Strengthening of existing column using steel plates: Finite Element Analysis

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Abstract— Concrete buildings are deteriorating, demanding their demolition or rehabilitation. However, structures with significant value cannot always be rebuilt. It requires restoration and repair. Non-destructive tests (NDT) can be used to evaluate the residual strength of aging structures, allowing for the selection of the best restoration options. The Finite element method can be used to verify whether the repair strategy we chose can be suited or not. Results from the FEM reveal characteristics of stress, shear and deformation of structural members that could withstand in their damaged state as well as their behavior after applying repair procedures to the existing load. This article comprises a column demonstrating the current condition and another with its steel plate encasement on the periphery of varying thicknesses or concrete jacketing which give better results as a repair measure supporting the current structural load.

Keywords: Finite Element Model [FEM], Non-destructive tests [NDT], Structural Audit of RCC structures, strengthening of column.

I. INTRODUCTION

The current activities in material science and technology include material evaluation using non-destructive testing (NDT) approaches. Evaluation connotes detection, appraisal, and decision-making. Early on in the industrial revolution, the necessary testing process for engineering goods and parts did not receive the same priority as the creation of the technology itself. Because of this, the in-service components had low levels of reliability, which frequently led to catastrophic breakdowns. Technologists began evaluating raw materials for components or models in damaging ways to determine their compatibility for the goal in order to prevent similar events.

However, the majority of the time, the outcomes of this kind of examination did not at all reveal the functional properties of the actual components. As a result, the proper evaluation's objective was still far off. Thus, techniques for pre-testing actual components were developed without compromising any of their features, giving rise to the non-destructive testing (NDT) field of study.

Non-destructive tests (NDT) are testing procedures that do not affect the components' structural integrity. NDT employs a number of inspection techniques to evaluate the components either individually or collectively.

Engineers and scientists can model and study intricate physical processes using the widely used finite element analysis (FEA) software suite ANSYS. However, ANSYS doesn't have a function specifically for "weak column modeling." We have to give all the input values of all the column parameters, material properties, load values to evaluate.

This study evaluates the residual strength of RCC buildings by presenting the findings of non-destructive tests done on them. ANSYS software's later FEM analysis of weak members and recommendations for strengthening the member. The purpose of the study is to demonstrate how FEM analysis may be used to strengthen weak members without doing any experiments.

II. AIM AND OBJECTIVES

When a building's load is about to increase, structural auditing is done to determine how much longer it can last and what repairs can be made to make it last longer. Test results will show us whether the structure can withstand the increased load or not.

It is suggested to conduct non-destructive tests at the selected location. What remedies can be taken to sustain the structural members under rising load are defined in accordance with the results and load calculation.

The focus of this research is on carrying out the necessary NDT testing and FEM analysis of steel plates used to encase columns.

OBJECTIVES

Following are the objectives for proposed research work –

1. To carry out preliminary survey of identified structure

2. To carry out relevant Non- Destructive Tests by observing type of damages in indentified structure

3. To prepare model of structural elements in Finite Element Analysis software

4. To validate on field results with the software results

5. To suggest corrective measures for the defects of identified structure modelled by Finite Element Analysis software.

PROBLEM STATEMENT FOR DISSERTATION WORK

For structural audit of a RCC structure-

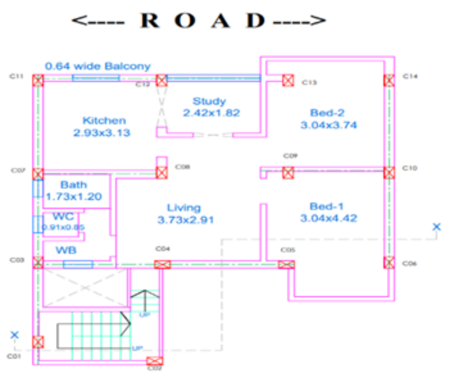
Type of Structure: RCC Structure

Type of Building: Residential or Commercial or Public Building

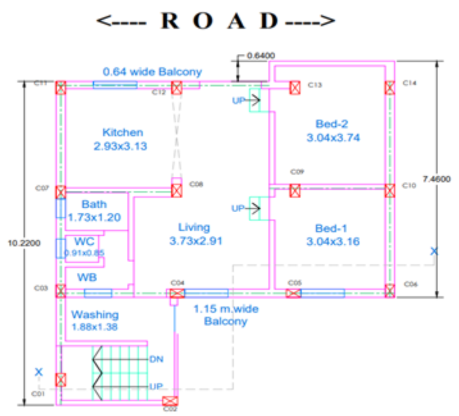
Age of Structure: Less than or more than 30 Years

Height of Building: Less than or more than 10 m

Special conditions if any: - Owner of the project site wants a non-destructive test to determine whether or not it can support the addition of another floor.



SECOND FLOOR PLAN



FIRST FLOOR PLAN

III. METHODOLOGY

In this project, a building is chosen for study, followed by a visual evaluation of the structure. One level must be built on the G+2 building in accordance with the requirement and any subsequent provisions. It was therefore important to determine whether the building is in a position or is in a state of operation that will allow it to withstand an increased load.

Therefore, non-destructive tests are performed to assess the remaining strength of concrete, including the digital rebound hammer test, ultrasonic pulse velocity test, carbonation test, and core test to assess the compressive strength of concrete of an existing building column.

Modelling of column in AutoCAD is done and imported in Finite Element Analysis software named ANSYS and to increase its strength, steel plates of size 3mm, 4mm, 7 mm applied on existing column. Results were evaluated in ANSYS considering following parameters-

1. Maximum Principal Stress

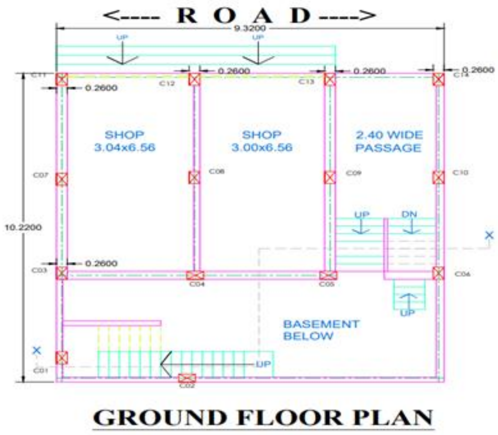
2. Maximum shear stress

3. Maximum Principal Elastic strain

4. Total Deformation

The findings are then compared to determine if the current column can support an increased load or not.

IV. DETAILS OF STRUCTURE



V. MODELLING OF COLUMN IN AUTOCAD

Column Details:

Size of existing column	0.23 m X 0.38 m
Height of existing column	2.9 m
Stirrups Diameter	6 mm @ 150 mm

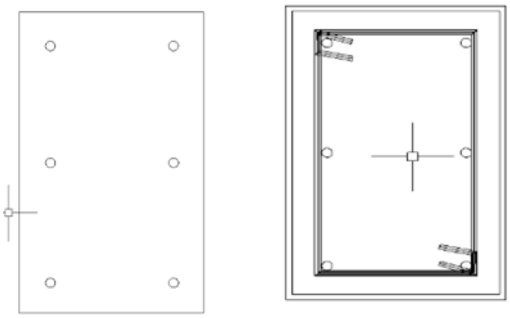


Fig. 1

(c/s of Main Span in Transverse Direction)

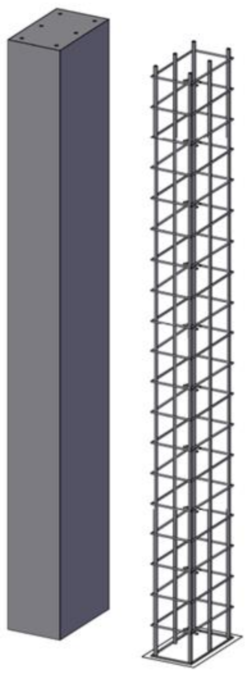


Fig. 3

3D Modelling of column in AUTOCAD

VI. NON-DESTRUCTIVE TESTING RESULTS

Concrete Core Compression Test:-

Test Conducted as per Code No. IS 516 : 2018, Correction factors as per SP 24-1983

Parameters	
Diameter D mm	75 mm
Length mm	94 mm
Dry wt. gms.	941.70
Saturated Weight gms.	965.30
% Water Absorption	2.51
Density Kg/m^3	2267.3
Brake Load In KN	43
Core Compressive Strength N/mm^2	09.73
Ratio ℓ/d	1.25
Correction for ℓ/d+	0.92
Corrected Comp. Strength N/mm^2	09.20
Equivalent Cube Strength+ + - of N/mm^2	11.50

NDT by Digital Rebound hammer Test

Digital Rebound Hammer as per as Is 13311(2): 1992, Ref-(IS-code 516:2018)

Sr.No	Location	Structural Member	Strength in N/mm²	Strength in kg/ sq. cm
1	Location 1	Column	15.00	152.85
2	Location 1	Beam	12.50	127.37

Ultrasonic Pulse Velocity Test-

NDT by Ultrasonic Pulse Velocity as per IS Code No. IS 13311(part- I): 2018

Location	Location-01
Structural Member	Column
Method of transmission	Semi Direct
Path length in mm.	180
Time in µs	54
Pulse Velocity (Km/Sec.)	3.33
Concrete Quality Grading	Medium

Velocity criterion for concrete quality grading

Pulse velocity (km/sec)	Concrete Quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

Reinforcement Corrosion by Half-Cell Potential Measurement

Description	Structural Member	Potential Value mV
Location -01	Column	-120

Potential Value as measured by Copper – Copper Sulphate Half-cell

1) More Positive than -200mV = Corrosion not taking place (Initial Phase)

2) Between -200mV & -350mV = Corrosion activity uncertain (Transient Phase)

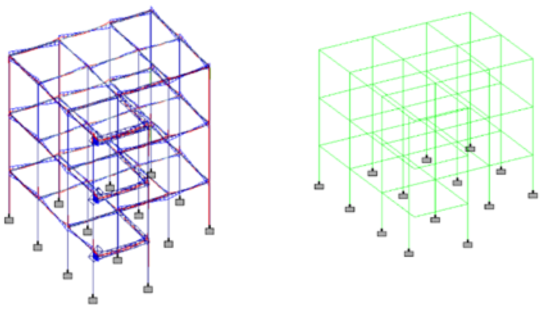
3) More negative than -350mV = Corrosion occurring positively (Final Phase)

Photos of conducting NDT test & Destructive test

Fig. 5

(Non-Destructive Tests)

VII. STAAD MODELLING OF STRUCTURE



STAAD MODELLING

Results from STAAD G+2 Model-

Column Number from AutoCAD Drawing	Location	Load (KN)

C6	GF	708

Results from STAAD G+3 Model-

This table consists load coming on columns of third floor to be added in building. Ultimately, loads coming on columns of second, first and ground floor get increased.

Column	Location	Load (KN)
C6	GF	918.1

VIII. LOAD CARRYING CAPACITY OF COLUMN

Load calculation coming on column as per IS 456: 2000-

fck = Compressive strength of concrete= 11.5 N/mm2

Ac = Area in concrete in compression

fy = Yeild strength of steel= 416 N/ mm2

Asc = Area of steel in compression

Pu = 0.4fck. Ac + 0.67 fy. Asc

= 0.4x 11.5x [230x380- 6xπ/4 x 122] + 0.67x 415x (6xπ/4 x 122)

= 587.59 KN

IX. ANSYS RESULTS OF COLUMN

Maximum Principal Stress from ANSYS Results

Parameters	Maximum Principal Stress			
Column condition	Existing column	Column with 3 mm steel plate	Column with 4 mm steel plate	Column with 7 mm steel plate
For load 708 KN (For G+2 building)	61301936.61	63553268.62	87770037.25	33428329.62
For load 918.1 KN (For G+3 building)	79493373.5	82412791.68	113815918.5	43348232.76

Maximum Shear Stress from ANSYS Results

Parameters	Maximum Shear Stress			
Column condition	Existing column	Column with 3 mm steel plate	Column with 4 mm steel plate	Column with 7 mm steel plate
For load 708 KN (For G+2 building)	61301936.61	44807982.01	45817950.99	38524390.3
For load 918.1 KN (For G+3 building)	79493373.5	58104814.37	59414491.1	49956558.61

Maximum Elastic Strain from ANSYS Results

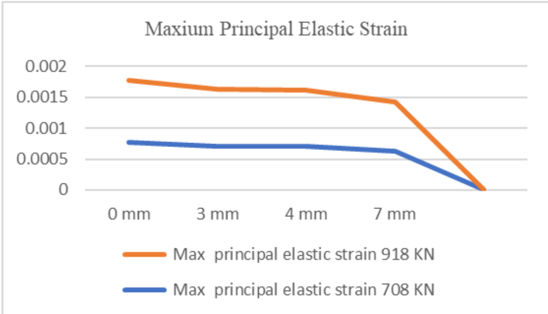
Parameters	Maximum Elastic Strain			
Column condition	Existing column	Column with 3 mm steel plate	Column with 4 mm steel plate	Column with 7 mm steel plate
For load 708 KN	0.000772631	4.14 E-10	0.000699962	0.000621444

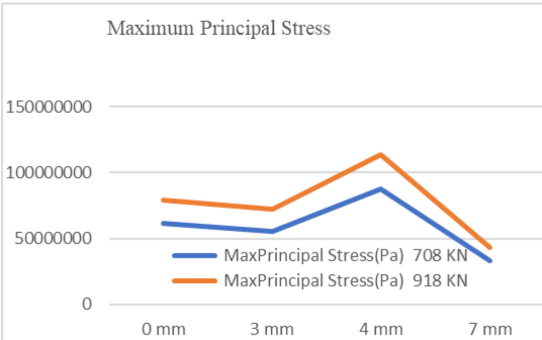
(For G+2 building)				
For load 918.1 KN (For G+3 building)	0.001001911	4.14 E-10	0.000907677	0.000805859

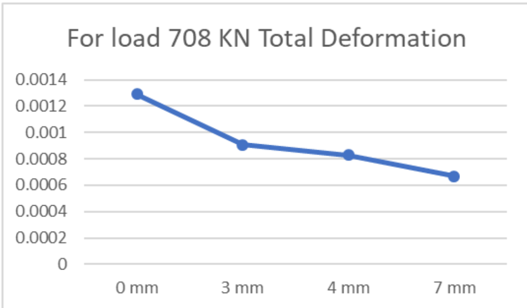
Total Deformation from ANSYS Results

Parameters	Total Deformation			
Column condition	Existing column	Column with 3 mm steel plate	Column with 4 mm steel plate	Column with 7 mm steel plate
For load 708 KN (For G+2 building)	0.00128906	0.000909184	0.000830006	0.000621444
For load 918.1 KN (For G+3 building)	0.00167159	0.001178986	0.001076311	0.000867669

X. RESULTS AND DISCUSSION







<u>For load 708 KN</u>

As the steel plate of 3 mm used on existing column, the deformation reduced upto 29.47%.

4 mm steel plate helped to reduce the total deformation upto 38% and 7 mm plate helped to reduce upto 51.179% total deformation comparing to existing column deformation.

<u>For load 918 KN</u>

As the steel plate of 3 mm used on existing column, the deformation reduced upto 29.58%.

4 mm steel plate helped to reduce the total deformation upto 35.61% and 7 mm plate helped to reduce upto 48.091% total deformation comparing to existing column deformation.

XI. CONCLUSION

The location, which is 30 years old, was selected for the structural assessment. The owner of the building wanted to extend the existing G+2 building by one level. Failure of the structure could result from this. It was necessary to reinforce the structural elements as a result.

According to STAAD data, the load on the building's column for a G+2 building was 708 KN. The load climbed to 918 KN when it was assessed for a G+3 building. In the finite modeling of the existing column, steel plates with thicknesses of 3 mm, 4 mm, and 7 mm were used. For loads of 708 and 918 KN, overall column deformation began to decrease as steel plate size increased. As a result, the ANSYS results demonstrated that adding steel plate to the area around the column faces reduced overall deformation.

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