UNIT - II

CAUSES & DETECTION OF DAMAGES
Explain the causes of damages in a structure

Effects

- **Leakage**
- **Settlement**
- **Deflection**
- **Wear**
- **Spalling/Disintegration**
- **Honeycombing/Delamination**
- **Scaling**
- **Cracking**

Causes

- Inadequate water tightness of concrete/plaster
- Improper joint details of 2 dissimilar materials
- Overdesigned SBC
- Underdesigned foundation
- Underdesigned structural member
- Overloading
- Inadequate abrasion resistance
- Corrosion
- Fire
- Impact/Accident
- Plaster – Poor surface preparation
- Concrete – Poor concreting
- Plaster – Leakage
- Stone – Weathering
- Structural steel – Corrosion

Structural
- Non structural
- Material

Material
Explain the causes of damages in a structure

**Leakages**
Explain the causes of damages in a structure

Settlement crack
Explain the causes of damages in a structure

Settlement crack
Explain the causes of damages in a structure

Deflection
Explain the causes of damages in a structure

Wear
Explain the causes of damages in a structure

Spalling / Disintegration
Explain the causes of damages in a structure

Honey combing & Delamination
Explain the causes of damages in a structure

Scaling
Cracking

Before hardening
- Drying
- Settlement shrinkage
- Plastic shrinkage
- Bleeding
- Delayed curing

Construction
- Early frost damage
- Formwork movement
- Excess vibration
- Sub grade settlement
- Finishing

After hardening
- Unsound material
  - Cement
  - Aggregate
  - Excess silt, mud, dust
- Long term drying shrinkage
- Thermal
  - Heat of hydration
  - External temperature
  - Joints in concrete
  - Elevated temp.
  - Freezing & Thawing
- Moisture movement
- Transition zone
- Biological
- Structural design deficiencies
- Chemical
  - Corrosion of R/F
  - Sulphate attack
  - Chloride attack
  - Alkali aggregate reaction
  - Sea water
  - Acid attack
  - Carbonation

Cracks in concrete

Next Point
Damage Evaluation/ Assessment

- Philosophy of repairs
- Root cause analysis
- Type of improvement needed
- Repairs / strengthening
- Study of material properties
Damage Evaluation/ Assessment

What is Partial Failure of structures?

- **Structural**
  - Material
  - Design

- **Architectural**
  - Design
  - Detailing

- **Services**
  - Design
  - Maintenance
Damage Evaluation/ Assessment

Structural Damage

- Member deformation
  - Sagging
  - Swaying
  - Buckling
  - Compression

- Structural cracking
  - Tensile
  - Bending
  - Shear
  - Torsion

- Material cracking
  - Corrosion
  - Chemical attack
  - Fire
Damage Evaluation/ Assessment

Sagging
Damage Evaluation/ Assessment

Buckling
Damage Evaluation/ Assessment

Bending
Damage Evaluation/ Assessment

Shear
Damage Evaluation/ Assessment

Corrosion
Damage Evaluation/ Assessment

Chemical attack
Damage Evaluation/ Assessment

Fire
Common Structural Failures

• Material

  - Corrosion
  - Leakage
  - Fire damage
  - Earthquake/Natural calamity
  - Salt (Sulphate) attack

• Design

  - Shear
  - Buckling
  - Bending
  - Crushing

Click here for next point
Damage Evaluation/ Assessment
Corrosion
Damage Evaluation/ Assessment

Corrosion

Cracks due to Corrosion of reinforcement in slab
Damage Evaluation/ Assessment

Corrosion

Cracks due to Corrosion of reinforcement in Water shed / Chajjas
Damage Evaluation/ Assessment

Leakages

Leakage through Terrace
Damage Evaluation/ Assessment

Leakages

Leakage through WC/Toilet block
Leakage through Openings
Damage Evaluation/ Assessment
Leakages

Leakage through Separation Cracks
Damage Evaluation/ Assessment

Leakages

Leakage through Dead walls
Damage Evaluation/ Assessment

Fire damage
Damage Evaluation/Assessment

Earthquake
Damage Evaluation/ Assessment

Salt attack
Damage Evaluation/ Assessment

Shear Crack
Damage Evaluation/ Assessment

Buckling
Damage Evaluation/ Assessment

Bending
Damage Evaluation/Assessment

Common Architectural Failures

- Leakage
- Plaster in structures
- Plumbing
- Waterproofing
- Planning failures

- Plumbing
- Roof
- Walls
- Cracking
- Delamination
- Maintenance - Inaccessibility
- Poor Design
- Light
- Ventilation
- Staircase
Damage Evaluation/ Assessment

Non structural Defects
Damage Evaluation/ Assessment

Deteriorated condition of R.C.C. beams due to bulging & spalling of cover concrete thus exposing reinforcement.
Damage Evaluation/ Assessment

Leakage

Leakage and Seepage through wooden roof

Severe Leakage and Seepage through toilet block
Water stagnation which is root cause of leakage
Damage Evaluation/ Assessment

Structural movement in precast slab of concrete jetty
Cracked steel sacrificial liner & corrosion cracking of pile concrete
Systematic approach of damages detection & repairs

1. Data Collection
2. Visual Inspection
3. Non Destructive Testing
4. Defect Evaluation
5. Remedy
6. Specifications & Costing
7. Tendering & Contractor selection
8. Execution
9. Certification
10. Handing Over
Systematic approach of damages detection & repairs

Data Collection

• Architectural / Structural/Services /Maintenance Drawings
• Maintenance Record
• History of use
• Type of Loading
• Type of problem cracking / Leakage / Vibrations
Systematic approach of damages detection & repairs

Visual Inspection

• No substitute

• Access System

• Identification of level of distress

• Various types of distress

• NDT Program

• Preparation of distress mapping drawings
## Methods of inspection & tools needed

<table>
<thead>
<tr>
<th>Visual Inspection</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hammer</td>
<td>Digital Camera</td>
</tr>
<tr>
<td><img src="hammer.png" alt="Hammer Image" /></td>
<td><img src="camera.png" alt="Digital Camera Image" /></td>
</tr>
</tbody>
</table>

**Inspection by advanced Non Destructive Techniques**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Endoscope</td>
<td>Infrared Camera</td>
<td>Drone</td>
</tr>
<tr>
<td><img src="endoscope.png" alt="Endoscope Image" /></td>
<td><img src="infrared.png" alt="Infrared Camera Image" /></td>
<td><img src="drone.png" alt="Drone Image" /></td>
</tr>
</tbody>
</table>
Methods of inspection & tools needed
Methods of inspection & tools needed

Findings of Visual inspection

- Corrosion in marine structure
- Concrete of Chemical plant
- Fire damaged structure
- Partial Collapse
Methods of inspection & tools needed

Inspection by Endoscopy

In cracks / crevice

Above false ceiling

In defects
Methods of inspection & tools needed

Inspection by Endoscopy
Methods of inspection & tools needed

Inspection by Endoscopy
Methods of inspection & tools needed

Inspection by Endoscopy

Endoscopy on wood
Methods of inspection & tools needed

Inspection by Endoscopy

Drilled hole with concrete wall and strand at depth 90 mm.

Voids in Tendons

Grout filled in Tendons
Methods of inspection & tools needed

Inspection by Infra red Thermography
Methods of inspection & tools needed

Inspection by Infra red Thermography
Methods of inspection & tools needed

Inspection by Infra red Thermography
Methods of inspection & tools needed

Inspection by Infra red Thermography
Methods of inspection & tools needed

Inspection by Infra red Thermography
Methods of inspection & tools needed

Inspection by Infrared Thermography
Methods of inspection & tools needed

Inspection by Drone
What is Non Destructive Testing (NDT)?

- It is a non-invasive technique to determine the integrity of component or structure & quantitatively measure some characteristic of an object.
- NDT can be performed repeatedly as and when required even at same location.
- Due to this virtue, NDT is so popular all over the world despite the greatest limitations the equipments have.
- NDT is more popular as investigative tool and not much used as quality assurance measure on new construction sites, in India, yet.
## Tests on Concrete Structures

<table>
<thead>
<tr>
<th>Strength Tests</th>
<th>Corrosion Assessment &amp; R/F Related Tests</th>
<th>For Detection Of Cracks/Voids/Delamination</th>
<th>Laboratory Tests</th>
<th>Durability Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Rebound Hammer Test</td>
<td>- Half Cell Potentiometer</td>
<td>- Ultrasonic Pulse Velocity Test</td>
<td>- Petrography</td>
<td>- Autoclamp Permeability Test</td>
</tr>
<tr>
<td>- Pull Off Test</td>
<td>- Resistively Meter Test</td>
<td>- Infrared Thermographic Technique</td>
<td>- Chemical Analysis</td>
<td>- Permit Ion Migration Test</td>
</tr>
<tr>
<td>- Pull Out Test</td>
<td>- Carbonation</td>
<td>- Acoustic Emission Techniques</td>
<td>- Compressive Strength On Core Sample</td>
<td>- Initial Surface Absorption Test</td>
</tr>
<tr>
<td>- Break Off Test</td>
<td>- Chloride Content Of Concrete</td>
<td>- Short Pulse Radar Methods</td>
<td>- Water Permeability</td>
<td>- Rapid Chloride Migration Test</td>
</tr>
<tr>
<td>- Penetration Resistance Test (Windsor Probe)</td>
<td>- Endoscopy Technique</td>
<td>- Stress Wave Propagation Methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Core Drilling Method</td>
<td>- Covermeter / Rebar Locator</td>
<td>- i. Pulse Echo Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Permeability Test</td>
<td></td>
<td>- ii. Impact Echo Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Bond Test</td>
<td></td>
<td>- iii. Response Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Maturity Method</td>
<td></td>
<td>- Crack Detection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Complete Structural Testing</td>
<td></td>
<td>- Microscope</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Endoscopy Technique</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Moisture Meter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Non destructive tests – standard methods

<table>
<thead>
<tr>
<th>Name of Test</th>
<th>Std. specification</th>
<th>Name of Test</th>
<th>Std. specification</th>
<th>Name of Test</th>
<th>Std. specification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ii. Impact Echo Method</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>iii. Response Method</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>i. Pulse Echo Method</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ii. Impact Echo Method</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>iii. Response Method</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>i. Pulse Echo Method</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ii. Impact Echo Method</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>iii. Response Method</td>
<td></td>
</tr>
<tr>
<td>Pull Off Test</td>
<td>ASTM D7234 - 12</td>
<td>Chloride content &amp; Sulphate content of concrete</td>
<td>ASTM C 1084, BS 1881 part 124</td>
<td>Petrography of concrete</td>
<td>ASTM C856-17</td>
</tr>
<tr>
<td>Break Off Test</td>
<td>ASTM C 1150-90,</td>
<td>Cover meter</td>
<td>BS 1881: Part 204: 1986, BS 4408: pt. 1</td>
<td>Initial Surface Absorption Test</td>
<td>BS 1881 part 5</td>
</tr>
<tr>
<td>Penetration Resistance Test</td>
<td>ASTM C 803-82</td>
<td>Infrared Thermographic Technique</td>
<td>ASTM D4788</td>
<td>Rapid Chloride Migration Test</td>
<td>ASTM 1202-2019</td>
</tr>
<tr>
<td>(Windsor Probe)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeability Test</td>
<td>IS 3085: 1965</td>
<td>Short Pulse Radar Methods</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ultrasonic pulse velocity (u.S.P.V.) Test

Principle

Voltage pulses are generated and transformed into wave bursts of mechanical energy by the transmitting transducer (which must be coupled to the specimen surface through a suitable medium).

A receiving transducer is coupled to the specimen at a known distance to measure the interval between the transmission and reception of a pulse.

There are three practical arrangements for measuring pulse velocity, namely direct, diagonal and surface techniques.
Ultrasonic pulse velocity (u.S.P.V.) Test

Application

- To assess the homogeneity of concrete, uniformity of concrete.
- To detect the voids, porosity and approximated extent of cracks in concrete.
- Defects such as voids, honeycombing, cracks and segregation may be determined. This technique is also useful when examining fire damaged concrete.
Ultrasonic pulse velocity (u.S.P.V.) Test

Calibration

- The instrument i.e., time indicator should be calibrated with help of calibration specimen which is provided by the manufacturer prior to commencement of testing at the site.
Ultrasonic pulse velocity (u.S.P.V.) Test

Site Preparation

• The test shall be carried out on the exposed surface of concrete wherever possible.

• If the concrete surface is rough, it should be leveled and smoothened by means of POP.

• Should use adequate coupling agent between concrete and transducers to avoid air gap between the two.
Ultrasonic pulse velocity (u.S.P.V.) Test

Do’s & Don’ts

• Should not be conducted on debonded concrete surface, dado etc

• Should not be conducted on Wet concrete

• Should not be conducted where R/F is parallel to pulse path

• Correct frequency transducers shall be used which depends on path length.

• Should not be used without coupling agent

• Minimum length for direct transmission 150 mm.
Ultrasonic pulse velocity (u.S.P.V.) Test

USPV has been carried out on debonded and POP surface of the column. Please note the thickness of POP.

USPV is carried out by indirect method when a direct method was easily possible.
Ultrasonic pulse velocity (u.S.P.V.) Test
Advantages

- Highly accurate for the assessment of interior of concrete member for honeycombing, porosity voids etc.
- Inexpensive test and portable equipment
- Micro cracking in the concrete member can be detected.
- Efficacy of grouting of the same can be checked.
- Efficacy of bonding between old and new concrete can be assessed.
Ultrasonic pulse velocity (u.S.P.V.) Test

Disadvantages/ Limitations

• Not accurate for prediction of compressive strength

• Spot checking of quality & material. Tomography machine using ultrasonic technique is available.
Ultrasonic pulse velocity (u.S.P.V.) Test

U.S.P.V testing in process – Direct Method
Ultrasonic pulse velocity (u.S.P.V.) Test

U.S.P.V testing Indirect Method
Ultrasonic pulse velocity (u.S.P.V.) Test

U.S.P.V Testing Indirect Method
Schmidt Rebound Hammer

N Type Rebound Hammer

N Type rebound Hammer in use

Contd..
Schmidt Rebound Hammer

P Type rebound hammer

P Type rebound hammer in use
Schmidt Rebound Hammer

M Type Rebound hammer

M Type Rebound hammer in use
Schmidt Rebound Hammer

Principle

• This instrument works on the principle of action and reaction are equal and opposite.

• It measures the hardness of concrete surface by impact plunger and is calibrated for the compressive strength of concrete.
Schmidt Rebound Hammer

![Graph showing Schmidt Rebound Hammer test results]

- Hammer horizontal
- Hammer vertical
- Wet
- Dry

Compressive Strength - MPa

psi

Rebound Number
Schmidt Rebound Hammer

Applications

• It is a very good tool in the qualitative assessment of concrete in old structures. It does not possess high level of accuracy in old structures, when quantitative assessment is carried out and only gives a range of compressive strengths.

• Can be used for compressive strength assessment for new concretes, less than 1 year old, effectively.
Schmidt Rebound Hammer

Calibration

- Anvil with known hardness shall be used for calibration. Hammer should be calibrated and serviced after every 2000 impacts.
Site Preparation

- The concrete surface should be smooth, clean and dry.

- Any loose particles should be rubbed off from the concrete surface with a grinding wheel or stone, before hammer testing.

- To avoid local variation in concrete surface, 16 rebound per location shall be taken on approximately 150 x150 mm area of concrete. (As per British standards)
Schmidt Rebound Hammer

Do’s & Don’ts

- Always use calibrated rebound hammer.
- The type of cement used for making the concrete should be checked. Hammers are generally calibrated for OPC.
- Rebound hammer test should not be conducted on rough surfaces.
- The point of impact of rebound hammer on concrete surface should be at least 20mm away from edge or shape discontinuity.
- Surface carbonation of concrete shall be taken into consideration while interpretation of results.
- Should not be used on repaired or wet concrete portion.
Impression marks of Rebound Hammer on the POP surface of a beam.
Schmidt Rebound Hammer

Advantages

• Quantitative assessment of compressive strength of concrete up to one year age can be carried out reasonably accurately.

• Qualitative assessment of surface hardness of concrete can be carried out very effectively, particularly for fire damaged structures.

• This instrument is handy and inexpensive for assessing compressive strength of concrete.
Schmidt Rebound Hammer

Disadvantages / Limitations

• Since the instrument measures the Rebound number of surface concrete it does not take into account the effects of voids or porosity below the cover zone.

• Not useful for concrete made out of blended cement, needs special calibration.

• Not useful for carbonated surfaces.
Rebound Hammer Test on Girder of the bridge using an MBIU

Rebound Hammer Test on bottom of deck slab of bridge
**Coring**

**Principle**

- Cylindrical shape concrete samples are extracted from hardened concrete by diamond segmented concrete core drill machines.
Coring

Applications

Extracted cylindrical shape specimen can be used for following tests

• Assessment of present in-situ compressive strength of concrete member.
• USPV on stress/strain free concrete for calibration
• Carbonation/Chemical analysis
• Density of Concrete
• Visual Inspection
• Petrography
• Depth & crack width inspection
Coring

Do’s & Don’ts

• Correct diameter core bit shall be used for extraction. (Min. 3 times of the max. size of aggregate)

• Avoid coring in damaged or deteriorated structure.

• Core shall be extracted for required length only. Excess coring shall be avoided.
Coring

Do’s & Don’ts

• Capping is necessary for evaluation of compressive strength. Capping material should have more strength than the concrete to be tested. Capped surfaces shall be at right angle to the axis of specimen and shall not depart from the plane by more than 0.05 mm.

• Transportation of extracted specimen from site to Laboratory is important, it has to be handled carefully.
Coring

Advantages

• This is the only test which provides direct compressive strength of in-situ concrete.

• Other lab tests such as carbonation, chemical analysis for Cl, SO₄, pH, assessment of cement content, visual inspection, USPV can be carried out on extracted sample.

• The hole left after coring can be inspected by Endoscope for assessing the quality of concrete.

Contd…
Coring

Advantages / Usages

• Various diameter holes can be extracted in concrete for various pipe lines required in structure.

• Small diameter holes are extracted for tendon duct bar locator, strengthening jobs of old RCC structures like external prestressing etc.
Disadvantages / Limitations

• It is extremely difficult to rectify the reinforcement once cut while coring.

• Improper instrument may induce micro cracking.

• Requires skilled and trained operators and Technicians.
Coring

25mm. Dia core drill to check depth of carbonation

Extraction of concrete core (100mm.Dia) for compressive strength test
Coring

Core Extraction of Pier – Smaller diameter for sampling for Tests - Chemical / Carbonation/ etc.

Core Extraction of Overlay / Deck slab. Higher Diameter for Compressive strength
Coring
Concrete Carbonation:
A Reaction between carbon di oxide in atmosphere and calcium hydroxide in concrete
Carbonation test performed on Extracted concrete core
Cover meter or Magnetometer test

Covermeter

Principle

- An electromagnet, when comes in contact with magnetic substances, generates current depending upon the overlap of magnetic fields.
Cover meter or Magnetometer test

Application

• It is useful to detect the position and cover of embedded reinforcement in concrete.

• Rebar dia also can be detected.

• Useful in preparing structural drawings of RCC structures.
Cover meter or Magnetometer test

Calibration

• Instrument may be calibrated with the calibration specimen provided by manufacturer.
Cover meter or Magnetometer test

Do’s & Don’ts

• Test to be conducted by trained technicians under supervision of trained engineers.

• Test to be conducted on smooth surface of concrete.
**Cover meter or Magnetometer test**

**Advantages**

- Reasonably accurate instrument for preparing basic structural drawings of RCC structures.
- Useful in projects where vertical extension is proposed to RCC structure.
- Pre-stressing tendons and secondary reinforcement also can be detected using special probes.
Cover meter or Magnetometer test

Disadvantages / Limitations

• Not very useful in case congestion of R/F.

• Not very accurate and time consuming for bar diameter evaluation.

• Requires structural engineer’s assistance in correct evaluation of test results.
Cover meter or Magnetometer test

Covermeter /Magnetometer test in process
Cover meter or Magnetometer test

Covermeter /Magnetometer test in process
Half Cell Potentiometer
**Half Cell Potentiometer**

**Principle**

The electrical potential difference between the steel rebars and a standard portable reference electrode in contact with the concrete surface is measured. The half cell is usually Copper/ Copper Sulphate. The concrete functions as an electrolyte and the corrosion of reinforcement in immediate region of the test location may be related empirically to the measured potential difference.
Half Cell Potentiometer

Applications

• To measure probability of corrosion of reinforcement inside the concrete.

• The half-cell is usually copper/copper sulphate cell.

• The bar is connected to the positive terminal of the voltmeter (Cathode) and half-cell end to the negative terminal of the voltmeter. (Anode)

• The concrete functions as an electrolyte.

• ASTM C876-91, the Standard test method.
Half Cell Potentiometer

Calibration

- Calibration of milli-voltmeter is essential.

Site Preparation

- R/F shall be exposed locally in the RCC member subjected to test.
- The concrete surface shall be kept wet uniformly before commencement of potential measurement.
Half Cell Potentiometer

Do’s & Don’ts

• Exposed steel bar must be cleaned with a polish paper before making electrical connection to ensure low electrical contact resistance.

• Concrete surface shall be kept wet using electrical contact solution such as liquid detergent thoroughly mixed with potable water.
**Half Cell Potentiometer**

**Advantages**

- Inexpensive equipment for detecting probability of corrosion.
- This testing can be done on any RCC member regardless of its size or depth of concrete cover.
- This test can be used at any time during life of concrete member.
Disadvantages / Limitations

• This instrument cannot be used for prediction of percentage corrosion or rate of corrosion of R/F. (Limitation of technique)

• Testing requires extensive prewetting of concrete surface and hence not very convenient for slab soffit and beam of residential structures which are occupied.
Half Cell Potentiometer
Half Cell Potentiometer
Moisture meter

Principle

Moisture content by moisture meter is determined by measuring electric resistance.

The resistance probe method involves measuring the electrical resistance of a material, which decreases as the moisture content increases. It consists of two closely spaced probes and a meter battery assembly enclosed in a housing. The probes are usually insulated except at the tips so that the region being measured lies between the tips of the probes.
Moisture meter

10.9%

10.00%

17.9%
Chemical Analysis
Chemical Analysis

Applications & Limitations

• Sampling shall be adequate, free from contaminants and reinforced steel

• Experience concrete analyst should be employed

• At least 4 – 5 samples are recommended for volumes up to 10 m$^3$ of concrete

• Generally Chloride and sulfate content are estimated. (BS 1881- Part 124)

• Aggregate cement ratio can be estimated provided cement used is OPC cement

( ASTM C-1084)
Petrographic Examination of Concrete
Petrographic Examination of Concrete

Thin section of concrete- 30µm

Basalt rock under microscope
Petrographic Examination of Concrete

Well compacted concrete

Alkali Silica Reaction
Petrographic Examination of Concrete

Applications

• Aggregate Type & Composition
• Quality of Aggregates
• Presence of Deleterious materials/alteration
• Cement clinker quality
• Phase composition
• Degree of Cement Hydration
• Presence and Relative Abundance of Fly Ash
• Presence and Relative Abundance of Slag Cement
• Total Air Void Content & their distribution, size & shape
• Alkali Silica Reaction etc.
Petrographic Examination of Concrete

Limitations

- Expertise is essential
- Set up is costly
- Accuracy of method depends on sampling of the concrete
- Thin section preparation is lengthy process, this needs expertise
- Background of the project must be known for correct interpretation
Load test

Principle

Test is conducted by loading a structure for specified load & measuring the responses of the member.

• Full load test
• Incremental load test
• Load test to failure.
Do's & Don'ts

• Safety of the structure – Avoid permanent damage

• Residual deflection

• Response measurements, such as deflection, strain, slip, and crack width, shall be made at locations where maximum response is expected. Additional measurements shall be made if required.
Load test

Applications

• Structural Strength evaluation of the existing structure

• To determine the ability of the structure to carry out additional load

• To establish safety of the structures

• To validate strengthening

• To gain knowledge on the behavior of a structure

• To supplement, validate or refine analytical model work.
Load test

Industrial Premises
Load test

Industrial Premises
GPR Survey

Principle:

GPR is a non-destructive technique that emits a short pulse of electromagnetic energy, which is radiated into the subsurface. When this pulse strikes an interface between layers of materials with different electrical properties, part of the wave reflects back, and the remaining energy continues to the next interface. GPR evaluates the reflection of electromagnetic waves at the interface between two different dielectric materials. The penetration of the waves into the subsurface is a function of the media relative dielectric constants ($\varepsilon$).

Application:

- To find out the thickness, voids, cracks, overlay thickness, positions of r/f steel.
- To locate underground utilities

Antennas:

1000 MHz – up to 500mm and 500MHz - up to 4.0m depth.
GPR Survey of different Metro structure, such as Flyover and Tunnel
GPR Survey of deck slab

GPR Survey of Pier
GPR Survey
GPR Survey
GPR Survey

Survey of roads

Survey of Industrial plant
GPR Survey

GPR Image

&

Core Sample

Appendix 1.22: GPR Image for Span P26 to P29 (b)
Durability Test

Rapid Chloride Penetration Test
Durability Test

Rapid Chloride Penetration Test

Principle:

The resistance of concrete against chloride is categorized by the total charge passing through the specimen in the first 6 hours.

The rate of ionic transport is measured and using Fick’s first law of diffusion the diffusion coefficient is calculated.
Durability Test

Rapid Chloride Penetration Test

Application :
• To assess the corrosion of the concrete
• To evaluate the performance of repair materials
• To evaluate service life of the concrete structure

Advantages :
• Is relatively quick—can be used for quality control
• Has simple and convenient setup and procedures
• Provides results that are easy to interpret
• Correlates well with 90-day chloride ponding test
Limitations:

• The temperature rise due to the high voltage can significantly affect the conductivity of ions and, hence, the final result in Coulombs.

• This test method does not replicate actual conditions that concrete would experience in the field. There is no condition where concrete is exposed to a 60-volt potential.

• The current that passes through the sample during the test indicates the movement of all ions in the pore solution (that is, the sample's electrical conductivity), not just chloride ions.
Durability Test

Water Permeability Test (DIN 1048)
Durability Test

Water Permeability Test (DIN 1048)

Principle:

• In this method the hydraulic head is applied by pressure which usually ranges between 0.1 and 0.7 MPa. The depth of penetration is found by observation of the split surface of the test specimen after a given length of time.

• The depth of penetration is used as a qualitative assessment of concrete.

• A depth of less than 50 mm classifies the concrete as impermeable and a depth of less than 30 mm as impermeable under aggressive conditions.
Durability Test

Water Permeability Test (DIN 1048)

Applications:
- To assess the porosity of the concrete
- To evaluate the performance of repair materials
- To evaluate service life of the concrete structure
- To assess the quality of the concrete mix.

Advantages:
- Is relatively quick—can be used for quality control
- Has simple and convenient setup and procedures
- Provides results that are easy to interpret
Limitations:

- It gives qualitative estimation of the concrete.
In – Situ Durability Test

• Permit Migration Test

• Autoclam Permeability Test
In – Situ Durability Test
Permit Migration Ion Test
In – Situ Durability Test

Permit Migration Ion Test

Permit ion migration test in process
**In – Situ Durability Test**

**Permit Migration Ion Test**

**Principle:**

The chloride ions move from the catholyte (Catholyte is the electrolyte on the anode side of cathode) towards the anolyte (Anolyte is the electrolyte on the anode side of anode.) through the concrete due to the application of an electric field. The chloride movement is monitored by conductivity of the anolyte solution and the in situ migration coefficient is evaluated by a modified Nernst-Planck equation.
In – Situ Durability Test

Permit Migration Ion Test

Applications:

• Measures ionic diffusivity to enable SERVICE LIFE PREDICTION of reinforced concrete structures.
• It is particularly suited to assess the susceptibility to chloride induced corrosion of steel.
• It is non-destructive, easy to use and portable for site use
• Allows tests to be completed within a day on site even for the most impermeable concrete encountered.
• Assess the effectiveness of mineral admixtures improving chloride resistance

Advantages:

• It measures ionic diffusion resistance of the near-surface zone of concrete and other building materials, including natural stone, without causing damage
• No need to extract cores from structures for laboratory testing for this property.
In – Situ Durability Test

Permit Migration Ion Test

Limitations:

- It is expensive
- Need trained & experienced personnel for computation of the results.
In – Situ Durability Test
Autoclam Permeability Test
IN – SITU DURABILITY TEST

Autoclam Permeability Test

Principle:

- Measures air and water permeability and water absorption into the near surface zone of concrete and other building materials, including surface repair materials, without causing damage.

- The rate of decay of air pressure is recorded for the air permeability test, whereas the volume of water penetrating into the concrete, at a constant pressure of 0.01 bar and 1.5 bar are recorded for the sorptivity and the water permeability tests respectively.
Applications

• Assessment of resistance to carbonation.
• Prediction of salt induced corrosion of steel in concrete.
• Determination of freeze-thaw deterioration and salt scaling.
• Measurement of the effect of curing of concrete.
• Measurement of the influence of special formworks, such as controlled permeability formwork.
• Quality assurance of building materials.

Advantages

• It can be tested both at site and laboratory without causing damage to the structure.
• It is an exceptionally good tool for assessing the durability of these surfaces when exposed to normal or aggressive environments.
• It works equally well on inclined, vertical and horizontal surfaces.
IN – SITU DURABILITY TEST

Autoclum Permeability Test

Autoclum permeability test in process
IN – SITU DURABILITY TEST

Limpet Pull out test
Principle:

- The pull-off method involves bonding a circular steel probe to the surface of the concrete under test, by means of an epoxy resin adhesive.

- Two basic approaches can be used. i) The metal disc is attached directly to the concrete surface. ii) Partial coring of the surface is used for concrete surface which is carbonated or altered and, therefore, having different physical properties compared with the interior.

- A slowly increasing tensile force is then applied to the probe and, so long as the tensile strength of the bond strength in adhesive is greater than the tensile strength of concrete, the latter will eventually fail in tension.
IN – SITU DURABILITY TEST
Limpet Pull out test

Applications :

• Determination of concrete strength in situ
• Assessment of the extent of damage to concrete due to deterioration mechanisms acting on concrete structures
• Monitoring the effect of microcracking on strength of building materials
• Assessment of the bond strength of patch repairs
• Determination of the effect of shrinkage and settlement cracking on strength of concrete
• Quality assurance of building materials

Advantages :

• Is equally suitable for on site and laboratory use.
• Is particularly suited when a strength result is required quickly and with minimal damage
• Measures the strength of concrete in situ and of materials used to repair them
• Works equally well on vertical, inclined and horizontal surfaces
• Is very light, easy to handle and so is very suitable for site use
IN – SITU DURABILITY TEST

Limpet Pull out test

Limitation:

Performance of the test depends on adhesive used to fix the disk.
IN – SITU DURABILITY TEST

Limpet Pull out test

Pull off test in process