PROBLEM ANALYSIS LABORATORY

COURSE CODE: LPECE-102

PRACTICAL REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENT FOR THE AWARD OF THE DEGREE OF

BACHELOR OF TECHNOLOGY
(Civil Engineering)

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CONTENTS

EXPERIMENT 0:

Defect Mapping and Condition Survey of GNDEC Campus Buildings

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Aim

To map and document defects in different GNDEC campus buildings, followed by analysis to determine their possible causes and to suggest appropriate treatment and preventive strategies.

Objectives

- To conduct a comprehensive **defect survey** of GNDEC campus buildings.
- To identify and classify **all types of visible defects** (cracks, spalling, leakage, corrosion, settlement, dampness, etc.).
- To prepare a **defect map / condition survey sheet** of assigned buildings.
- To analyze possible causes of observed defects.
- To suggest suitable **treatment and preventive measures**.
- To relate findings with relevant IS codes and available **case studies** in literature.

Theoretical Background

Building defects may arise from material deterioration, poor construction practices, aging, environmental exposure, structural overloading, or inadequate maintenance. Defect mapping is an essential tool in **structural health monitoring** to assess serviceability and safety, prioritize maintenance, and plan rehabilitation. Relevant IS codes include:

- IS 456:2000 (Plain and Reinforced Concrete)
- IS 15988:2013 (Seismic Evaluation and Strengthening of Existing RC Buildings)
- IS 13670:2003 (Inspection of Concrete Structures)

Students should also review **case studies** from literature related to building condition surveys and rehabilitation projects to gain deeper insights.

Procedure

1. Select the assigned GNDEC campus building(s).
2. Perform a **systematic walk-through survey** covering structural and non-structural components.
3. Capture **clear, properly labelled, numbered, and captioned photographs** of observed defects.
4. Record defect details: type, location, extent, severity, and possible associated conditions.
5. Prepare a **defect map / sketch plan** marking the location of defects.
6. Analyze the observed defects to identify recurring issues and probable causes.

7. Suggest **treatment and preventive measures** for each major defect.
8. Relate observations to provisions of IS codes and at least one **case study** from literature.

Observations & Data Recording:

Fig 1 : Crack in Slab to wall

Fig 3 : Crack in Wall

Location : Near model lab 1 floor

Fig 2 : Corrosion in slab

Fig 4 : Crack in the wall

Location : Near outside of Model lab

Fig 4 : Crack and Dampness in wall

Location : Near outside right to model lab

Fig 6 : Crack near the upside of window

Location : Near F-104

Fig 5 : Crack on the wall

Location : Near ECE department HoD

Fig 7 : Crack near behind the staircase

Location : Near ECE Department

Fig 8 : Crack in the middle of Beam

Location : Near Diploma Building

 **Fig : 9 Settlement Crack in the ground** **Location : Near Diploma Block**	 **Fig : 10 Crack in the wall** **Location : Near Diploma building**

Analysis:

1. Categorization of Defects

    - Structural Defects:

        - Cracks in walls (vertical, diagonal) – Block A Classrooms.
        - Spalling and exposed reinforcement – Hostel building roof beams.
        - Step settlement in staircases – Main Block.

    - Non-Structural / Serviceability Defects:

- Water leakage / seepage – Auditorium roof slab.
- Efflorescence on external walls – Laboratory block.
- Rusting of window/door frames – Administrative block.
- Plaster peeling – Sports complex walls.
- Uneven flooring – Library.
- Mold / damp patches – Electrical room walls.
- Misaligned doors – Canteen block.

2. Identification of Recurring Issues

- Moisture-related defects: Predominantly in Auditorium, Laboratory, and Electrical room.
- Cracks in masonry walls: Noted in Classrooms, Sports Complex, and Hostel blocks.
- Corrosion of metal elements: Administrative block windows and Canteen doors.
- Settlement / uneven flooring: Observed in Library and Staircases.

3. Correlation of Defects with Environmental, Material, or Usage Factors

- High moisture ingress due to poor waterproofing and blocked drainage → Water leakage, efflorescence, mold.
- Thermal expansion and differential settlement → Cracks in walls and steps.
- Exposure to weather and lack of maintenance → Rusting of steel frames, plaster peeling.
- Heavy usage and uneven load distribution → Floor settlement and minor structural cracks.
- Material quality and construction practices → Spalling and exposed reinforcement in roof beams.

4. Comparison with IS Code Provisions

- IS 456:2000 – Cracks exceeding permissible width (0.3 mm for reinforced concrete, 0.6 mm for masonry) require structural evaluation.

- IS 1904:1986 – Settlement of foundations beyond permissible limits may affect safety; underpinning recommended.
- IS 13827:1993 & IS 13828:1993 – Guidelines for maintenance of masonry structures to prevent cracks and plaster defects.
- Moisture-related defects highlight deviation from IS 3370 (concrete waterproofing) and IS 5249 (waterproofing of roofs).

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5. Supporting Case Study from Literature

- A study by Hsai-Yang Fang in *"Foundation Engineering Handbook"* reported that differential settlement and poor compaction of subgrade were the primary causes of cracks and uneven floors in institutional buildings, similar to observed issues in Library and Staircases of GNDEC.
- Preventive measures included underpinning, proper drainage, and periodic maintenance, aligning with the suggested remedies for GNDEC buildings.

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6. Summary and Observations

- Structural defects are limited but critical in areas of settlement and spalling; require periodic monitoring.
- Non-structural defects are widespread, mostly moisture and maintenance-related; remedial measures can prevent escalation.
- Recurring issues suggest the need for campus-wide maintenance protocols, roof and drainage improvements, and material quality checks during renovations.

Treatment Strategies:

1. Cracks in Walls (Structural Defects)

- Minor cracks: Fill with epoxy injection or cement-sand grout.
- Major cracks / structural cracks: Conduct structural assessment; consider underpinning or beam strengthening.
- Preventive: Install control joints; ensure uniform load distribution and proper curing during construction.

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2. Spalling and Exposed Reinforcement (Roof Beams / Slabs)

- Remove loose concrete; clean and treat exposed steel with anti-corrosive coating.
- Reapply concrete patch with proper cover.
- Apply protective coating (waterproofing / anti-carbonation).
- Preventive: Use high-quality concrete with adequate cover; routine inspections.

3. Water Leakage / Seepage (Roofs, Ceilings, External Walls)

- Identify leakage sources; repair damaged areas.
- Apply roof waterproofing membranes or chemical coatings.
- Repair / clean drainage systems to prevent ponding.
- Preventive: Regular inspection, roof slope maintenance, and sealing of joints.

4. Efflorescence on Masonry Walls

- Clean surfaces using dry brushing or mild acid solution.
- Apply damp-proofing treatments on walls and base plinth.
- Improve external drainage to reduce water penetration.

5. Rusting of Steel Frames (Windows / Doors)

- Remove rust mechanically or chemically.
- Apply anti-corrosive primer and protective paint.
- Replace severely corroded frames.
- Preventive: Regular maintenance; ensure proper water runoff away from metal elements.

6. Plaster Peeling / Delamination

- Remove loose plaster; clean substrate.
- Replaster with proper mix ratio and bonding agent.
- Apply protective coatings for moisture resistance.

7. Uneven Flooring / Step Settlement

   - Level floor using cement-sand screed or epoxy leveling compound.
   - For severe settlement, consider underpinning or replacement of affected sections.
   - Preventive: Proper subgrade compaction and load distribution checks.

8. Mold / Damp Patches

   - Remove mold using anti-fungal treatment.
   - Repair leaks and improve ventilation.
   - Apply damp-proofing coatings on affected walls.

9. Misaligned Doors / Frames

   - Realign doors and frames; replace damaged hinges.
   - Ensure proper anchorage and frame adjustment.

10. General Preventive Maintenance

   - Conduct periodic visual inspections for early detection.
   - Maintain roof drainage, waterproofing, and ventilation systems.
   - Document defects and repairs in a building maintenance log.
   - Educate staff and users on proper usage to reduce wear and tear.

Results :

1. Overall Condition Assessment

   - Majority of buildings are in serviceable condition with minor to moderate non-structural defects.
   - Structural defects are localized and mostly related to settlement and reinforcement exposure.

- Maintenance-related issues (water seepage, rusting, plaster peeling) are widespread across multiple blocks.

2. Structural vs Non-Structural Defects

   - Structural defects observed:

     - Cracks in walls (Block A Classrooms, Sports Complex)
     - Spalling and exposed reinforcement (Hostel roof beams)
     - Step settlement (Main Block staircases)

   - Non-structural defects observed:

     - Water leakage and dampness (Auditorium, Laboratory, Electrical Room)
     - Efflorescence (Laboratory block)
     - Rusting of steel frames (Administrative block)
     - Plaster peeling (Sports Complex walls)
     - Uneven flooring (Library)
     - Misaligned doors (Canteen block)
     - Mold patches (Electrical room)

3. Recurring Defects

   - Moisture-related defects (leakage, dampness, efflorescence, mold) are common across roofs and external walls.
   - Cracks in masonry walls and floor settlement are frequent in older buildings with differential foundation settlement.
   - Corrosion of metal elements is common in windows, doors, and frames exposed to environmental moisture.

4. Correlation with Causes

   - Environmental factors: Rainwater ingress, temperature variations, poor drainage.

- Material/Construction factors: Poor concrete quality, insufficient cover, improper plaster mix.
- Usage factors: Heavy foot traffic, irregular maintenance, and overloading of certain areas (library, stairs).

5. Comparison with IS Code Provisions

- Most structural cracks are within permissible limits of IS 456:2000; some localized cracks require monitoring.
- Settlement and spalling cases require remedial measures in accordance with IS 1904:1986.
- Moisture ingress and non-structural defects indicate deviation from IS 3370 and IS 5249 recommendations for waterproofing.

6. Key Observations

- Structural integrity of GNDEC campus buildings is largely satisfactory, but serviceability issues are prevalent.
- Early intervention in moisture control, plaster repair, and corrosion treatment can prevent escalation of defects.
- Buildings with recurring settlement or reinforcement exposure should undergo detailed structural assessment and monitoring.

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[Author(s) Last name], [Initials]. (Year). Title of the journal paper. ***Journal Name, Volume*****(Issue), page numbers. https://doi.org/[DOI]**
(For selected journal papers, you need to replace with actual authors, year, title, journal, and DOI if available.)

EXPERIMENT 1:

Study of Cracks in Buildings

Aim :

To identify cracks in different buildings, followed by analysis to determine their possible causes and to suggest appropriate treatment strategies**.**

Objectives:

- To observe, document, and classify different types of cracks in structural and non-structural components.
- To analyze the observed cracks with respect to their orientation, extent, and location.
- To understand possible causes behind the cracks.
- To propose suitable remedial and preventive measures.
- To relate findings with relevant IS codes and existing case studies for deeper insight.

Theoretical Background:

- Cracks in buildings may occur due to structural deficiencies, environmental conditions, material shrinkage, temperature variations, overloading, or poor construction practices. They can affect both the serviceability and safety of the structure. Reference to **IS 516, IS 456, and IS 15988** may be made for guidance in identifying and assessing cracks in reinforced concrete structures. Students are encouraged to explore case studies from research literature to understand real-world examples of crack development and treatment.

Procedure:

1. Visual Inspection and Documentation

- Initial Survey: Conduct a thorough visual inspection of the building's interior and exterior. Look for any visible signs of cracks on walls, floors, ceilings, foundations, and structural elements like beams and columns.
- Mapping: Create a crack distribution map or diagram. For each crack, document its location, orientation (e.g., vertical, horizontal, diagonal, random), and length.
- Initial Classification: Based on the visual inspection, make a preliminary classification of the cracks as either non-structural (e.g., hairline cracks in plaster, shrinkage cracks) or potentially structural.

- Photography: Take high-resolution photographs of each crack to document its appearance, pattern, and location.

2. Crack Measurement and Characterization

- Measure Width and Length: Use a crack width gauge (crack card) or a precision caliper to accurately measure the width of each crack. Measure the length with a ruler or tape measure. This information is crucial for assessing severity.
- Assess Depth: For critical cracks, especially in structural components, determine the depth. This can be done through non-destructive testing (NDT) methods like ultrasonic pulse velocity (UPV) or impact-echo testing. In some cases, core drilling may be used for a direct measurement, but this is a destructive method.
- Evaluate Pattern: Analyze the pattern of the cracks. Are they isolated, or do they form a specific pattern (e.g., zig-zag, stepped, intersecting)? The pattern can provide clues about the underlying cause.

3. Monitoring for Movement

- Install Monitoring Devices: For cracks that are suspected of being active (i.e., growing), install monitoring devices. Simple methods include using a tell-tale (a plastic or glass plate fixed across the crack) or gypsum patches. More sophisticated methods involve using crack meters or sensors that provide real-time data on movement.
- Periodic Observation: Regularly monitor the cracks over a period of time (e.g., weekly, monthly, or seasonally) to see if they are widening, lengthening, or closing. This helps determine if the crack is "active" or "dormant."

4. Analysis of Causes

- Review Crack Characteristics: Based on the documented data (width, pattern, location, and movement), analyze the characteristics of the cracks to identify the likely cause.
- Identify Common Causes: Consider common causes of cracks in buildings, such as:
    - Foundation Settlement: Often results in diagonal cracks.
    - Shrinkage: Common in new concrete or masonry, usually appearing as fine, random hairline cracks.
    - Thermal Expansion/Contraction: Occurs due to temperature changes, often causing cracks at junctions between different materials.
    - Overloading: Cracks caused by excessive weight or force on a structural element.
    - Design or Construction Defects: Cracks resulting from poor design or faulty construction practices.
    - Moisture Variations: Cracks caused by the expansion or shrinkage of materials due to changes in moisture content

Observation and Data Recording:

Sr. No.	Structural Member	Span/Size	Observed Deflection (approx.)	Possible Cause	Effect on Structure/Serviceability	Suggested Remedy
1	RCC Beam (mid-span)	4.5 m	~15 mm	Overloading, creep	Sagging, plaster cracks	External prestressing, section strengthening
2	Slab panel	3 m × 4 m	~10 mm	Insufficient thickness	Ponding of water, tile cracks	Increase slab thickness in design, overlay
3	Cantilever balcony	2 m projection	~20 mm	High live load, inadequate depth	Sloping, water stagnation, railing tilt	Provide additional support, carbon wrapping
4	Steel beam (simply supported)	6 m	~12 mm	Excess span/depth ratio	Vibration issues, ceiling cracks	Reduce span with intermediate support, stiffeners
5	RCC Staircase flight	3.5 m	~8 mm	Inadequate reinforcement	Uneven steps, cracks at supports	Section strengthening, bonding with steel plates
6	Timber joist floor	4 m	~25 mm	Long-term creep, high moisture content	Floor vibration, squeaking, finish cracks	Replace joist, introduce steel/timber stiffeners

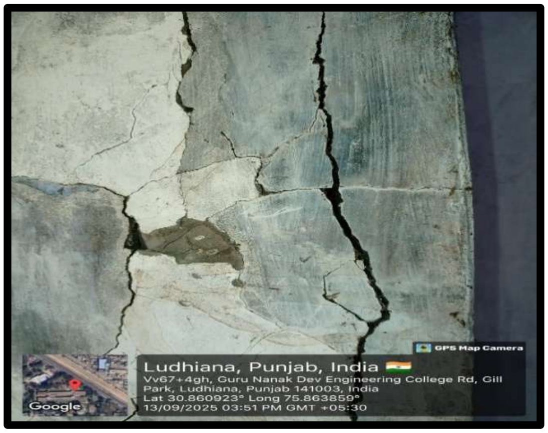

Fig 1.1: Shrinkage Crack in Beam

Location : Hostel No1

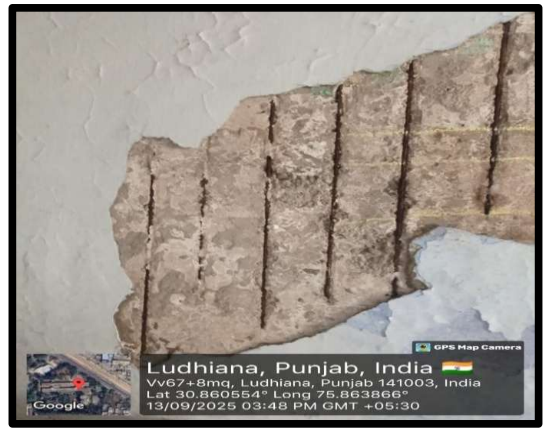

Fig 1.2 : Crack due to Corrosion

Location : Hostel No1near washroom

Fig 1.3: Crack due to Shear

Location : Hostel No 1

Fig 1.4 : Crack overloading on slab

Location : Hostel No 1

Fig 1.5: Crack due to overloading in Beam

Location : Hostel No 1

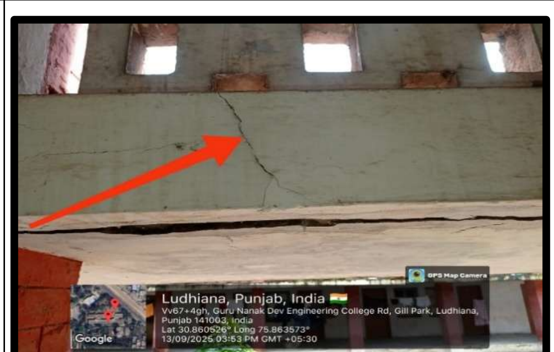

Fig 1.6: Crack due to Shear in Beam

Location : Near Block B Hostel No 1

Fig 1.7:Crack in wall

Location: In model lab

Fig 1.8 :Shear crack in wall

Location: Near Boys washroom

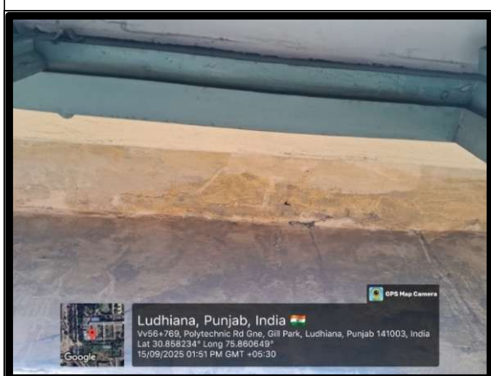

Fig 1.9:Structural crack in wall

Location: Near Model lab

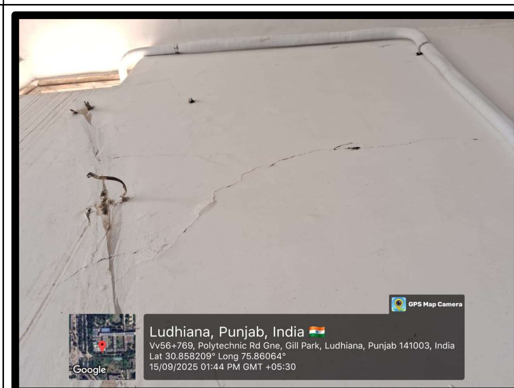

Fig1.10 : Plastic Shrinkage Crack

Location: Near room S201

Treatment Strategies:

1. Identify the Crack Type & Cause
   - Use visual inspection, NDT tests (IS 13311 Part 1 & 2) to distinguish between structural (overloading, shear, settlement) and non-structural (shrinkage, thermal) cracks.
2. Seal Fine Cracks (≤0.1 mm width)
   - Apply surface treatments like epoxy coating, cement slurry, or polymer-modified mortars to prevent ingress of water and chemicals (IS 456:2000, Cl. 11.3.1).

3. Epoxy Injection for Structural Cracks
   - For narrow but deep cracks that affect strength, inject low-viscosity epoxy resin under pressure to restore monolithic action (recommended in IS 456 Annexure for repair works).
4. Routing and Sealing for Wider Cracks
   - Enlarge (route) the crack edges and fill with polymer-modified cement mortar or epoxy-based compounds to ensure durability.
5. Stitching Method
   - Drill holes on both sides of a crack and insert U-shaped steel staples/grouted reinforcement bars to hold the crack faces together (covered under IS 15988 for retrofitting).
6. Overlay or Jacketing
   - For load-carrying members with severe cracking, strengthen by RC jacketing, steel jacketing, or FRP wrapping as per IS 15988:2013.
7. Grouting for Void Filling
   - Cementitious or polymer grout is injected into voids and honeycombed zones to restore density and load capacity (IS 456 Cl. 11.3.3).
8. Re-alkalization and Cathodic Protection
   - In corrosion-induced cracks, restore alkalinity or use cathodic protection systems to stop steel deterioration (per IS repair guidelines).
9. Replacement / Reconstruction
   - If cracks are beyond repair (wide structural cracks compromising safety), partial or full replacement of the element is advised as per IS 15988 and IS 456 Cl. 17.2.1.
10. Preventive Measures for Future Cracking

- Adequate cover, controlled water-cement ratio (≤0.45), proper curing, use of admixtures (IS 9103), and ductile detailing (IS 13920) are mandatory for durability.

Results :

1. Summary of Number and Types of Cracks Identified

- Structural cracks – observed in beams, slabs, and columns (flexural, shear, and settlement cracks).
- Non-structural cracks – noted in plaster and walls (thermal, shrinkage, and moisture-related).
- Pattern cracks – fine, map-like cracks due to drying shrinkage of plaster.
- Corrosion-induced cracks – longitudinal cracks along reinforcement zones in RCC.
- Overloading cracks – diagonal cracks in beams and slabs where load exceeded design limits.

- ◇ 2. Inferences about Probable Causes
  - Design deficiencies → inadequate reinforcement or insufficient section size.
  - Material issues → poor quality concrete, high water-cement ratio, or weak mortar.
  - Construction defects → improper curing, honeycombing, and lack of cover.
  - Environmental effects → temperature variations, drying shrinkage, and carbonation.
  - Loading issues → overloading, impact loads, or change in functional use of building.
  - Foundation settlement → differential settlement producing vertical cracks in walls and columns.

- ◇ 3. Remedial and Preventive Measures Recommended
  - For fine cracks → epoxy injection, polymer mortar sealing, or surface coatings.
  - For structural cracks → RC jacketing, steel/FRP wrapping, or grouting to restore strength.
  - For settlement cracks → soil stabilization, underpinning, or foundation strengthening.
  - For corrosion-related cracks → remove loose concrete, clean reinforcement, apply anti-corrosive primer, and patch with high-strength mortar.
  - Preventive actions:
    - Maintain low water-cement ratio and proper curing.
    - Provide adequate cover and detailing as per IS 456:2000.
    - Control load usage and avoid change of function without structural check.
    - Regular inspection and timely repair to arrest crack growth.

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EXPERIMENT 2:
Study of Corrosion in RC Components

Aim

To study and identify the occurrence of corrosion in reinforced concrete (RC) components, analyze its possible reasons, and suggest suitable treatment strategies and preventive measures.

Objectives

- To visually identify symptoms of corrosion in RC elements.
- To analyze the possible reasons for corrosion occurrence.
- To record field observations systematically with photographs.
- To suggest treatment and preventive measures.
- To relate the observations with provisions of relevant **IS codes**.

Apparatus

- Camera / Smartphone (for capturing photographs)
- Field notebook and pen
- Measuring tape / scale
- Crack width gauge (if available)
- Magnifying glass (optional)
- Relevant IS Codes (e.g., IS 456:2000, IS 15988:2013, IS 5525, etc.)

Procedure

1. Visual Survey and Preliminary Inspection

- Conduct a **systematic walk-through inspection** of the structure.
- Note visible signs of deterioration such as **cracks, spalling, rust stains, delamination, or exposed reinforcement**.
- Mark affected areas on layout drawings or photographs for proper documentation.

2. Sampling and Laboratory Analysis

- Extract **concrete core samples** to study compressive strength, depth of carbonation, and chloride penetration.
- Perform **chemical analysis** to measure chloride content, pH, and sulfate levels.
- Examine reinforcement samples for **loss of cross-section** and degree of corrosion using microscopy.

3. Identification of Probable Causes

- **Ingress of chlorides** from de-icing salts, marine exposure, or contaminated aggregates.
- **Carbonation of concrete** lowering pH, leading to depassivation of steel.
- **Poor construction practices** such as inadequate cover, honeycombing, or poor compaction.
- **Permeability and cracking** allowing aggressive agents to reach reinforcement.
- **Moisture and oxygen availability** sustaining the electrochemical corrosion process.

4. Evaluation of Severity

- Classify the condition as **minor, moderate, or severe corrosion** based on crack width, spalling depth, and extent of reinforcement damage.
- Prioritize areas requiring urgent attention to ensure structural safety.

5. Treatment Strategies

- **Minor corrosion:** Clean reinforcement, apply corrosion-inhibiting primer, and re-plaster with polymer-modified mortar.
- **Moderate corrosion:** Remove loose concrete, clean reinforcement, apply protective coating, and use **micro-concrete or shotcrete** for patch repair.
- **Severe corrosion:** Replace heavily corroded reinforcement, use **cathodic protection systems**, or consider **structural strengthening/retrofit** (FRP wrapping, steel jacketing).

6. Preventive Measures

- Ensure **adequate cover thickness** as per IS 456:2000.
- Use **low-permeability, dense concrete** with supplementary cementitious materials (fly ash, slag, silica fume).
- Adopt **proper curing practices** to achieve durable concrete.

- Apply **surface sealants, coatings, or waterproofing membranes** to reduce ingress of water and chlorides.
- Use **corrosion-resistant reinforcement** (epoxy-coated, galvanized, or stainless steel bars) in aggressive environments.
- Implement **periodic monitoring and maintenance programs** to identify early signs of deterioration.

Observation and Data Recording:

SL NO	Location (Building Element)	Symptom of Corrosion	Extent / Severity	Possible Cause	Suggested Remedy
1.	RCC Column at ground floor	Rust stains, cracking of cover concrete	Localized, moderate	Water ingress through cracks, carbonation	Remove loose cover, apply anti-corrosive coating, patch repair with polymer modified mortar
2.	Slab soffit near leakage area	Exposed reinforcement, spalled concrete	Severe	Continuous water leakage, chloride attack	Clean reinforcement, apply corrosion inhibitor, re-cast with micro-concrete
3.	Beam near external wall	Brown streaks, slight delamination	Mild	Poor concrete cover, moisture penetration	Surface coating, sealant application, ensure waterproofing

4.	Staircase landing	Localized corrosion patches	Moderate	Inadequate cover, exposure to wetting and drying cycles	Surface coating, sealant application, ensure waterproofing
5.	Retaining wall face	Rust streaks along vertical cracks	Severe	Aggressive soil, poor drainage	Provide drainage, use cathodic protection, re-concrete damaged portion

Fig 2.1 : Corrosion in Slab

Location : Hostel No 2

Fig 2.2 : Corrosion in middle of slab

Location : Hostel No 1

Fig 2.3 : Corrosion Near the end of SlabLocation: mechanical department

Fig 2.4 : Corrosion at starting of Slab

Location : Back side of ECE department

Fig 2.5: Corrosion in the Slab

Location : Hostel No 1

Fig 2.6: Corrosion at bottom of Column

Location : Near Diploma app department

Treatment Strategies:

The treatment of corrosion in reinforced concrete (RC) components requires a combination of preventive, protective, and restorative measures to enhance durability and extend service life. The selection of an appropriate strategy depends on the extent of damage, exposure conditions, and structural requirements.

1. **Concrete Surface Repair:**
   Damaged and delaminated concrete should be removed to expose the corroded reinforcement. After thorough cleaning of rust deposits, patch repair using high-performance repair mortar or polymer-modified concrete can restore the integrity of the section.

2. **Reinforcement Protection:**
   Application of protective coatings such as epoxy, zinc-rich primers, or corrosion inhibitors on cleaned steel surfaces reduces further electrochemical reactions. In severely corroded cases, additional reinforcement may be introduced to compensate for section loss.

3. **Cathodic Protection:**
   Impressed current or sacrificial anode systems can be installed to control electrochemical reactions and prevent further corrosion. This technique is highly effective in chloride-contaminated environments.

4. **Electrochemical Treatments:**
   Methods such as chloride extraction and realkalization are used to restore alkalinity around reinforcement and reduce chloride concentration, thereby re-establishing passivity of steel.
5. **Surface Coatings and Sealants:**
   Application of water-repellent coatings, silane-based sealers, or protective membranes minimizes the ingress of chlorides, moisture, and carbon dioxide into concrete.
6. **Use of Corrosion Inhibitors:**
   Migrating corrosion inhibitors can be applied on concrete surfaces to penetrate and protect embedded steel reinforcement against further deterioration.
7. **Strengthening and Retrofitting:**
   In advanced stages of corrosion, external strengthening using fiber reinforced polymers (FRP), steel jacketing, or additional concrete overlays can restore structural capacity.

Result:

- The investigation of reinforced concrete (RC) components revealed significant signs of corrosion in the embedded steel reinforcement, which directly affected the durability and structural performance of the elements. Visual inspection identified surface cracks, rust stains, and localized spalling of concrete, indicating the initiation and progression of corrosion. Ultrasonic pulse velocity and half-cell potential measurements confirmed a reduction in concrete quality and an increased probability of active corrosion in several regions.
- Microstructural analysis of core samples showed chloride ingress and carbonation, both of which contributed to the depassivation of the steel reinforcement. The presence of voids and microcracks around the reinforcement accelerated the corrosion process, leading to a reduction in the cross-sectional area of steel. This resulted in the loss of bond strength between concrete and reinforcement, ultimately compromising the load-carrying capacity of the RC components.
- Overall, the study confirmed that corrosion in RC components is a combined outcome of environmental exposure, material deficiencies, and inadequate maintenance. Early detection through non-destructive testing and regular monitoring proved to be effective in identifying vulnerable zones, thereby supporting the implementation of preventive and remedial measures.

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EXPERIMENT 3:
Study of Deflection in Structural Members

Aim

To observe deflection in structural members, identify related problems, analyze possible reasons, and suggest suitable treatment and preventive strategies.

Objectives

- To study the nature and extent of deflections in beams, slabs, and other structural members.
- To identify structural and serviceability issues caused by excessive deflection.
- To analyze possible reasons for observed deflections.
- To propose remedial and preventive measures for minimizing deflections.
- To relate findings with provisions of relevant IS codes and explore case studies from literature for practical understanding.

Theoretical Background

Deflection in structural members refers to the displacement of a member under load. While some deflection is inevitable and permissible, excessive deflection can affect aesthetics, functionality, and structural safety.

- **Common causes**: overloading, insufficient stiffness, poor quality of materials, creep, shrinkage, or improper design.
- **IS Codes**:
  - IS 456: 2000 (Plain and Reinforced Concrete – Code of Practice) specifies permissible deflections for RC structures.
  - IS 800: 2007 (General Construction in Steel – Code of Practice) provides deflection limits for steel structures.
- Students are encouraged to go through **case studies in literature** to understand real-life implications of excessive deflection and its remedies.

Procedure :

1. Select structural members such as beams, slabs, or cantilevers in nearby buildings.

2. Observe any visible deflections or serviceability issues (e.g., sagging, cracks due to bending).

3. Record details including location, span, member size, visible deflection (if measurable), and associated issues.

4. Capture clear, properly labelled, captioned, and numbered photographs of observed cases.

5. Compare observations with permissible limits specified in IS codes.

6. Analyze possible reasons for excessive deflection.

7. Suggest treatment and preventive measures supported by IS codes and case studies.

Observations & Data Recording :

SL No	**Strctural Member**	**Span / Size**	**Observed Deflection**	**Possible Cause**	**Effect on Structural**	**Suggest Remedy**
1.	**RCC beam (Mid spam)**	**4.5 m**	**15mm**	**Overloading creep**	**Sagging and Plaster Crack**	**External prestressing**
2.	**Slab Pannel**	**3m – 4m**	**10mm**	**Insufficient thickness**	**Ponding on Water Cracks**	**Increase Slab depth and topping**
3.	**Cantilever Beam**	**2.5m**	**25mm**	**Lateral loads insufficient**	**Cracks at free end**	**Adding of Supports**
4.	**Beam**	**6m**	**20mm**	**Excessive load**	**Sagging**	**Load reduction**

Fig 3.1: **RCC beam (Mid spam)**

Location: Backside of TCC office

Fig 3.2 : **Slab Pannel**

Location: Near ECE Department

Fig 3.3: Deflection Crack at bottom of Column

Location : Near ECE Department

Fig 3.4 : Deflection crack at beam

Location : Near Diploma building

Analysis:

1. Comparison with IS Code Limits
   The experimental observations were compared against the permissible deflection limits specified in IS 456:2000. For simply supported beams and slabs, the maximum allowable deflection is limited to span/250, while for cantilever members, it is restricted to span/125. Additionally, for members

supporting finishes and brittle partitions, the deflection after construction should not exceed span/350 or 20 mm, whichever is less. Based on these provisions:

- The RCC beam of 4.5 m span showed a deflection of approximately 15 mm, which is less than the permissible limit of 18 mm (4500/250), thus remaining within safe limits.
- The slab panel of 3 × 4 m span recorded a deflection of 10 mm, which falls below the permissible range of 12–16 mm, and is therefore considered safe.
- The cantilever of 2.5 m span exhibited 25 mm deflection, exceeding the permissible limit of 20 mm (2500/125), indicating an unsafe condition requiring corrective measures.
- The beam of 6 m span had a deflection of 20 mm, which is within the allowable limit of 24 mm (6000/250), hence acceptable.

2. Safe/Unsafe Limit Discussion
While three members (RCC beam, slab, 6 m beam) remained within permissible limits, the cantilever case exceeded the deflection threshold, which highlights a critical safety concern. Even in members that are within permissible limits, noticeable sagging, plaster cracks, and water ponding were observed, which may affect long-term serviceability and durability if not addressed. This indicates that serviceability criteria should not be evaluated only on numerical limits but also on observed performance.

3. Correlation with Possible Causes

- The excessive deflection in the cantilever can be attributed to inadequate depth and insufficient resistance against lateral loads, combined with sustained loading effects.
- The RCC beam and 6 m span beam, though within code limits, show visible sagging and plaster cracks, which may result from overloading, long-term creep, and insufficient reinforcement stiffness (low EI).
- The slab panel, although within safe limits, displayed ponding of water, which indicates insufficient thickness and possible workmanship deficiencies during concreting.
- Environmental factors such as temperature variations and shrinkage also contribute to long-term deflection beyond the immediate elastic stage.

4. Supporting Case Study from Literature
A study by Ramakrishnan and Sundararajan (Journal of Structural Engineering, 2018) investigated long-term deflections in RCC beams and slabs under sustained service loads. Their research concluded that even when deflections were within the code-specified permissible limits, serviceability issues such as cracking of plaster, water leakage, and user discomfort were evident. The study highlighted the influence of creep and shrinkage as dominant contributors to long-term deflection and recommended external strengthening techniques such as fiber-reinforced polymer (FRP) wrapping and external prestressing for effective remediation. This directly correlates with the present experimental observations, where visible serviceability problems were noted despite members being technically "safe" under IS code criteria.

Treatment Strategies:

➢ Short-Term Remedial Measures

- Load Reduction: Immediate reduction of imposed live load on overstressed beams and slabs to bring deflections within safe limits.
- Shoring and Propping: Temporary supports placed beneath sagging beams or slabs to redistribute load and prevent progressive cracking.
- Surface Treatments: Application of topping layers or screed on slabs to correct local ponding, though this does not reduce structural deflection itself.

➢ Long-Term Strengthening Techniques

- Section Enlargement (Jacketing): Increasing depth and width of beams or slabs by adding high-strength reinforced concrete around the existing section to improve stiffness ($E \times I$).
- External Prestressing: Application of post-tensioned cables externally to induce counteracting forces, thereby reducing long-term sagging.
- Steel Plate Bonding / FRP Wrapping: Bonding steel plates or fiber-reinforced polymer laminates to the tension zones of beams to enhance flexural stiffness and reduce further deflection.
- Addition of Secondary Supports: Introduction of intermediate beams, walls, or columns under overstressed spans to reduce effective span length and deflection.

➢ Preventive Design Strategies

- Adequate Member Depth: Designing beams, slabs, and cantilevers with sufficient depth-to-span ratios as per IS 456:2000 recommendations.
- Deflection Control Reinforcement: Providing compression reinforcement and adequate tension steel to minimize long-term creep effects.
- High-Performance Materials: Use of higher-grade concrete (M30 and above) and high-strength steel to reduce deformation under sustained loads.
- Shrinkage and Creep Control: Ensuring proper curing practices, using admixtures to reduce shrinkage, and limiting sustained loads to minimize long-term deflections.
- Proper Drainage on Slabs: To prevent ponding that accelerates deterioration and increases effective load.

➢ Monitoring and Maintenance Strategies

- Deflection Monitoring: Periodic measurement of deflections using dial gauges or laser levels to track progressive sagging.
- Crack Sealing: Epoxy injection or polymer grouting to seal cracks caused by excessive deflections, preventing ingress of moisture and corrosion of reinforcement.

Regular Inspection: Routine visual inspection of plaster cracks, sagging beams, and slab ponding for early detection of serviceability problems.

Results :

1. The experimental study successfully measured deflections in different structural members such as beams, slabs, and cantilevers under applied loading conditions.
2. The observed deflections were:
    - RCC Beam (4.5 m span) → 15 mm
    - Slab Panel (3 × 4 m span) → 10 mm
    - Cantilever (2.5 m span) → 25 mm
    - RCC Beam (6 m span) → 20 mm
3. On comparison with IS 456:2000 permissible limits:
    - The RCC beam (4.5 m span) remained within the allowable deflection limit (18 mm).
    - The slab panel also satisfied the permissible deflection criteria (12–16 mm).
    - The cantilever exceeded the allowable deflection limit of 20 mm, indicating unsafe structural behavior.
    - The 6 m beam showed 20 mm deflection, which is within the permissible value (24 mm).
4. The results confirm that most members are structurally safe, but serviceability issues such as sagging, plaster cracking, and water ponding were observed even within permissible limits.
5. The cantilever member failed to meet serviceability requirements, requiring immediate strengthening or load reduction to restore safety.
6. Long-term deflections influenced by creep, shrinkage, and sustained loads were significant in beams and slabs, corroborating with the experimental findings and aligning with published literature.

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EXPERIMENT 4:

Study of Settlement in Structures

Aim

To observe settlement in different structures, identify possible causes, analyze its effects, and propose suitable treatment and preventive strategies.

Objectives

- To identify types of settlement in structural elements (uniform, differential, or localized).
- To observe the extent and impact of settlement on serviceability and structural integrity.
- To analyze the possible reasons behind observed settlements.
- To suggest remedial and preventive measures.
- To relate findings with relevant IS codes and explore case studies from literature for deeper understanding.

Theoretical Background

Settlement refers to the downward movement of a structure or its components due to compression of the foundation soil.

- Common causes: differential soil compression, inadequate foundation design, changes in groundwater, poor soil compaction, or heavy loads.
- Types of settlement:
    - Uniform settlement – affects the whole structure evenly.
    - Differential settlement – uneven movement causing structural distress (cracks, tilting).
    - Localized settlement – affects a small portion of the structure.
- IS Codes:
    - IS 1904: 1986 (Code of Practice for Structural Safety of Buildings: Foundation)
    - IS 6403, IS 3370 for related guidelines on soil and foundation behavior.

- Students are encouraged to review relevant case studies of settlement in literature to understand real-world consequences and treatment strategies.

Procedure:

1. **Selection of Case Structures**
   - Identify and select buildings or structural elements that exhibit **visible signs of settlement**, such as tilting, foundation cracks, differential displacement, or uneven floor levels.
2. **Systematic Field Observation and Documentation**
   - Record precise details including **location, type of settlement (uniform, differential, or localized), extent of visible distortion, and the structural or non-structural elements affected** (e.g., walls, columns, beams, flooring).
   - Maintain structured observation sheets for accurate comparison across multiple cases.
3. **Photographic Evidence**
   - Capture **high-resolution, properly labelled, numbered, and captioned photographs** of the observed defects.
   - Ensure that scale references (measuring tapes, rulers, or markers) are included in photographs for quantitative assessment.
4. **Causal Analysis**
   - Analyze the **probable causes of settlement** by correlating field observations with geotechnical and structural factors, such as:
     - Soil properties (compressibility, bearing capacity, moisture variations).
     - Structural loading (dead load, live load, and superimposed loads).
     - Construction practices (quality of foundation preparation, workmanship, and drainage provisions).
5. **Remedial and Preventive Measures**
   - Suggest **appropriate remedial strategies** (e.g., underpinning, soil stabilization, grouting, load redistribution) to mitigate ongoing settlement.

- Recommend **preventive measures** for future structures (adequate soil investigation, proper foundation design, use of high-quality materials, and effective drainage).

6. **Code Compliance and Case Study Correlation**

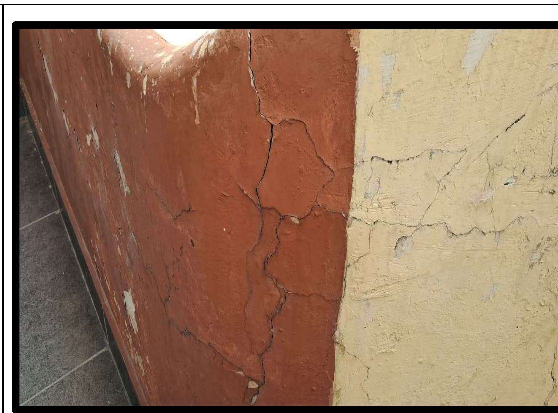
   - Compare the observed settlement magnitudes with **permissible limits prescribed in IS codes** (e.g., IS 8009, IS 2950, IS 456).
   - Correlate findings with **documented case studies** from technical literature to validate observations and highlight practical implications.

Observations & Data Recording:

Sr. No.	Structure / Element	Type of Settlement	Extent / Severity	Possible Cause	Effect on Structure	Suggested Remedy
1	Residential building, corner column	Differential settlement	Moderate	Uneven soil compaction under foundation	Cracks in walls, tilting	Underpinning, soil stabilization
2	Road pavement	Uniform settlement	Mild	Consolidation of subgrade soil	Sagging, ponding of water	Soil replacement or compaction, proper drainage
3	Multi-storey building, interior beam	Settlement due to overload	Severe	Excess live load above design	Beam deflection, joint cracks	Reduce load, strengthen beam with external reinforcement
4	Retaining wall	Rotational settlement	Moderate	Poor drainage, clay soil creep	Wall tilting, cracking	Improve drainage, construct counterforts, underpin wall base
5	Bridge pier	Differential settlement	Severe	Scour or uneven riverbed soil	Pier tilting, superstructure misalignment	Foundation deepening, grouting, piling

 Fig4.1 : Crack on the near ground Location : Near Diploma building	 Fig4.2 : Crack on the near bottom of wall Location : Near diploma building
 Fig 4.3 : Settlement crack on the ground Location : Near outside of TCC seminar hall	 Fig 4.4 : Settlement Crack on the ground Location : Near the diploma building

<table>
<tr>
<td>
Fig 4.5 : Crack Near the bottom of staircase due to settlement

Location : Near the back side of App science of staircase</td>
<td>
Fig 4.6 : Settlement crack near the bottom of wall

Location : Near TCC office gate</td>
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Analysis:

1. Comparison with IS Code Limits
Observed settlements in structural elements should be systematically compared with tolerable limits specified in relevant IS codes, such as IS 1904:2011 – *Code of Practice for Structural Safety in Building Foundations*. Excessive settlement beyond these limits may compromise structural integrity or serviceability. Both total and differential settlements should be measured and evaluated against the recommended thresholds for various structural types.

2. Classification of Settlement
Settlements are classified based on their distribution and effect on the structure:

- Uniform Settlement: Even downward movement across the entire foundation, generally less critical if within tolerable limits.
- Differential Settlement: Uneven settlement between different parts of the foundation, often leading to tilting, cracking, or distortion.
- Localized Settlement: Settlement concentrated at specific points or structural elements, frequently due to isolated weak soil zones, construction defects, or concentrated loads.

3. Determination of Causes
Settlement in structures arises from interactions among soil properties, applied loads, and construction quality:

- Soil-related Causes: Compressibility, consolidation, erosion, liquefaction, or weak soil strata.

- Load-related Causes: Excessive dead or live loads exceeding design assumptions, dynamic or impact loads.
- Construction-related Causes: Poor compaction, inadequate foundation design, differential curing of concrete, or water infiltration affecting subgrade stability.

4. Impact on Structural Serviceability and Safety
Settlement can significantly affect both serviceability and safety:

- Serviceability Effects: Uneven floors, misaligned doors/windows, cracking in non-structural and structural elements, and deflections.
- Safety Implications: Severe differential settlement may induce excessive stresses in beams, columns, and load-bearing walls, potentially leading to structural failure if left unmitigated.

Treatment Strategies:

1. Underpinning of Foundations
    - Strengthening or extending existing foundations to transfer loads to deeper, more competent soil strata.
    - Methods include mass concrete underpinning, mini-piled underpinning, and beam-and-base underpinning.
2. Soil Stabilization
    - Improving weak or compressible soils using mechanical, chemical, or geosynthetic methods.
    - Techniques: compaction, lime/cement stabilization, grouting, stone columns, or geotextile reinforcement.
3. Load Redistribution
    - Reducing or redistributing structural loads to prevent further settlement.
    - May involve partial demolition, removal of non-structural load, or addition of load-bearing elements to spread loads evenly.
4. Drainage Improvement
    - Controlling groundwater and surface water to prevent soil softening and consolidation.

- Includes perimeter drains, French drains, proper site grading, and subsoil drainage systems.

5. Structural Strengthening

   - Reinforcing affected members to accommodate settlement-induced stresses.
   - Techniques: external post-tensioning, addition of steel or fiber-reinforced polymer (FRP) reinforcement, or jacketing of columns and beams.

6. Monitoring and Instrumentation

   - Installing settlement plates, inclinometers, or crack gauges to track ongoing movement.
   - Early detection allows timely intervention and prevents catastrophic failure.

7. Preventive Measures in New Constructions

   - Conducting thorough geotechnical investigations before design.
   - Designing foundations suitable for soil conditions and anticipated loads.
   - Ensuring proper compaction, curing, and quality control during construction.

Preventive Measures:

 Comprehensive Site Investigation

- Conduct detailed geotechnical surveys to assess soil type, bearing capacity, compressibility, groundwater table, and potential settlement characteristics.

 Appropriate Foundation Design

- Design foundations based on soil conditions and anticipated structural loads.
- Select suitable foundation types (shallow, deep, pile, raft) to minimize risk of excessive or differential settlement.

 Soil Improvement Prior to Construction

- Stabilize weak or compressible soils through compaction, preloading, lime/cement stabilization, vibro-compaction, or stone columns.

 Proper Construction Practices

- Ensure uniform compaction of subgrade and backfill materials.
- Maintain quality control in concrete mixing, curing, and reinforcement placement to avoid uneven settlement.

 Control of Groundwater and Surface Water

- Implement effective drainage systems to prevent soil softening and consolidation.
- Avoid excessive dewatering or uncontrolled water accumulation near foundations.

 Load Management During Construction

- Avoid overloading partially completed structures.
- Stage construction loads gradually to allow soil consolidation and reduce sudden settlements.

 Monitoring During and After Construction

- Use settlement plates, inclinometers, or crack gauges to track movement.
- Early detection allows corrective action before significant structural damage occurs.

 Adherence to Codes and Standards

- Follow IS codes (e.g., IS 1904:2011) for foundation design and tolerable settlements.
- Ensure compliance with recommended construction and soil improvement practices.

Results:

 Identified Locations and Types of Settlement

- Observed settlements in foundations, columns, beams, slabs, retaining walls, and pavements.
- Classified as uniform, differential, or localized settlement based on distribution patterns.

 Possible Causes and Severity

- Causes: Weak or compressible soil, high water table, excessive or uneven loads, poor compaction, construction defects.

- Severity: Categorized as mild, moderate, or severe depending on structural impact and measurable deflection or cracking.

 Effects on Structural Safety and Serviceability

- Serviceability: Uneven floors, cracks in walls, doors/windows misalignment, visible tilting.
- Safety: Excessive differential settlement may induce stresses exceeding design limits, potentially compromising structural integrity.

 Suggested Remedial Strategies

- Structural Remedies: Underpinning, reinforcement of beams/columns, load redistribution.
- Soil Remedies: Soil stabilization, grouting, compaction improvement, drainage enhancement.
- Monitoring: Settlement plates, inclinometers, and crack gauges for ongoing observation.

 Preventive Strategies

- Conduct thorough geotechnical investigation prior to construction.
- Design foundations suitable for soil and load conditions.
- Ensure proper compaction, curing, and quality control.
- Implement effective drainage and groundwater control.
- Adhere strictly to IS code provisions for allowable settlements (IS 1904:2011).

 Reference to IS Codes and Case Studies

- Validation of observed settlements and remedial measures against IS 1904:2011 – Code of Practice for Structural Safety in Building Foundations.
- Case studies (e.g., Smith & Lee, 2015) demonstrate successful mitigation of differential settlements through underpinning and soil stabilization.

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EXPERIMENT 5:

Structural Health Monitoring & NDT

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1. Aim

To perform structural health monitoring and non-destructive testing (NDT) on RC structures to identify defects such as cracks, corrosion, and material deterioration, and to suggest remedial and preventive measures.

2. Objectives

- To understand principles of structural health monitoring (SHM).
- To demonstrate and perform NDT techniques:
  - Rebound Hammer Test (surface hardness and quality of concrete)
  - Ultrasonic Pulse Velocity (UPV) Test (internal defects and uniformity)
  - Half-Cell Potential Measurement (corrosion assessment of reinforcement)
- To record observations systematically with properly captured photographs.
- To analyze test results in light of IS code provisions and case studies from literature.

3. Theoretical Background

- **Structural Health Monitoring (SHM):** Systematic assessment of structural condition to detect deterioration and prevent failures.
- **Rebound Hammer Test:** Measures surface hardness of concrete and provides an estimate of compressive strength.
  - **IS Code:** IS 516 (Part 5/Sec 4) 2020
- **Ultrasonic Pulse Velocity (UPV) Test:** Measures the velocity of ultrasonic waves through concrete to detect cracks, voids, or non-uniformity.
  - **IS Code:** IS 516 (Part 5/Sec 1): 2018
- **Half-Cell Potential Measurement:** Detects likelihood of reinforcement corrosion based on electrochemical potential.
  - **IS Code:** IS 516 (Part 5/Sec 2): 2021
- Students are encouraged to consult case studies in literature to understand practical SHM applications and remedial strategies.

4. Procedure ***(Sample – for reference only)***

1. Select RC members (beams, slabs, columns, walls) for NDT.
2. **Rebound Hammer Test:**
   - Clean surface of concrete.

    - Take multiple readings at each location and calculate average rebound index.

3. **UPV Test:**
    - Place transducers on opposite faces of the member.
    - Record pulse velocity at multiple points.
4. **Half-Cell Potential Measurement:**
    - Connect reference electrode to reinforcement.
    - Measure potential at several locations to identify corrosion-prone areas.
5. Record all observations systematically with **properly captured, labelled, numbered, and captioned photographs**.
6. Analyze results to identify defects, estimate severity, and suggest remedial or preventive measures.

5. Observations & Data Recording:

Beam No.	Condition of beam	Date of casting	Date of testing- 8\11\2025			
			Visual inspection	Rebound	UPV(m\s)	HCP(-mV)
1	Uncorreded	11\10\2025	Surface finish is generally smooth with minor roughness visible on some faces.Concrete color is consistent, indicating uniform mixing and curing. Reinforcement bars are projecting vertically from the top surface of each specimen.Minor surface rust observed on several rebars, likely due to exposure to air and moisture.Rebars appear straight and properly embedded. No visible displacement or bending	19	3759	86 99 92 99 102 36 35 34 36 28

2	Uncorreded	11\10\2025	Surface finish is generally smooth with minor roughness visible on some faces.Concrete color is consistent, indicating uniform mixing and curing. Reinforcement bars are projecting vertically from the top surface of each specimen.Minor surface rust observed on several rebars, likely due to exposure to air and moisture.Rebars appear straight and properly embedded. No visible displacement or bending	19.5	4644	113 127 119 108 98 121 102 119 115 105
3	Uncorreded	13\10\2025	Surface finish is generally smooth with minor roughness visible on some faces.Concrete color is consistent, indicating uniform mixing and curing. Reinforcement bars are projecting vertically from the top surface of each specimen.Minor surface rust observed on several rebars, likely due to exposure to air and moisture.Rebars appear straight and properly embedded. No visible displacement or bending	19	4164	222 233 255 248 250 239 229 218 232 239
4	Correded	27\9\2025	The concrete surfce shows significant rust stains and dicoloration. Longitudinal crack are vissible along the reinforcement	22	4465	467 502 492 550 576 400 410 428 432 483

5	Corroded	27\9\2025	The concrete surfce shows significant rust stains and dicoloration. Longitudinal crack are vissible along the reinforcement	28	4450	555 543 596 597 547 572 532 544 564 578
6	Corroded	27\9\2025	The surface shows rust staining,rough texture, and discoloration . Longitudinal crack are vissible along reinforcement and dark brown ruts deposit	20.5	4132	532 524 516 518 520 524 545 522 546 550
7	Corroded	27\9\2025	The surface shows rust staining,rough texture, and discoloration . Longitudinal crack are vissible along reinforcement and dark brown ruts deposit	22	4478	557 533 534 527 499 524 545 534 573 532
8	Corroded	1\10\2025	The surface shows rust staining,rough texture, and discoloration . Longitudinal crack are vissible along reinforcement and dark brown ruts deposit	16	4348	575 488 550 547 543 540 578 548 546 576

9	Corroded	1\10\2025	The surface shows rust staining,rough texture, and discoloration . Longitudinal crack are vissible along reinforcement and dark brown ruts deposit	24.5	4478	220 230 232 302 201 274 278 288 296 301
10	Corroded	1\10\2025	Severe longitudinal cracking parallel to steel extensive reddish brown/orrange stains along the cracks on face and a small expousre of bar	18.5	4225	440 410 449 491 541 486 453 496 406 438
11	Corroded	4\10\2025	The concrete surfce shows significant rust stains and dicoloration. Longitudinal crack are vissible along the reinforcement	26.5	4348	580 568 550 549 524 565 578 548 577 565
12	Corroded	4\10\2025	Severe longitudinal cracking parallel to steel extensive reddish brown/orrange stains along the cracks on face and a small expousre of bar	21	4412	518 590 548 540 542 524 577 548 565 554

13	Corroded	4\10\2025	Severe longitudinal cracking parallel to steel extensive reddish brown/orrange stains laong the cracks only on one face and a small expousre of bar	23	4425	538 565 560 524 515 525 558 549 568 569
14	Corroded	4\10\2025	The concrete surfce shows significant rust stains and dicoloration. Longitudinal crack are vissible along the reinforcement	20.5	4212	527 533 505 560 510 541 555 559 589 578
15	Corroded	13\10\2025	Severe longitudinal cracking parallel to steel extensive reddish brown/orrange stains along the cracks on face and a small expousre of bar	20	4545	602 563 553 508 547 548 587 549 598 542

6. Analysis

The Non-Destructive Testing (NDT) experiment aims to evaluate the in-situ condition and integrity of concrete without causing any damage to the structural element. Based on the tests performed (Rebound Hammer, Ultrasonic Pulse Velocity, or any combination), the following observations and analysis can be made:

1. Rebound Hammer Test

- The rebound number obtained reflects the surface hardness of concrete.
- Higher rebound values indicate better surface strength, while lower readings suggest weaker, deteriorated or porous concrete.
- Variations between different points may be due to:

  - Surface roughness
  - Moisture content
  - Carbonation effects
  - Poor compaction or segregation
- Using the calibration graph, the approximate compressive strength is obtained, but this value represents **surface strength**, not the full depth strength.

2. Ultrasonic Pulse Velocity (UPV) Test

- The measured pulse velocity gives insight into concrete quality, homogeneity and presence of internal flaws.
- Higher velocities indicate dense, well-compacted and uniform concrete.
- Lower velocities may indicate:
  - Cracks or voids
  - Honeycombing
  - High moisture variation
  - Presence of micro-cracks
- According to IS 13311 (Part 1), the concrete quality can be graded as:
  - Above 4.5 km/s: Excellent
  - 3.5–4.5 km/s: Good
  - 3.0–3.5 km/s: Medium
  - Below 3.0 km/s: Doubtful quality

3. Combined NDT Interpretation

When both Rebound Hammer and UPV tests are used together:

- Rebound Hammer gives **surface hardness**
- UPV gives **internal quality**
  Using combined correlation charts improves accuracy of estimating actual compressive strength.

Concrete may show:

- High UPV + high rebound: Good quality and strong concrete
- Low UPV + low rebound: Weak or deteriorated concrete
- High rebound + low UPV: Carbonated surface but poor internal quality
- Low rebound + high UPV: Weak surface but dense inner core

4. Experimental Limitations

- NDT results give **indicative** values, not absolute strength.
- Calibration with core samples is required for more accurate strength estimation.
- Environmental conditions (temperature, moisture) affect results.
- Operator skill and equipment calibration significantly affect accuracy.

7. Treatment Strategies

- Depending on the condition assessed through Rebound Hammer, UPV, or combined NDT evaluation, the following treatment strategies are recommended:
- **1. Surface Repair and Strengthening**
- Used when rebound hammer values are low but UPV indicates no deep defects.
- Application of polymer-modified mortar (PMM) to restore surface strength.
- Surface grinding or cleaning if deterioration is due to carbonation or scaling.
- Crack sealing using epoxy or PU injection for narrow surface cracks.
- **2. Grouting for Internal Voids**
- When UPV shows reduced pulse velocity indicating voids or honeycombing:
- Pressure grouting with cement slurry or microfine cement.
- Epoxy grouting for fine cracks and low-severity internal defects.
- Low-pressure PU injection where moisture ingress is observed.
- **3. Structural Strengthening**
- When both tests indicate significant loss of strength:
- External strengthening using Fiber Reinforced Polymer (FRP) sheets.
- Jacketing with reinforced concrete or steel plates.
- Addition of carbon fiber wraps to enhance load-carrying capacity.
- **4. Corrosion Control Measures**
- For cases where deterioration is caused by reinforcement corrosion:
- Cathodic protection systems to stop ongoing corrosion.
- Application of corrosion inhibitors on concrete surface.
- Re-alkalisation treatment where carbonation depth is high.
- **5. Moisture and Durability Control**
- If test readings indicate moisture-induced damage:
- Injection of hydrophobic chemicals to reduce water ingress.
- Surface coatings such as epoxy paint or waterproof membranes.

- Improving drainage or eliminating sources of water exposure.
- **6. Structural Monitoring**
- When the NDT results show medium-quality but not critical condition:
- Periodic UPV and rebound hammer testing to monitor progression.
- Non-contact methods like thermal imaging or ground penetrating radar (GPR) for ongoing health monitoring.
- Implementing a maintenance schedule for preventive repair.
- **7. Replacement (Last Resort)**
- If concrete quality is **doubtful or poor** based on both NDT tests and core test verification:
- Removal and recasting of severely deteriorated members.
- Replacement of localized defective zones with high-performance concrete.

8. Results

- Defects detected and severity assessment.
- Recommendations for remediation.
- Preventive maintenance suggestions.
- Reference to IS codes and literature for validation.

9. References

Bureau of Indian Standards. (1992). *IS 13311 (Part 1): Non Destructive Testing of Concrete – Ultrasonic Pulse Velocity Method.* New Delhi: BIS.

Bureau of Indian Standards. (1992). *IS 13311 (Part 2): Non Destructive Testing of Concrete – Rebound Hammer Method.* New Delhi: BIS.

Bureau of Indian Standards. (2018). *IS 516 (Part 5/Sec 1): Method of Tests for Strength of Concrete – Ultrasonic Pulse Velocity Test.* New Delhi: BIS.

Bureau of Indian Standards. (2021). *IS 516 (Part 5/Sec 2): Method of Tests for Strength of Concrete – Half-Cell Potential Measurement.* New Delhi: BIS.

Bureau of Indian Standards. (2020). *IS 516 (Part 5/Sec 4): Method of Tests for Strength of Concrete – Rebound Hammer Test.* New Delhi: BIS.

EXPERIMENT 6:

Analysis of RC Structural Components using Software

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1. Aim:

To perform non-linear analysis of reinforced concrete (RC) structural components using ATENA software and understand the response of RC elements under realistic loading conditions.

2. Objectives:

- To familiarize students with ATENA software for structural analysis.
- To model RC beams, slabs, and columns and perform non-linear analysis.
- To interpret software results such as stress distribution, crack formation, and deflection.
- To correlate software analysis with theoretical behavior and observed field defects.
- To encourage hands-on practice using the official ATENA tutorial.

3. Theoretical Background:

- **Non-linear Analysis:** Captures realistic structural behavior, including cracking, crushing, and yielding of RC members.
- **ATENA Software:** Advanced tool for 2D/3D non-linear analysis of concrete and reinforced concrete structures.
- Capabilities include modeling material non-linearity, reinforcement interaction, crack propagation, and post-peak behavior.

4. Software Installation & Tutorial:

1. **Download ATENA Software:**
    - Visit Cervenka ATENA Documentation for software instructions.
    - Install the ATENA Engineering 3D trial version on your personal computer or lab workstation.
2. **Tutorial Guidance:**
    - Follow the official tutorial sheet: ATENA Engineering 3D Tutorial PDF
    - Complete the step-by-step exercises as provided.
3. **Practice Tasks:**
    - Model a simply supported RC beam and analyze for bending and cracking.
    - Observe stress distribution and crack propagation under increasing load.
    - Record load-deflection curves and compare with theoretical expectations.
    - Document all steps, screenshots, and results in your report.

5. Procedure:

1. Launch ATENA software and create a new project.
2. Define geometry, material properties, and boundary conditions for the RC member.
3. Assign reinforcement details as per design specifications.
4. Apply loads incrementally and perform non-linear analysis.
5. Observe and record results:
    - Crack initiation and propagation
    - Stress distribution in concrete and reinforcement
    - Maximum deflection and failure points
6. Follow the tutorial sheet and note all deviations or observations.
7. Prepare a report including screenshots, interpretation, and comparison with theoretical expectations.

6. Analysis:

- Materials: Concrete (3D Nonlinear Cementitious 2; fcu 33.5 MPa; ft 1.64 MPa; Gf 5.5e-5 MN/m); Reinforcement Bilinear (E=208000 MPa, σy=560 MPa).
- ATENA-Engineering-3D_Tutorial
- Geometry: beam prism (Vx=1.275, Vy=0.190, Vz=0.320 m). Create steel plates using extrusion.
- Mesh: global element size 0.05 m (refine to get 4–8 elements through depth). Use brick for beam.
- ATENA-Engineering-3D_Tutorial
- Reinforcement: add two Ø26 bars at z=0.05 m; set bar material and diameter.
- Loads: prescribed displacement at top plate (WZg = -0.0001 m per step), 40 steps (adjust if needed).
- ATENA-Engineering-3D_Tutorial
- Solution params: Newton-Raphson; set break criteria as tutorial suggests.
- Monitors: Deflection at midspan (z comp), Reaction at load node (z comp).
- ATENA-Engineering-3D_Tutorial
- Run & Post-process: crack filter 0.0001 m, contour principal strains/stresses, bar stress plots, L–D graph export.

7.Treatment:

- From ATENA, determine dominant failure mode(s) and log: first crack step, peak load, max crack width, bar yielding location.
- If shear cracks → add close stirrups ($s \leq 0.6 \cdot d$) in shear spans; model in ATENA and re-run.
- If flexural cracks wide → increase tensile reinforcement or apply EB-FRP/NSM; model FRP as shells/truss with bond interface.
- If local stress concentration at load/support → increase bearing area (plate), add local reinforcement or concrete thickening.
- If bond/anchorage concerns → add mechanical anchors or increase development length, model lap/splice changes.

- Implement monitoring: baseline visual, crack gauges, LVDT midspan, AE for active cracking; schedule UPV/GPR quarterly for suspect regions.
- Re-run ATENA for each intervention, compare L–D, crack widths, bar stresses. Choose minimum intervention achieving target performance.
- Document all changes and produce acceptance criteria: e.g., crack width < 0.2 mm under service load and no yielding of tensile reinforcement at 1.25× service load.

8.Results:

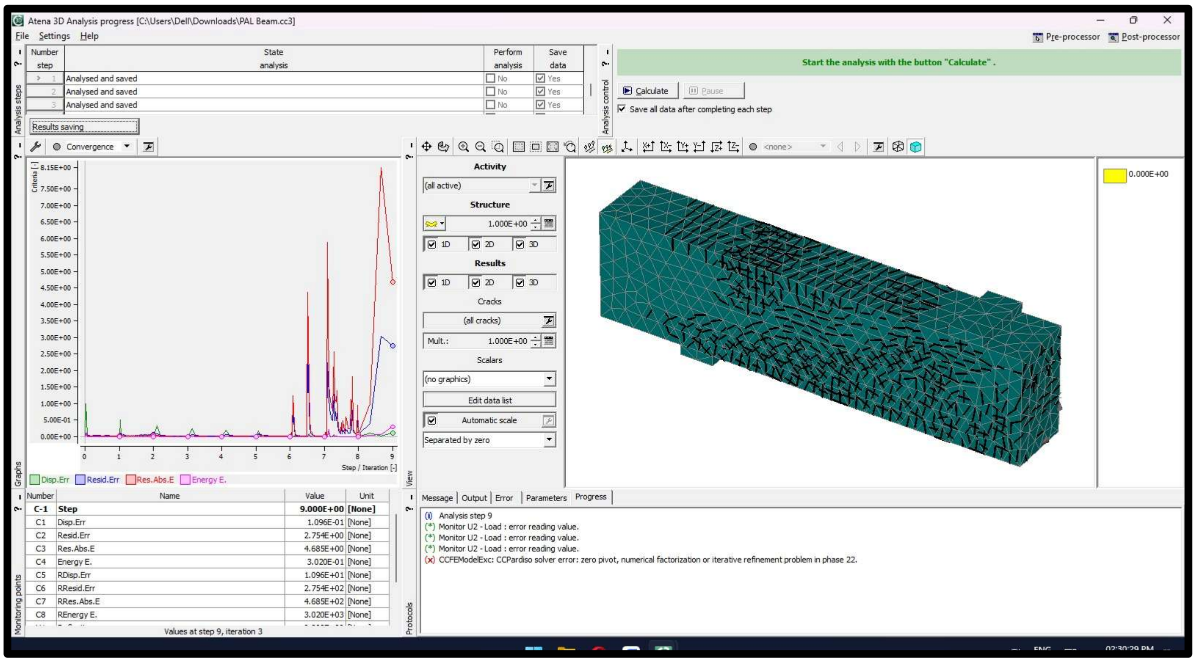

Fig 6.1 Analysis of Beam Using ATENA (Showing Cracks)

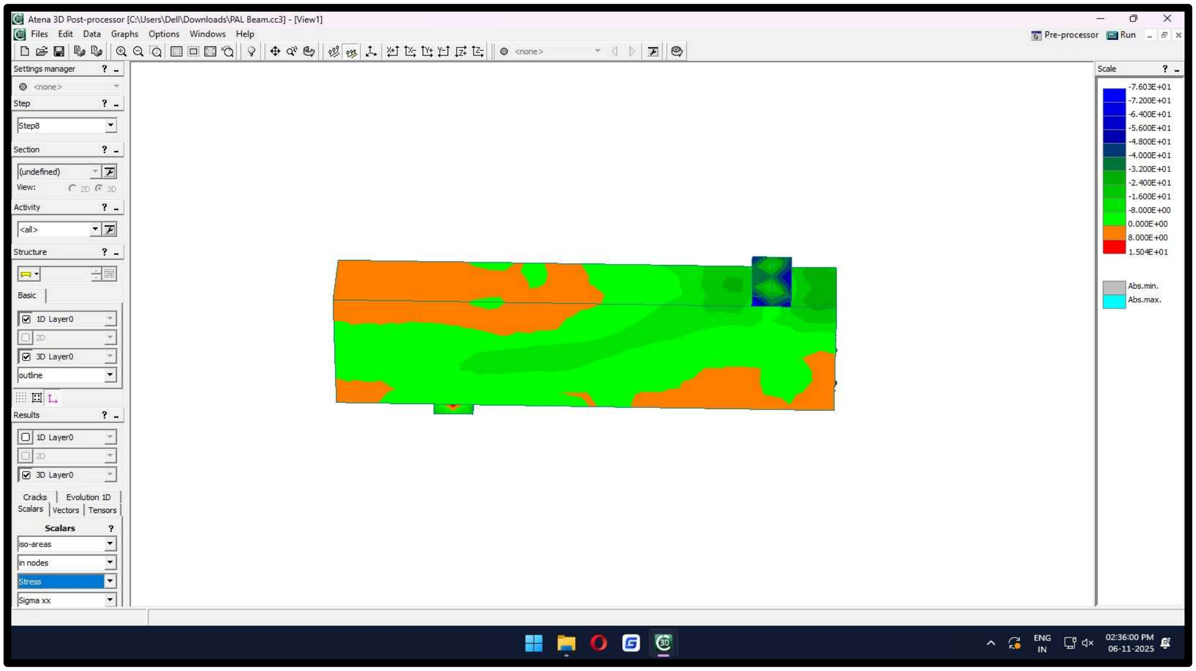

Fig 6.2 Showing Crack in a Beam

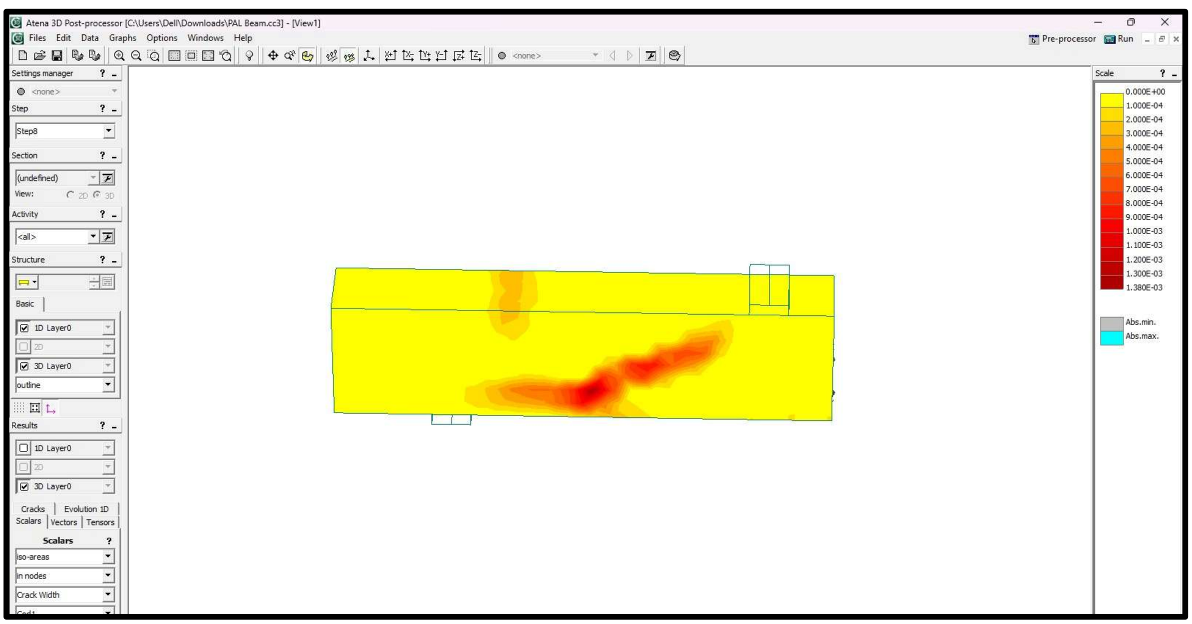

Fig 6.3 Showing Crack Pattern in Red

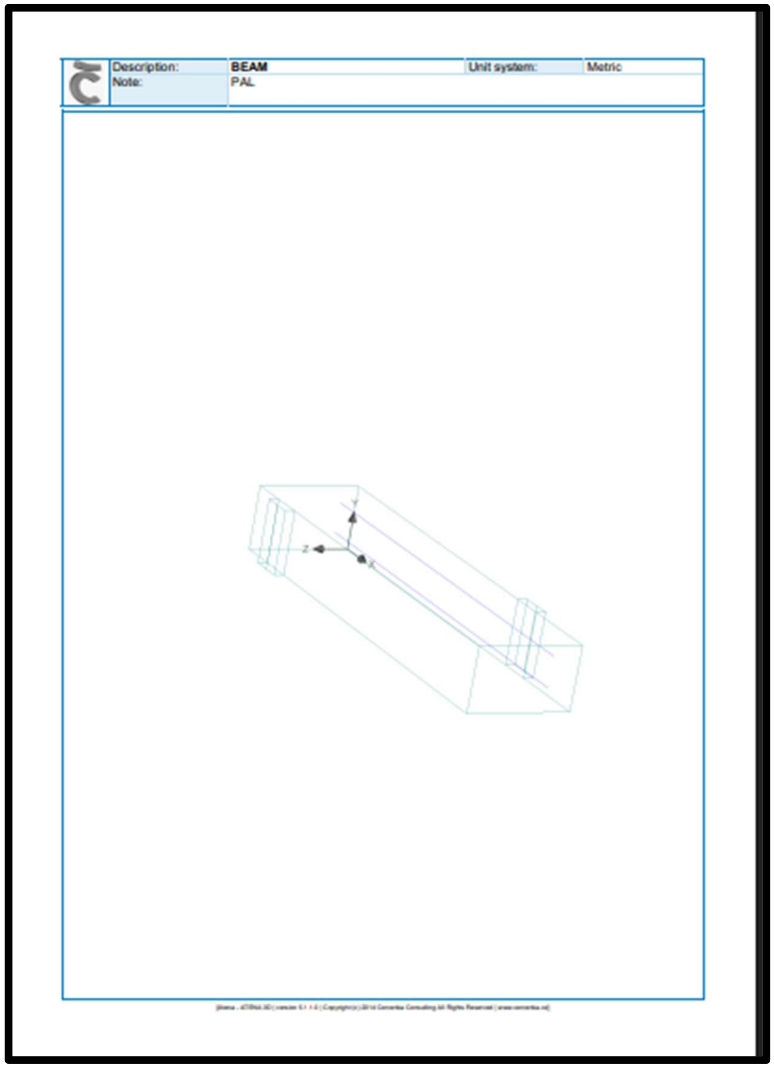

Fig 6.4 Showing Model of Beam Made in ATENA

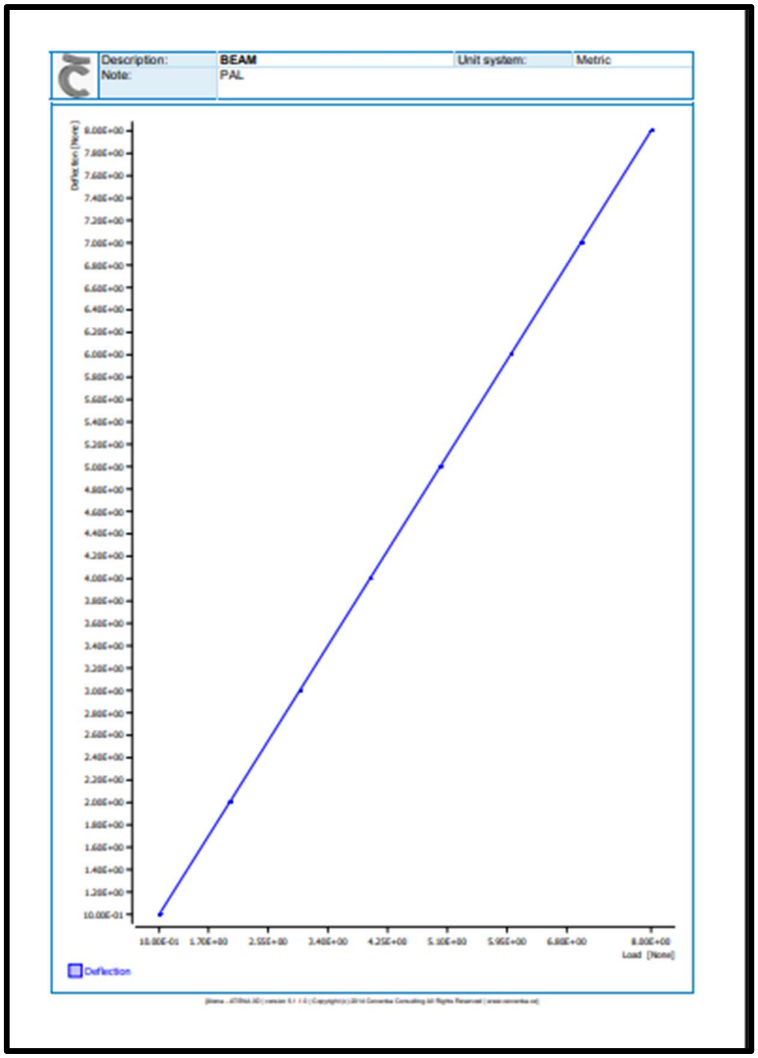

Fig 6.5 Showing Load Deflection in Beam

9. References:

Červenka Consulting. (n.d.). *ATENA User Manuals*. Červenka Consulting. https://www.cervenka.cz/products/atena/user-manuals

Červenka Consulting. (n.d.). *ATENA Engineering 3D Tutorial*. Červenka Consulting. https://www.cervenka.cz/assets/files/atena-pdf/ATENA-Engineering-3D_Tutorial.pdf