PCA

Concrete Technology and Codes

The Condition Survey and Evaluation of Hardened Concrete

PCA

Portland Cement Association

Evaluation Techniques

- Condition Survey
- Nondestructive Testing
- Analytical Methods
- Destructive Testing

Resources

- ACI 349.3 R- *Evaluation of Existing Nuclear Safety-Related Concrete Structures*
- ACI 364.1 R- *Guide for Evaluation of Concrete Structures Prior to Rehabilitation*
  - Table 6.1a and Table 6.1b

Purpose of Investigation

- Property Assessment
- Determine Future Serviceability
- Conform with Construction Specifications
- Obtain Data for Litigation
- Evaluate Performance of Components
- Establish Methods for Repair or Replacement

Scope of Investigation

- Limited to Isolated Areas of Distress
- Entire Structure

Prioritization

- Safety Significance
- Location/
  Accessibility
- Exposure
  Conditions

Frequency

Table 6.1—Frequency of inspection

Structure category	Frequency of visual inspection
Below-grade structures	10 years (each ISI interval)
Structures exposed to natural environment (direct and indirect)	5 years (two per ISI interval)
Structures inside primary containment	5 years (two per ISI containment interval)
Continuous fluid-exposed structures	5 years (two per ISI structures interval)
Structures retaining fluid and pressure	5 years (two per ISI pressure interval)
Controlled interior environment	10 years (each ISI interval)

Qualifications of Inspectors

- Responsible in-charge:
  - P.E., or civil or structural engineer w/10 years experience
- Personnel performing inspections:
  - Civil or structural engineer w/ minimum 1 year experience; or personnel with 5 years experience

Condition Survey

Determine Extent of Problem

- Visual Observations
- Speak to Construction Personnel
- Records
- Do Not Overlook Details
- Most Problems Are a Combination

- When troubleshooting concrete problems it is important to relate the symptom to causes of distress and deterioration.

Identify Concrete Surface Defects

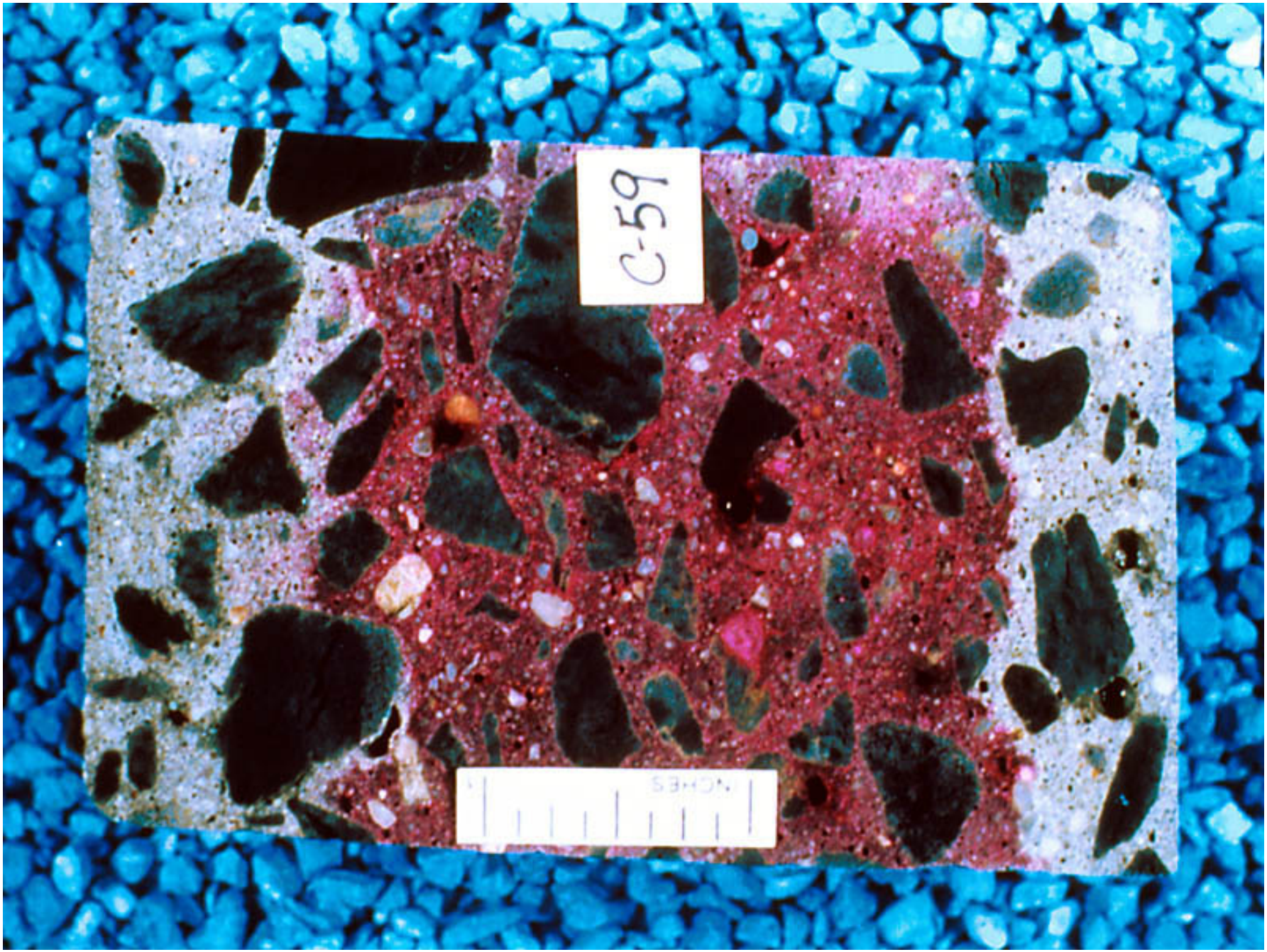
ACI 201.1 R

- Blisters
- Delaminations
- Crazing
- Cracking
- Honeycombing
- Discoloration
- Efflorescence
- Dusting
- Popouts
- Mortar Flaking & Scaling
- Spalling
- Corrosion

Field Kit Essentials

- Camera, Film
- Flashlight
- Tape Measure
- Crack Comparator
- Hammer, Chisel
- Sample Bags
- Marking Pen
- Chalk
- Thermometer
- Compass

Another Helpful Tool….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Visual

- Use All Your Senses
  - Touch
  - See
  - Smell
  - Hear
  - Taste
- Look For the Obvious...
- Use Common Sense
- Don’t Jump to Conclusions!!!!!

Interviews

- Contractors
- Engineers
- Inspectors
- Tradesmen
- Suppliers
- Owners
- Occupants

Review Reports and Documents

- Project Specifications
- Contract Drawings
- Shop Drawings
- Submittals
- Change Orders
- Field Reports

Document Field Observations

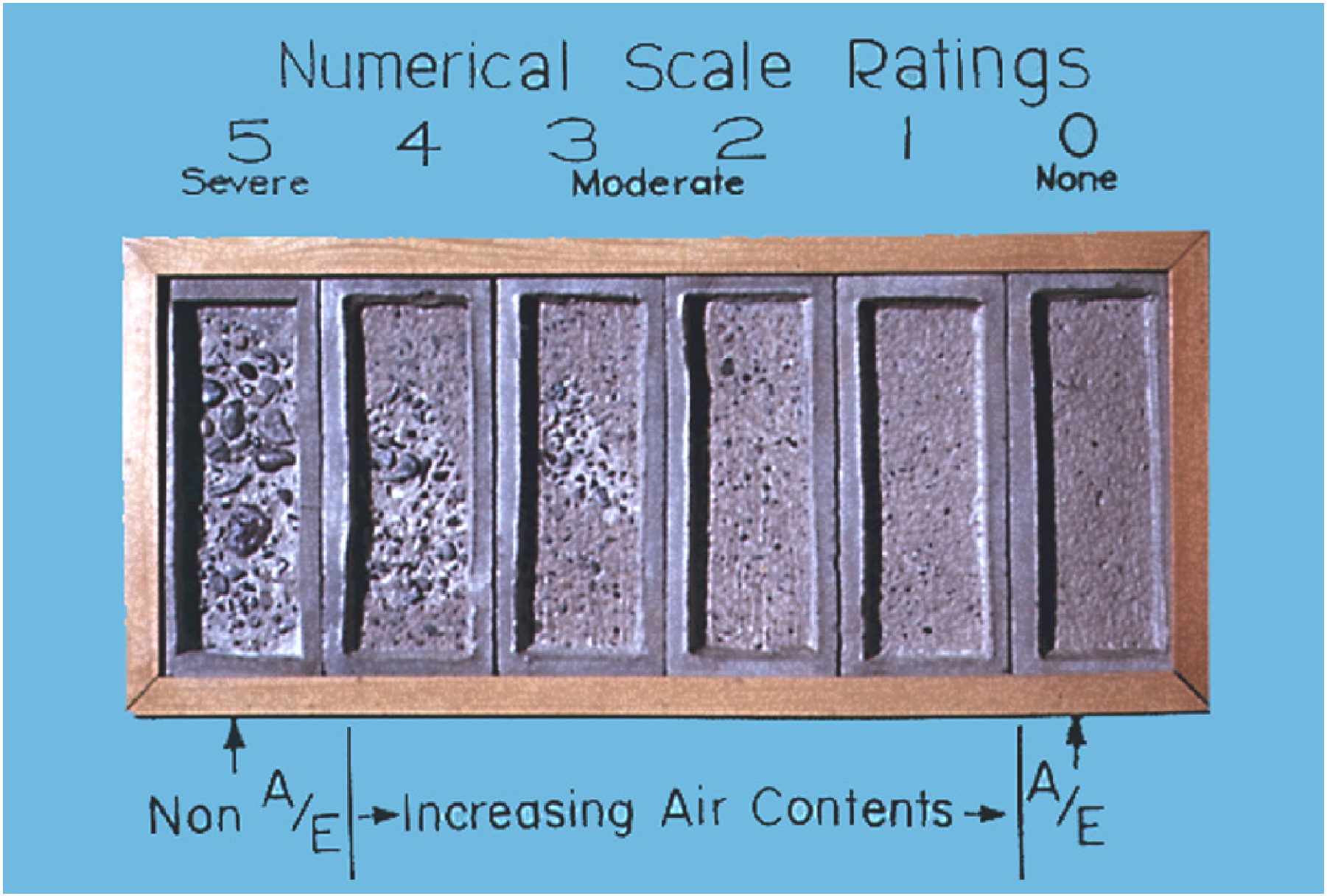
- Condition of Exposed Surfaces: Spalling, Popouts, Discoloration, etc.
- Nature and Extent of Cracking
- Secondary Deposits
- Evidence of Building Movement: Volume Changes, Deflection, Settlement, etc.
- Previous Repair Work Performed

Rate Level of Distress

- Scaling
  - Light-
    - Loss of surface mortar without exposure of coarse aggregate.
  - Medium-
    - Loss of surface mortar up to 5-10 mm (0.2-0.4 in.) in depth and exposure of coarse aggregate.

Rate Level of Distress

- Scaling
  - Severe-
    - Loss of surface mortar up to 5-10 mm (0.2-0.4 in.) in depth with some loss of mortar surrounding aggregate particles 10-20 mm (0.4-0.8 in.) in depth, so that aggregate is clearly exposed and stands out from the concrete.
  - Very Severe
    - Loss of coarse aggregate particles as well as surface mortar and surrounding aggregate, generally to a depth of greater than 20mm (0.8 in.)


Numerical Scale Ratings
5 4 3 2 1 0
Severe
Moderate
None
Non A/E
Increasing Air Contents
A/E

Rate Level of Distress

- Spalling
  - Small-
    - Not greater than 20mm (0.8 in.) in depth nor greater than 150mm (6 in.) in any dimension.
  - Large-
    - Deeper than 20mm (0.8 in.) and greater than 150mm (6 in.) in any dimension.

Observations on Cracking

- Surface Appearance
- Depth & Width of Cracking
- Current State of Activity
- Physical State of Concrete When Crack Occurred
- Structural Nature of the Crack

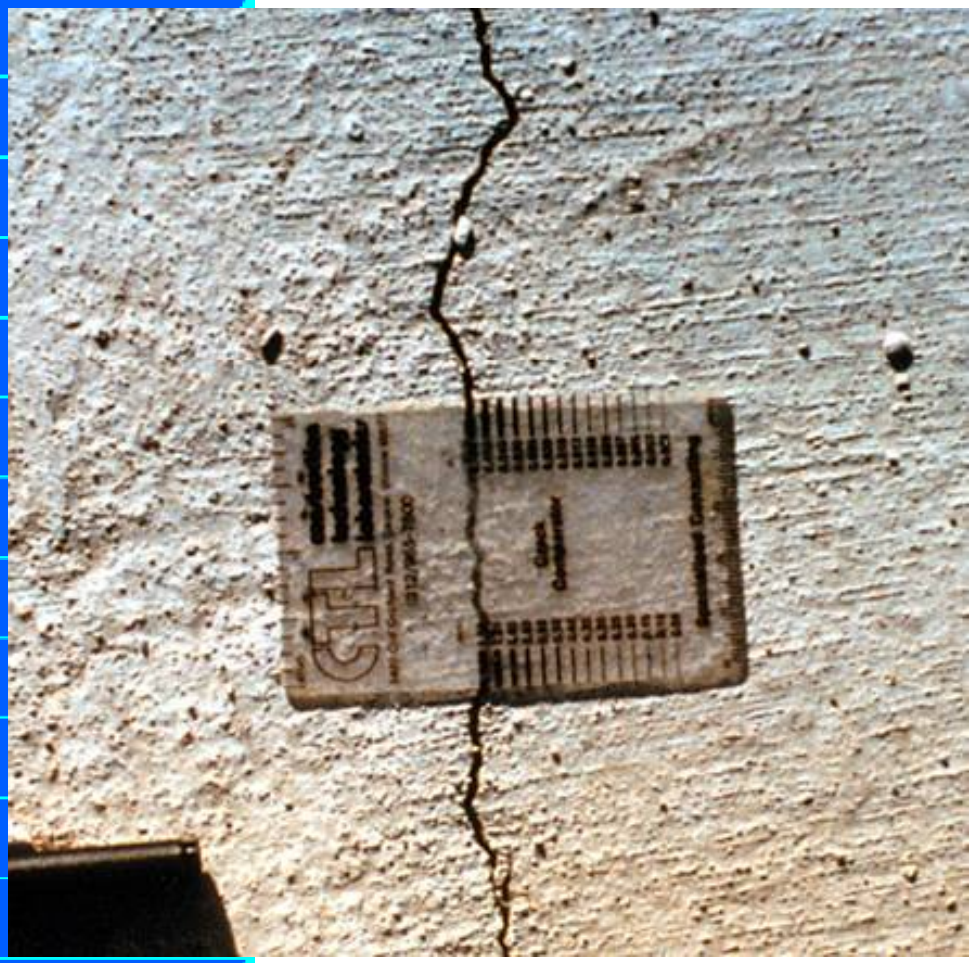
Surface Appearance

- Pattern Cracks
  - map cracks, crazing, checking, D-cracking
- Individual Cracks (Isolated)
  - diagonal, longitudinal, transverse, vertical, horizontal

Depth of Cracking

- Depth-
  - Surface, Shallow, Deep, Through

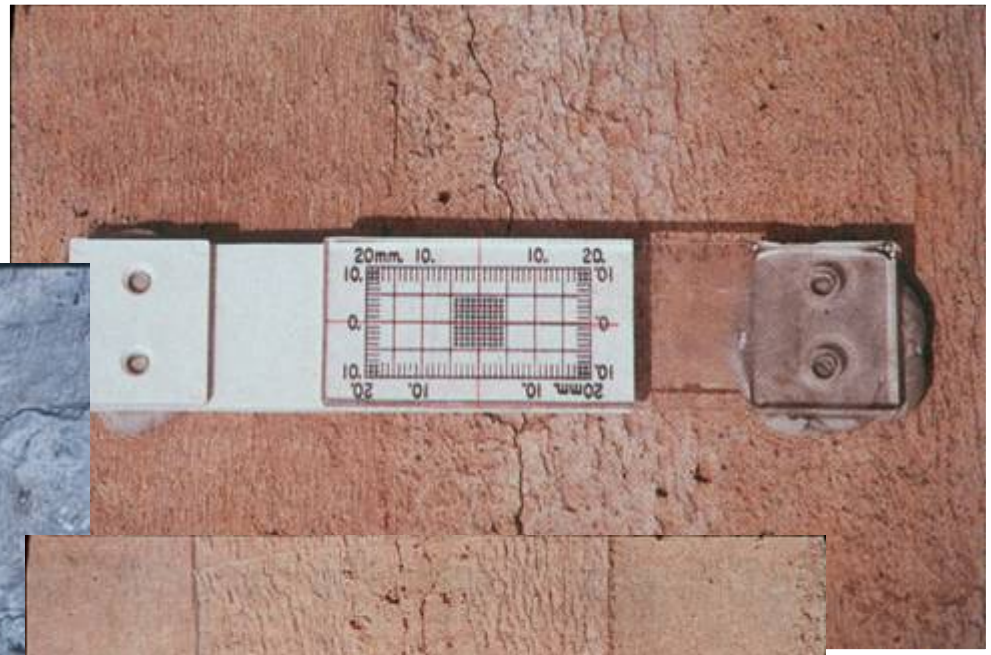
Width of Cracking



- Width-
  - Fine
    generally less than 1 mm (0.04 in.)
  - Medium
    between 1-2 mm (0.04-.08 in.)
  - Wide
    over 2 mm (0.08 in.)

Current State of Activity

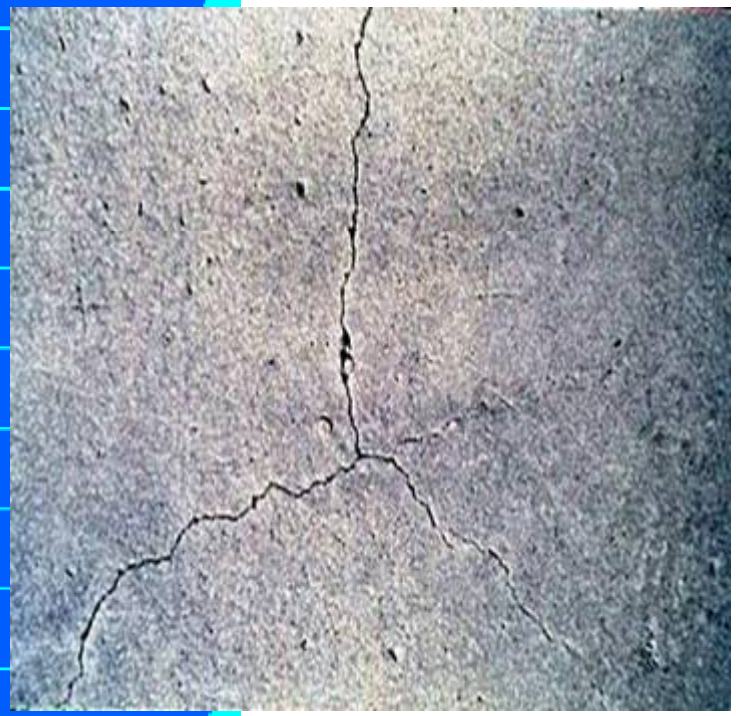
- Active
- Dormant



Physical State of Concrete When Cracking Occurred

- Before Hardening
  - Plastic
    - Shrinkage
    - Settlement
  - Construction Movement
    - Formwork Movement
    - Subgrade Movement

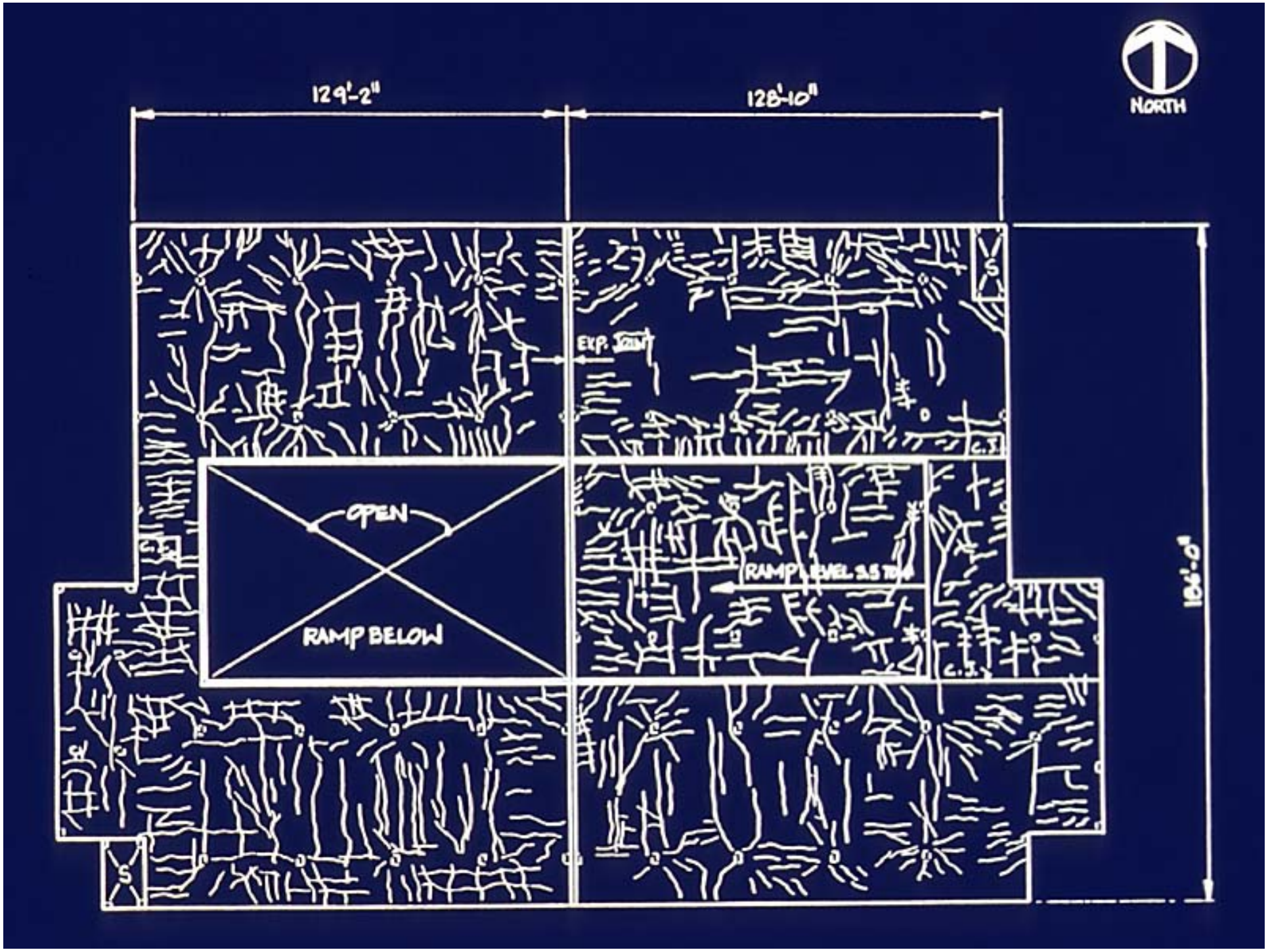
Physical State of Concrete When Cracking Occurred



- After Hardening
  - Physical
    - Drying Shrinkage
    - Crazing
  - Chemical
    - Corrosion of Reinforcement
    - Alkali-Aggregate Reactions
  - Thermal
    - Thermal Contraction
    - Freeze-Thaw Cycles

Physical State of Concrete When Cracking Occurred

- After Hardening
  - Structural
    - Accidental Overload
    - Creep
    - Design Loads


129'-2"
128'-10"
NORTH
EXP. JOINT
OPEN
RAMP BELOW
RAMP LEVEL 3.5 TOP
184'-0"

Nondestructive Testing

ACI 228.2R-3

NDT Evaluation of Concrete

- To determine soundness or integrity
- Strength
- Locate voids, delaminations, cracks
- Locate reinforcing steel or dowels
- Locate contamination
- Determine thickness
- Bond strength, strength development etc.

Nondestructive Evaluation Methods

Property	Recommended Methods	Possible Methods
Strength	Penetration Probe Rebound Hammer Pullout Methods	Pulse Velocity
Rebar Size and Location	Covermeter (Pachometer) Gamma Radiography	X-ray Radiography Ultrasonic Pulse Echo Reader
Presence of Subsurface Voids	Acoustic Impact Gamma Radiography Ultrasonic Pulse Velocity	Thermal Inspection X-Ray Radiography Ultrasonic Pulse Echo

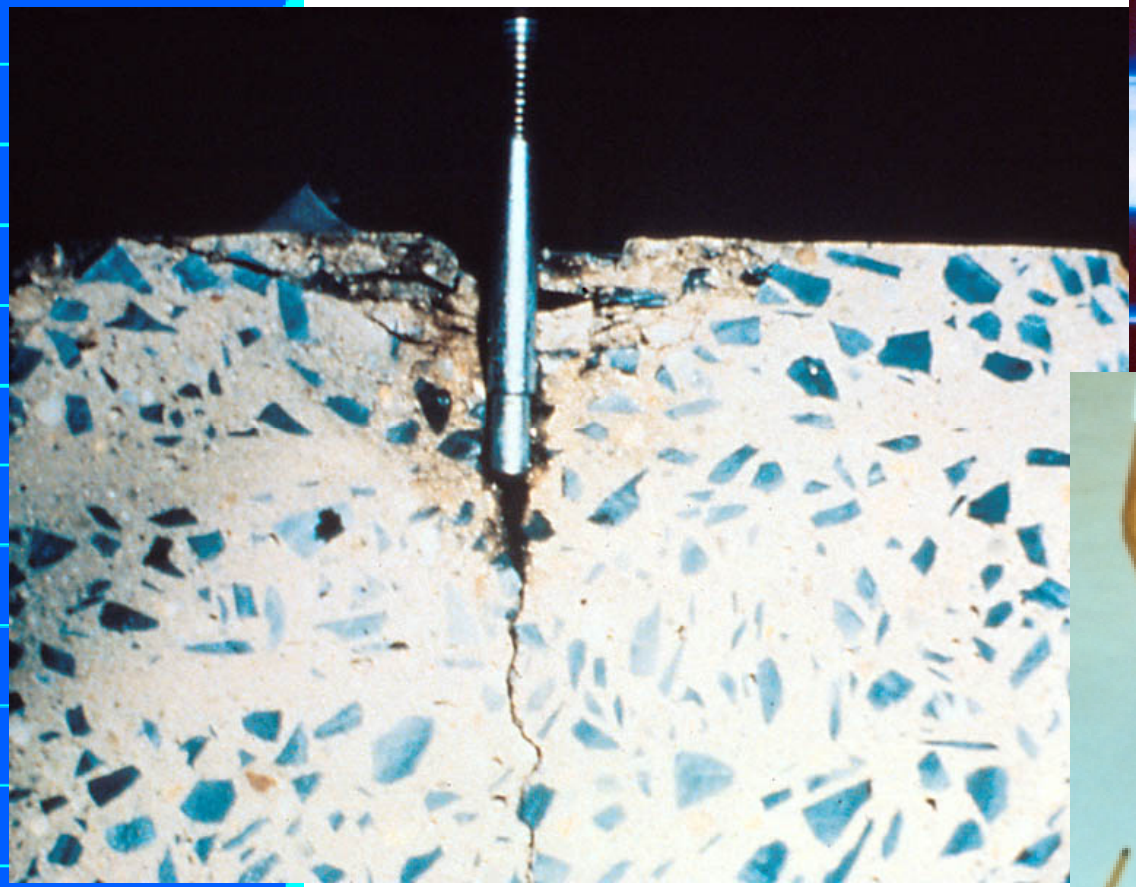
Pachometer (covermeter)

- Assesses- Location of Embedded Metals

Soundness Testing

- Hammers, Steel Rods, Chain Dragging
- Used to Assess
  - Delaminations
  - Voids

Reliability of NDT?



Analytical Methods

Strength Evaluation of Existing Structures

- Safety/structural integrity
- Low cylinder strength results
- Strength Evaluation:
  - Analytical Investigation
  - Load Tests

Analytical Investigation

- Perform Field Investigation of Dimensions and Details of Members, Properties of Materials, etc.
- Perform Analysis to Determine Structural Integrity
  - Hand Calculations
  - Computer Analysis

Load Testing

Monitor

- Deflections

Destructive Testing

Sampling Plan

- ASTM C823- *Standard Practice for Examination and Sampling of Hardened Concrete in Constructions*
- Good vs. Bad
- Sample Location-

  Strategic Random Sampling
- Is Coring Necessary??

Sampling Procedures
ASTM C 42

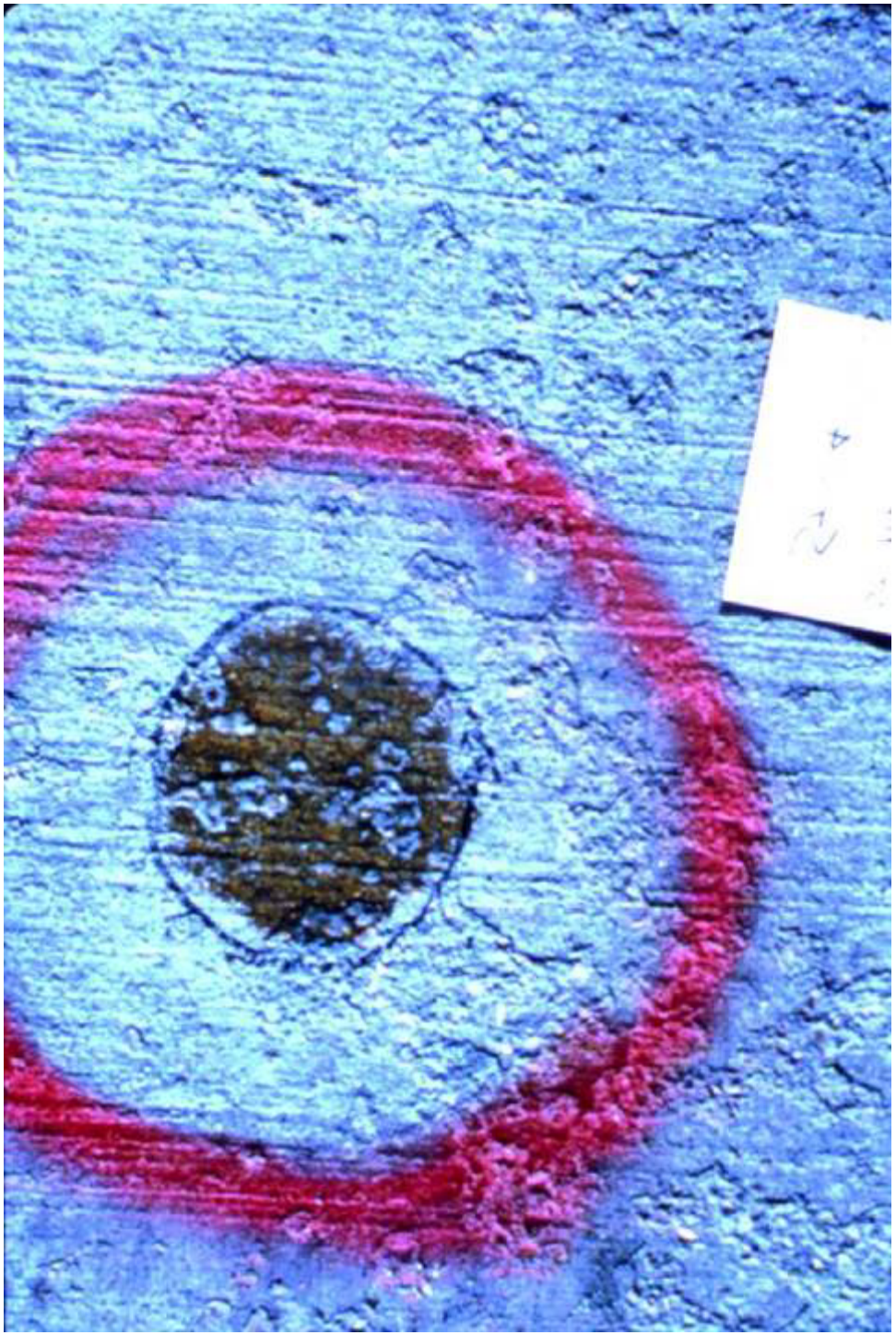
- Coring
- Sawing

Drilling

Sledges, Chisels, etc. Should Not Be Permitted

Sample Identification

- Document
- Chain of Custody
- Field Notes
- Photographs



Sample Prep

- Mark Location of Core With Paint
- Keep Sample Condition Intact

Core Length

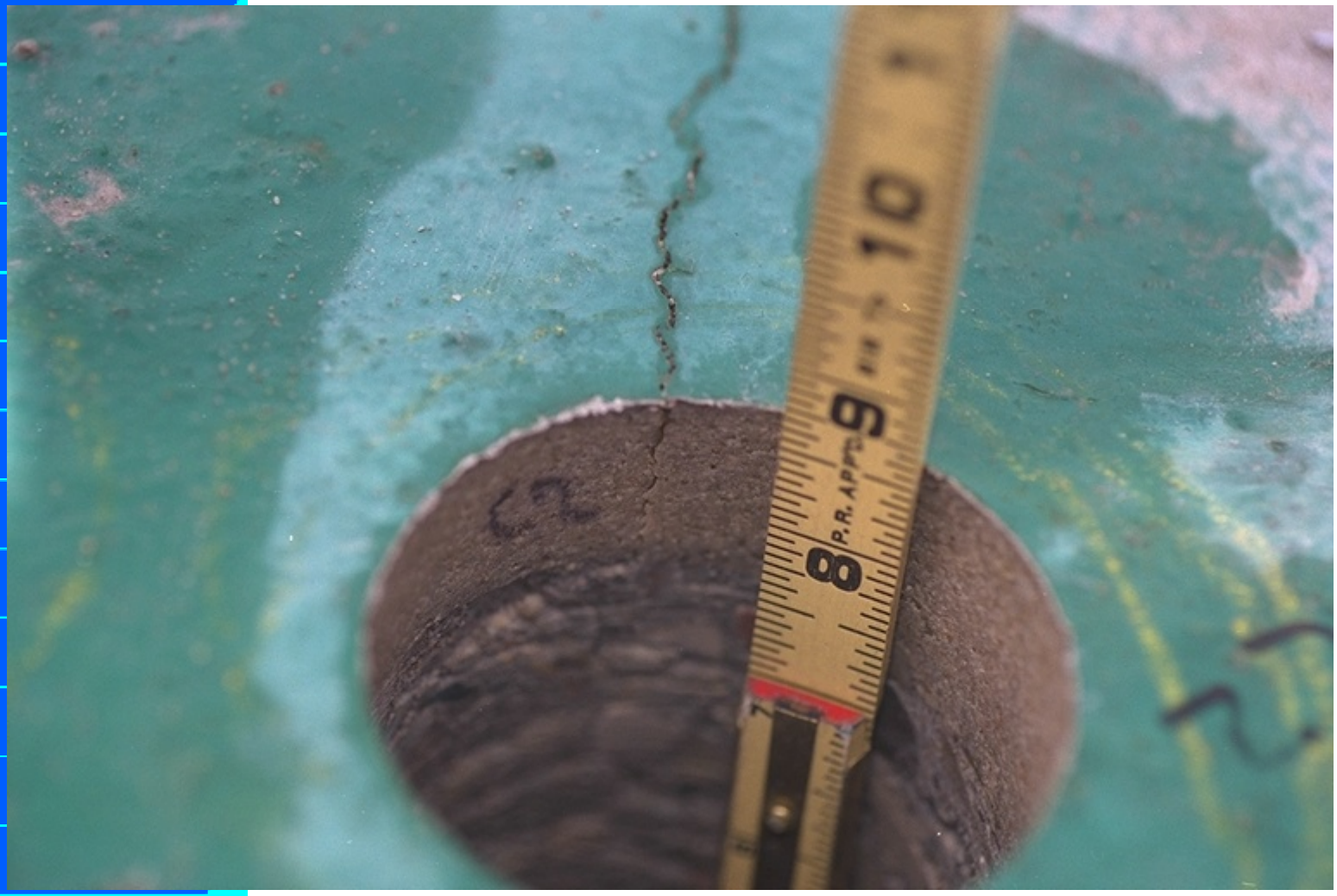
Correction Factor

Ratio of Length to Diameter (L/D)	Strength Correction Factor
1.75	0.98
1.50	0.96
1.25	0.93
1.00	0.87

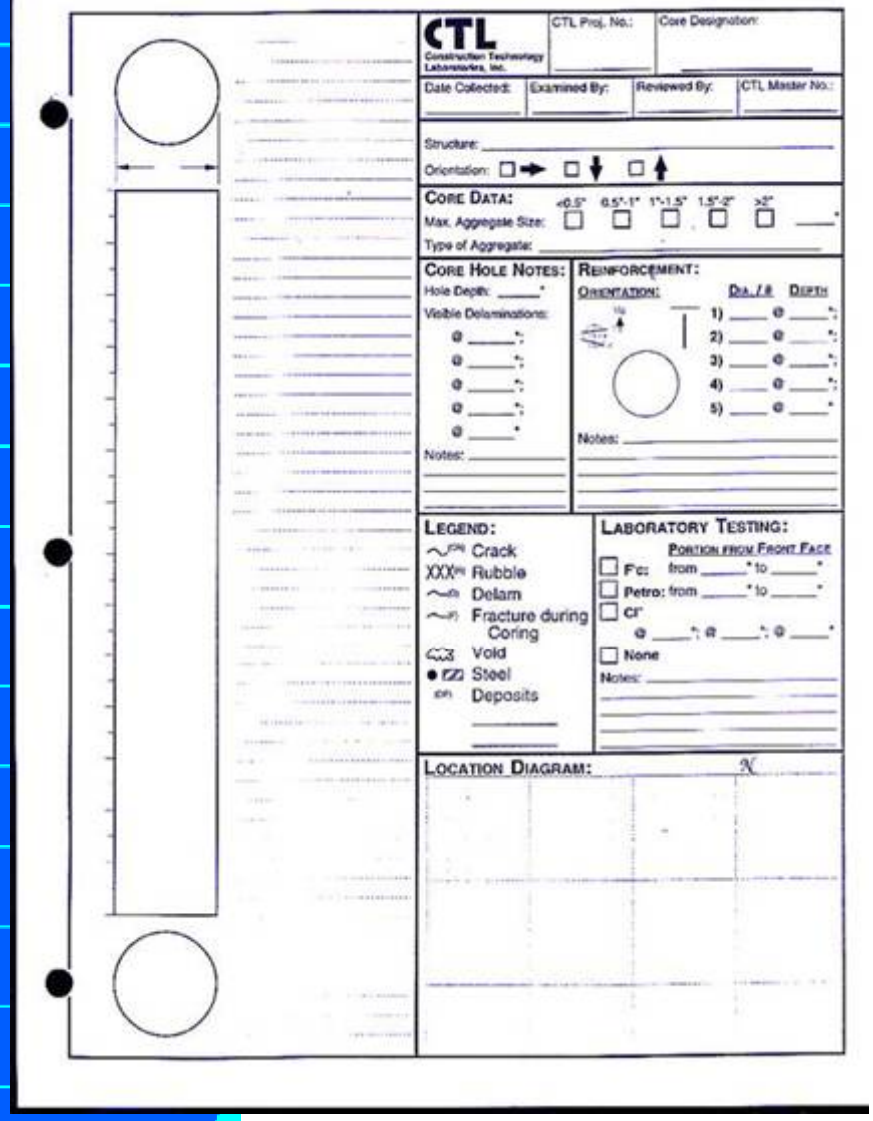
If a Core Has a Max. Length < 95% of Diameter Prior To Capping- It May Not Be Included in Test Results

Full Length Cores

Always Evaluate Interior of Core Hole



What If Core Breaks During Removal?



Document Core Observations In The Field

Including:

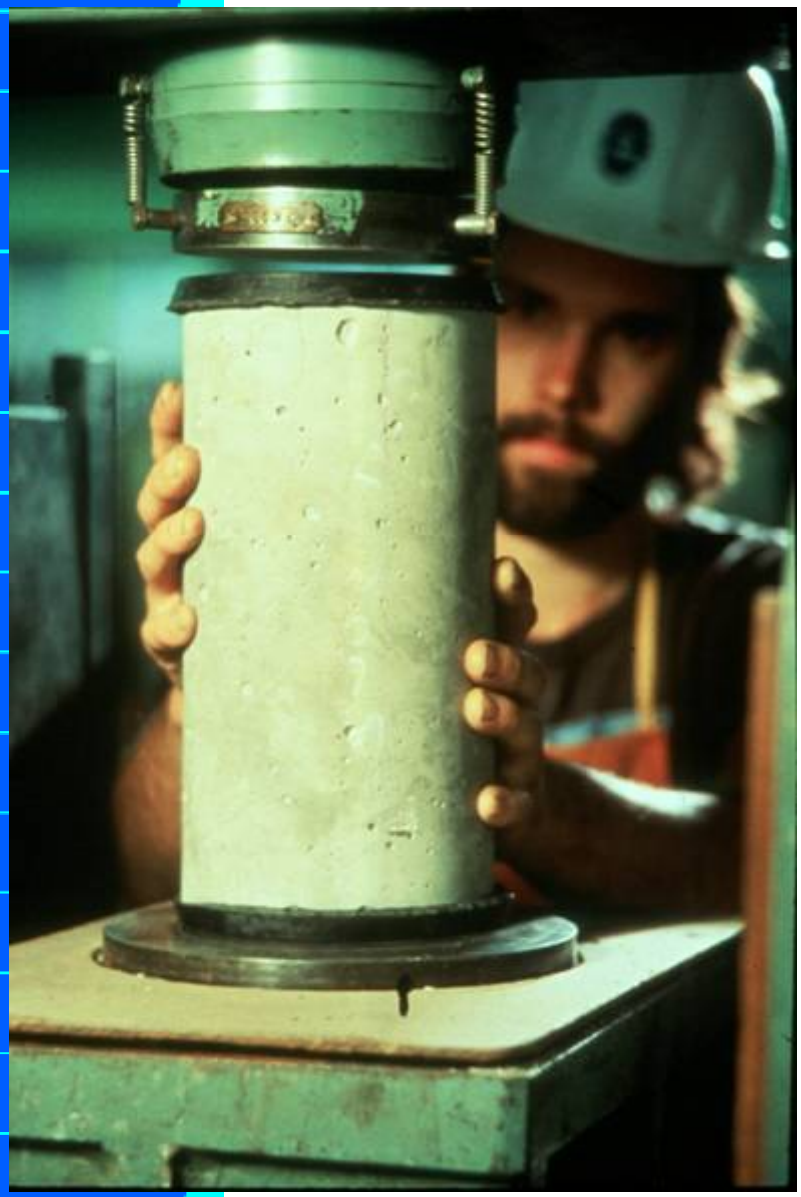
- Core Dimensions
- Hole Depth
- Aggregate Size
- Reinforcement Location
- Visible Cracking
- Voids, Rubble
- Delaminations

Contributed by: M. Thomas

Transportation of Samples

- Identify By Orientation and Location
  - Top and Bottom
- Protect By Wrapping and Sealing
  - Bubblewrap
- Pack and Deliver in Safe Environment
  - Cooler

Laboratory Testing



- Visual Assessment
- Strength
- Modulus
- Pulse Velocity
- Absorption, Density, Voids
- Petrographic Analysis
- Air-Void System (AVS)
- Permeability
- Chemical Analysis
- Expansion Testing
- & Many Others

Chemical Analysis

- Chemical Composition
- X-Ray Diffraction
- Thermal Analysis
- Acid/Base Indicator

Petrographic Examination

ASTM C856

- Cement
- Aggregates
- Cracks
- Voids
- Secondary Deposits

Evaluation Procedure- ACI 364.1 R Petrographic Analysis

To Test Concrete For: (Table 6.1a)

- Acidity
- Air Content
- Alkali-Carbonate Reaction
- Alkali-Silica Reaction
- Cement Content
- Chemical Composition
- Chloride Content
- Contaminated Aggregate
- Contaminated Mixing Water
- Frozen Components
- Permeability
- Quality of Aggregate
- Freeze/Thaw Resistance
- Soundness
- Sulfate Resistance
- Uniformity
- W/C

Evaluation Procedure- ACI 364.1 R Petrographic Analysis

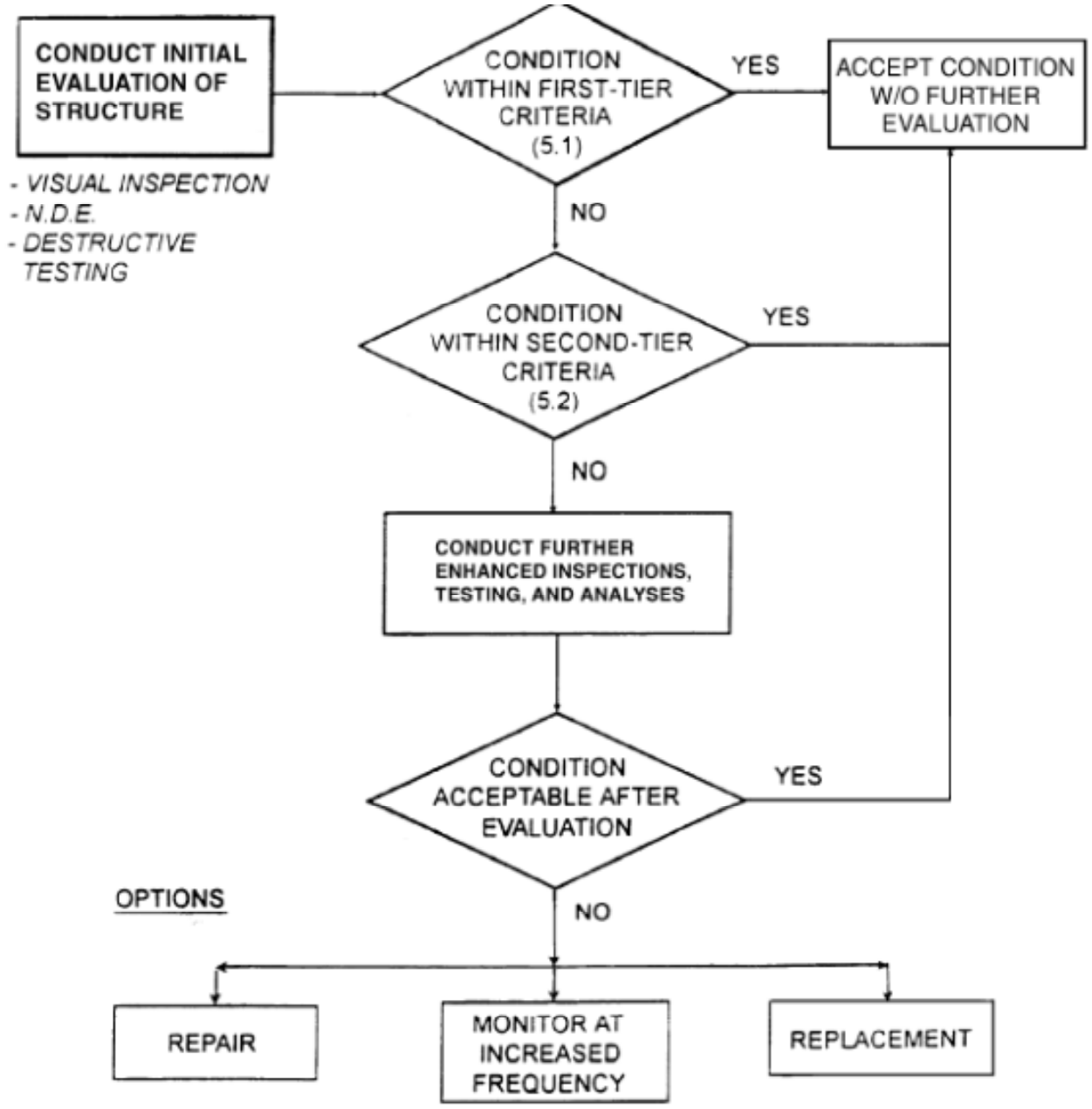
To Test Concrete For: (Table 6.1b)

- Bleeding Channels
- Chemical Deterioration
- Corrosion of Steel
- Cracking
- Delamination
- Discoloration
- Disintegration
- Efflorescence
- Erosion
- Freeze/Thaw Damage
- Honeycombing
- Uniformity of Concrete

Testing

- Samples Should Be Sufficient In Size and Number To Permit Application of All Necessary Laboratory Tests
- Once Samples are Obtained, Certain Samples Should Be Selected And Submitted For Testing **Without Bias**

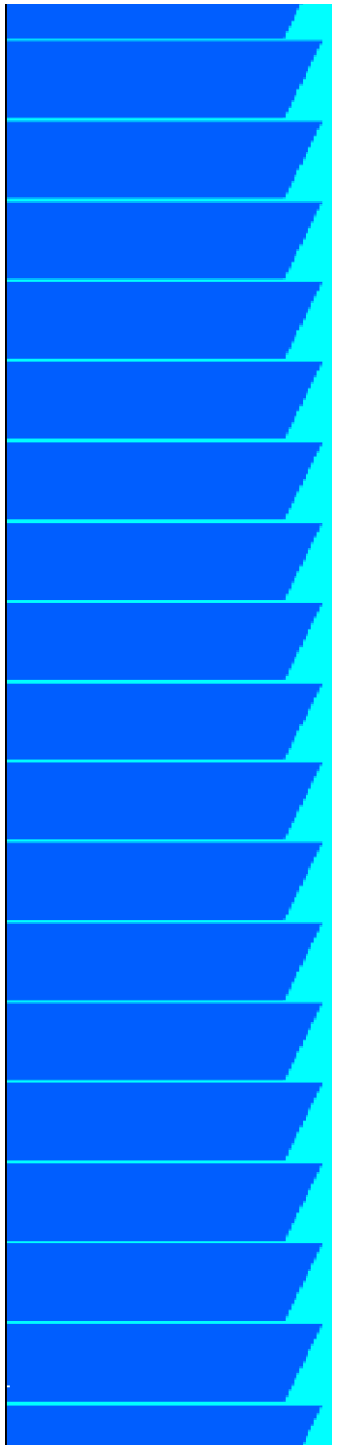
Summary of Evaluation



Summary

To Effectively Evaluate a Concrete Structure All Of These Steps Play a Key Role:

- Visual Observations
- NDT
- Analytical Methods
- Creating a Concrete Sampling Plan
- Documenting Field Sampling Procedures



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