International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

Vol.3, Special Issue 1 Aug - 2017

Upgradation of Existing Multi-Storey RC Building by Retrofitting

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ABSTRACT

Retrofitting of the existing reinforced concrete (RC) building is currently a major economic activity for the redevelopment of congested urban areas. Reversible technologies by special concreting are capable of protecting the building from damage, providing high levels of structural safety. One should properly assess the vulnerability of the existing multi-storey buildings and accordingly adopt protective measures. The retrofitting techniques are technically sound and economically feasible to upgrade the deficient and damaged multi-story structures. The present study describes a retrofitting system of the existing four-storey reinforced concrete building located in PES University Bangalore, designed for vertical loads of extra two-storey structure. The structural analysis performed on the inspected building has shown its inability to withstand any additional loads. Therefore, the redesign of such building through retrofitting of existing columns and footings has been assessed through structural analysis carried out using STAAD-Pro software. These results have shown a safe design of the retrofitted building in terms of strength, stiffness and ductility.

Keywords: Multi-Storey RC Building, STAAD-Pro Software, Concrete Jacketing

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INTRODUCTION

The strategy of retrofitting refers to options of increasing the strength, stiffness and ductility of the elements or the building as a whole. Several retrofit strategies may be selected under a retrofit scheme of a building. The aim of retrofitting can be summarized as follows:

- Increasing the lateral strength and stiffness of the building
- Increasing the ductility and enhancing the energy dissipation capacity
- Giving unity to the structure
- Eliminating sources of weakness or those that produce concentration of stresses
- Enhancement of redundancy in the number of lateral load resisting elements
- The retrofit scheme should be cost effective.
- Each retrofit strategy should consistently achieve the performance objective.

To decide the retrofit scheme, a performance based approach can be adopted. The performance based approach identifies a target buildings covered in this project, the basic safety objective can be selected. Under this objective, the dual requirement of life safety under design basis earthquake (DBE) and structural stability under maximum considered earthquake is aimed.

In this study an attempt is made to increase the number of storeys of an existing multi storey reinforced concrete (RC) structure through retrofitting techniques using STAAD-Pro software. A case study of an existing multi-storey building is carried out. An exact similar existing structure is modelled using STAAD-Pro. All loads are applied on the building which is similar to the existing structure and the model has been analysed and designed using STAAD-PRO. Because the building was designed as per existing four-storey structure, we need to verify, if there are any deficient (failed) columns till four-storey. Considering an increase of two more storeys on top of existing four-storey structure, the analysis of structure should reveal the number of failed columns and footings. For these failed elements retrofitting through jacketing has to be carried out in order to make them safe. Various case studies of retrofitting of RC building by jacketing have been carried out [1,2,3,4,5]. A similar work has been carried out by Ranjan and Dhiman (2016), where they have modelled an existing building as per cross-section of columns provided and load applied and analysed using STAAD-Pro V8i and found that till four-storey there is no deficient (failed) columns because initially building was designed as per four-storey structure. Thereafter, adding each extra floor, analysis shows:

- As they model 5th storey, some of columns of building failed. Columns that fail, are of cross-section of 300mm×300mm.
- As they model 6th storey, many columns failed.

For failed columns, they have carried out retrofitting by column jacketing techniques. In our study in addition to failed columns identified using STAAD-Pro, we have compared the amount of steel required for particular columns with the reinforcement provided in the existing structure. If the provided reinforcement in a column is lesser than required reinforcement then that column is also considered as failed column and retrofitting is carried out for that column also. In addition to columns, the footings are also checked with respect to safe bearing capacity (SBC) of soil and retrofitting is carried out for failed footings.

METHODOLOGY

We have collected the detailed design of the existing G+3 reinforced concrete (RC) building and inspected the building about the present state-of-art condition. Fig-1 shows the grid system of the existing G+3 reinforced concrete building, where we could observe that the deferent sizes of footings and columns are considered for optimizing the overall load distribution. This existing G+3 building is modelled using STAAD-Pro [6] as shown in Fig-2. With the extension of two more storeys on existing G+3 building, i.e., G+5 storey building is also modelled using STAAD-Pro (Fig-3). For G+5 building, same sizes of footings and columns as considered in G+3 building are adopted in order to assess the pressure, Pmax (KN/m2) from footings to soil for given site. Also loads on columns in each level are assessed by using area of steel provided, which are safe or not. After analysing G+5 building with existing footings and columns, we identify all failed footings and columns which are required for retrofitting, so that the retrofitted G+5 building is safe from all loadings. After retrofitting of footings and columns upto required levels, we further analyse the retrofitted G+5 building using STAAD-Pro and cross-check whether the structure is safe.

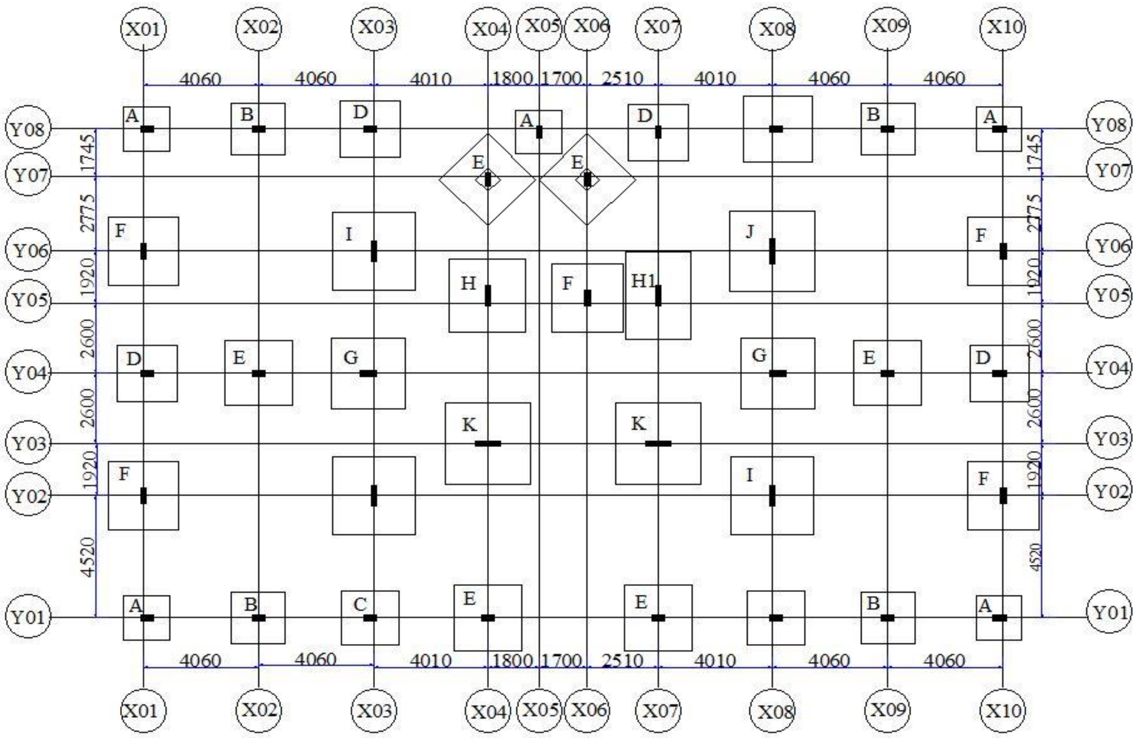

Fig-1 Grid system of existing G+3 reinforced concrete building

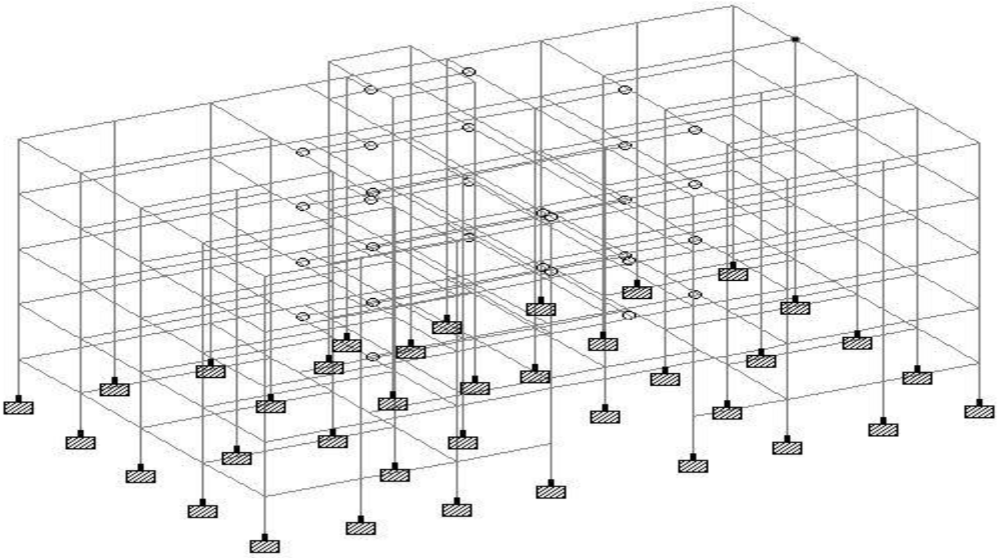

Fig-2 3D Structural model using STAAD-Pro

RESULTS AND DISCUSSION

The STAAD-Pro software is widely used by designers for structural analysis of multi-storey RC buildings. Structural analysis of the existing G+3 reinforced concrete building is carried out using STAAD-Pro. Also similar studies are carried out for G+5 building with existing footings and columns and retrofitted G+5 building. The required retrofitted (thick) columns are shown in Fig-3. This shows that some columns are required to be retrofitted upto level 2 and some are upto level 3. Comparative results of footings and columns are shown in Table-1 and Table-2 respectively.

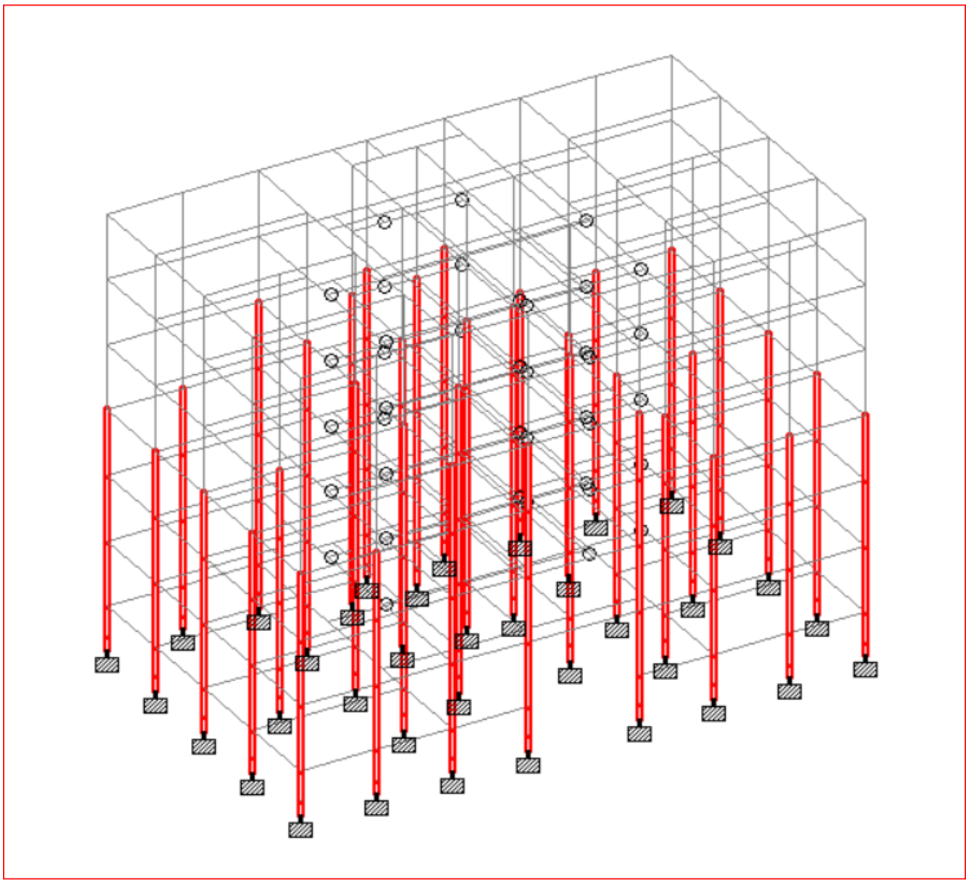

Fig-3 Retrofitted columns of G+5 RC building using STAAD-Pro.

In Table-1, the total pressure from the footing to soil, Pmax (KN/m^2) for the existing G+3 building and upgraded G+5 building is compared with the safe bearing capacity (SBC) of soil for given site (250KN/m^2). If the total pressure from the footing to soil is less than the SBC of soil then footings are said to be safe, if the total pressure from the footing to soil is more than the SBC of soil then footings are said to be unsafe. Initially Pmax for the existing footings are calculated as shown in column-3 of Table-1, which are all less than 250KN/m^2. Hence all existing footings are safe for the G+3 RC building. Also, for increased number of floors, Pmax of footings for the G+5 RC building are calculated, which show that most of peripheral footings are unsafe (column-4 of Table-1). Here we observe that the sizes of existing footings are not sufficient to take the loads of the G+5 building, hence accordingly footings sizes are increased to make all footings safe.

In Table-2, analysis of columns for the G+5 building has been carried out to determine whether the existing column section and provided reinforcement is sufficient to take the load on it. If any column section is not sufficient or provided reinforcement is less than the required reinforcement, then the column is likely to be failed as shown in column-3 of Table-2, where failed columns' areas are more than that of column-2 of Table-2. For failed columns, each column size is increased by 100mm from all four sides as specified by IS-15988 code book. A minimum of 4 bars is provided for retrofitted columns since the reinforcement required for increased section is less than the provided reinforcement. Thereafter, all columns of the retrofitted G+5 RC building are checked against failure. This study would help to upgrade similar many old existing multi-storey buildings.

Table-1 Total pressure (Pmax) from footings to soil for given site

Grid number	Existing footing size (mxm)	G+3 building **Pmax** (KN/m2	G+5 building **Pmax** (KN/m2	Increased footing size (mxm)	G+5 building after retrofitting **Pmax** (KN/m2
A8,1	1.6X1.6	205.270	**311.007**	1.9X1.9	238.160
B8,2	1.9X1.9	184.510	**276.060**	2.1X2.1	232.320
D8,3	2.1X2.1	217.430	**296.376**	2.5X2.5	230.310
A8,5	1.6X1.6	225.970	**453.065**	2.3X2.3	228.830
D8,7	2.1X2.1	211.520	**308.491**	2.6X2.6	226.700
E8,8	2.4X2.4	142.250	209.817	2.4X2.4	232.360
B8,9	1.9X1.9	185.930	**275.099**	2.1X2.1	233.924
A8,10	1.6X1.6	225.970	**331.165**	2.0X2.0	231.593
E7,4	2.4X2.4	153.780	237.185	2.5X2.5	233.255
E7,6	2.4X2.4	171.180	222.538	2.5X2.5	216.573
F6,1	2.5X2.5	170.220	**253.971**	2.6X2.6	247.888
I6,3	2.9X2.9	163.340	249.641	3.1X3.1	226.199
J6,8	3.0X3.0	157.280	241.109	3.1X3.1	230.091
F6,10	2.5X2.5	166.950	**250.245**	2.7X2.7	227.898
H5,4	2.7X2.7	188.700	**251.754**	2.8X2.8	242.571
F5,6	2.5X2.5	132.820	185.265	2.3X2.3	234.137
H1 5,7	3.2X3.2	158.320	238.503	2.8X2.8	223.507
D4,1	2.1X2.1	193.620	**290.280**	2.4X2.4	237.626
E4,2	2.4X2.4	154.540	233.764	2.5X2.5	222.042
G4,3	2.6X2.6	171.100	233.236	2.8X2.8	231.976
G4,8	2.6X2.6	166.710	**255.233**	2.7X2.7	243.879
E4,9	2.4X2.4	154.180	233.313	2.5X2.5	226.679
D4,10	2.1X2.1	198.549	**295.554**	2.9X2.9	243.777
K3,4	3.0X3.0	139.254	234.524	2.9X2.9	246.091
K3,7	3.0X3.0	139.447	235.758	2.7X2.7	233.714
F2,1	2.5X2.5	171.097	**254.881**	2.9X2.9	245.610
I2,3	2.9X2.9	154.479	244.839	2.9X2.9	244.648
I2,10	2.9X2.9	155.367	245.741	2.6X2.6	245.836
F2,10	2.5X2.5	117.188	175.244	1.8X1.8	232.903
A1,1	1.6X1.6	185.834	**290.253**	2.0X2.0	249.529
B1,2	1.9X1.9	182.720	**270.849**	2.3X2.3	223.917
C1,3	2.0X2.0	127.935	199.492	2.3X2.3	239.804
E1,4	2.4X2.4	133.742	227.976	2.4X2.4	229.001
E1,7	2.4X2.4	134.673	232.915	2.4X2.4	242.418

C1,8	2.0X2.0	181.980	**287.152**	2.1X2.1	232.361
B1,9	1.9X1.9	186.613	**278.964**	2.1X2.1	228.510
A1,10	1.6X1.6	207.819	**314.779**	1.9X1.9	230.595

Table-2 Retrofitting details of columns

Grid number of Level I	Area of steel provided in columns of G+3 building (mm^2)	Area of steel required in columns of G+5 building (same sizes) (mm^2)	Area of steel required in columns of G+5 building (increased sizes) (mm^2)
A8,1	1029.92	1802	651
B8,2	1482.08	3024	817
D8,3	2738.08	4933	1129
A8,5	1029.92	3647	889
D8,7	2738.08	F	1168
E8,8	3541.92	4293	1029
B8,9	1482.08	3024	817
A8,10	1029.92	1891	661
E7,4	3541.92	F	1173
E7,6	3541.92	4649	1043
F6,1	4700.58	5889	1378
I6,3	6113.58	8567	1800
J6,8	6663.08	7675	1840
F6,10	4700.58	5840	1378
H5,4	4954.92	6142	1534
F5,6	4700.58	3093	952
H1 5,7	4954.92	5894	1508
D4,1	2738.08	4910	1111
E4,2	3541.92	F	1152
G4,3	4700.58	F	1472
G4,8	4700.58	6806	1466
E4,9	3541.92	F	1152
D4,10	2738.08	4935	1112
K3,4	7369.58	6912	1769
K3,7	7369.58	7056	1784
F2,1	4700.58	5917	1379
I2,3	6113.58	7749	1733
I2,10	4700.58	7782	1733
F2,10	6113.58	5905	1379
A1,1	1029.92	1819	657
B1,2	1482.08	3024	817
C1,3	2285.92	3985	992
E1,4	3541.92	F	1155
E1,7	3541.92	F	1177
C1,8	2285.92	4035	994
B1,9	1482.08	3024	817
A1,10	1029.92	1819	657

*F-particular section failed in STAAD-Pro.

CONCLUSION

Based on structural analysis of existing G+3 reinforced concrete building using STAAD-Pro, we get the following conclusions:

- Present footings and columns are just capable of taking all loads for the existing G+3 building.
- Present footings and columns are not capable of taking the loads of G+5 building with existing sizes of footings and columns.
- The retrofitting design carried out for G+5 building shows that the retrofitted G+5 building is safe from all loads except seismic load which is not considered for the present study.

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