



Repair & Diagnostic Methods for RCC Structures

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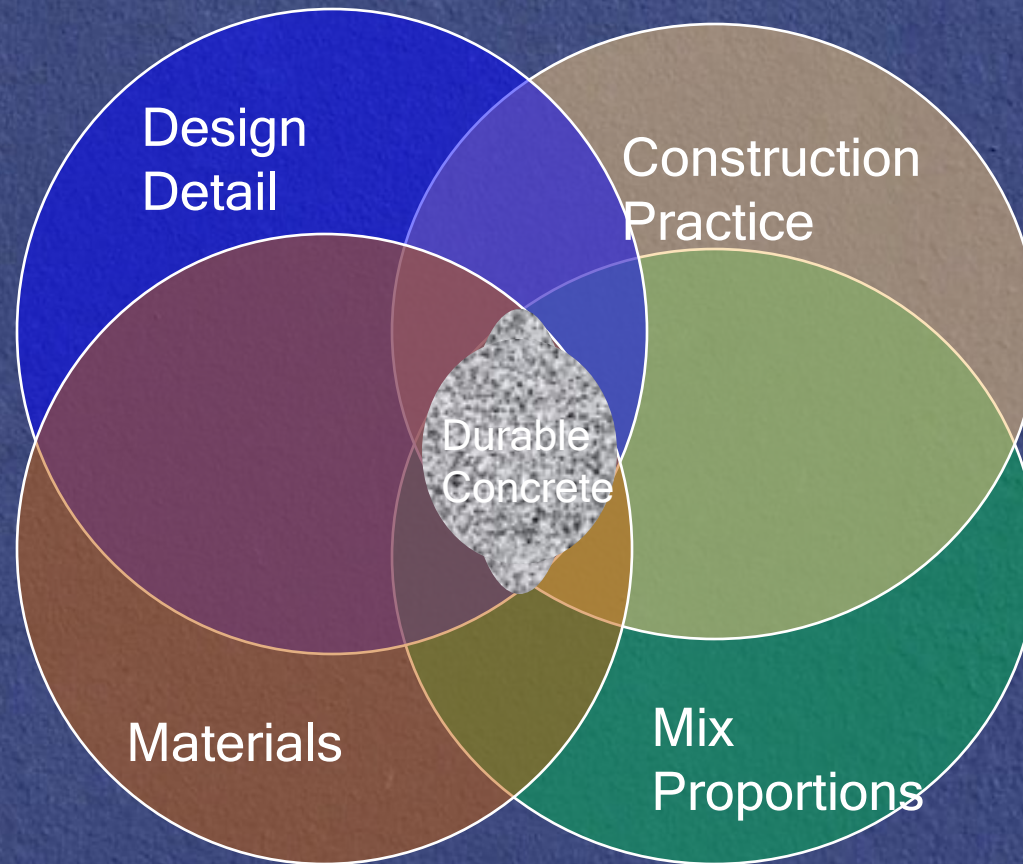
Content

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- Service life & Deterioration
- Causes of Repair Failures
- Advanced Diagnostic Methods
- Application of NDT for Durable Repair
- Summary

Service Life Requirements for Concrete Structures-ISO 2394 & EN1990

Class	Notional Design Service Life (Years)	Example
1	1-5	Temporary Structures
2	25	Replaceable Structural Parts
3	50	Building Structures and other common structures
4	100	Monumental Building Structures, Bridges and other Civil Engineering Structures.

Durable concrete



Cause of Deterioration

Whether the cause is corroding rebar, poor resistance, high impact, abrasion, chemical attack or other reasons, addressing and correcting the cause of deterioration is the primary requirement in a durable repair.

MECHANICAL

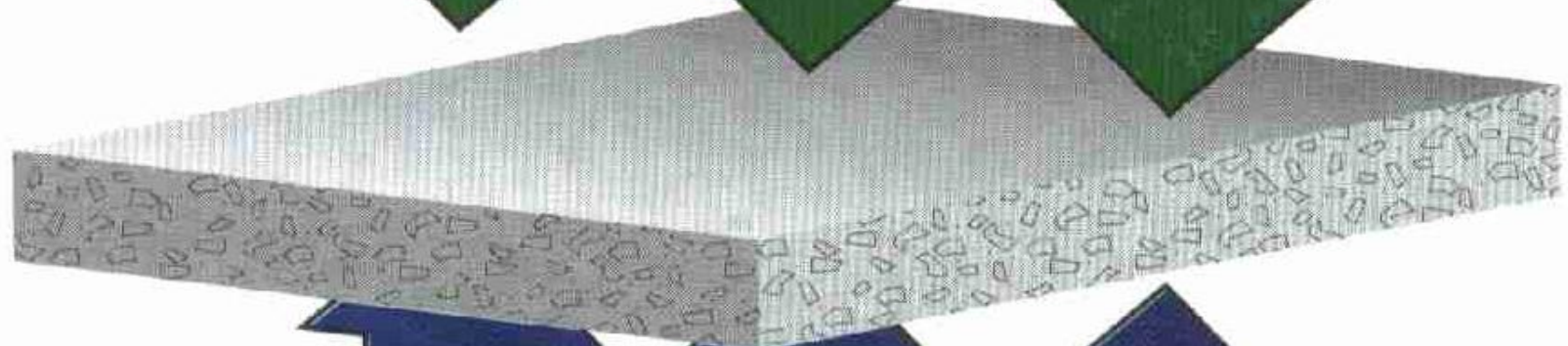
- Live Loads
- Dead Loads
- Abrasion

PHYSICAL

- Settlement/Heave
- Humidity
- Impact damage

**CHEMICAL/
BIOLOGICAL**

- Acids, Alkalies
- Oils
- Microorganisms



- Assumptions
- Standards
- Dimensioning

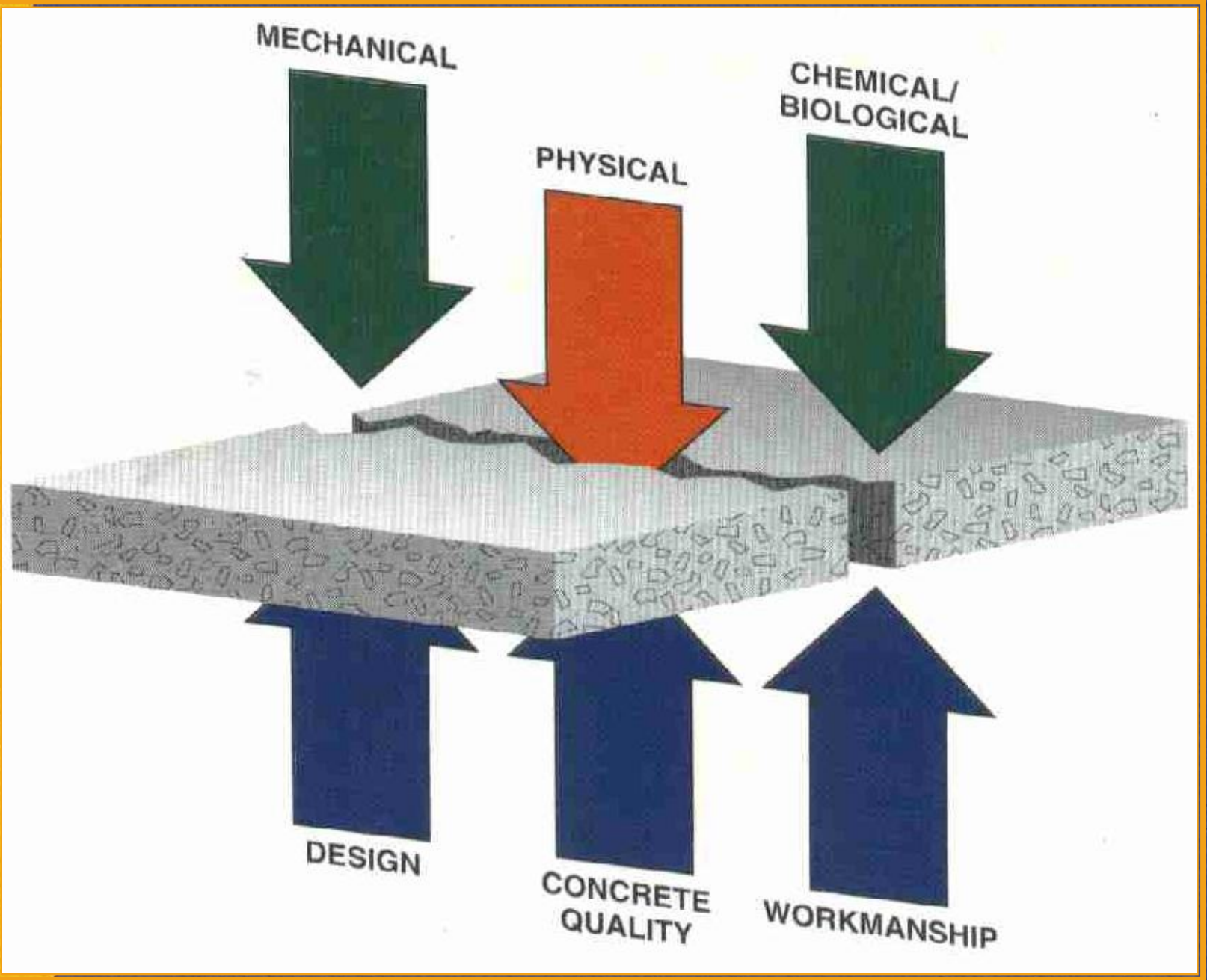
DESIGN

- Mix Design
- W/C Ratio
- Admixtures

**CONCRETE
QUALITY**

- Placing
- Finishing
- Curing

WORKMANSHIP



MECHANICAL

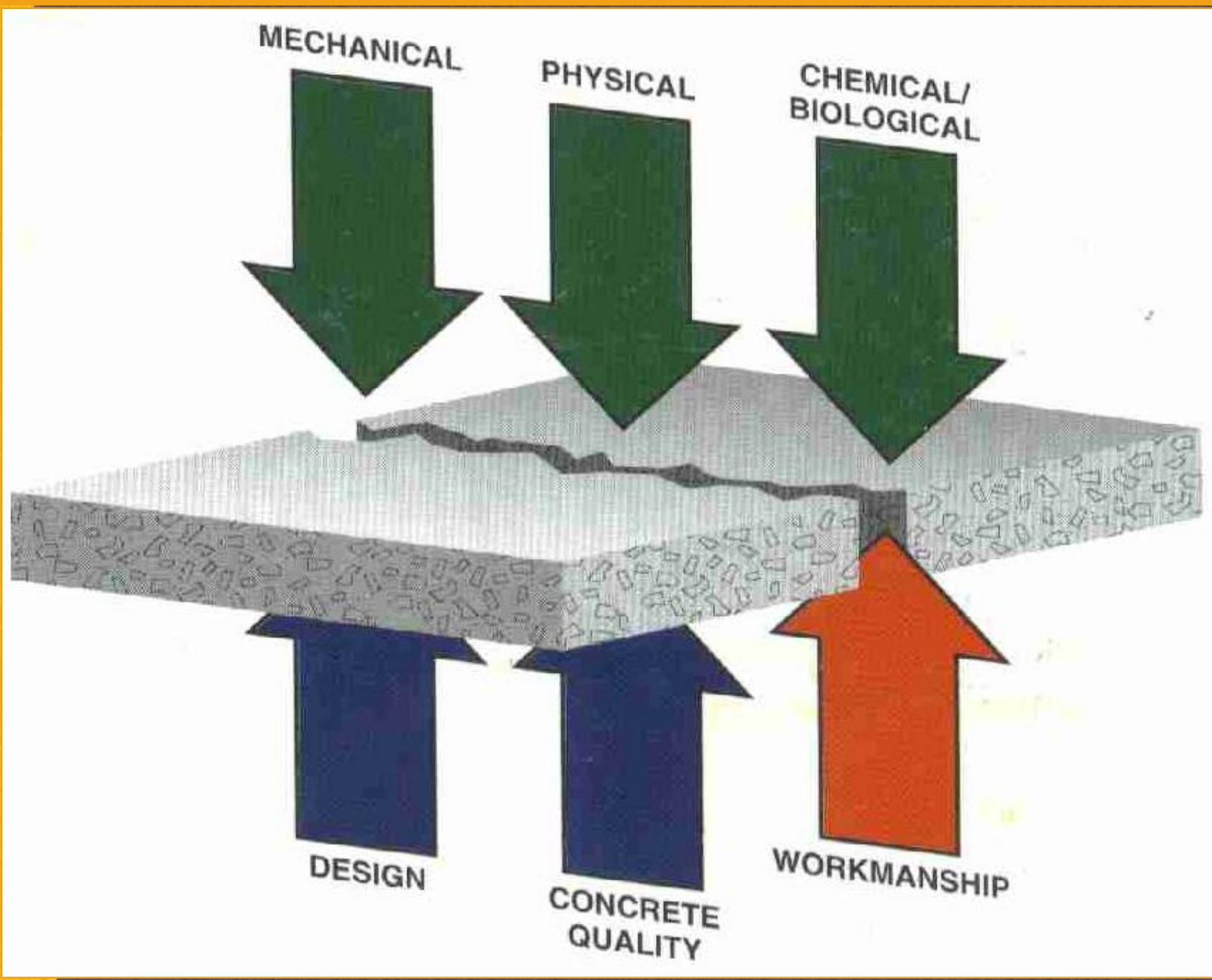
CHEMICAL/
BIOLOGICAL

PHYSICAL

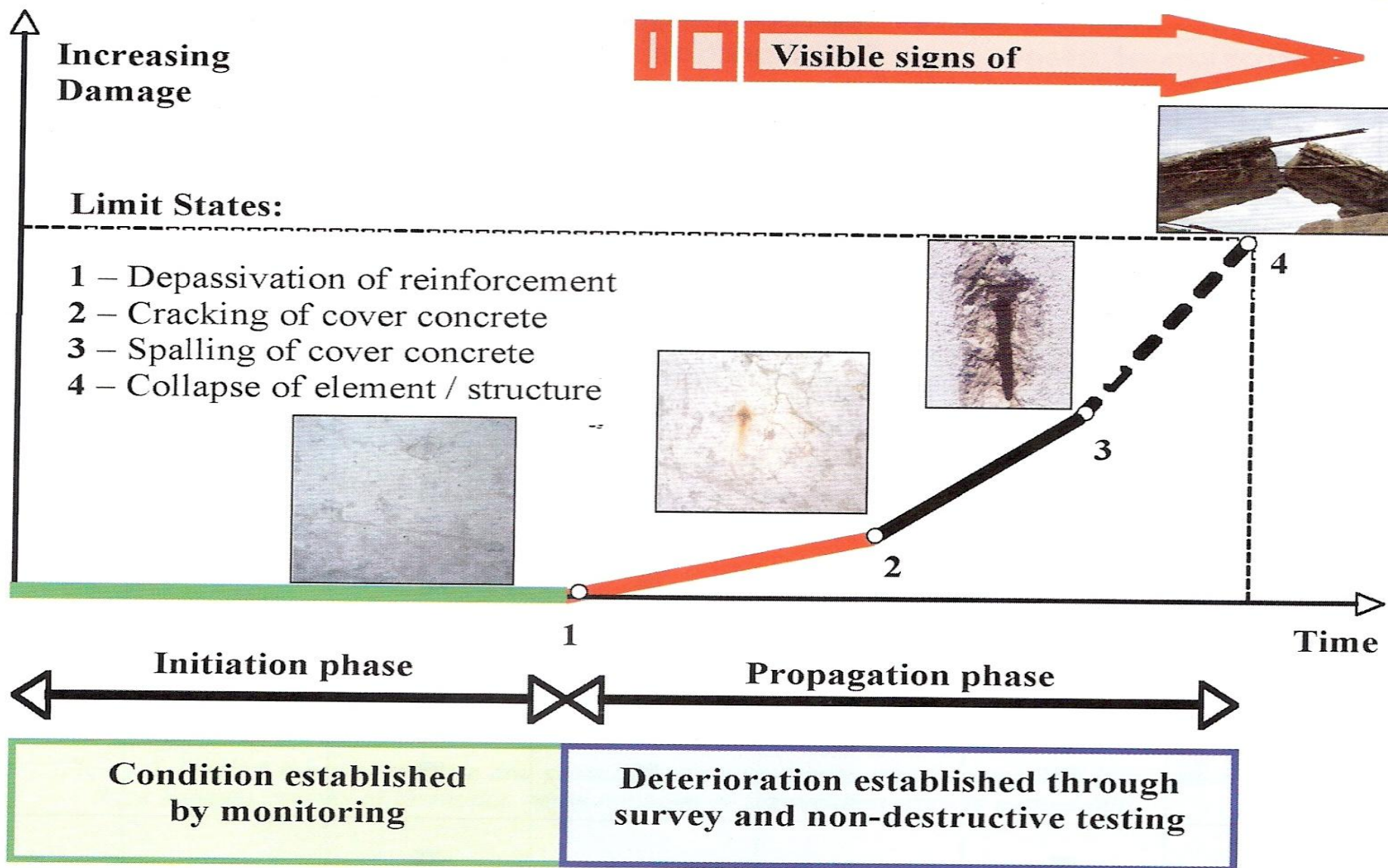
DESIGN

CONCRETE
QUALITY

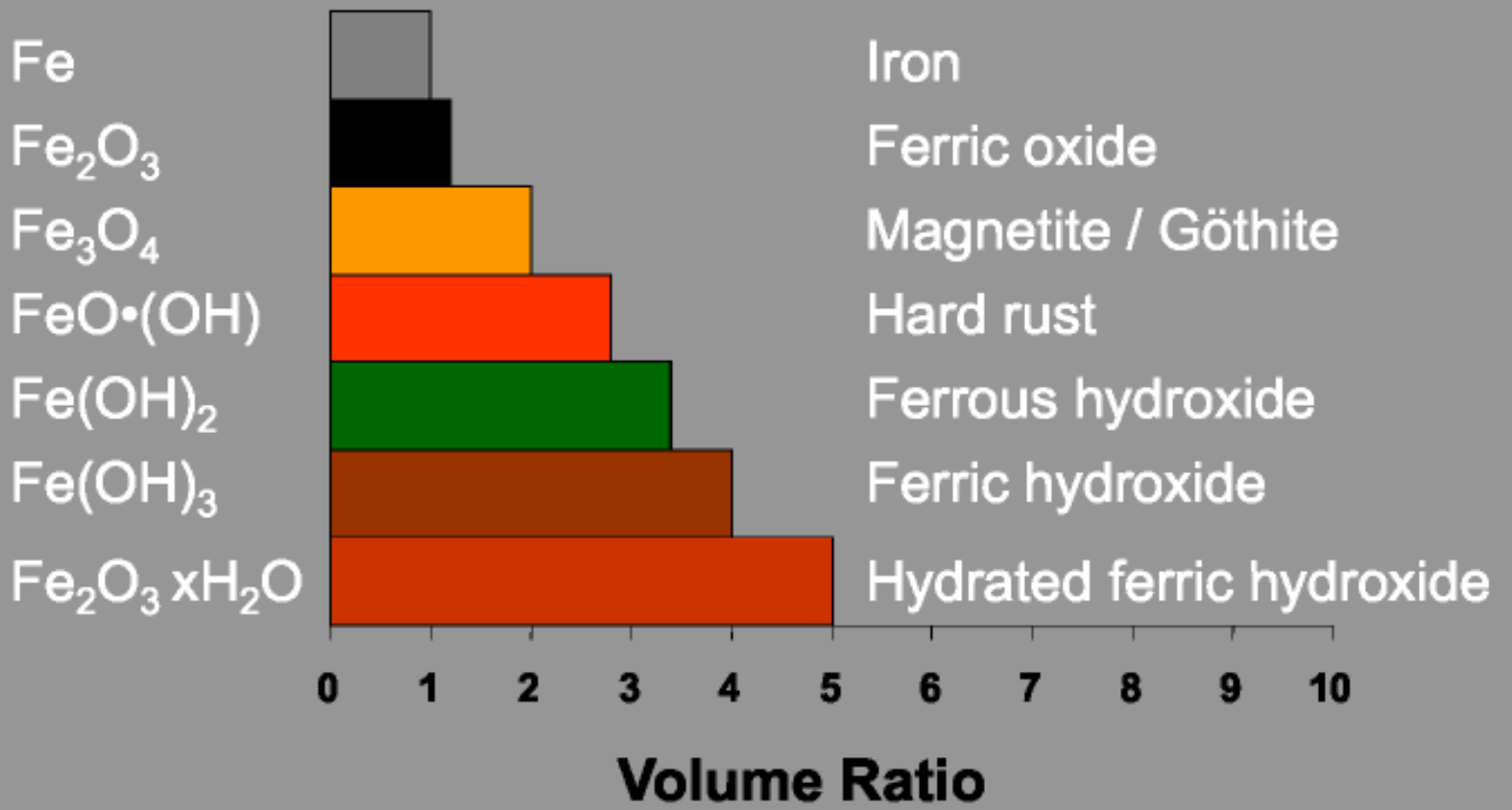
WORKMANSHIP



Induced Deterioration of a Concrete Structure



Corrosion process



Stages of corrosion induced

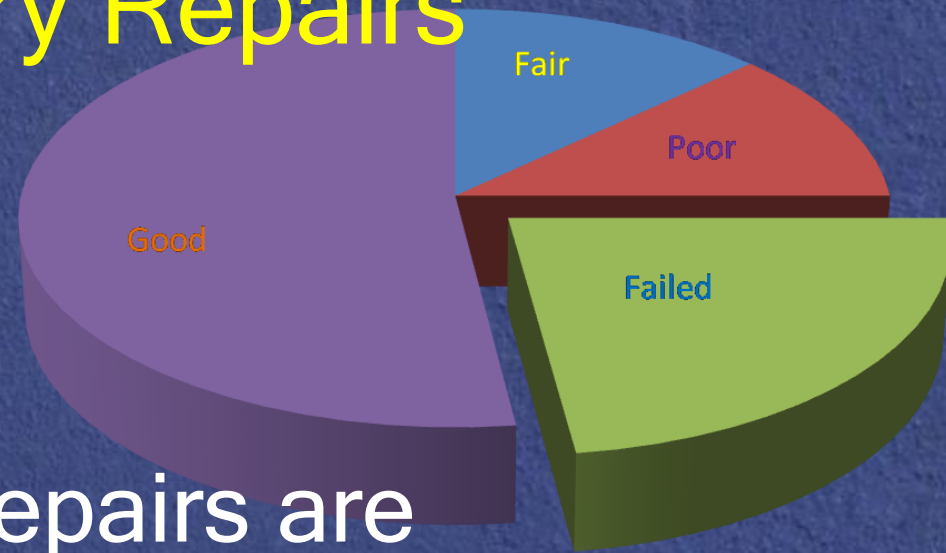
- Initiation Phase - Condition established by monitoring
- Propagation phase - Deterioration established through survey and NDT

Causes of Repair Failures

It is very difficult to identify a single cause for a particular failure, since, frequently. There are several reasons which are inter-related,

- Incorrect design of the repair
- Use of incorrect materials
- Poor workmanship
- **Wrong diagnosis**
- Other factors

Unsatisfactory Repairs



- The failure of repairs are attributable to -
 - Design or **Evaluation errors,**
 - Installation or Application errors
 - Materials Performance

* Source :- U.S.Army Corps of Engineers

Approach to Repair

- Investigate the causes & identify the problems and understand
- Use NDT methods to understand damages and defects
- Consider structural and operational requirements to select the repair method
- Selection of right Repair Materials with appropriate methodology

Common

Advanced NDT

Schmidt Rebound Hammer

Corrosion Analyser

Ultrasonic Pulse Velocity

Infrared Thermography

Cover Meter

Petrography

Cores

Carbonation Depth

Pull off Test

Schmidt Hammer

- Simplest & Quickest estimation of surface hardness of concrete
- Carbonation is not the only important factor influencing rebound numbers
- The strength estimated from the manufacturer's regression curve is to be multiplied by a time factor.



Corrosion Assessment

- Chloride ion and carbonation testing help to establish whether passive film has been destroyed
- If film not destroyed, when will it be destroyed?
- If film has been destroyed, what is state of corrosion?
- Half-cell potential
- Concrete resistivity
- Corrosion rate (polarization resistance)

Corrosion Rate !

- Chennai 2nd most corrosion prone city - 0.5 mm/y
- Sriharikota - 1.6 milli metres per year mm/y
- Marmogoa - 0.45 milli meters per year mm/y

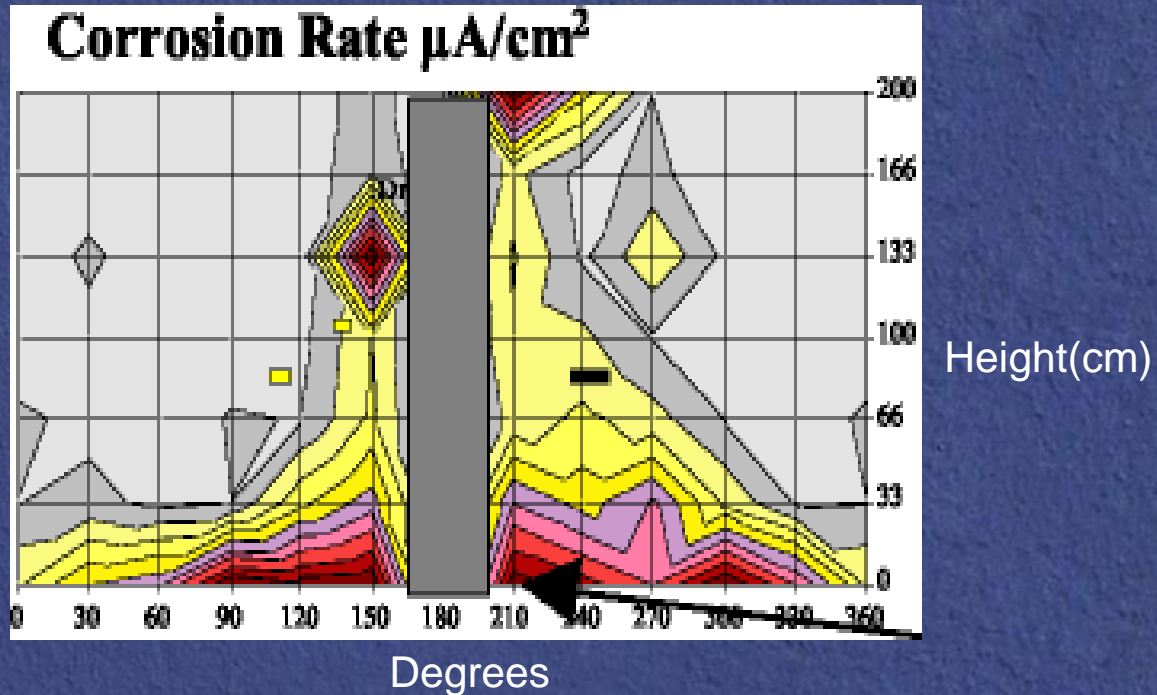
Source :- Study conducted by CECRI, Karaikudi
(1993 - 2003 ~ 33 field stns)

Corrosion Analyser



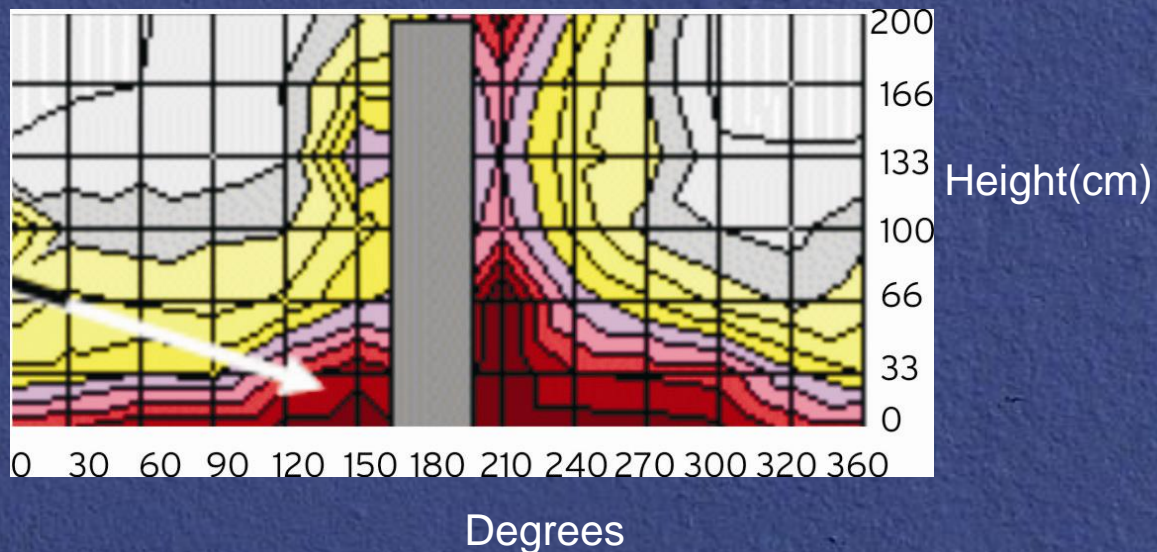
- Potential measurement (potential mapping), corrosion rate measurement, galvanostatic pulse technique (GPM)
- Linear polarisation resistance technique (LPR) and service life estimate.

Rate of corrosion measured on circumference of the column



At the marked point rate of corrosion was $220\mu\text{m}$. For 20 years period@0.22 mm per year = 4.4 mm

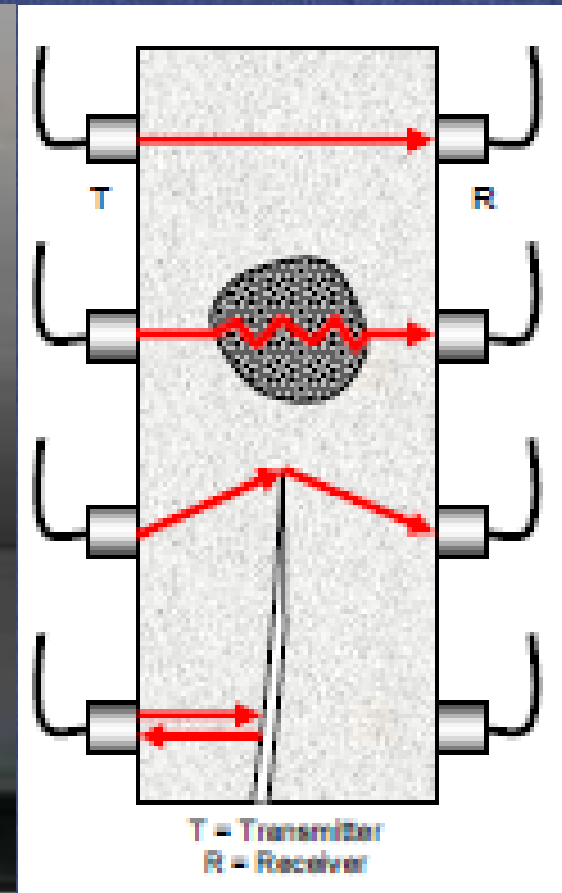
Half cell potential measured on circumference of the column
= - 500 mV



How to locate voids and delamination ?

- Impact-Echo
- Impulse Response Method
- Ground Penetrating Radar
- **Ultrasonic Measurements**
- **Infrared Thermography**
- **Petrography**

- Good for assessing uniformity and identifying areas for further investigation
- To identify the honey combs, voids & cracks inside the concrete



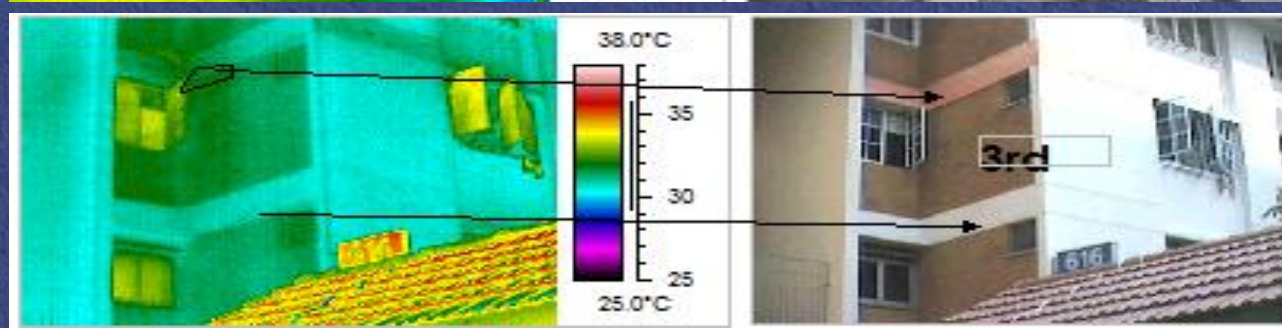
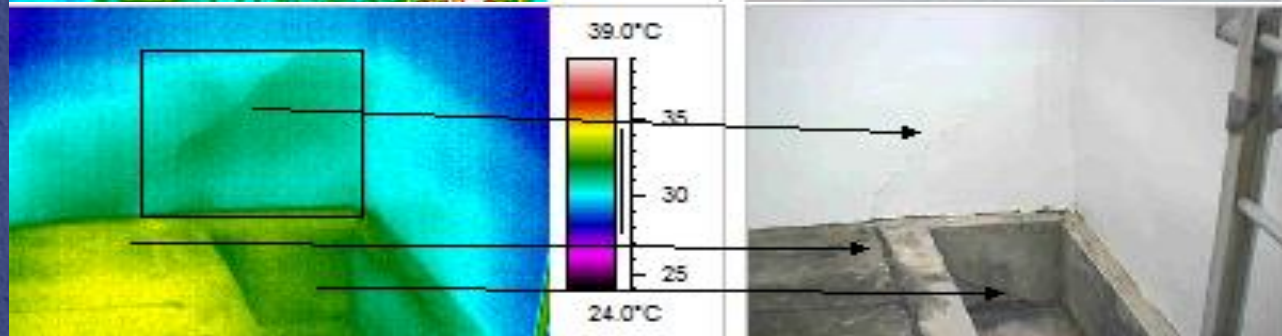
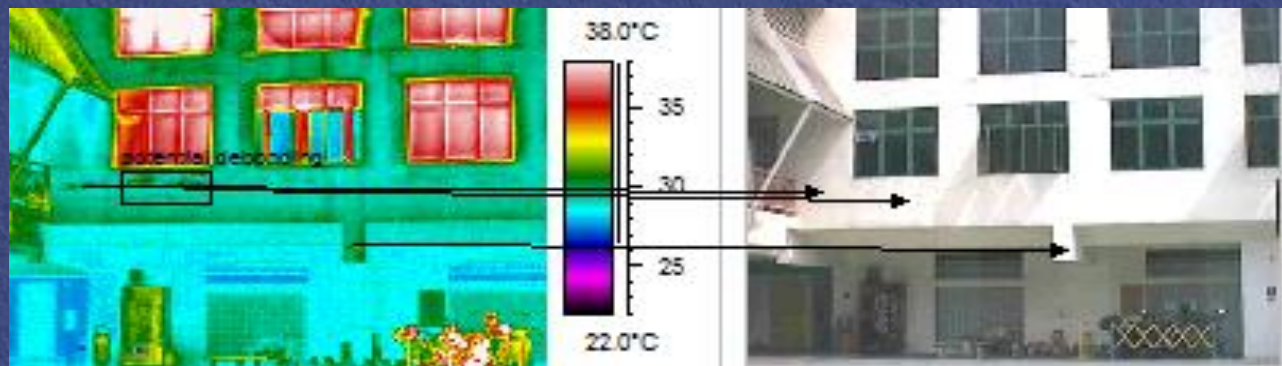
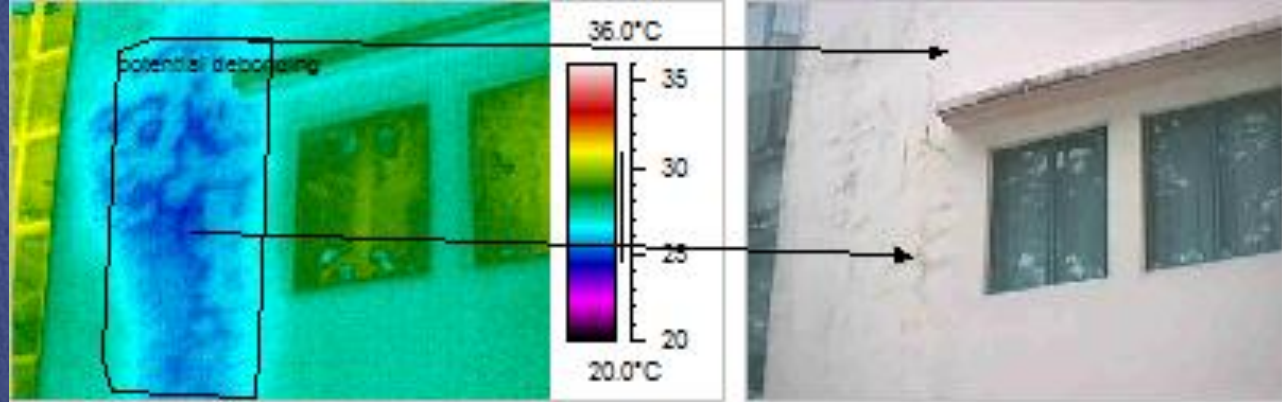
Potential
seepage

Potential
deboning
plaster

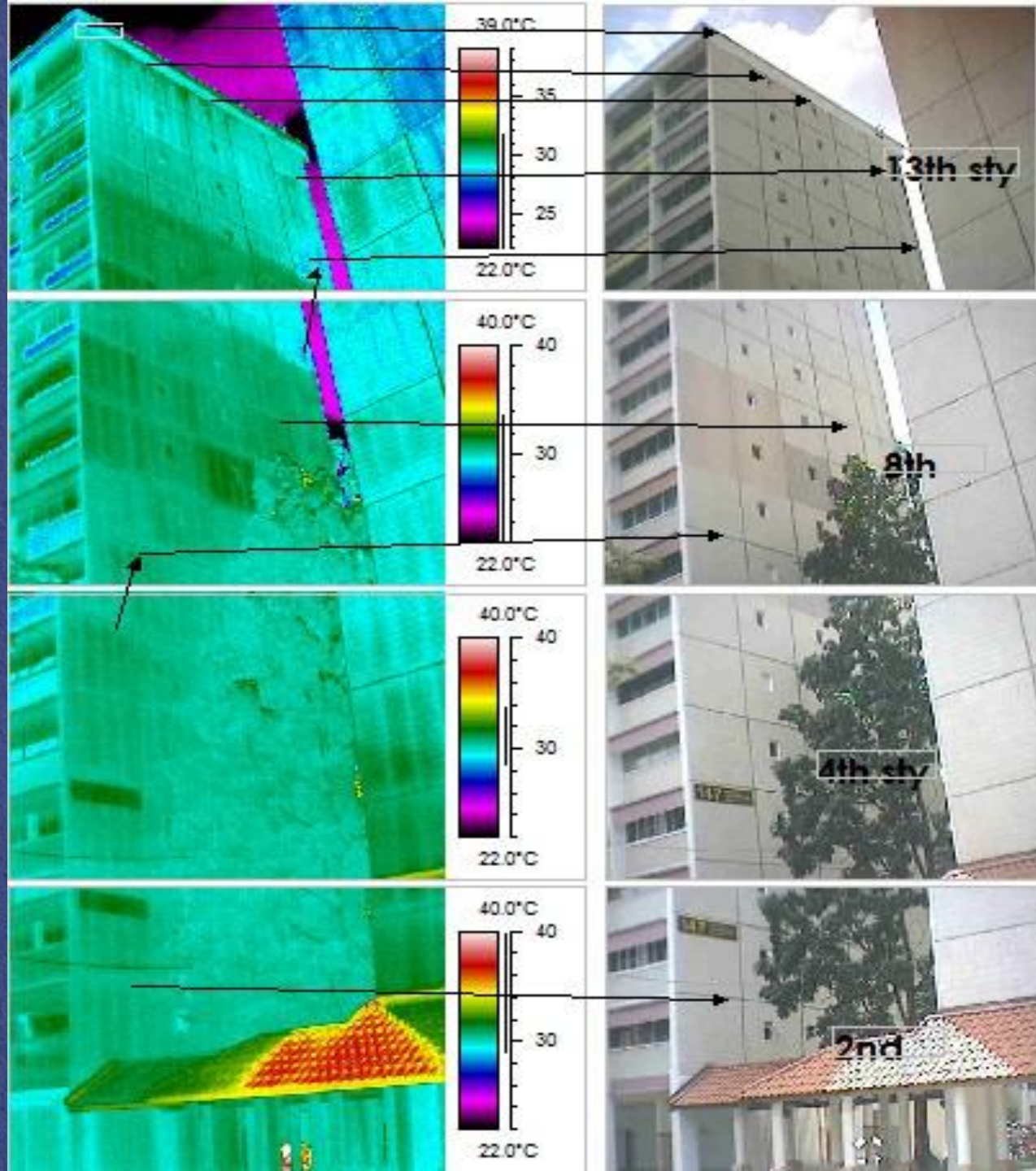
Potential
spalling
concrete



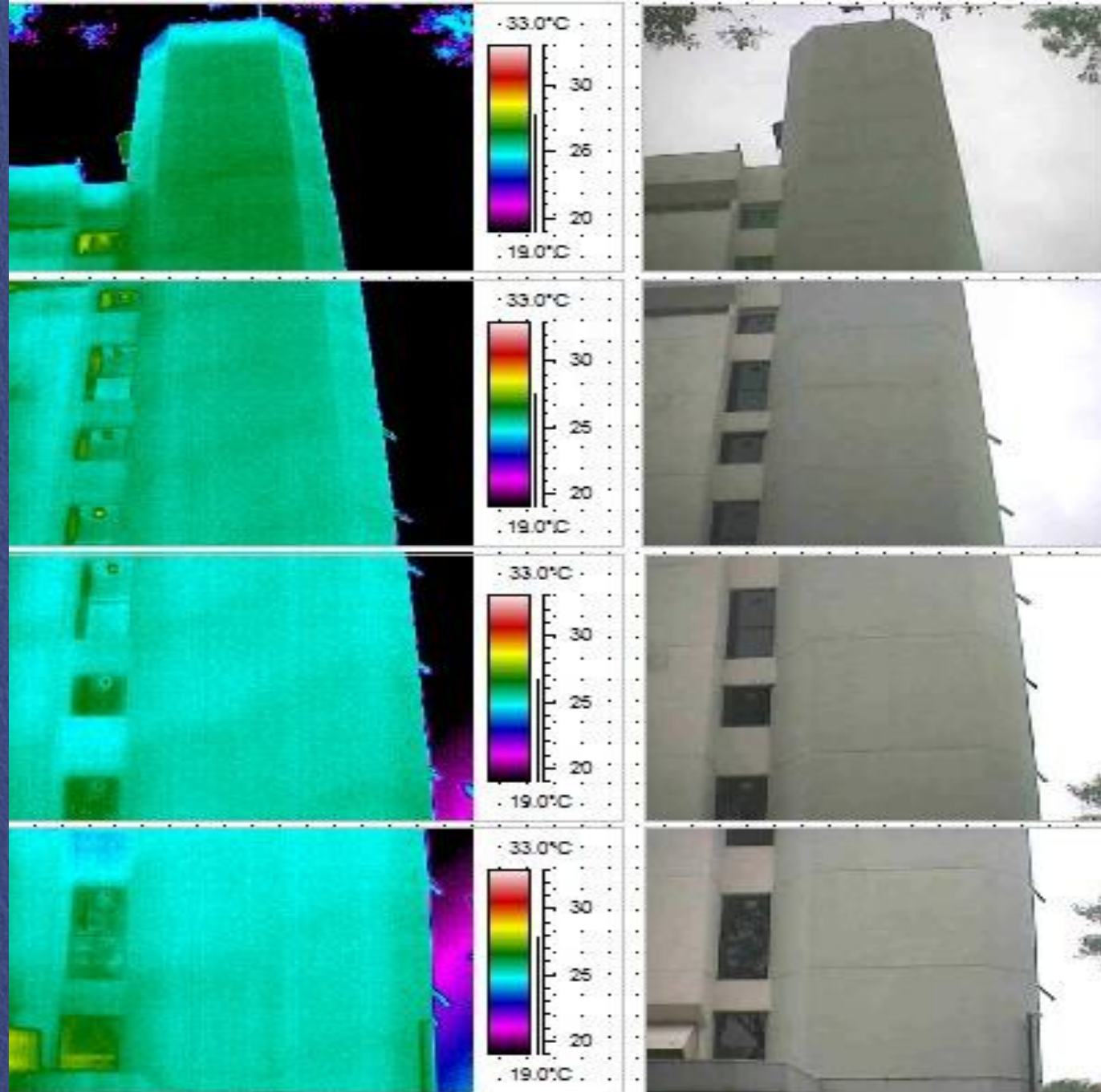
Potential
debonding
plaster to be
hacked and
restored



Seepage
along
groove lines



Facade in good condition, do not require repair works



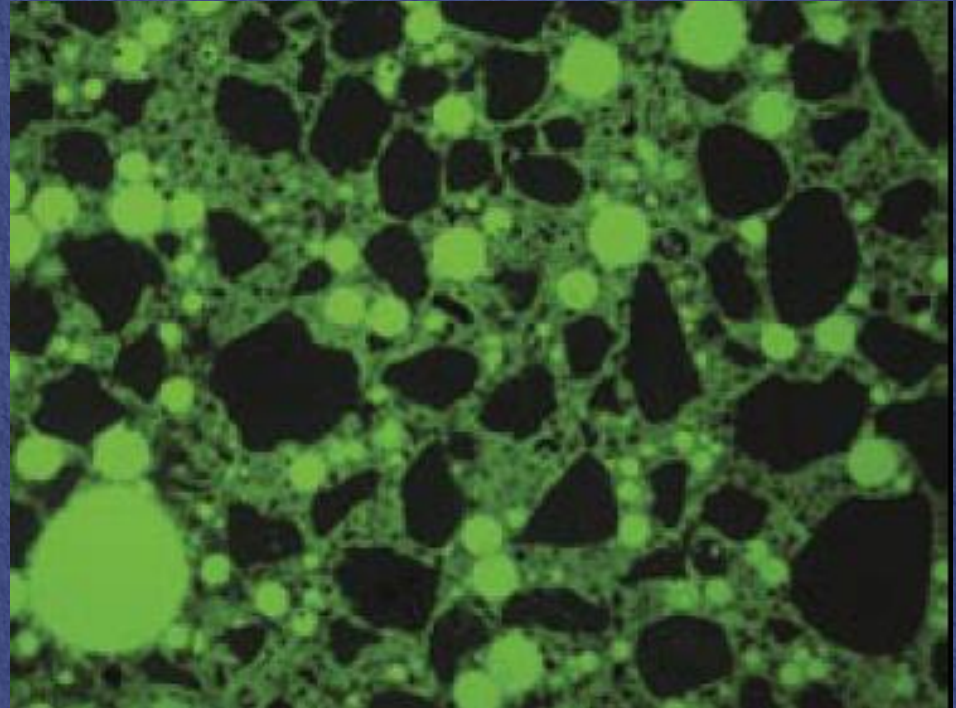
Polarised Optical Microscope



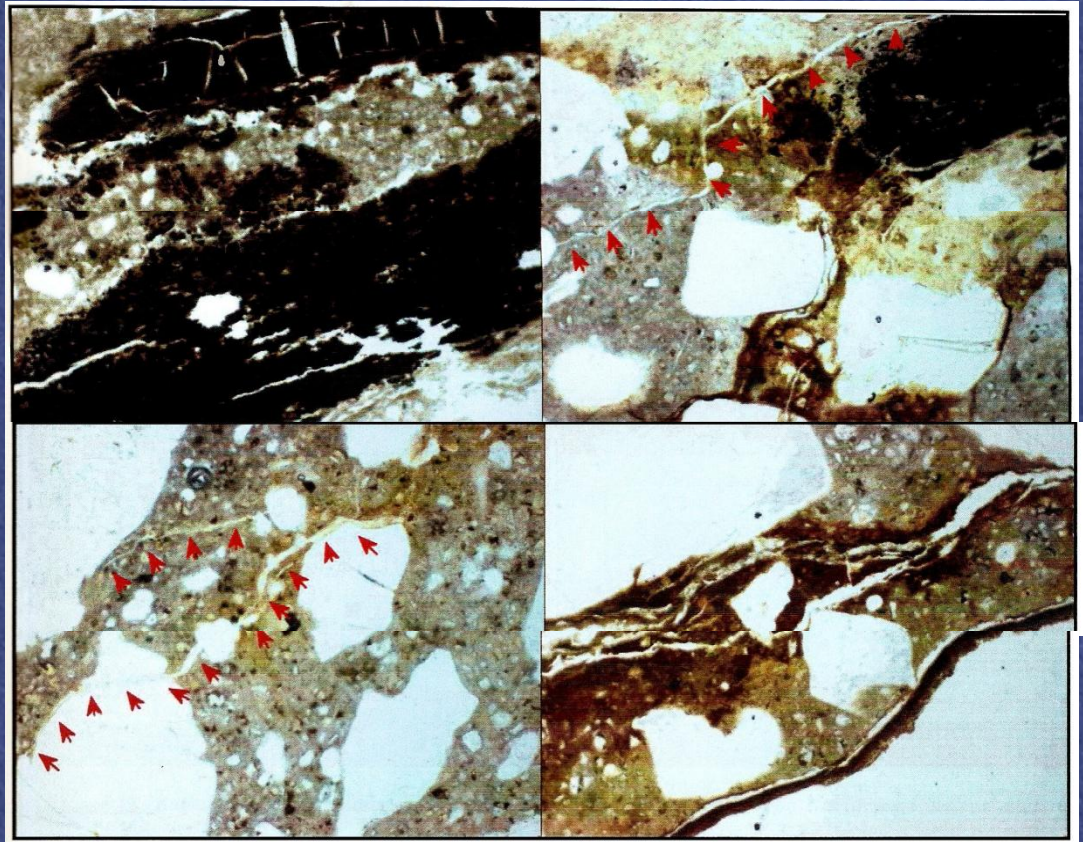
Application of Petrography in Repair

- Alkali Silica Reaction (ASR)
- Chemical Attack
- Delayed Ettringite Formation
- Fire Damage
- Cause of Cracking

Microscope
photo of air
entrained,
homogeneous
concrete



The photograph shows the cracked oxidized pyrite grain at the surface region, and extension of cracking and reddish brown iron oxide and hydroxide oxidation products into the neighboring paste. Field widths of all photos are 5 mm

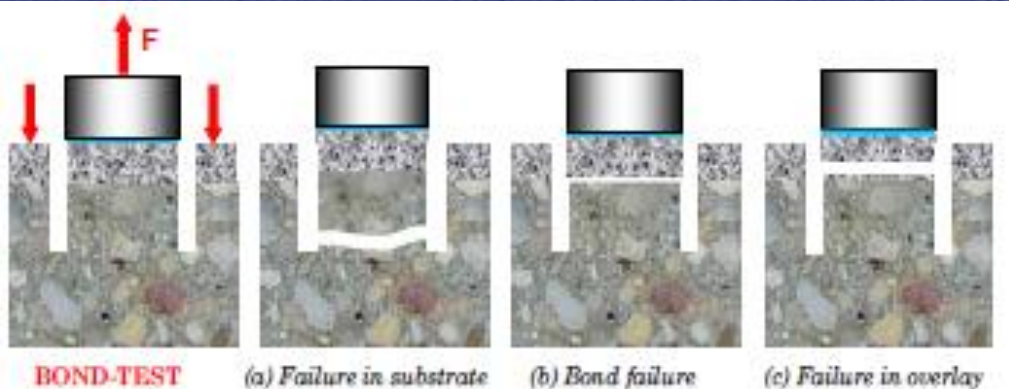
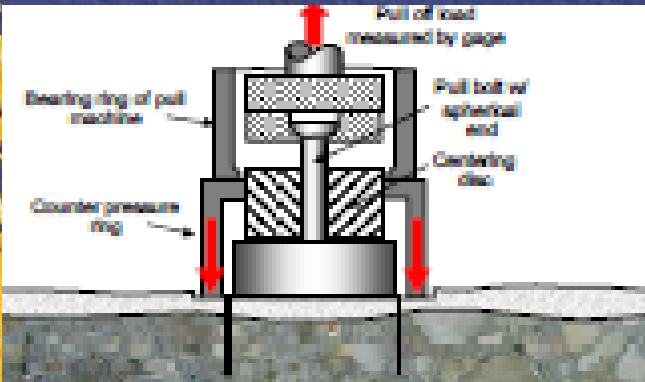


Photomicrographs of thin sections of cores (in plane polarized light mode)

Pull-off Test

ASTM C1583/C1583M

- Direct tensile strength
- Evaluate condition of concrete surface before application of overlay or repair Material
- Measure bond strength of overlay or surface of repair materials



Summary

- Regular Inspections/Monitoring helps early detection of any deterioration
- **Diagnosis of defects and condition assessments are essential pre requisites for a successful concrete repair**
- Advance NDT method helps to locate exactly the place of seepages, leakages, defects, honeycombs, cracks in the structures so that repair becomes durable
- **Repair cost increases without proper diagnosis**

**Thank You for Your
Kind Attention !**