

# Structural Assessment and Rehabilitation of RCC Structures by RCC Strengthening Techniques

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**Abstract** - Structural deterioration of reinforced cement concrete (RCC) structures has become a major concern due to aging infrastructure, environmental exposure, corrosion of reinforcement, and increasing load demands. In many situations, demolishing and reconstructing such structures is economically impractical and environmentally undesirable. Therefore, structural assessment and rehabilitation techniques play an important role in extending the service life of existing structures.

This study focuses on the evaluation and strengthening of RCC structural components through systematic condition assessment and suitable rehabilitation methods. The structural condition was initially investigated using non-destructive testing (NDT) techniques to determine concrete quality, detect internal defects, and estimate the remaining load-carrying capacity of structural members. Based on the assessment results, appropriate strengthening strategies were identified.

Strengthening techniques such as concrete jacketing and section enhancement were considered to improve structural performance. These methods contribute to increasing the load-bearing capacity, stiffness, durability, and ductility of the structural system. Analytical investigation was carried out using ETABS software through pushover analysis to understand the seismic behavior of the structure.

The study demonstrates that proper assessment combined with suitable strengthening techniques can significantly improve the performance and service life of RCC structures. The findings highlight the importance of adopting systematic evaluation and rehabilitation strategies to ensure structural safety and long-term durability.

**Keywords:** Structural Assessment, RCC Rehabilitation, Strengthening Techniques, NDT, Jacketing, Durability, Ductility.

## 1. INTRODUCTION

Reinforced cement concrete (RCC) is one of the most widely used construction materials due to its strength, durability, and versatility in structural applications. Despite its advantages, the performance of RCC structures may gradually deteriorate over time because of environmental exposure, corrosion of reinforcement, construction defects, increased loading conditions, and seismic influences. Such deterioration can reduce the structural capacity and affect the overall safety and serviceability of buildings.

To maintain the structural integrity of aging infrastructure, it is essential to carry out proper condition assessment before implementing any repair or strengthening measures. Structural assessment involves detailed inspection, evaluation of visible damage, and the use of appropriate testing methods to determine the current state of the structure. Non-destructive testing (NDT) techniques are particularly useful in this process, as they allow engineers to evaluate the in-situ condition of concrete without causing damage to structural members.

Once the condition of the structure has been determined, suitable rehabilitation techniques can be applied to restore or enhance its performance. Rehabilitation generally includes repairing damaged regions, strengthening structural components, and improving the load-carrying capacity of the system. Common strengthening methods include concrete jacketing, steel reinforcement enhancement, and the use of advanced materials such as fiber-reinforced polymers.

Proper implementation of these rehabilitation strategies helps extend the functional life of existing structures while reducing the need for complete reconstruction. As a result, structural rehabilitation has become an effective and economical solution in modern civil engineering practice.

## 2. RELATED WORK

Several researchers have investigated the assessment and rehabilitation of RCC structures in order to improve their structural performance and durability. Studies indicate that the deterioration of reinforced concrete structures is commonly associated with reinforcement corrosion, environmental exposure, poor construction practices, and increased service loads during the life of the structure.

Earlier investigations primarily relied on visual inspection and destructive testing methods for evaluating structural condition. With technological advancements, non-destructive testing (NDT) methods have become widely adopted for assessing the in-situ properties of concrete. Techniques such as the rebound hammer test, ultrasonic pulse velocity test, half-cell potential measurement, and core sampling are frequently used to estimate concrete strength, detect internal defects, and evaluate durability characteristics.

Various strengthening approaches have also been explored to enhance the performance of deteriorated structural members. Conventional techniques such as concrete jacketing and steel plate bonding have been shown to significantly improve load-carrying capacity and stiffness of structural elements. In recent years, advanced materials such as fiber-reinforced polymers (FRP) have gained attention due to their high strength-to-weight ratio, corrosion resistance, and ease of installation.

Research findings suggest that jacketing methods effectively increase axial strength and flexural capacity, while FRP strengthening improves ductility and resistance to cyclic loading. However, the success of these strengthening systems depends greatly on factors such as surface preparation, bonding quality, and proper design considerations.

Standards and guidelines such as IS 15988 provide procedures for evaluating and strengthening existing reinforced concrete structures, particularly in seismic regions. Case studies reported in the literature demonstrate that combining detailed structural assessment with suitable rehabilitation techniques can significantly improve structural safety and extend the operational life of RCC structures..

### • Current Research Gap

Although significant progress has been made in the field of structural assessment and rehabilitation of RCC structures, several limitations and gaps still exist that require further investigation. One of the major gaps is the lack of a unified and standardized methodology for selecting appropriate strengthening techniques based on the actual condition of the structure. In many cases, rehabilitation methods are chosen based on experience rather than detailed performance-based evaluation.

Another important limitation is the dependency on individual Non-Destructive Testing (NDT) methods. While NDT techniques provide valuable insights, relying on a single method may not accurately represent the true condition of the structure. There is a need for integrated assessment approaches that combine multiple testing methods with analytical modeling for more reliable results.

In terms of strengthening techniques, conventional methods such as jacketing are widely used, but they often increase the dead load and alter the geometry of the structure. On the other hand, advanced materials like FRP offer better performance but are still limited by higher costs, lack of skilled application, and insufficient long-term performance data under varying environmental conditions.

Additionally, there is limited research on the behavior of rehabilitated structures under combined loading conditions, especially seismic and dynamic loads. The long-term durability, bond performance, and failure mechanisms of strengthened elements also require deeper study.

Furthermore, many rehabilitation practices are not adequately supported by field-based case studies and real-time monitoring data. This creates a gap between theoretical research and practical implementation.

Therefore, there is a need for more comprehensive research focusing on integrated assessment techniques, performance-based rehabilitation strategies, cost-effective strengthening solutions, and long-term monitoring of rehabilitated RCC structures to ensure safety, durability, and sustainability.

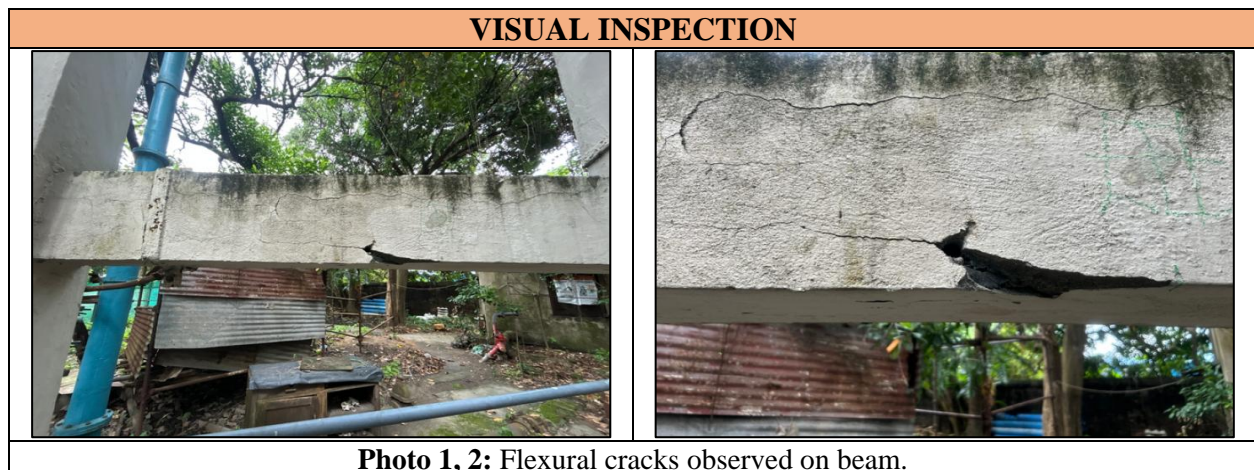
### 3. METHODOLOGY

The rehabilitation process is executed in five strategic phases, moving from initial field diagnostics to high-tech structural reinforcement.

#### Phase 1: Visual Inspection of the Structure

The first step is a comprehensive "walk-through" to identify visible distress signals.

- **Photographic Survey:** High-resolution images are taken of every structural element. We capture wide-angle shots for context and macro (close-up) shots of specific distress points. This includes "mapping" cracks with a crack-width gauge placed in the frame for scale.
- **Mapping Defects:** We noted crack patterns (flexural or shear), spalling of concrete, and exposed or corroded reinforcement, Sagging, etc.
- **Audit Report:** This report include visual inspection photographs with caption (determine/ observation in this picture or on site). On the basis of visual inspection we categories defect, following are the categories:
  - **Good:** The member is in proper situation without a visible signs and symptoms of damage or distress. There are not any cracks, spalling, corrosion, or deformation located. The member is appearing satisfactorily and does not require any heavy repair work at present, just conduct routine maintenance.
  - **Minor :** The structural member is in good condition; however small defects such as hairline cracks, minor surface spalling, peeling of paint, spalling of plaster, beginning to spalling of concrete due to minor corrosion on reinforcement etc. the issues are cosmetic & not affected to stability of structure. The simple repair & routine maintenance is sufficient to restore the member.
  - **Moderate:** Observed defects in the member include wider cracks, moderate spalling, exposed reinforcement with corrosion just beginning to take place or minor deformation of the member. Overall stability is not threatened; however durability and serviceability may be compromised. Repair of the member should take place as soon as possible.
  - **Major:** Member observed in damaged condition. Major spalling of concrete with exposed corroded reinforcement, deflection, major cracks. As a result, the member's structural integrity and its ability to resist load are compromised. Immediate repair with strengthening is required.





**Photo 3, 4:** Combination of Flexural & shear crack observed on beam.



**Photo 5, 6:** Bulging of column with beginning of developing vertical cracks. The reason behind this is due to increase load/ inadequate design.



**Photo 7, 8:** Vertical cracks observed on column members.

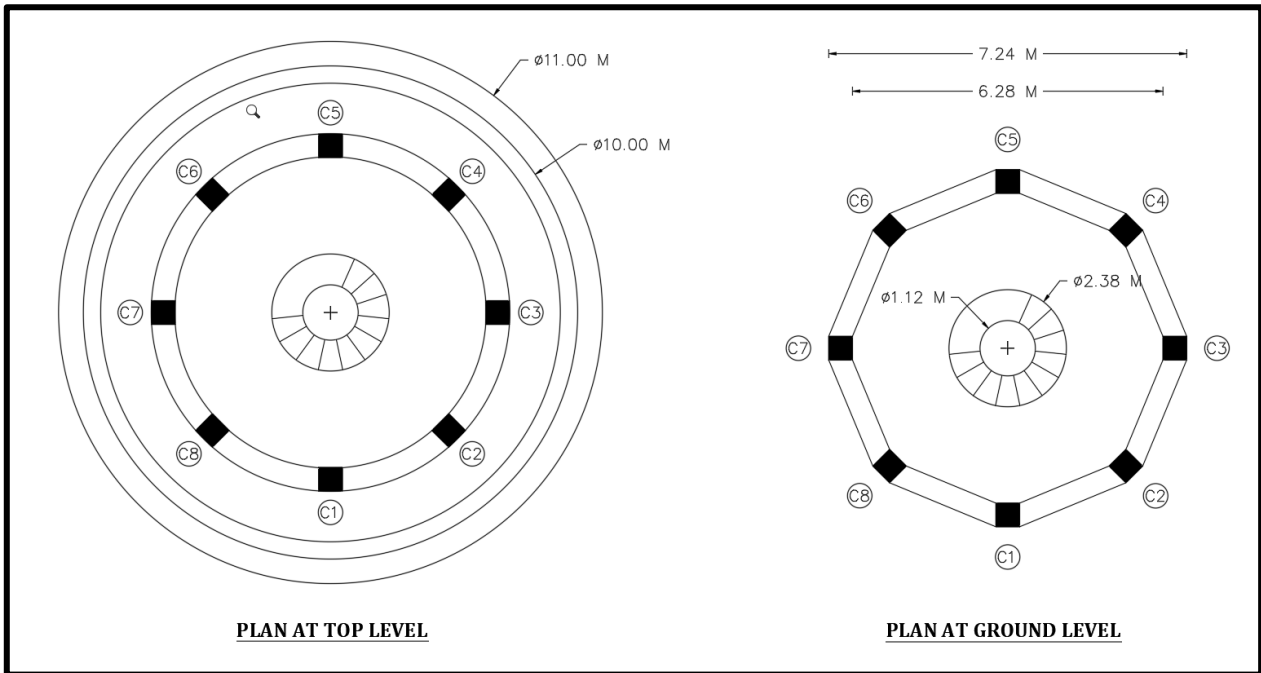


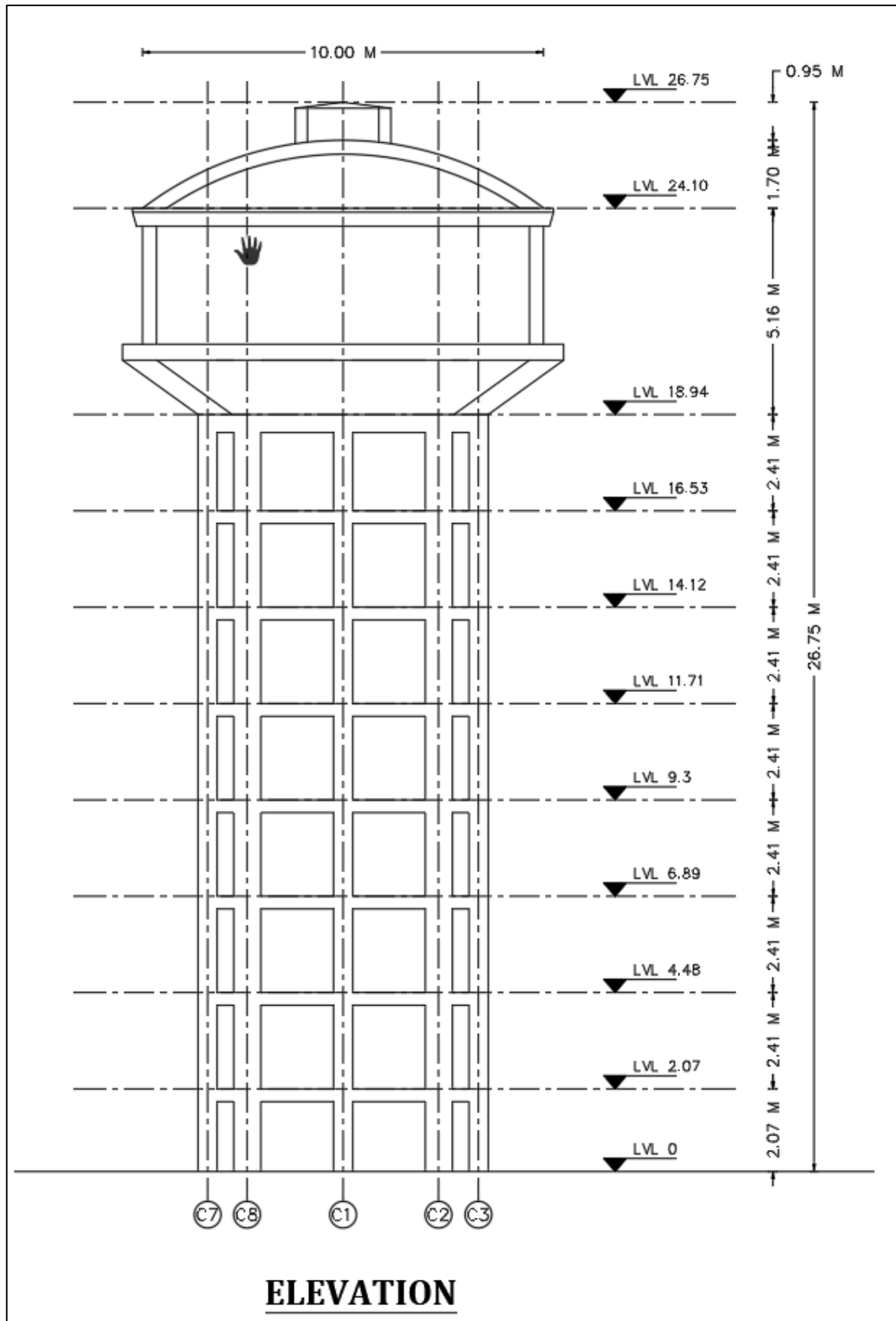
**Photo 9, 10:** Vertical cracks observed on column members.

## Phase 2: Site Data Collection:

Ones the visual inspection is completed, we gather structural member information as following: -

- **Geometry of structural members:** - We measure actual size of structural members such as column cross-section, beam size.
- **Any repair work is done, if yes in which year:** - There is no repair work is done before.
- **Year of construction: 2015.**



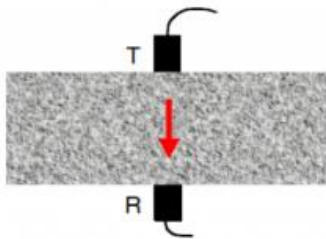


Phase 3: NDT Testing and Interpretation:

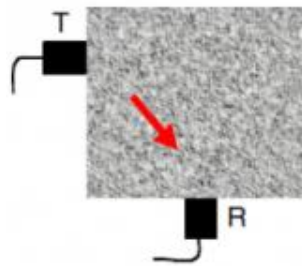
1. **Ultrasonic Pulse Velocity Test:** IS 516 (Part 2/Sec 1): 2018

It is a non-destructive testing to evaluate concrete quality in terms of homogeneity, uniformity, honeycombing, internal voids/ cracks. In this apparatus two probes, one is transducer pass pules & another is receiver to measure velocity. The pulse travel time is less then it shows good quality of concrete in term of homogeneity & when pulse travel time is more the it means presence of internal cracks, voids.

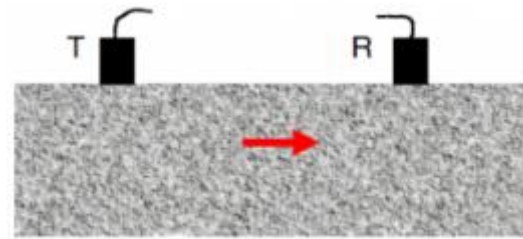
There are three method of testing



**Direct Method**



**Semi-direct Method**



**Indirect Method**

➤ Procedure:

- A. Chipping plaster from surface of structural member.
- B. Clean the surface.
- C. Apply gel/ grease between concrete surface & probe.
- D. Record time taken by ultrasonic pulse to travel through concrete.
- E. Calculate pulse velocity by using formula & compare the result from IS 516 (Part2/Sec1):2018.

➤ Formula

$$V = \frac{L}{T}$$

Where:

- V = Pulse Velocity (km/s)
- L = Length between probes
- T = Time taken (Sec)

ULTRASONIC PULSE VELOCITY TEST								
Test is conducted random basis on structural members.								
Sr. No.	Location			On Site Reading		Temp. Corrected Velocity Km/Sec	Quality of Concrete	UPV Method
	Member	ID/Block	Position	Length	Time			
1	Column	C1	Middle	480	183.2	2.62	Doubtful	Direct
2	Column	C2	Middle	480	234.6	2.05	Doubtful	Direct
3	Column	C3	Middle	480	219.2	2.19	Doubtful	Direct
4	Column	C4	Middle	480	208.7	2.30	Doubtful	Direct
5	Column	C5	Middle	480	189.6	2.53	Doubtful	Direct
6	Column	C6	Middle	480	218.5	2.20	Doubtful	Direct
7	Column	C7	Middle	480	78.3	6.13	Excellent	Direct
8	Column	C8	Middle	480	93.2	5.15	Excellent	Direct
9	Beam	C1-C2	Middle	260	108.2	2.40	Doubtful	In-Direct
10	Beam	C2-C3	Middle	260	82.6	3.15	Doubtful	In-Direct
11	Beam	C3-C4	Middle	260	96.2	2.70	Doubtful	In-Direct
12	Beam	C4-C5	Middle	260	96.2	2.70	Doubtful	In-Direct

13	Beam	C5-C6	Middle	260	96.2	2.70	Doubtful	In-Direct
14	Beam	C6-C7	Middle	260	96.2	2.70	Doubtful	In-Direct
15	Beam	C7-C8	Middle	260	96.2	2.70	Doubtful	In-Direct
16	Beam	C8-C1	Middle	260	96.2	2.70	Doubtful	In-Direct
17	RCC Wall	P1	Middle	400	210.2	1.90	Doubtful	In-Direct
18	RCC Wall	P2	Middle	400	218.2	1.83	Doubtful	In-Direct
19	RCC Wall	P3	Middle	400	231.4	1.73	Doubtful	In-Direct
20	RCC Wall	P4	Middle	400	183.2	2.18	Doubtful	In-Direct
21	Slab	P5	Bottom	400	305.2	1.31	Doubtful	In-Direct
22	Slab	P6	Bottom	400	314.4	1.27	Doubtful	In-Direct
23	Slab	P7	Bottom	400	282.8	1.41	Doubtful	In-Direct
24	Slab	P8	Bottom	400	319.7	1.25	Doubtful	In-Direct
<b>Test Result Interpretation:</b>	Quality of concrete is Doubtful for Column, Beam RCC Wall & OHWT Slab (in terms of <b>Deterioration of concrete</b> , homogeneity, Presence of internal flaws, cracks and segregation, level of workmanship etc.)							

Velocity Criterion or Concrete Quality Grading as per IS 516 (Part/Sec.1): 2018. Amendment No.- 01. November-2019		
For Concrete { < M 25 }:-		
Sr.No.	Pulse velocity by cross probing (Km/sec)	Concrete quality grading
1	Below 3.5	Doubtful
2	3.5 - 4.5	Good
3	Above 4.5	Excellent

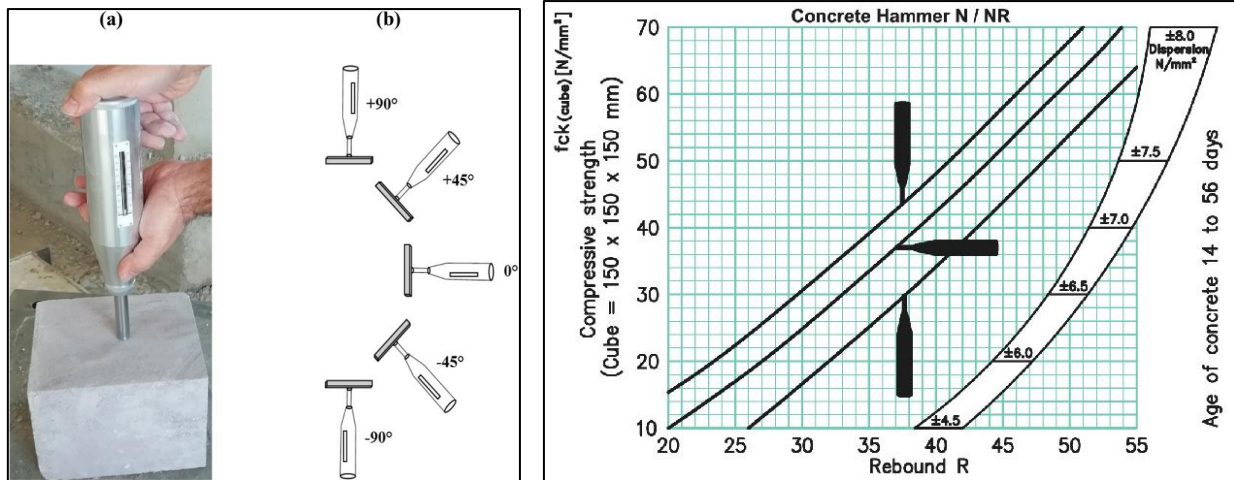
**2. Rebound Hammer Test: IS 516 (Part 5/Sec 4) : 2020**

It is a non-destructive testing (NDT) method used to estimate the surface hardness and approximate compressive strength of concrete without damaging the structure. This test is commonly used during structural audits and quality assessment of existing concrete structures. The test works on the principle that harder concrete surfaces will cause a greater rebound of a spring-controlled mass inside the hammer.



➤ Procedure:

- A. Chipping plaster from surface of structural member.
- B. Clean the surface.
- C. Hold the hammer perpendicular to the surface of structural member.
- D. Press the plunger until the hammer impacts & record the rebound number.
- E. Take min 10 to 14 reading at one location.



REBOUND HAMMER TEST							
Sr. No.	Structural member	Mark	Mean Rebound Number	Anvil Correction Factor	Corrected Rebound Number	Avg. Comp. Strength	Hammer held Position
1	Column	C1	25.21	0.00	25.21	16.00	90°
2	Column	C2	27.00	0.00	27.00	19.00	90°
3	Column	C3	30.29	0.00	30.29	23.00	90°
4	Column	C4	29.64	0.00	29.64	22.00	90°
5	Column	C5	28.93	0.00	28.93	20.50	90°
6	Column	C6	27.79	0.00	27.79	19.00	90°
7	Column	C7	28.00	0.00	28.00	20.50	90°
8	Column	C8	29.50	0.00	29.50	22.00	90°
9	Beam	C1-C2	28.36	0.00	28.36	20.50	90°
10	Beam	C2-C3	27.79	0.00	27.79	19.00	90°
11	Beam	C3-C4	28.71	0.00	28.71	20.50	90°
12	Beam	C4-C5	27.50	0.00	27.50	19.00	90°
13	Beam	C5-C6	29.86	0.00	29.86	22.00	90°
14	Beam	C6-C7	29.64	0.00	29.64	22.00	90°
15	Beam	C7-C8	29.71	0.00	29.71	22.00	90°
16	Beam	C8-C1	27.21	0.00	27.21	19.00	90°
17	RCC Wall	P1	29.57	0.10	26.61	18.00	90°
18	RCC Wall	P2	29.57	0.10	26.61	18.00	90°
19	RCC Wall	P3	32.14	0.10	28.93	20.50	90°
20	RCC Wall	P4	30.29	0.10	27.26	19.00	90°
21	Slab	P5	26.71	0.10	24.04	15.00	- 90°
22	Slab	P6	26.79	0.10	24.11	15.00	- 90°
23	Slab	P7	27.79	0.10	25.01	16.00	- 90°
24	Slab	P8	28.14	0.10	25.33	16.00	- 90°
<b>Test Result Interpretation</b>	Surface Hardness of Concrete is categorized Fair layer for Column, Beam, Slab & RCC Wall as per Rebound Hammer Test.						

Rebound Number Criterion for Concrete Quality Grading as per IS 516 (Part 5/Sec 4) : 2020		
Average Rebound Number	Compressive strength (N/mm <sup>2</sup> )	Quality of Concrete
> 40	> 40	Very Good Hard Layer
30 to 40	24 to 39	Good Layer
20 to 30	10 to 23	Fair
<20	Below 10	Poor Concrete

**Phase 4: Analysis of structure by using Pushover Analysis via ETABS:**

When we have finished processing the site data and the NDT results, then create a digital model of the structure using ETABS. This digital model is, like a copy of the thing so we can get a better understanding of behaviour the structure at current loading condition. We use ETABS to make this twin of the structure.

- A. Modeling the state of the structure is what we do first. We make a model of the structure. This model includes the strength of the materials and the current shape of the parts.
- B. We do a kind of test called Non-Linear Static or Pushover Analysis. This test is different from a test. We apply a load to the structure, from the side. Keep pushing it until it reaches a certain point or falls down.
- C. We do a kind of test called Non-Linear Static or Pushover Analysis. This test is different from a test. We apply a load to the structure, from the side. Keep pushing it until it reaches a certain point or falls down.
- D. We use a tool to see where the structure will break first. This tool is called ETABS. It helps us find out which parts of the structure will bend or break. We call these points "hinges".
- E. We make a graph that shows how strong the structure is. This graph is called the Capacity Curve. It shows us if the structure is strong enough to meet the rules for earthquakes.
- F. When we look at the results of the Pushover Analysis we can see if the structure is weak or stiff. If it is weak we use the results to find out where we need to add support to make the structure stronger. We want to change the way the structure breaks so it is not weak anymore. We do this by adding Hybrid EB and NSM reinforcements to the structure.

**ANALYSIS PART**

**A) STRUCTURAL DESIGN CONSIDERATION**

- 1. Building Design For = Ground + 9
- 2. Building Design For = Over Head Water Tank Structure
- 3. Floor to Floor Height Approximately = 2.41m
- 4. Plinth Height = N.A
- 5. Number & Type of Staircase = 1 Numbers, Structural Steel Staircases
- 6. Number of Lift = NA.
- 7. Type of Wall = RCC Pardi(300 mm External Wall)
- 8. Partition Wall = N.A
- 9. Toilet/Bathroom Sunk = NA.
- 10. Overhead Water Tank Location & Capacity Approximately = 3,24,130 Ltr.
- 11. SBC = 25 T/sq.m.

Indian Standard Codes.		
1.	IS 456 : 2000	Pain and Reinforced Concrete
2.	IS: 800 : 2007	General Construction in Steel – Code of Practice
3.	IS 1893 : 2016	Code of practice for Earthquake Resistant Design of Structure.

4.	IS 875 (Part 1) :2015	Dead Load – Design Loads For Building and structures.
5.	IS 875 (Part 2) :2015	Live Load – Design Loads For Building and structures.
6.	IS 875 (Part 3) :2015	Wind Load – Design Loads For Building and structures.
7.	IS 3370 (Part 1) : 2009	Concrete Structures For Storage Of Liquids - Code Of Practice
7.	IS 13920 : 1993	Ductile Detailing of Reinforced Concrete Structures to seismic forces – Code of practice.

### B) GEOMETRICAL PROPERTIES

Area Section properties						
Section	Material	Area Type	Type	Thickness (m)	Cover (m)	Rebar
S1-Two Way	M15	Shell	Shell-Thin	0.20	0.020	MILD 250
S2-One Way	M15	Shell	Shell-Thin	0.20	0.020	MILD 250

Frame Section properties						
Section	Material	Shape	t3 (m)	t2 (m)	Cover (m)	Rebar
Column 1 - (480 x 480)	M15	Rectangular	0.48	0.48	0.040	MILD 250
Column 2 - (150)	M15	Circular	0.15 (Dia)		0.040	MILD 250
Beam1 - (230 x 750)	M15	Rectangular	0.23	0.75	0.025	MILD 250
Beam2 - (230 x 350)	M15	Rectangular	0.23	0.35	0.025	MILD 250

### C) MATERIAL PROPERTIES

Sr. No.	Material	Fc (KN/m <sup>2</sup> )	ES(N/mm <sup>2</sup> )
1	M15	15	15000

Sr. No.	Material	Fy (KN/m <sup>2</sup> )	Fu (KN/m <sup>2</sup> )
1	MILD 250	250 000	250000

### D) LOADS & COMBINATIONS:

1. **Dead Load** =

1.1. Self-weight = Software will calculate by its own

1.2. Floor Finished Load = 1.5 kN/Sq.m

2. **Live Load** = 2 kN/Sq.m top slab for maintenance.

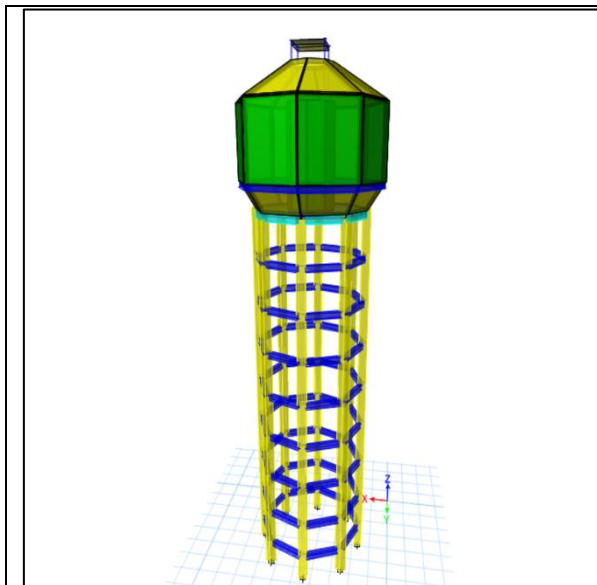
3. **Water Pressure Load** = 61.78 kN/m

4. **Earthquake Load** = The “Overhead Tank” Situated At “Kolkata” India region lies under earthquake zone-III as per IS-1893-2016, hence zone factor of 0.24 is considered, an Importance factor of 1.5 is considered, response reduction factor of 5 and the natural period is program calculated. The soil is considered as soft soil as per the soil test report provided.

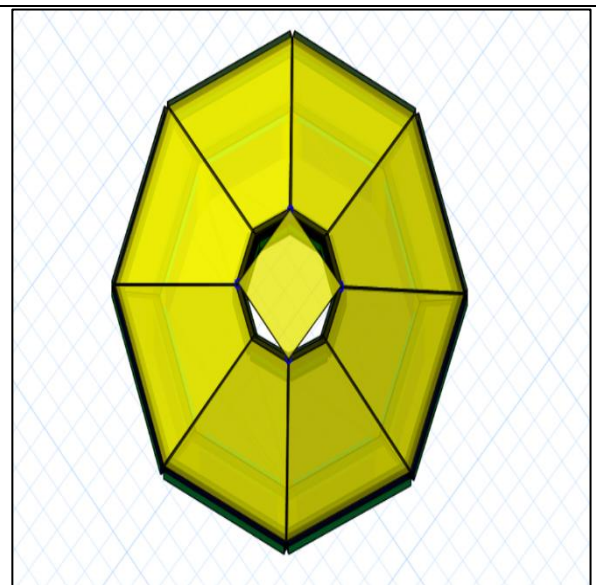
5.

WSM criteria	LSM criteria
(DL+LL)	1.5 (DL+LL)
(DL+0.8*LL±0.8*EQX)	1.2[DL+LL±(EQX)]
(DL+0.8*LL±0.8*EQZ)	1.2[DL+LL±(EQZ)]
(DL±EQX)	1.5[DL±(EQX)]
(DL±EQZ)	1.5[DL±(EQZ)]
	0.9DL±1.5(EQX)

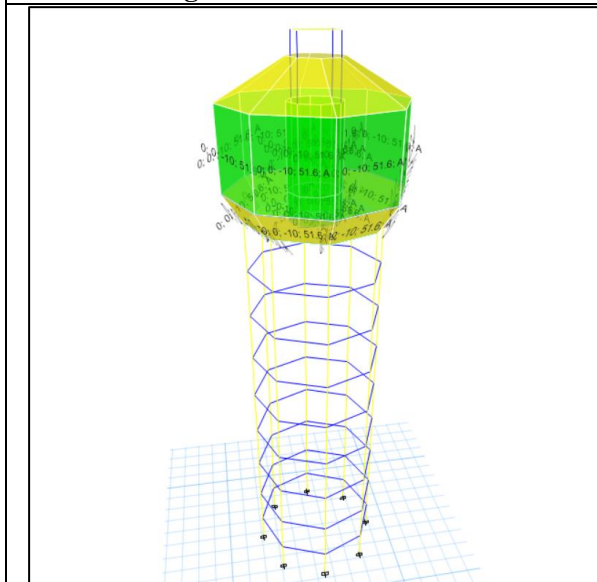
**E) MODEL PHOTOS**



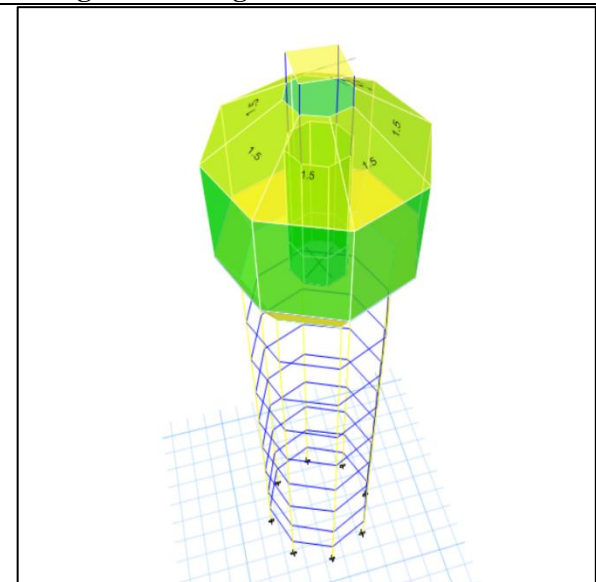
**Fig. 1: 3D View of Model.**



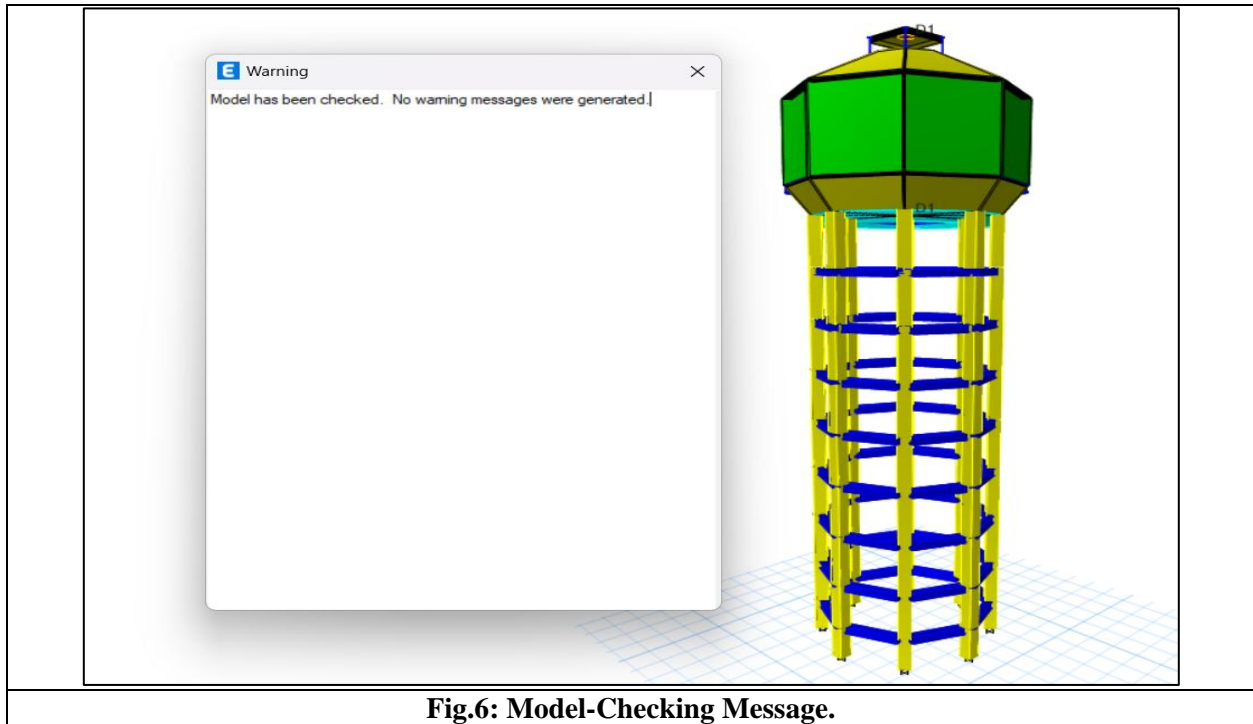
**Fig. 2: Framing Plan of First Floor Level**



**Fig.3: Live Load Applied on the structure.**



**Fig.4: Floor Finish Load Applied on the structure.**



**Fig.6: Model-Checking Message.**

#### **F) PUSHOVER ANALYSIS IN ETABS**

The ETABS model we made for the Educational Structure is a model. To do an analysis we need to change this simple model into a more complex model. We do this by adding parts called frame non-linear hinges. We put these hinges on the beams and columns of the Educational Structure. This makes the Educational Structure behave in a -linear way. The way we assigned these hinges to the Educational Structure is shown in the figure;

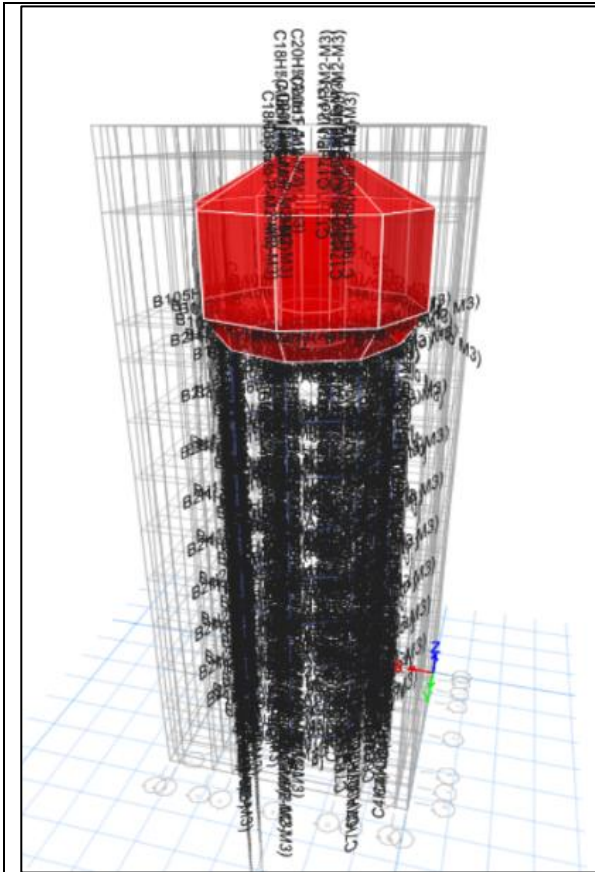


Fig.7: Assignment hinges on structure.

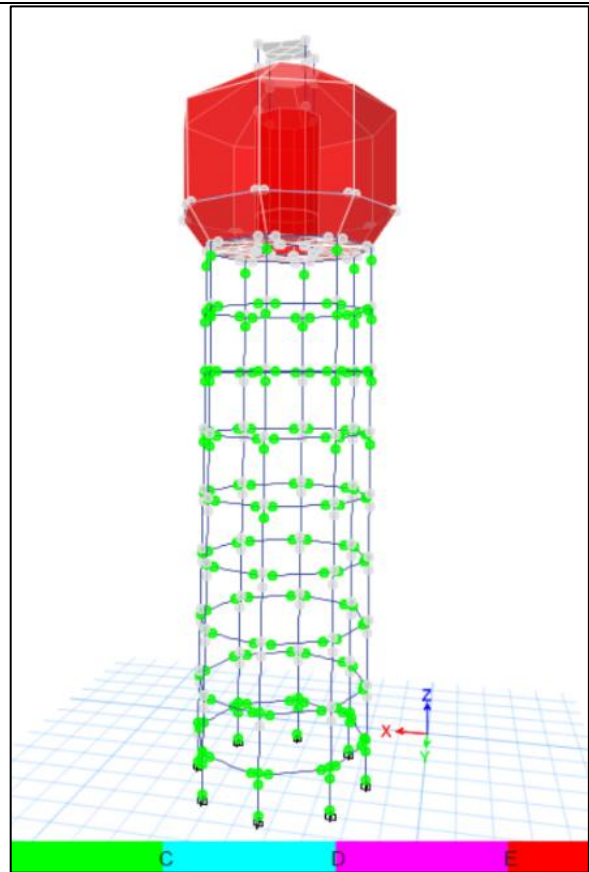
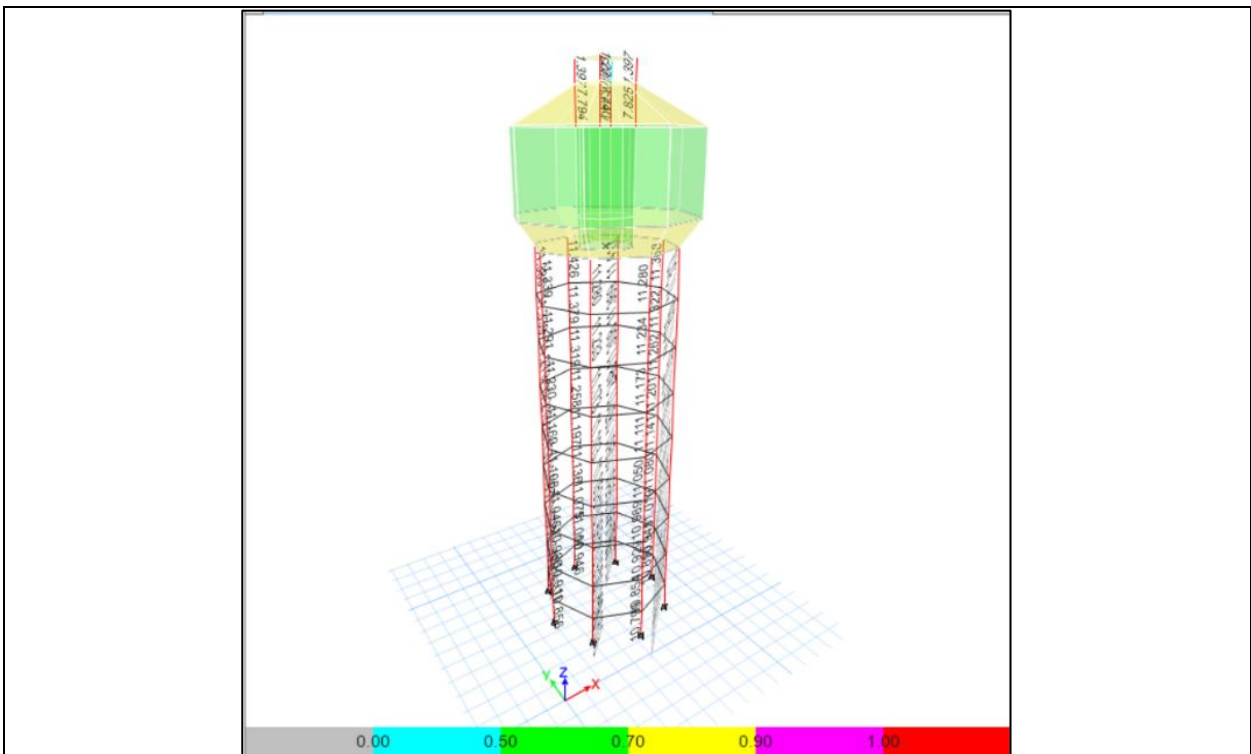
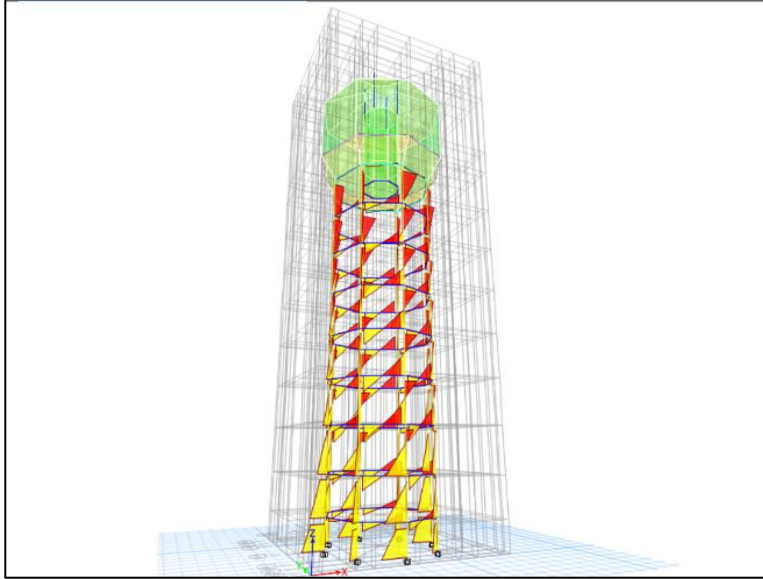


Fig.8: Pushover Non-linear Hinges formed after analysis (PAX and PAY).

G) SUMMARY OF DESIGN RESULTS:

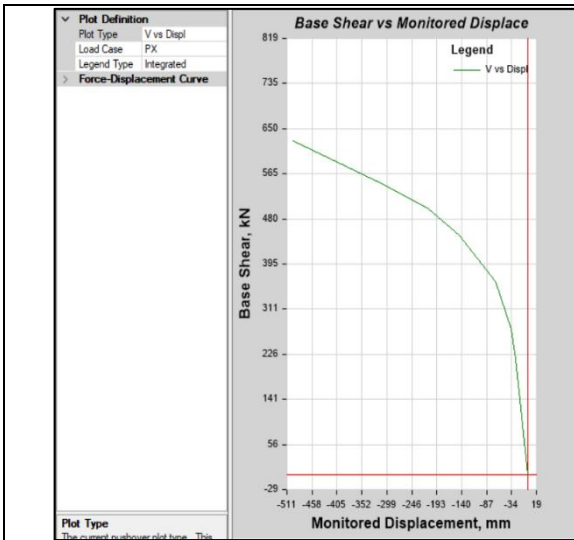


**Fig.9: After Design Column Interaction Ratio/failure of beam and column.**

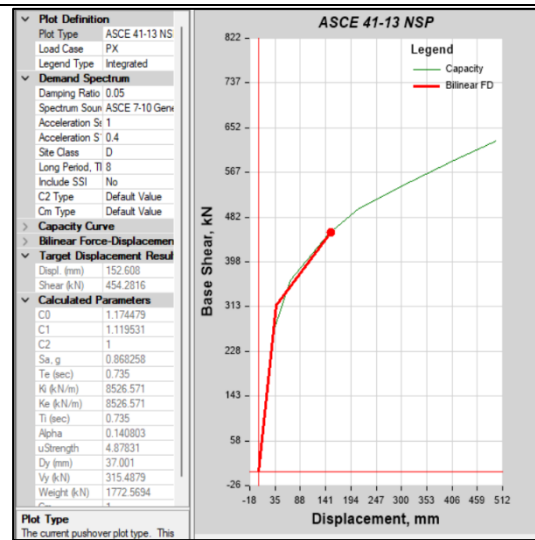


**Fig.10: Assignment BMD on floor of structure.**

**H) RESULT OF PUSHOVER ANALYSIS USING ETABS**



**Fig.11: Curve- Base Shear vs. Displacement (Pa-X)**



**Fig. 12: Push over Curve**

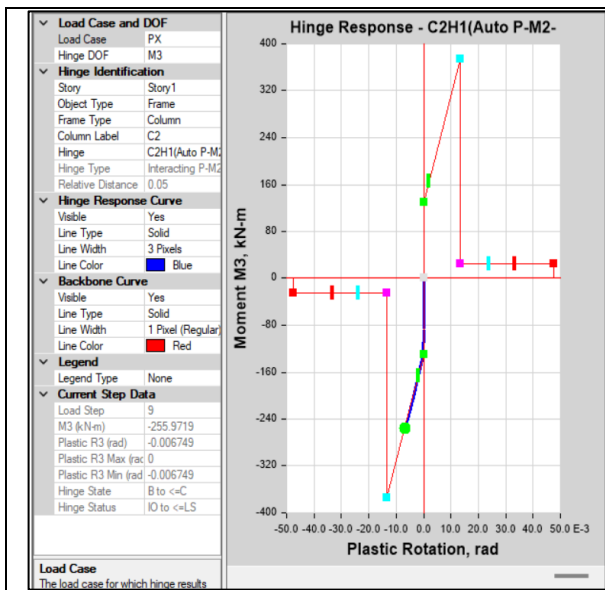


Fig. 13: Hinges Result.

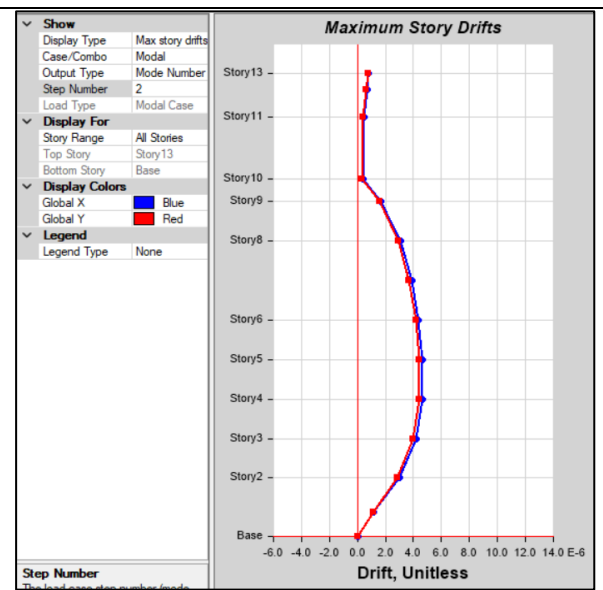


Fig. 14: Maximum Story Drift.

**TABLE: Concrete Column PMM Envelope - IS 456-2000**

Label	Unique Name	Section	Location	P	M Major	M Minor	PMM Combo	PMM Ratio
				kN	kN-m	kN-m		
C17	802	C-150	Top	12.24	2.31	3.96	DConS2	1.177
C17	802	C-150	Bottom	12.87	-1.89	-5.14	DConS2	1.397
C18	801	C-150	Top	0.03	0.00	0.00	DConS2	0.00015
C18	801	C-150	Bottom	0.63	0.01	0.00	DConS2	0.003
C19	803	C-150	Top	0.76	-3.73	0.02	DConS2	0.976
C19	803	C-150	Bottom	1.38	4.71	-0.03	DConS2	1.231
C20	804	C-150	Top	12.24	2.38	-3.96	DConS2	1.188
C20	804	C-150	Bottom	12.87	-1.86	5.16	DConS2	1.397
C17	798	C-150	Top	1575.13	31.50	-1.86	DConS2	7.794
C17	798	C-150	Bottom	1576.25	-31.53	1.07	DConS2	7.785
C18	797	C-150	Top	1555.78	-1.57	31.12	DConS2	7.693
C18	797	C-150	Bottom	1556.90	0.81	-31.14	DConS2	7.685
C19	799	C-150	Top	1562.89	2.22	31.26	DConS2	7.74
C19	799	C-150	Bottom	1564.01	-1.54	-31.28	DConS2	7.733
C20	800	C-150	Top	1581.06	31.62	1.98	DConS2	7.825
C20	800	C-150	Bottom	1582.19	-31.64	-1.20	DConS2	7.817
C2	682	C1-480x480	Top	-5367.83	5.21	-107.63	DConS2	11.28
C2	682	C1-480x480	Bottom	-5351.20	-2.36	107.30	DConS2	11.246
C3	683	C1-480x480	Top	-5436.87	-0.24	109.02	DConS2	11.426
C3	683	C1-480x480	Bottom	-5420.24	0.00	-108.69	DConS2	11.391
C4	684	C1-480x480	Top	-5395.58	-108.19	0.90	DConS2	11.339
C4	684	C1-480x480	Bottom	-5378.96	107.86	-1.02	DConS2	11.304
C5	685	C1-480x480	Top	-5409.56	108.47	-5.61	DConS2	11.368
C5	685	C1-480x480	Bottom	-5392.94	-108.14	1.39	DConS2	11.334

C6	686	C1-480x480	Top	-5367.35	-107.63	-0.56	DConS2	11.28
C6	686	C1-480x480	Bottom	-5350.73	107.29	0.50	DConS2	11.245
C7	687	C1-480x480	Top	-5417.57	-1.55	108.63	DConS2	11.385
C7	687	C1-480x480	Bottom	-5400.95	0.15	-108.30	DConS2	11.351
C8	688	C1-480x480	Top	-5432.37	108.93	-0.67	DConS2	11.417
C8	688	C1-480x480	Bottom	-5415.75	-108.60	0.04	DConS2	11.382
C9	689	C1-480x480	Top	-5382.43	-0.77	-107.93	DConS2	11.312
C9	689	C1-480x480	Bottom	-5365.80	0.24	107.59	DConS2	11.277
C2	3	C1-480x480	Top	-5339.83	-1.78	108.26	DConS2	11.234
C2	3	C1-480x480	Bottom	-5322.29	0.10	-107.90	DConS2	11.197
C3	11	C1-480x480	Top	-5408.86	-0.02	-109.66	DConS2	11.379
C3	11	C1-480x480	Bottom	-5391.33	-0.05	-109.30	DConS2	11.342
C4	19	C1-480x480	Top	-5367.25	108.81	-0.90	DConS2	11.291
C4	19	C1-480x480	Bottom	-5349.72	-108.46	-0.06	DConS2	11.255
C5	27	C1-480x480	Top	-5381.72	-109.11	1.00	DConS2	11.322
C5	27	C1-480x480	Bottom	-5364.19	-108.75	-0.28	DConS2	11.285
C6	35	C1-480x480	Top	-5339.43	108.25	0.11	DConS2	11.233
C6	35	C1-480x480	Bottom	-5321.89	-107.89	0.05	DConS2	11.196
C7	43	C1-480x480	Top	-5389.93	0.27	-109.27	DConS2	11.339
C7	43	C1-480x480	Bottom	-5372.40	-108.92	-0.20	DConS2	11.302
C8	51	C1-480x480	Top	-5404.23	-109.56	-0.16	DConS2	11.369
C8	51	C1-480x480	Bottom	-5386.70	109.21	0.01	DConS2	11.333
C9	59	C1-480x480	Top	-5354.90	0.29	108.56	DConS2	11.266
C9	59	C1-480x480	Bottom	-5337.37	-108.21	0.05	DConS2	11.229
C2	4	C1-480x480	Top	-5310.69	0.01	107.67	DConS2	11.173
C2	4	C1-480x480	Bottom	-5293.16	0.02	-107.31	DConS2	11.136
C3	12	C1-480x480	Top	-5380.03	-0.03	-109.07	DConS2	11.319
C3	12	C1-480x480	Bottom	-5362.49	-0.07	108.72	DConS2	11.282
C4	20	C1-480x480	Top	-5337.98	108.22	-0.19	DConS2	11.23
C4	20	C1-480x480	Bottom	-5320.44	-107.87	-0.10	DConS2	11.193
C5	28	C1-480x480	Top	-5353.11	-108.53	-0.27	DConS2	11.262
C5	28	C1-480x480	Bottom	-5335.57	108.17	-0.20	DConS2	11.225
C6	36	C1-480x480	Top	-5311.02	107.67	-0.05	DConS2	11.173
C6	36	C1-480x480	Bottom	-5293.49	-107.32	-0.08	DConS2	11.136
C7	44	C1-480x480	Top	-5361.12	-0.25	-108.69	DConS2	11.279
C7	44	C1-480x480	Bottom	-5343.59	-0.25	108.33	DConS2	11.242
C8	52	C1-480x480	Top	-5375.22	-108.98	-0.09	DConS2	11.308
C8	52	C1-480x480	Bottom	-5357.69	108.62	-0.05	DConS2	11.271
C9	60	C1-480x480	Top	-5325.91	-0.19	107.98	DConS2	11.205
C9	60	C1-480x480	Bottom	-5308.37	-0.30	-107.62	DConS2	11.168
C2	5	C1-480x480	Top	-5281.62	-107.08	0.05	DConS2	11.111
C2	5	C1-480x480	Bottom	-5264.08	0.03	-106.72	DConS2	11.075
C3	13	C1-480x480	Top	-5351.11	-0.04	-108.49	DConS2	11.258
C3	13	C1-480x480	Bottom	-5333.58	-0.08	108.13	DConS2	11.221
C4	21	C1-480x480	Top	-5308.83	0.19	-107.63	DConS2	11.169
C4	21	C1-480x480	Bottom	-5291.30	-107.27	-0.12	DConS2	11.132

C5	29	C1-480x480	Top	-5324.38	-107.95	-0.15	DConS2	11.201
C5	29	C1-480x480	Bottom	-5306.85	107.59	-0.24	DConS2	11.164
C6	37	C1-480x480	Top	-5282.49	107.10	-0.11	DConS2	11.113
C6	37	C1-480x480	Bottom	-5264.96	-106.74	-0.09	DConS2	11.076
C7	45	C1-480x480	Top	-5332.30	-0.18	-108.11	DConS2	11.218
C7	45	C1-480x480	Bottom	-5314.77	-0.21	107.75	DConS2	11.181
C8	53	C1-480x480	Top	-5346.31	-108.39	-0.13	DConS2	11.248
C8	53	C1-480x480	Bottom	-5328.78	108.03	-0.05	DConS2	11.211
C9	61	C1-480x480	Top	-5296.94	-107.39	0.15	DConS2	11.144
C9	61	C1-480x480	Bottom	-5279.41	-0.25	-107.03	DConS2	11.107
C2	6	C1-480x480	Top	-5252.61	-0.06	106.49	DConS2	11.05
C2	6	C1-480x480	Bottom	-5235.07	0.01	-106.13	DConS2	11.014
C3	14	C1-480x480	Top	-5322.16	-0.06	-107.90	DConS2	11.197
C3	14	C1-480x480	Bottom	-5304.63	-0.07	107.54	DConS2	11.16
C4	22	C1-480x480	Top	-5279.76	107.04	-0.19	DConS2	11.108
C4	22	C1-480x480	Bottom	-5262.23	-106.69	-0.15	DConS2	11.071
C5	30	C1-480x480	Top	-5295.57	-107.36	-0.19	DConS2	11.141
C5	30	C1-480x480	Bottom	-5278.04	107.01	-0.23	DConS2	11.104
C6	38	C1-480x480	Top	-5253.85	106.52	-0.11	DConS2	11.053
C6	38	C1-480x480	Bottom	-5236.32	-106.16	-0.10	DConS2	11.016
C7	46	C1-480x480	Top	-5303.49	-0.17	-107.52	DConS2	11.157
C7	46	C1-480x480	Bottom	-5285.95	-0.19	107.17	DConS2	11.121
C8	54	C1-480x480	Top	-5317.46	-107.80	-0.11	DConS2	11.187
C8	54	C1-480x480	Bottom	-5299.93	107.45	-0.07	DConS2	11.15
C9	62	C1-480x480	Top	-5268.01	-0.18	106.80	DConS2	11.083
C9	62	C1-480x480	Bottom	-5250.47	-0.21	-106.45	DConS2	11.046
C2	7	C1-480x480	Top	-5223.64	-0.06	105.90	DConS2	10.989
C2	7	C1-480x480	Bottom	-5206.11	-0.01	-105.55	DConS2	10.953
C3	15	C1-480x480	Top	-5293.22	-0.06	-107.31	DConS2	11.136
C3	15	C1-480x480	Bottom	-5275.68	-0.06	106.96	DConS2	11.099
C4	23	C1-480x480	Top	-5250.75	106.45	-0.20	DConS2	11.046
C4	23	C1-480x480	Bottom	-5233.21	-106.10	-0.17	DConS2	11.01
C5	31	C1-480x480	Top	-5266.73	-106.78	-0.20	DConS2	11.08
C5	31	C1-480x480	Bottom	-5249.19	106.42	-0.22	DConS2	11.043
C6	39	C1-480x480	Top	-5225.13	105.93	-0.12	DConS2	10.993
C6	39	C1-480x480	Bottom	-5207.60	-105.58	-0.10	DConS2	10.956
C7	47	C1-480x480	Top	-5274.67	-0.16	-106.94	DConS2	11.097
C7	47	C1-480x480	Bottom	-5257.13	-0.18	106.58	DConS2	11.06
C8	55	C1-480x480	Top	-5288.61	-107.22	-0.11	DConS2	11.126
C8	55	C1-480x480	Bottom	-5271.07	106.86	-0.09	DConS2	11.089
C9	63	C1-480x480	Top	-5239.09	-0.17	106.22	DConS2	11.022
C9	63	C1-480x480	Bottom	-5221.55	-0.20	-105.86	DConS2	10.985
C2	8	C1-480x480	Top	-5194.71	-0.05	105.32	DConS2	10.929
C2	8	C1-480x480	Bottom	-5177.17	-0.02	-104.96	DConS2	10.892
C3	16	C1-480x480	Top	-5264.29	-0.05	-106.73	DConS2	11.075
C3	16	C1-480x480	Bottom	-5246.76	-0.05	106.37	DConS2	11.038

C4	24	C1-480x480	Top	-5221.76	105.86	-0.20	DConS2	10.986
C4	24	C1-480x480	Bottom	-5204.22	-105.51	-0.18	DConS2	10.949
C5	32	C1-480x480	Top	-5237.88	-106.19	-0.20	DConS2	11.019
C5	32	C1-480x480	Bottom	-5220.34	105.84	-0.21	DConS2	10.983
C6	40	C1-480x480	Top	-5196.36	105.35	-0.12	DConS2	10.932
C6	40	C1-480x480	Bottom	-5178.82	-104.99	-0.11	DConS2	10.895
C7	48	C1-480x480	Top	-5245.84	-0.16	-106.35	DConS2	11.036
C7	48	C1-480x480	Bottom	-5228.30	-0.18	106.00	DConS2	10.999
C8	56	C1-480x480	Top	-5259.74	-106.63	-0.12	DConS2	11.065
C8	56	C1-480x480	Bottom	-5242.21	106.28	-0.09	DConS2	11.029
C9	64	C1-480x480	Top	-5210.17	-0.16	105.63	DConS2	10.961
C9	64	C1-480x480	Bottom	-5192.64	-0.19	-105.27	DConS2	10.924
C2	9	C1-480x480	Top	-5165.79	-0.03	103.32	DConS2	10.854
C2	9	C1-480x480	Bottom	-5151.05	-0.01	-103.02	DConS2	10.823
C3	17	C1-480x480	Top	-5235.38	-0.04	-104.71	DConS2	11
C3	17	C1-480x480	Bottom	-5220.64	-0.04	104.41	DConS2	10.969
C4	25	C1-480x480	Top	-5192.79	103.86	-0.20	DConS2	10.911
C4	25	C1-480x480	Bottom	-5178.05	-103.56	-0.18	DConS2	10.88
C5	33	C1-480x480	Top	-5209.03	-104.18	-0.20	DConS2	10.945
C5	33	C1-480x480	Bottom	-5194.29	103.89	-0.21	DConS2	10.914
C6	41	C1-480x480	Top	-5167.55	103.35	-0.13	DConS2	10.858
C6	41	C1-480x480	Bottom	-5152.80	-103.06	-0.11	DConS2	10.827
C7	49	C1-480x480	Top	-5216.99	-0.15	-104.34	DConS2	10.962
C7	49	C1-480x480	Bottom	-5202.24	-0.17	104.04	DConS2	10.931
C8	57	C1-480x480	Top	-5230.87	-104.62	-0.13	DConS2	10.991
C8	57	C1-480x480	Bottom	-5216.12	104.32	-0.10	DConS2	10.96
C9	65	C1-480x480	Top	-5181.27	-0.15	103.63	DConS2	10.886
C9	65	C1-480x480	Bottom	-5166.52	-0.18	-103.33	DConS2	10.856
C2	2	C1-480x480	Top	-5139.83	0.01	102.80	DConS2	10.799
C2	2	C1-480x480	Bottom	-5129.76	0.01	-102.60	DConS2	10.778
C3	10	C1-480x480	Top	-5209.42	-0.01	-104.19	DConS2	10.946
C3	10	C1-480x480	Bottom	-5199.35	-0.02	103.99	DConS2	10.925
C4	18	C1-480x480	Top	-5166.78	103.34	-0.19	DConS2	10.856
C4	18	C1-480x480	Bottom	-5156.71	-103.13	-0.18	DConS2	10.835
C5	26	C1-480x480	Top	-5183.13	-103.66	-0.21	DConS2	10.89
C5	26	C1-480x480	Bottom	-5173.07	103.46	-0.21	DConS2	10.869
C6	34	C1-480x480	Top	-5141.64	102.83	-0.15	DConS2	10.803
C6	34	C1-480x480	Bottom	-5131.57	-102.63	-0.14	DConS2	10.782
C7	42	C1-480x480	Top	-5191.06	-0.13	-103.82	DConS2	10.907
C7	42	C1-480x480	Bottom	-5180.99	-103.62	0.12	DConS2	10.886
C8	50	C1-480x480	Top	-5204.92	-104.10	-0.14	DConS2	10.936
C8	50	C1-480x480	Bottom	-5194.85	0.07	-103.90	DConS2	10.915
C9	58	C1-480x480	Top	-5155.30	-0.14	103.11	DConS2	10.832
C9	58	C1-480x480	Bottom	-5145.24	-0.15	-102.90	DConS2	10.811

#### D) CONCLUSION OF PUSHOVER ANALYSIS:

A structural analysis was conducted on the existing structure using E-TABS software, incorporating material properties such as reinforcement sizes, concrete grade, and other parameters obtained from non-destructive testing (NDT). The analysis, which applied current loads including dead load, live load, floor finish load and seismic load, reveals that; the structure is structurally stable for dead load, live load, floor load, but unstable for current seismic load condition. Hence, which required major revamping and retrofitting work to make it structurally sound. Additionally, the rest of the structure requires major repairs.

Details here with shown in the following table:

Sr. No.	Grid location	Actual Column size	Retrofitting column size	Retrofitting Bars
1.	B-4	480 X 480	630 X 630	12-16 $\phi$
2.	C-3	480 X 480	630 X 630	12-16 $\phi$
3.	C-5	480 X 480	630 X 630	12-16 $\phi$
4.	D-2	480 X 480	630 X 630	12-16 $\phi$
5.	D-6	480 X 480	630 X 630	12-16 $\phi$
6.	E-3	480 X 480	630 X 630	12-16 $\phi$
7.	E-5	480 X 480	630 X 630	12-16 $\phi$
8.	F-4	480 X 480	630 X 630	12-16 $\phi$

#### REFERENCES

Sr. No.	Title of Paper	Authors	Year	Topic	Key Focus / Findings
1	Strengthening and Repair of Reinforced Concrete Columns by Jacketing: State-of-the-Art Review	Saim Raza et al.	2019	RCC Jacketing	Comprehensive review of jacketing techniques; improves load capacity, ductility, and durability
2	Performance Evaluation of RC Columns Retrofitted with Steel Jacketing	Villar Salinas et al.	2021	RCC Jacketing	Steel jacketing significantly improves seismic performance and reduces drift
3	Structural Enhancement of RCC Beams using Prestressing & Jacketing	Kamerkar et al.	2023	RCC Jacketing	Combined techniques improve stiffness, crack control, and load capacity
4	Application of Non-Destructive Testing (NDT) Techniques on RCC Structure: A Review	Umap & Rao	2023	NDT Testing	NDT helps in assessing durability, corrosion, and residual life of RCC structures
5	Non-Destructive Testing and Evaluation of Structures (Review)	Bing Wang et al.	2020	NDT Testing	Discusses ultrasonic, thermography, X-ray methods and their advantages/limitations
6	Review Paper on Seismic Assessment and Analysis of RCC Structure for Retrofitting	Dande & Mohod	2024	Structural Audit	Emphasizes need for assessment before rehabilitation and importance of condition evaluation
7	Assessment of Seismic Retrofitting Interventions in RC Structures	—	2023	Structural Audit + Pushover	Uses analytical models to evaluate retrofitting efficiency
8	Seismic Vulnerability Assessment of Existing RC Building using Pushover Analysis	Shruthi et al.	2014	Pushover Analysis	Pushover analysis helps determine capacity curve and failure mechanism (IJERT)