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STRENGTHENING OF EXISTING RCC BUILDING FOR ADDITION OF STOREYS

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Abstract: As India is still a developing country, many old and weak structures need to be demolished and reconstructed due to their insufficient bearing capacity or due to increase in population demand and many other several factors. But alternatively strengthening of structural elements of existing building proves to be more economical and time saving rather than demolishing the entire structure and reconstructing. Based on the correct survey and analysis of the existing structure with appropriate strengthening measures we can achieve required strength of a structural element to fulfill the current demand of the structure. Many of the Indian buildings are constructed of Reinforced Cement Concrete, hence RCC jacketing to existing structural elements is most commonly practiced in India. Many case studies have proved that RCC jacketing method gives satisfactory results. In this study a commercial RCC building is taken where it is required to strengthen its structural elements so that it can withstand the proposed additional floor loads.

Index Terms - Vertical Extension, RCC Jacketing, Strengthening, Structural Elements, ETABS, SAFE.

I. INTRODUCTION

Strengthening of any structure may be required due to one or more of the following reasons – faulty construction, enhance the durability of the structure, prolong its lifespan, to reduce its maintenance cost, meet the required safety standards, withstand external forces such as wind and earthquake, strengthen the weak elements, vertical extension of structure as per demand and many other such factors.

In this study strengthening is required due to vertical extension of the existing structure. The existing building that is to be strengthened is located in Mumbai, India. The existing building is used as Commercial Office building and the proposed additional floors will also be used for Commercial purpose only. The existing building consists of RCC Column and Wall with Flat Slab system, whereas the proposed floors will be having RCC Column and Wall with Conventional Slab (i.e. beam-slab) system.

Existing building details: - 2 Basements + Ground Floor + 6 Commercial Floors + Terrace.

Proposed building details: - Existing Terrace floor will be converted to 7th commercial floor + 9 New Commercial Floors above 7th floor (i.e. 8 th to 16th Floor) + Terrace + OHT / LMR.

The existing structural members were designed for G+7 stories only to meet the demand at that time keeping only 1 provisional floor but now 10 new floors will be added above the existing top floor as per the current requirement. Hence modelling in ETABS software was done with existing structure sizes and proposed no. of floors.

II. REVIEW OF LITERATURE

Elsamny M. Kassem and Abd El Samee W. Nashaat [2] Wael Nashaat Abd El Samee [10] Zumrawi M. M. E. and Aldaw H. K. E [11] Ajai Kumar Rai and Brajesh Mishra [13] Sunil Brahamne and Dr. Raghvendra Singh [18] have studied on various strengthening measures for foundation of an existing structure.

Konstantinos G. Vandoros and Stephanos E. Dritsos [1] Mohd Irfan, Dr. Abhay Sharma and Dr. Vivek Garg [3] Tabish Rasool Sheikh, Mohd Kashif Khan and Tabish Izhar [7] M. Karankumar, S. Sujith and G. Karthikeyan [16] have presented their work specifically on strengthening of columns and shear walls of the existing structure.

Ankit M. Mungale and Dr. Deepa A. Joshi [4] Caitlin McRae, John McClure, Liv Henrich, Caspian Leah and Andrew Charleson [5] Dipesh Majumdar [6] D. Jawaharlal and Dr. T. Felix Kala [8] Jay Kumar Sah, Prem Shankar Singh and Chinmay Kumar Kundu [12] Nusa Setiani Triastuti [14] Jitesh Vithoba Hiware, Prof. Harshwardhan Rangari and Prof. Girish Savai [19] Mr. Rahul S. Pardeshi and Prof. Dr Shyambhau Ban [20] Vijaysingh Sohansingh Rawat and Vishwajeet Kadlag [21] Rakesh Katam, Sairam Neidu, Ajay Kumar Sreerama, Venkata Dilip Kumar Pasupuleti and Prafulla Kalapatapu [23] have researched on analysis, design and strengthening of RC structures due to various damaging factors (e.g.- earthquake, fire damage, etc.)

Rui Marques, Paula Lamego, Paulo B Lourenco and Maria L Sousa [9] have studied on efficiency and cost-Benefit Analysis of Seismic strengthening techniques for residential buildings.

Bapireddy Srinivasareddy and Sahil Jagggi [15] have researched on recent advancements in retrofitting and strengthening of RCC structures.

Pramod F. Dabhale1 and Prof. Ishant B. Dahat [17] studied on rehabilitation of load bearing structures by providing new RCC basement.

Manoj Chopdey and Professor Dr. Rajeev Chandak [22] performed wind and seismic analysis of RCC building using ETABS software.

III. OBJECTIVES OF THE STUDIES

1. To prepare analytical model of entire superstructure in ETABS software (i.e. with existing & new floors) and run the analysis to study the performance of structure under various loads.
2. Detail review of structural members of existing building (especially for columns, walls and coupling beams) and to identify the inadequacies & deficiencies in member size and reinforcements.
3. Modification & finalization of structural member sizes to strengthen the existing structure to carry load from new floors.
4. To prepare analytical model in SAFE software for foundation and carry out the assessment of design adequacy and deficiencies for various checks.

IV. METHODOLOGY

A. OVERVIEW OF PROCEDURE

Initially information on existing building like its location, structural drawing, etc. is gathered. Post that Structural review and Structural Audit of existing building is done to know the concrete strength of existing structural elements. Then an analytical model of existing building with proposed building in ETABS software is prepared. Failing structural members of existing building are identified in this stage. The sizes of failed members were increased by trial-and-error method to know the final sizes such that all the members are capable to withstand the additional load of proposed building.

The base reactions are extracted from ETABS software and used as input for SAFE software. Modelling of existing foundation is now done in SAFE software. All the failed foundation members are identified in this software. The sizes of the failed members are increased by trial-and-error method until the existing foundation is totally safe to withstand the total load of the structure.

B. PARAMETERS CONSIDERED

Following parameters are used for analyzing and designing of the structure:

Earthquake Parameters:

Analysis Type = Response Spectrum

Type of slab = Flat Slab

Response Reduction Factor = 5

Importance Factor = 1.5

Seismic Zone = III

Zone Factor = 0.16

Soil Type = Hard Rock

Wind Parameters:

Basic wind pressure = 44 m/sec

Risk Coefficient factor = 0.89

Terrain Category = 2

Topography Factor = 1

Importance Factor = 1

Foundation Parameters:

Soil Type = Hard Rock

Soil Bearing Capacity = 55 Tons/m^2

Allowable Settlement = 12 mm

Subgrade Modulus = 45,000 KN/m/m^2

Loading Parameters:

Office area:

1. LL = 4 KN/m^2
2. Floor Finishes = 2 KN/m^2
3. Partition Wall Load = 1.5 KN/m^2

Toilet area:

1. LL = 2 KN/m^2
2. Floor Finishes = 2 KN/m^2
3. Sunk Filling = 3.6 KN/m^2

Staircase area:

1. LL = 4 KN/m^2
2. Floor Finishes = 2 KN/m^2

Parking area:

1. LL = 5 KN/m^2
2. Floor Finishes = 3 KN/m^2

Design Load Combinations:

All the load combinations as per IS codes as considered as below:

1. 1.5 DL + 1.5 IL
2. 1.2 [DL + IL ± (ELX ± 0.3 ELY ± 0.3 ELZ)]
3. 1.2 [DL + IL ± (ELY ± 0.3 ELX ± 0.3 ELZ)]
4. 1.5 [DL ± (ELX ± 0.3 ELY ± 0.3 ELZ)]
5. 1.5 [DL ± (ELY ± 0.3 ELX ± 0.3 ELZ)]
6. 0.9 [DL ± 1.5 (ELX ± 0.3 ELY ± 0.3 ELZ)]
7. 0.9 [DL ± 1.5 (ELY ± 0.3 ELX ± 0.3 ELZ)]
8. 1.2 (DL + IL ± WLX)
9. 1.2 (DL + IL ± WLY)
10. 1.5 (DL ± WLY)
11. 1.5 (DL ± WLY)
12. 0.9 DL ± 1.5 WLX
13. 0.9 DL ± 1.5 WLY

C. DETAILED ANALYSIS AND DESIGN PROCEDURE

The building is L shaped building and ETABS model is prepared with reference to existing structural drawings as shown below:

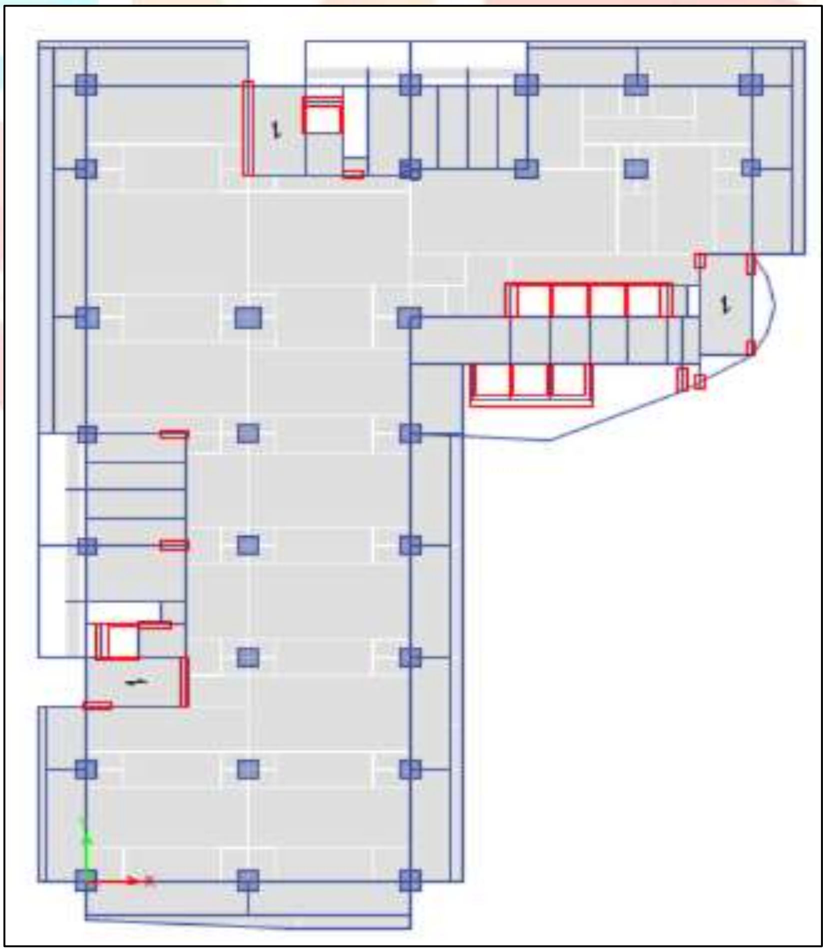


Fig. 1 Typical floor plan model in ETABS

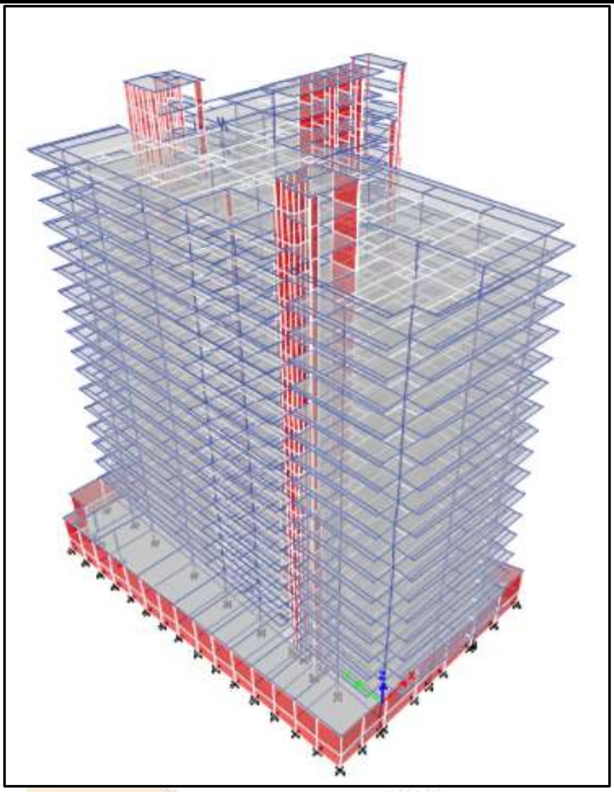
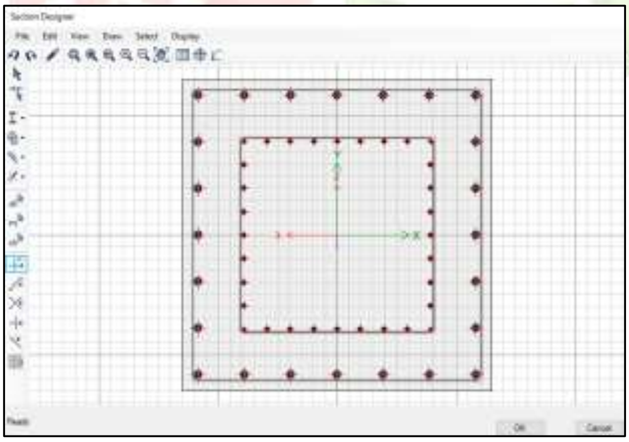


Fig. 2 Elevation of Building in ETABS

As the existing building was not designed for the additional 10 floors, all the columns and shear walls failed due to insufficient load carrying capacities. Hence, RCC jacketing technique was used for strengthening of weak columns and shear walls of the existing building.

As the column and wall schedule of existing building is available Section Designer option in ETABS is used to model exactly the existing bar position. The jacketing bars in addition to existing bars are modelled in section designer by trial-and-error method until the column gets passed. The typical section designer modelling of column and shear wall is as shown below in Fig. 3 and Fig. 4 respectively. The inner bars represent the existing bars whereas the outer bars represent the bars used for jacketing.



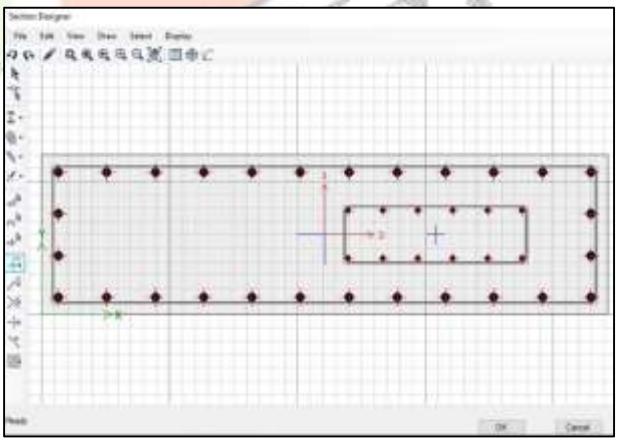


Fig. 3 Section Designer of Column in ETABS

Fig. 4 Section Designer for Shear Wall in ETABS

As the reinforcement was modelled in section designer, the reinforcement to be checked option was used for designing. To know that any of the column or shear wall is sufficient in size and reinforcement provided, its D/C (Demand to Capacity) ratio is checked. If D/C ratio is less than 1 it means the element is passed i.e. it can bear the load coming on it. If the D/C ratio is greater than 1 it means the element is failing and it cannot withstand the load coming on it, in this case increase the size of that element and if it is restricted than increase the rebar diameter or reduce the spacing of rebar such that minimum spacing requirement is met. Optimizing the sizes floor wise proves more beneficial in cost reduction.

In this building the ground floor was fully surrounded by the driveway due to which only 100mm jacketing was allowed in the outer side of the peripheral columns and shear wall at the ground floor. Due to very less space available for concreting micro concreting will be used in these columns as the normal concrete will lead to honeycombing due to presence of jacketing rebars and shear reinforcements.

Now once all the final sizes of column and shear walls are freezed by trial-and-error method, the reactions at the base are extracted from ETABS and used as input in the SAFE software. Now the modelling of the existing foundation is done in SAFE software as shown in Fig. 5.

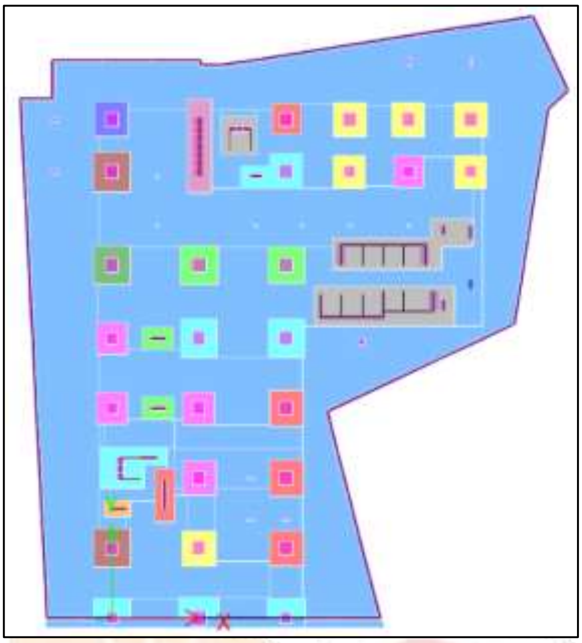


Fig. 5 Foundation Model in SAFE

The type of foundation adopted for existing building is raft foundation having localized pad footing over raft. All the loads are incorporated in this model such as filling load on top of the raft, parking load over it and the entire superstructure load.

This analytical and design model of foundation is run and checked for inadequacies for the following parameters of the footing: - allowable settlement, soil pressure, punching shear criteria and flexural criteria.

First the settlement criteria have to be met for that all the footings where the settlements exceed the allowable settlement (i.e. 12 mm) the plan dimensions were increased by trial-and-error method until all the footings have pass this criteria.

Secondly the soil pressure criteria have to be met for that all the footings where the soil pressure exceed the limiting soil pressure (i.e. 55 Tons/m^2) the plan dimensions were increased by trial-and-error method until all the footings have pass this criteria.

After increasing the plan dimensions of all the insufficient footings such that they pass the above two criteria's then punching shear check has to be done for all the footings. In this the footing is checked so that the column should not punch into the footing, to achieve this the depth of the footing that fails this criteria has to be increased by trial and error so that it passes this criteria.

Lastly flexural check has to be done as the existing reinforcement may not be sufficient to withstand the additional floor loads. The reinforcement required may be more than the existing reinforcement in some cases. To satisfy this check, depth of the footing is increased so that required reinforcement becomes sufficient.

Thus, by passing all these checks the foundation can be designed safely. The design may vary according to one or more failing criteria mentioned above.

V. RESULTS & DISCUSSION

As the structure was existing structure the service checks were assumed to be satisfied for the existing structure and no additional walls or columns were allowed as per architectural and clients point of view so the service check for the building as whole was not performed.

However, building was satisfied in design checks. All the columns and shear walls D/C ratio were kept between 0.7 to 0.85 with appropriate margin left for onsite construction faults. All the footings were made passed in all the criteria and appropriate designing was done.

The approximate cost of strengthening of whole existing structure was estimated and it came out to be 35 Crore rupees.

VI. CONCLUSION

1. Strengthening of structure is more economical than demolishing and reconstructing the whole structure.
2. Strengthening saves more time than reconstructing.
3. Due to no. of studies available for RCC jacketing, RCC jacketing is one of the simplest and more commonly used strengthening method.
4. Due to jacketing the section sizes are increased and thereby there is reduction in free space on that floor.
5. Jacketing significantly improves Shear strength capacity, Moment resisting capacity and Axial load carrying capacity of the column.
6. Strengthening of foundation by sectional enlargement using RCC strengthening is found to be the most effective and economical strengthening technique to increase the load carrying capacity of existing foundations.

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