

The Condition Survey and Evaluation of Hardened Concrete





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

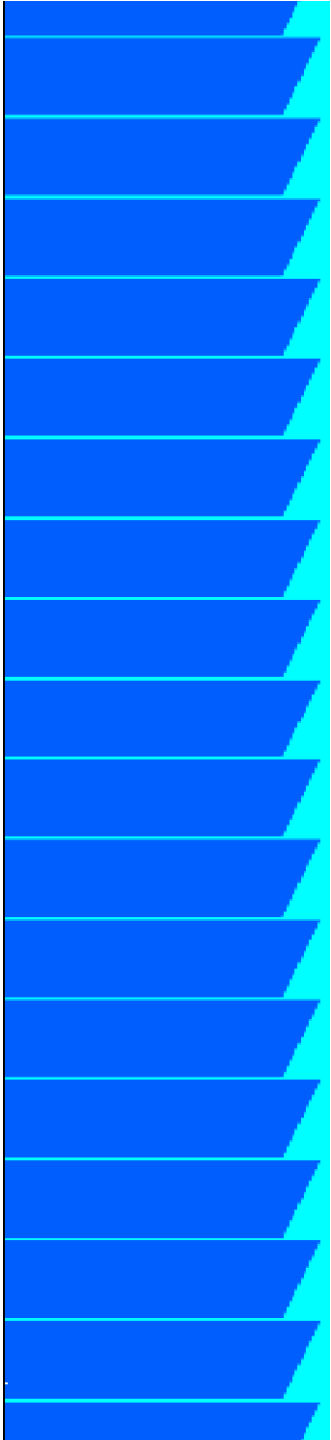
- Responsible in-charge:
 - ◆ P.E., or civil or structural engineer w/10 years experience
- Personnel performing inspections:
 - ◆ Civil or structural engineer w/ minimum 1 year experience; or personnel with 5 years experience



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

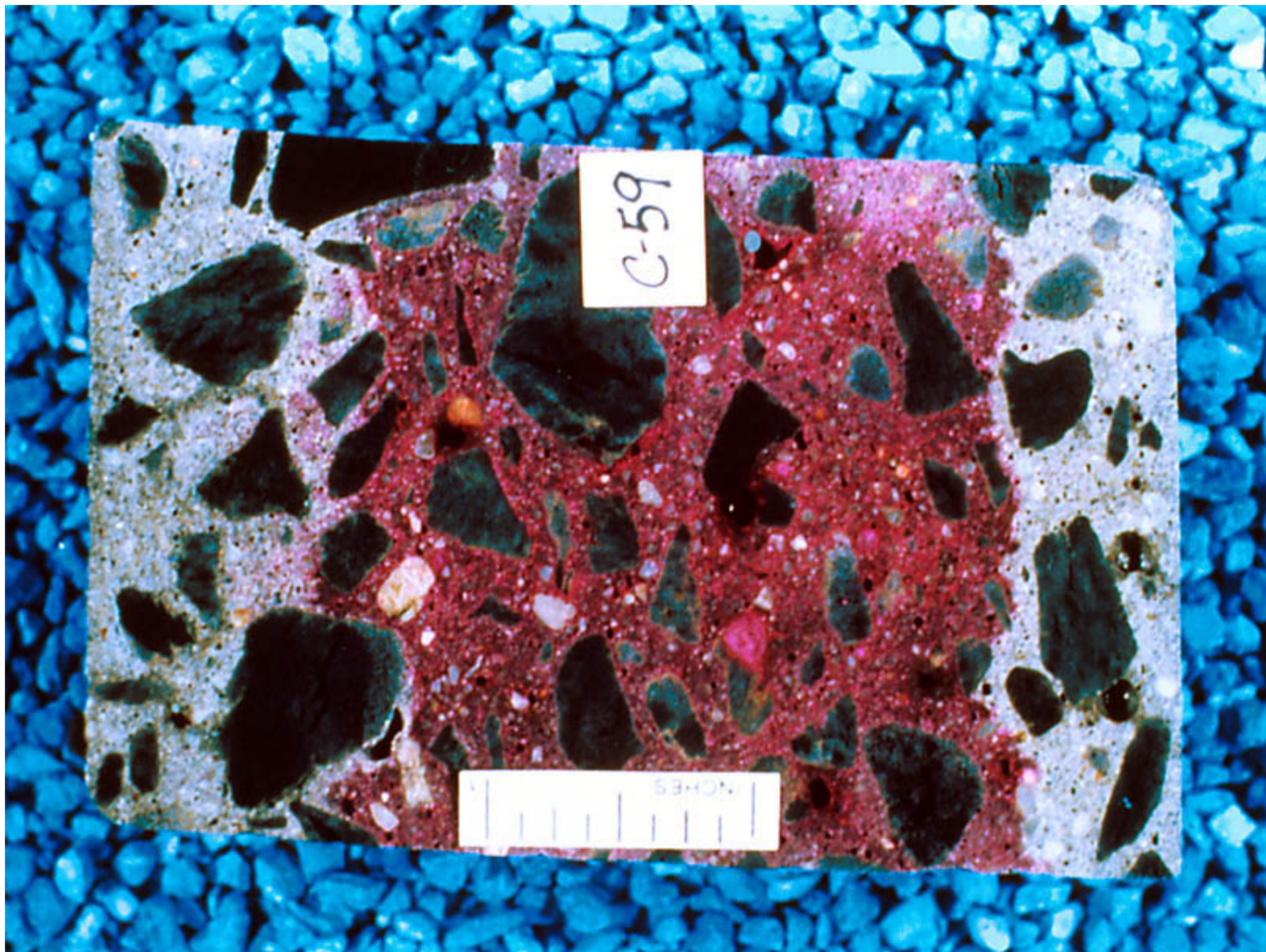


- Camera, Film
- Flashlight
- Tape Measure
- Crack Comparator
- Hammer, Chisel
- Sample Bags
- Marking Pen
- Chalk
- Thermometer
- Compass

Another Helpful Tool....



Contributed by: M. Thomas



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-

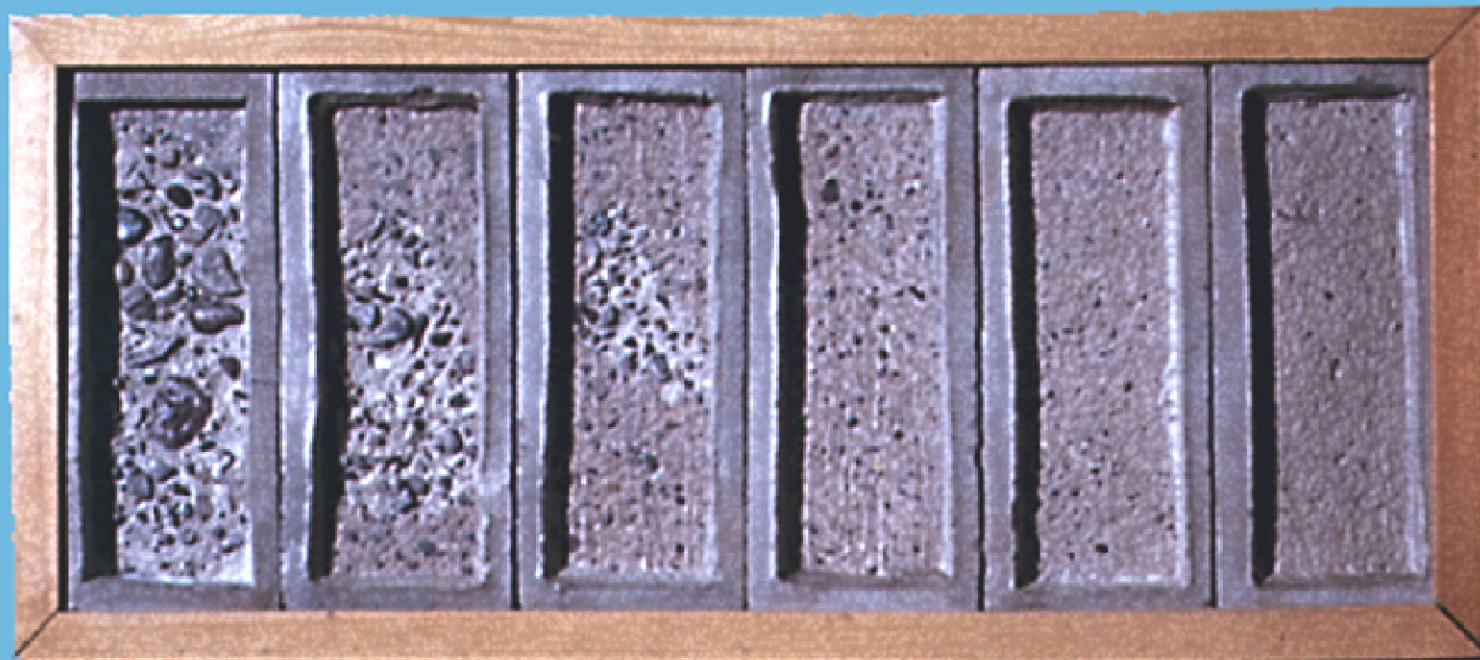
- Loss of surface mortar up to 5-10 mm (0.2-0.4 in.) in depth with some loss of mortar surrounding aggregate particles 10-20 mm (0.4-0.8 in.) in depth, so that aggregate is clearly exposed and stands out from the concrete.

- ◆ 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-

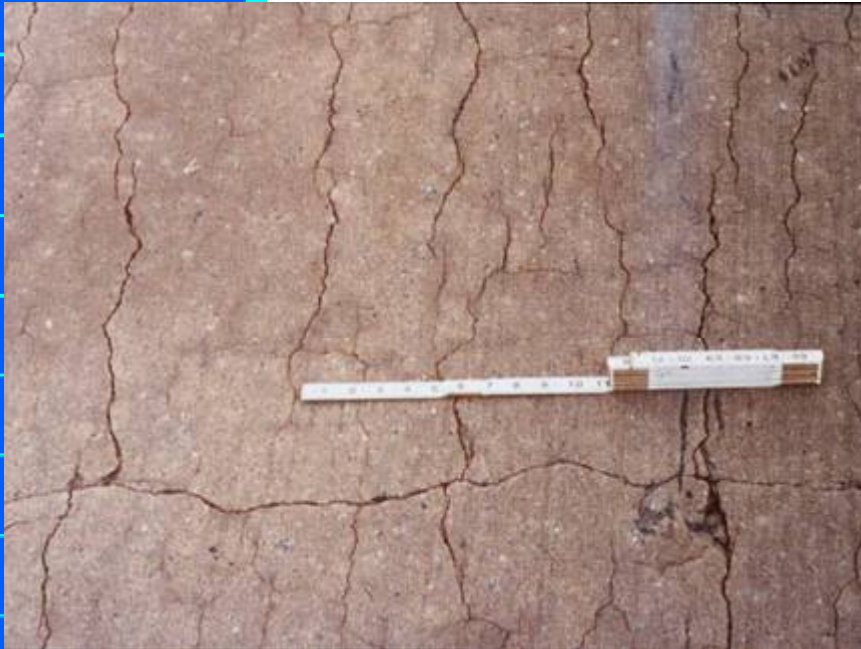
- Deeper than 20mm (0.8 in.) and greater than 150mm (6 in.) in any dimension.



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

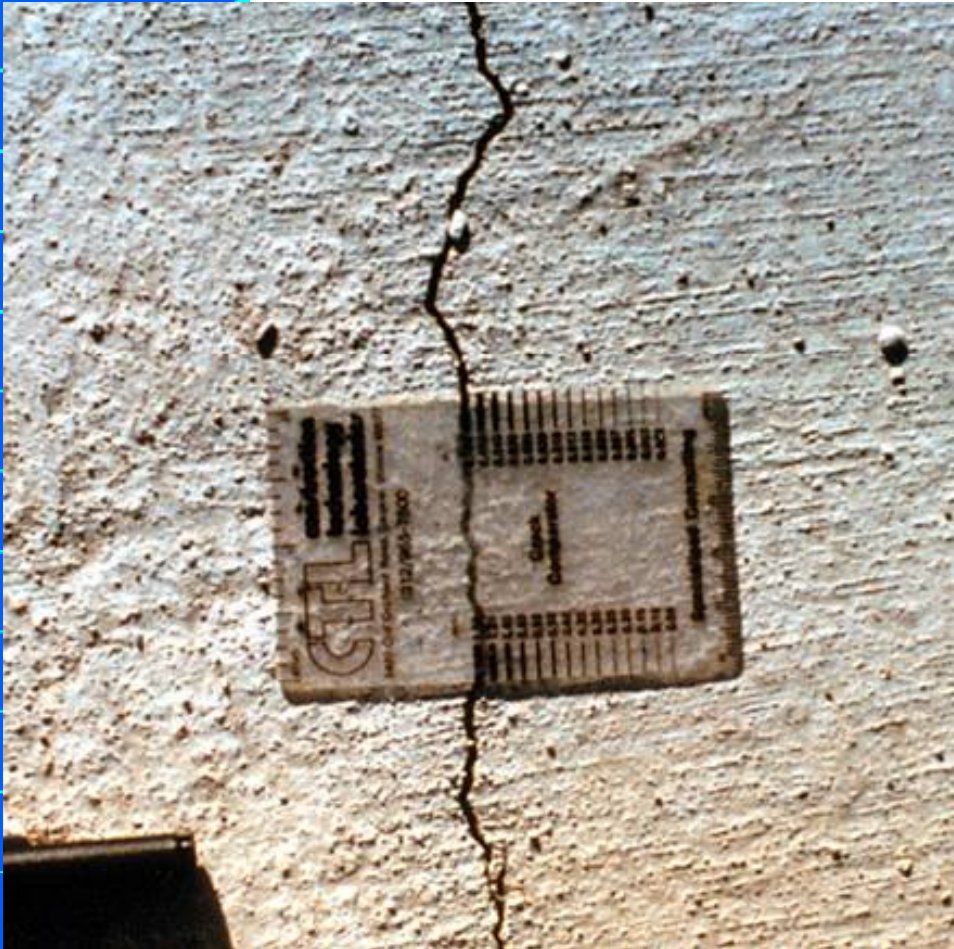
Depth of Cracking

- Depth-
 - ◆ Surface, Shallow, Deep, Through



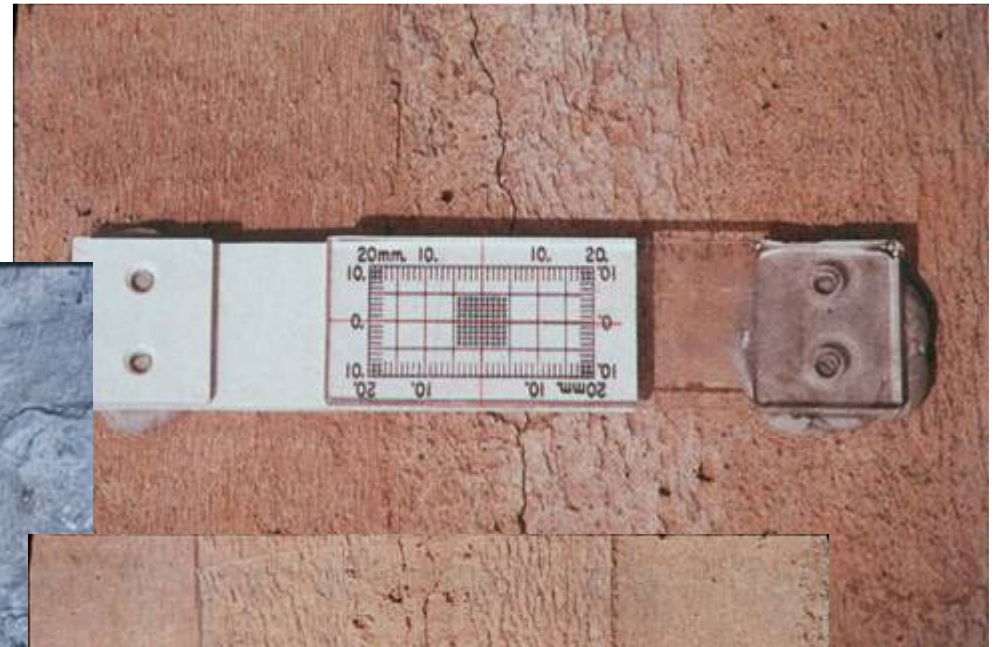
Width of Cracking

- 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

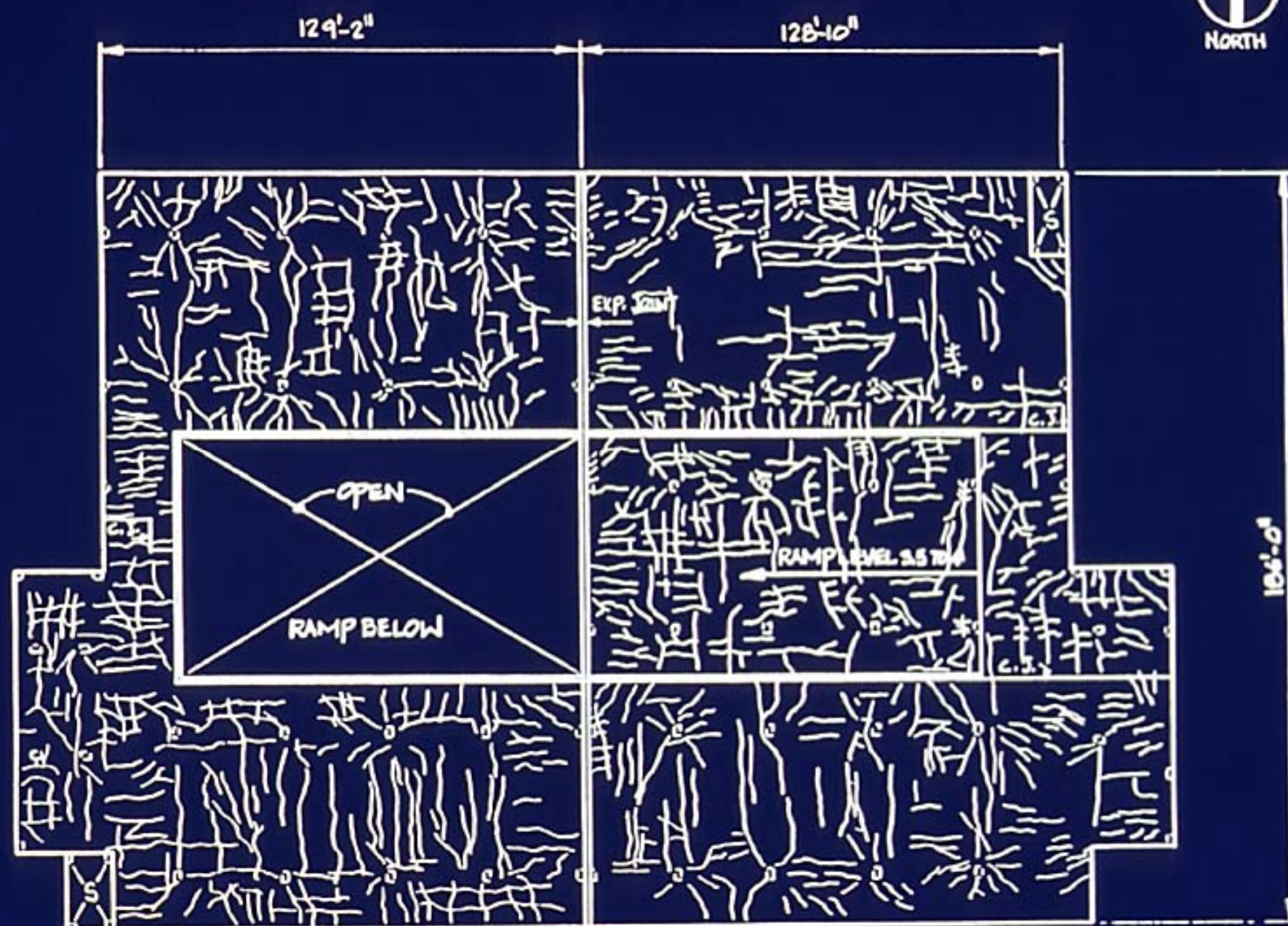
- ◆ Structural

- Accidental Overload

- Creep

- Design Loads





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



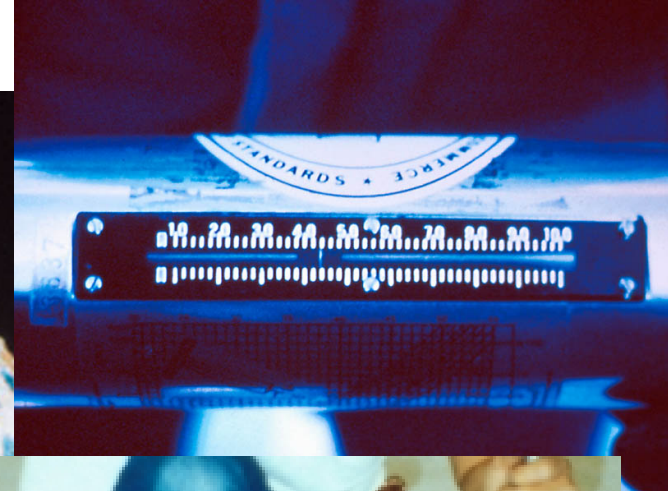
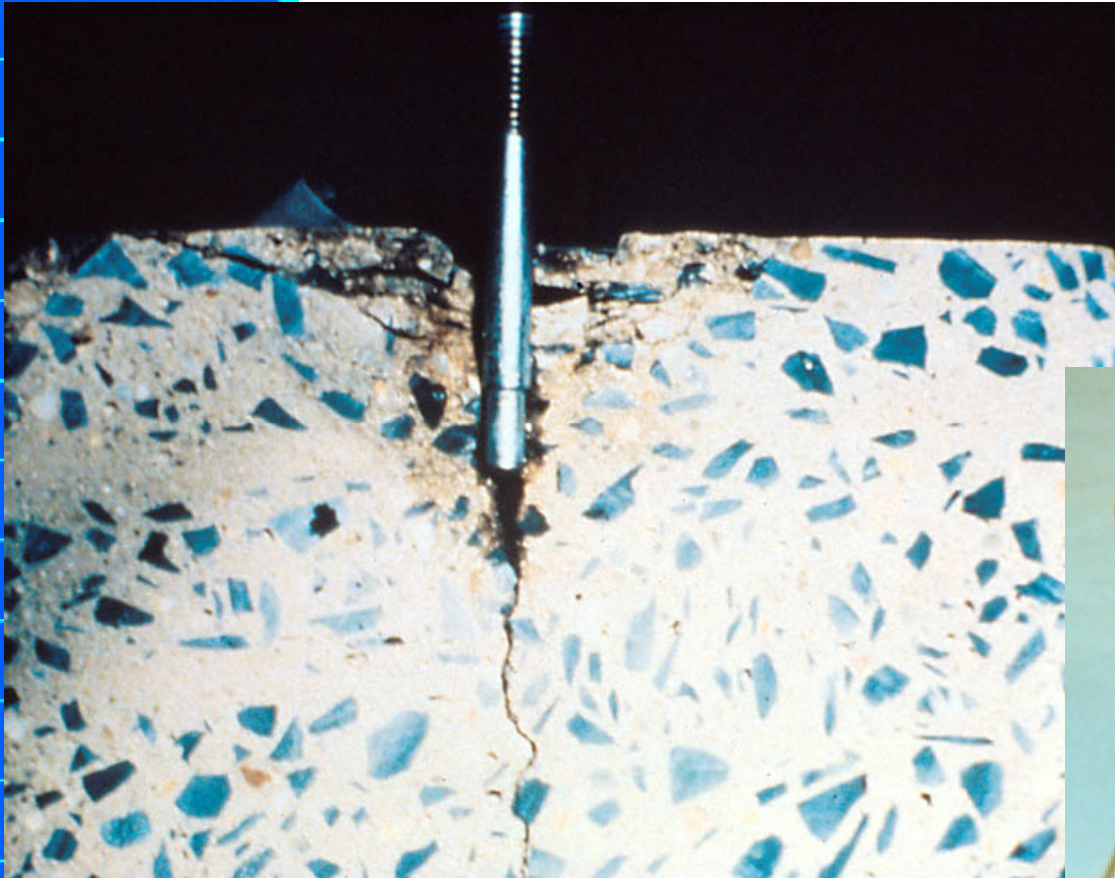
Soundness Testing



- 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

The form is titled 'CTL Construction Technology Laboratories, Inc.' and includes fields for 'CTL Proj. No.', 'Core Designation', 'Date Collected', 'Examined By', 'Reviewed By', and 'CTL Master No.'. It contains several specialized sections: 'Structure' with orientation arrows, 'CORE DATA' for aggregate size and type, 'CORE HOLE NOTES' for hole depth and delaminations, 'REINFORCEMENT' with a circular diagram for location, 'LEGEND' for symbols like cracks and voids, 'LABORATORY TESTING' for material properties, and a 'LOCATION DIAGRAM' at the bottom right. A large vertical rectangle on the left is intended for a core drawing, with circular end views at the top and bottom.



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)

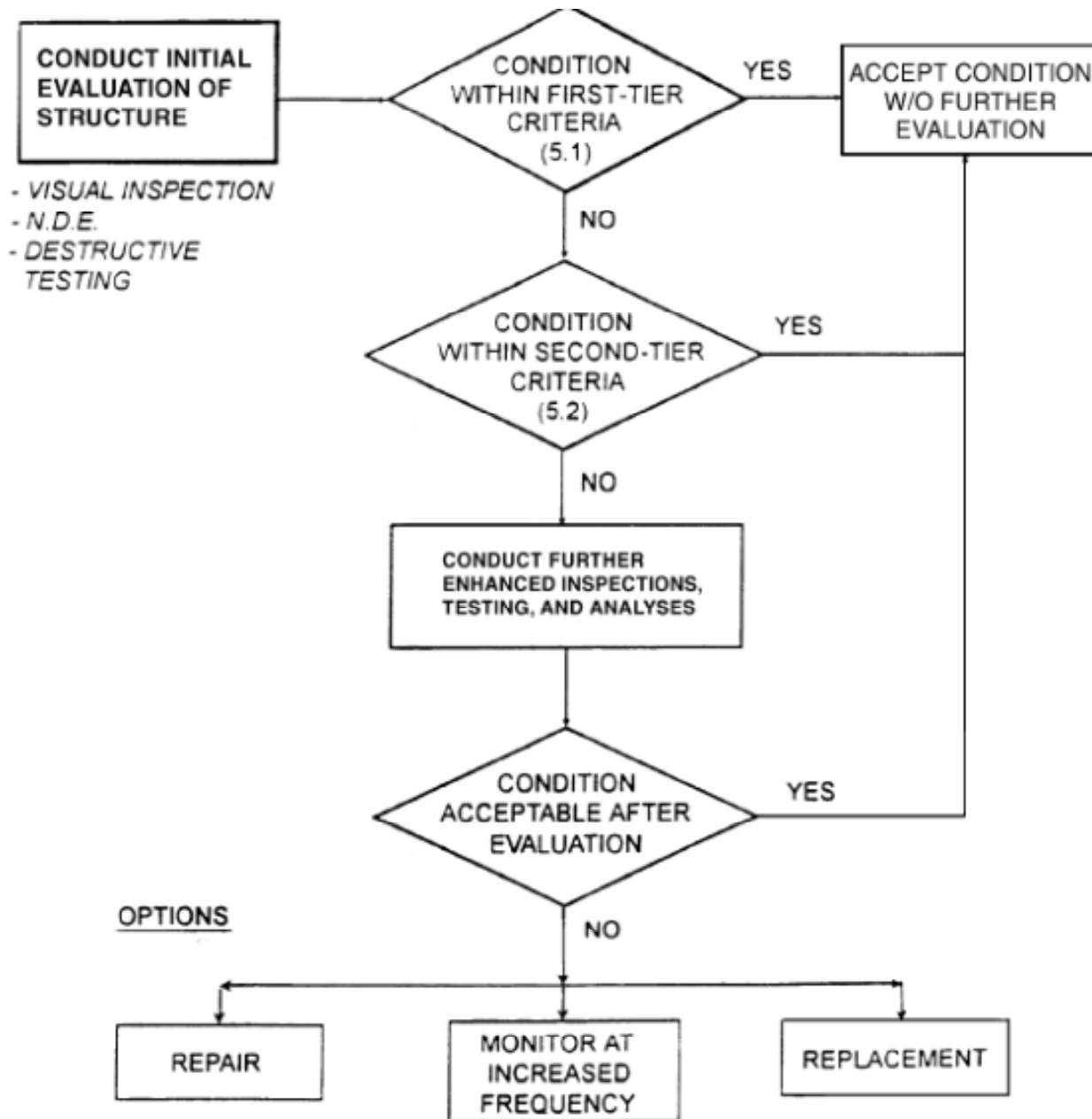
- Bleeding Channels
- Chemical Deterioration
- Corrosion of Steel
- Cracking
- Delamination
- Discoloration
- Disintegration
- Efflorescence
- Erosion
- Freeze/Thaw Damage
- Honeycombing
- Uniformity of Concrete



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

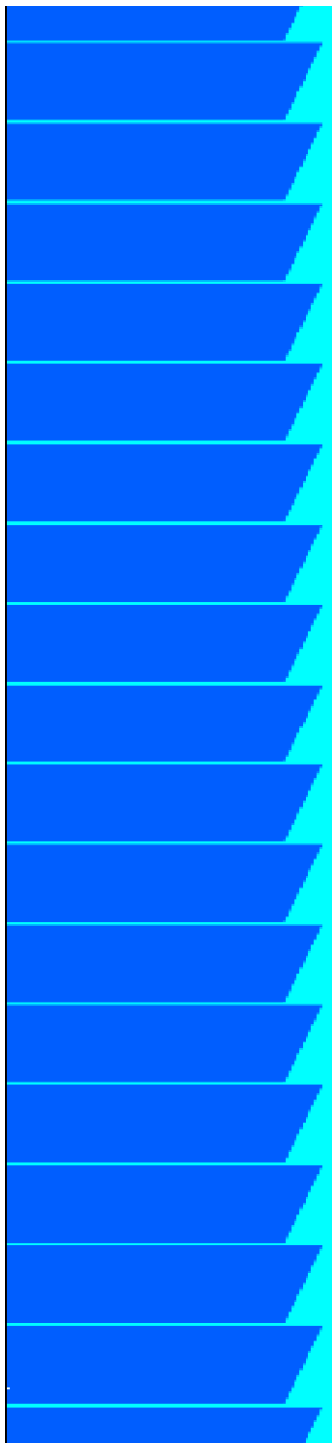




Summary

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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