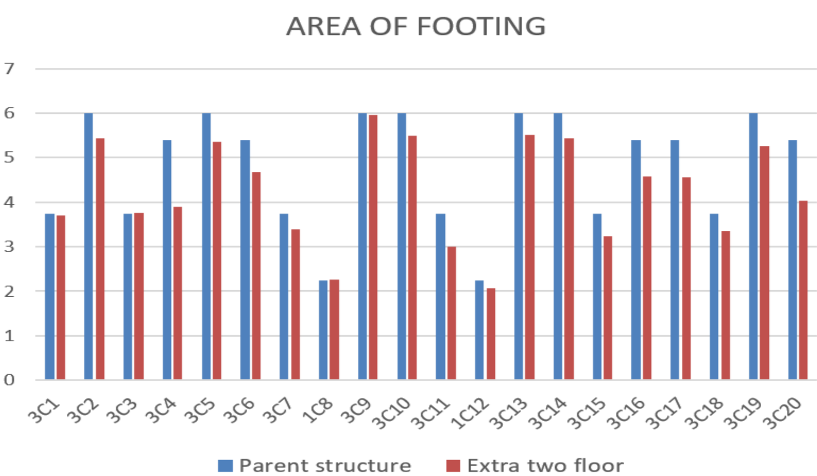

Figure 14 Loads of Footing for parent model + 2 storey extension

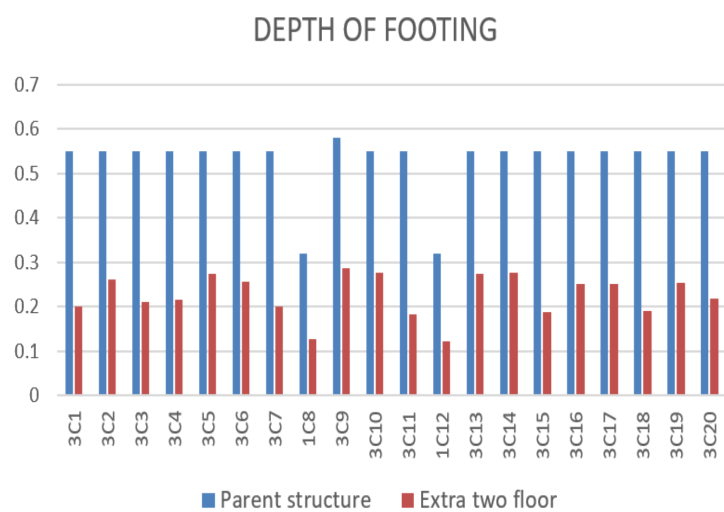

Figure 15 Area of Footing for parent model +2 storey extension

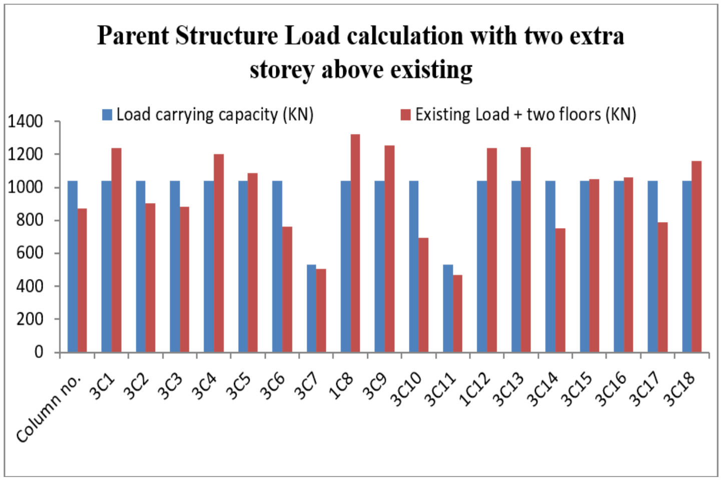

Figure 16 Graph of Parent structure load calculation with two extra storey above existing

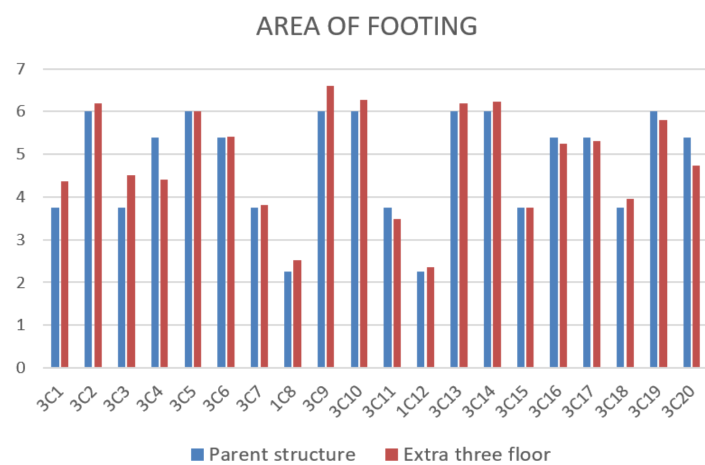

Figure 17 Loads of Footing for parent model + 3 storey extension

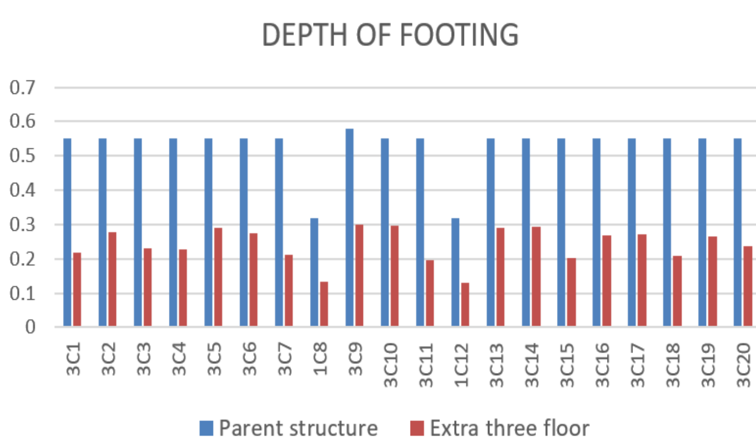

Figure 18 Area of Footing for parent model +3 storey extension

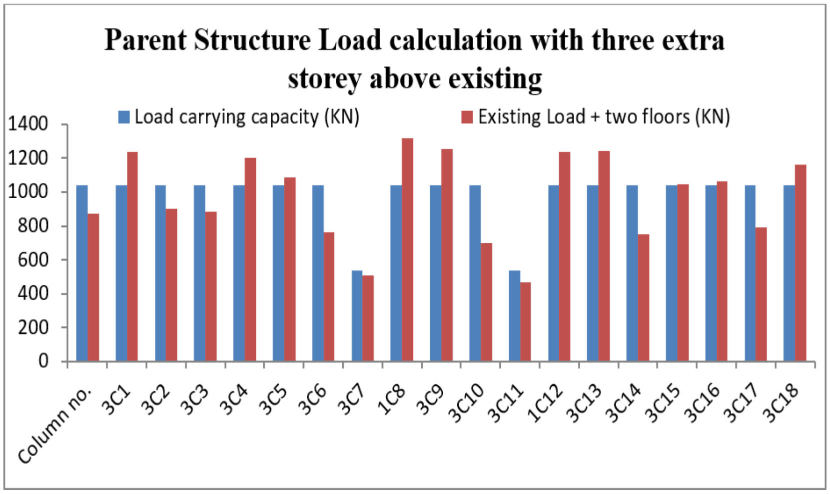

Figure 19 Graph of Parent structure load calculation with three extra storey above existing

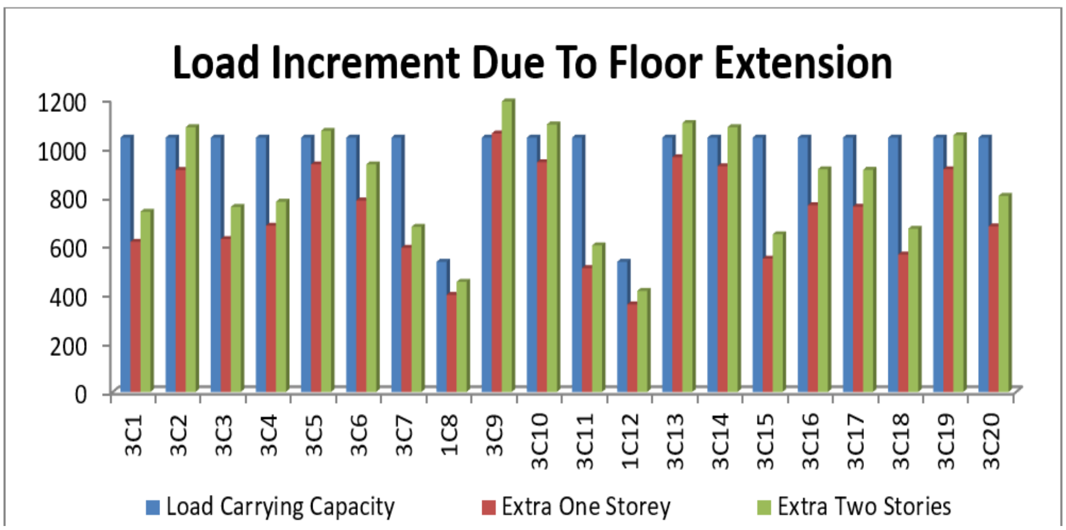

Figure 20 Graph of Load Increment Due to Floor Extension

Table 4. Loading details of Extra two floors

Columnno.	Existing + Extra two floors			
	Area Required (mm^2)	Depth Required(m)	One waySF (KN)	Two way S
3C1	4.37	0.2184	304.6175	761.86
3C2	6.19	0.2788	493.9835	1185.
3C3	4.51	0.2305	314.4196	786.3
3C4	4.40	0.2277	390.4649	829.40
3C5	6.01	0.2893	552.3859	1151.
3C6	5.42	0.2747	553.2942	1020.4
3C7	3.82	0.2121	266.3008	666.03
1C8	2.52	0.134	116.6781	480.91
3C9	6.59	0.2997	584.2529	1249.7
3C10	6.26	0.2954	575.6745	1199.6
3C11	3.47	0.194	242.4226	606.31
1C12	2.34	0.1295	108.5007	447.20
3C13	6.19	0.2904	569.0062	1185.7
3C14	6.22	0.2943	571.5458	1191.0
3C15	3.75	0.2025	261.8073	654.79
3C16	5.24	0.2682	534.9446	986.60
3C17	5.31	0.2701	542.3691	1000.2
3C18	3.95	0.2077	275.3923	688.77
3C19	5.79	0.2666	462.4703	1109.9
3C20	4.73	0.236	419.2192	890.47

3.Results and Discussion

After modeling an existing building using STAAD Pro software calculated and tabulated load carrying capacity of structural members. Approximate existing load carrying capacity of building is calculated, also the extra load coming from one and two stories are also calculated and presented in above graphs and tables. After studying a result obtained from structural auditing and modeling following inferences are presented.

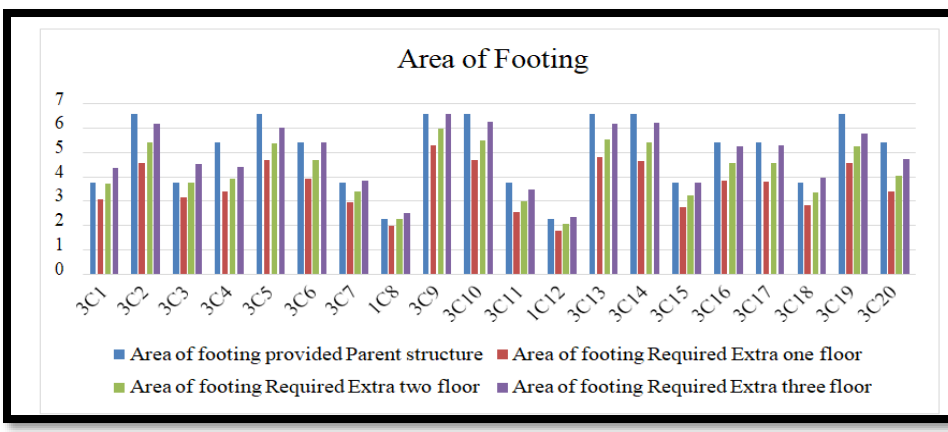

Figure 21 Area of Footing for column

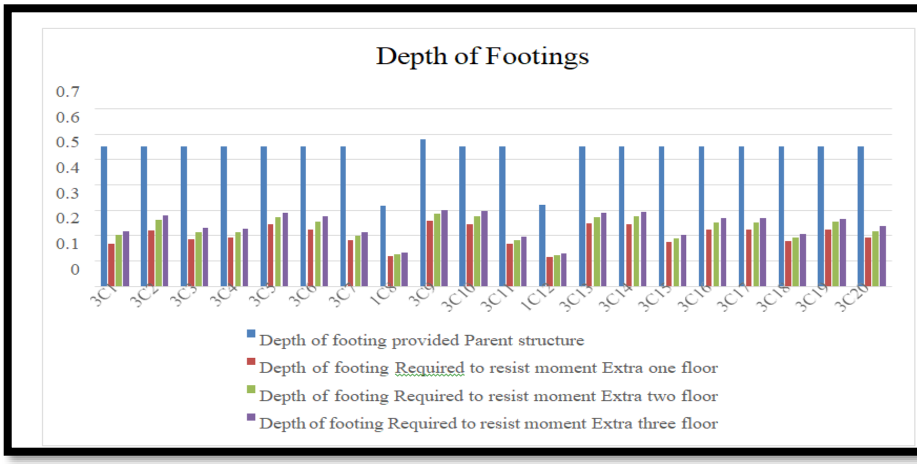

Figure 21 Depth of footing for column

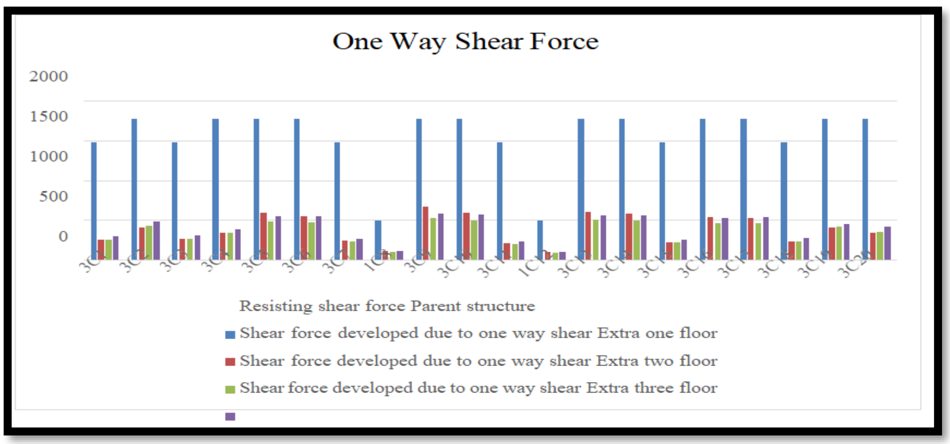

Figure 22 One way Shear force of column

Figure 23 Punching Shear of Column

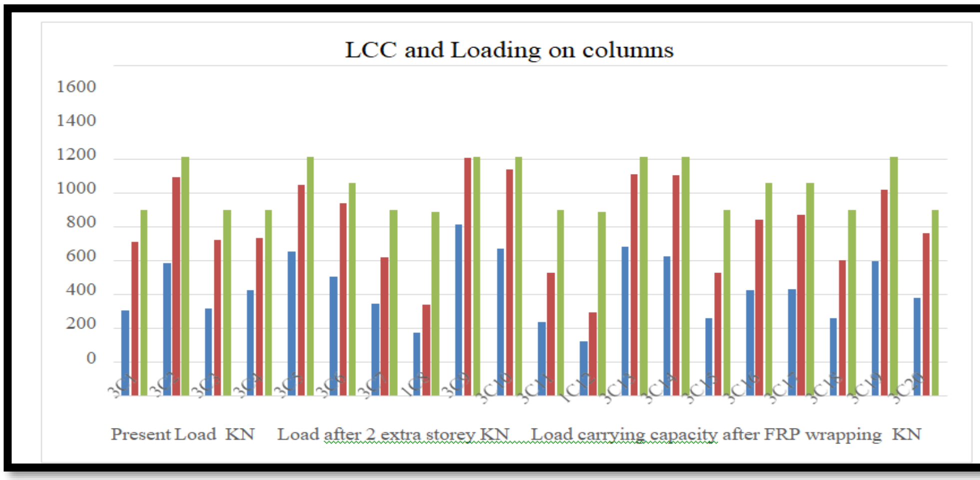

Figure 24 LCC and Loading on column

4 CONCLUSIONS

The aim of this work is to provide easy procedure for floor expansion of the existing building, to execute the said task of extension over existing structure following concluding remarks are presented,

1. From the structural audit, it was concluded that the structure was in good condition. There were no signs of deterioration and deflection. No cracks were present that may affect the strength of structure. NDT (rebound hammer test) verifies that the minimum strength of concrete is greater than M20, and safe for further construction, which have been correlated and verified from calibrated Rebound hammer at PRMIT&R, Badnera
2. The Staad Pro model of every extension shows that there is 30% to 40% increase in the load as compared to the present load for two storey extension. Use of AAC block were said mandatory for exterior and internal walls for extended floors.
3. Form the analysis of footings, it is found that footing has a safe storey extension limit for the selected structure and hence it can be concluded that the footings for the two-storey expansion are safe for area required, depth required, and shear force resistance for both one-way and punching shear actions developed due too extra loading.
4. After analysis of existing building, it was found that foundation have enough strength to carry extra load coming from extended stories but some columns are insufficient to carry extra loads if Three floor extension is proposed and hence it required to strengthened by using different strengthening/retrofitting measures more than two storey extension is planned.
5. It is also found that the columns of the ground floor are more susceptible to failure than the upper floors, whereas the columns of the above floors are safe to carry the extra load up to two floors expansion; Hence, Structural strengthening/ retrofitting measures were not suggested in the given structure till existing plus two storey extensions. Furthermore, if it is intended to extend more than two floors more rigorous and exhaustive NDT work along with analytical tool is warranted along with strengthening measures.

References

[1] Anu Soikkelia. (2016). "Additional Floors in Old Apartment Blocks", A University of Oulu, PB 4100, 900140 Oulu, Finland. SBE16 Tallinn and Helsinki Conference; Build Green and Renovate Deep, 5-7 October 2016, Tallinn and Helsinki

[2] IS 456:2000. (2000). "Plain and Reinforced Concrete- Code of Practice." Bureau of Indian Standards.

[3] DM Mcanan, M. C. Forde. (2001). "Review of NDT methods in the assessment of concrete and masonry structure". NDT and E international Journal.

[4] Mohamed B.D. Elsawy, Kamal M. Hafez Ismail, "Influence of aging on bearing capacity of circular footing resting on soft soil", HBRC Journal (2013) 9, 256–262, 1687-4048 ª 2013 Housing and Building National Research Center. Production and hosting by Elsevier B.V. All rights reserved. http://dx.doi.org/10.1016/j.hbrcj.2013.05.01

[5] Johansson, B. & Thyman, M. (2013). Strengthening of buildings for storey extension. Master's Thesis, Department of Civil and Environmental Engineering, Division of Structural Engineering, Chalmers University of Technology, Göteborg, Sweden, p 113.

[6] Zumrawi M. M. E et al. (2018). A study on Strengthening of Building foundation for Storey Extension, J. Build. Mater. Struct. 5: 218-226.

[7] IS 1893: 2016 "Earthquake resistant design of structures " Part 1, Bureau of Indian Standards

[8] Song, Y.; Wu, F (2015). Rail Damage Detection Based on AE Technology and Wavelet Data Processing. Appl. Mech. Mater. Trans. Tech. Publ., 744, 1339–1343.

[9] Rathod, H.; Gupta, R (2019). Sub-surface simulated damage detection using Non-Destructive Testing Techniques in reinforced-concrete slabs. Constr. Build. Mater. 2019, 215, 754–764.

[10] Ghosh, A.; Edwards, D.J.; Hosseini, M.R.; Al-Ameri, R.; Abawajy, J.; Thwala, W.D (2020). Real-time structural health monitoring for concrete beams: A cost-effective 'Industry 4.0'solution using piezo sensors. Int. J. Build. Pathol. Adapt, 39, 283–311.

[11] Yuan, F.; Yu, Y.; Li, L. (2021); Tian, G. Investigation of DC electromagnetic-based motion induced eddy current on NDT for crack detection. IEEE Sensors J. 2021

[12] Tian, L.; Wang, Z.; Liu, W.; Cheng, Y.; Alsaadi, F.E.; Liu, X (2022). An improved generative adversarial network with modified loss function for crack detection in electromagnetic nondestructive testing. Complex Intell. Syst., 8, 467–476.

[13] Sahar Hasani (2023) Systematic Review of Advanced Sensor Technologies for Non-Destructive Testing and Structural Health Monitoring, 477-493