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Guide for Making a Condition Survey of Concrete in Service

Reported by ACI Committee 201

Cameron MacInnis*
Chair

Mauro J. Scali
Secretary

Barry W. Butler	Jens Holm	Katharine Mather*	Peter Smith
Ramon L. Carrasquillo*	Robert D. Hooten	Tarun R. Naik*	George V. Teodoru
Paul D. Carter	Gunnar M. Idorn	Michael Pigeon	J. Derle Thorpe
Kenneth C. Clear	John M. Jaffe	Robert E. Price	P. J. Tikalsky
Bernard Erlin	Paul Klieger	Rasheeduzzafar	Claude B. Trusty, Jr.
Emery Farkas	Joseph F. Lamond*	Thomas J. Reading	George J. Venta
Per Fidjestol	Kenneth R. Lauer*	Hannah C. Schell	Gary L. Vondran
John F. Gibbons	Stella L. Marusin	Charles F. Scholer	David A. Whiting
Eugene D. Hill, Jr.	Timothy B. Masters	Jan P. Skalny	J. Craig Williams

*Task group members who revised the guide.

This guide provides a system for reporting on the condition of concrete in service. It includes a checklist of the many details that may be considered in making a report, and repeats the ACI 116R standard definitions of terms associated with the durability of concrete. Its purpose is to establish a uniform system for evaluating the condition of concrete.

The guide was revised by a task group chaired by K. R. Lauer. The other task group members are indicated by an asterisk.

Keywords: bridges (structures); buildings; concrete construction; concrete durability; concrete pavements; concretes; corrosion; cracking (fracturing); deterioration; environments; freeze-thaw durability; inspection; joints (junctions); popouts; quality control; scaling; serviceability; spalling; strength; surveys.

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CHAPTER 1—INTRODUCTION

This guide presents a system for making a condition survey of concrete in service. A condition survey is an examination of concrete for the purpose of identifying and defining areas of distress. The system is designed to be used in recording the history of a project from inception through construction and subsequent life of the structure.

While it probably will be used most often in connection with the survey of concrete that is showing some degree of distress, its application is recommended for all concrete structures. In any case, records of the materials and construction practices used should be maintained because they are difficult to obtain at a later date.

The committee has attempted to include pertinent items that might have a bearing on the performance of the concrete. Those making the survey should, however, not limit their investigation to the items listed, thereby possibly overlooking other contributing factors. Following the guide does not eliminate the need for intelligent observations and the use of sound judgment.

ACI 201.1R-92 supersedes ACI 201.1R-68 (Revised 1984) and became effective October 1, 1992.

Those performing the survey should be experienced and competent in this field. In addition to verbal descriptions, numerical data obtained by laboratory test and field tests and measurements should be obtained wherever possible. Photographs, including a scale to indicate dimensions, are of great value in showing the condition of concrete.

The checklist is provided to facilitate a thorough survey. Tile definition of terms and associated photographs are an attempt to standardize the reporting of the condition of the concrete in a structure.

This guide should be used in conjunction with the following:

1. ACI Committee 116 "Cement and Concrete Terminology" (ACI 116R).

2. ACI Committee 311 "Recommended Practice for Concrete Inspection" (ACI 311.1R).

3. ACI Committee 201, "Guide to Durable Concrete" (ACI 201.2R).

CHAPTER 2—CHECKLIST

Personnel conducting the condition survey must select those items important to the specific concerns relating to the reasons for the survey. Other factors may be involved and should not be overlooked during the survey.

Checklist

1. Description of structure or pavement
   - 1.1 Name, location, type, and size
   - 1.2 Owner, project engineer, contractor, when built
   - 1.3 Design
     - 1.3.1 Architect and/or engineer
     - 1.3.2 Intended use and history of use
     - 1.3.3 Special features
   - 1.4 Construction
     - 1.4.1 Contractor—general
     - 1.4.2 Subcontractors—concrete placement
     - 1.4.3 Concrete supplier
     - 1.4.4 Agency responsible for testing
     - 1.4.5 Other subcontractors
   - 1.5 Photographs
     - 1.5.1 General view
     - 1.5.2 Detailed close-up of condition of area
   - 1.6 Sketch map—orientation showing sunny and shady and well and poorly drained regions

2. Present condition of structure
   - 2.1 Overall alignment of structure
     - 2.1.1 Settlement
     - 2.1.2 Deflection
     - 2.1.3 Expansion
     - 2.1.4 Contraction
   - 2.2 Portions showing distress (beams, columns, pavement, walls, etc., subjected to strains and pressures)
   - 2.3 Surface condition of concrete
     - 2.3.1 General (good, satisfactory, poor, dusting, chalking, blisters)
     - 2.3.2 Cracks
       - 2.3.2.1 Location and frequency
       - 2.3.2.2 Type and size (see definitions)
       - 2.3.2.3 Leaching, stalactites
     - 2.3.3 Scaling
       - 2.3.3.1 Area, depth
       - 2.3.3.2 Type (see definitions)
     - 2.3.4 Spalls and popouts
       - 2.3.4.1 Number, size, and depth
       - 2.3.4.2 Type (see definitions)
     - 2.3.5 Extent of corrosion or chemical attack, abrasion, impact, cavitation
     - 2.3.6 Stains, efflorescence
     - 2.3.7 Exposed reinforcement
     - 2.3.8 Curling and warping
     - 2.3.9 Previous patching or other repair
     - 2.3.10 Surface coatings
       - 2.3.10.1 Type and thickness
       - 2.3.10.2 Bond to concrete
       - 2.3.10.3 Condition
     - 2.3.11 Abrasion
     - 2.3.12 Penetrating sealers
       - 2.3.12.1 Type
       - 2.3.12.2 Effectiveness
       - 2.3.12.3 Discoloration
   - 2.4 Interior condition of concrete (in situ and samples)
     - 2.4.1 Strength of cores
     - 2.4.2 Density of cores
     - 2.4.3 Moisture content
     - 2.4.4 Evidence of alkali-aggregate or other reaction
     - 2.4.5 Bond to aggregate, reinforcing steel, joints
     - 2.4.6 Pulse velocity
     - 2.4.7 Volume change
     - 2.4.8 Air content and distribution
     - 2.4.9 Chloride-ion content
     - 2.4.10 Cover over reinforcing steel
     - 2.4.11 Half-cell potential to reinforcing steel
     - 2.4.12 Evidence of reinforcement corrosion
     - 2.4.13 Evidence of corrosion of dissimilar metals
     - 2.4.14 Delaminations
     - 2.4.15 Depth of carbonation
     - 2.4.16 Freezing and thawing distress (frost damage)
     - 2.4.17 Extent of deterioration
     - 2.4.18 Aggregate proportioning and distribution

3. Nature of loading and detrimental elements
   - 3.1 Exposure
     - 3.1.1 Environment—arid, subtropical, marine, freshwater, industrial, etc.
     - 3.1.2 Weather—(July and January mean temperatures, mean annual rainfall and months in which 60% of it occurs)
     - 3.1.3 Freezing and thawing
     - 3.1.4 Wetting and drying
     - 3.1.5 Drying under dry atmosphere
     - 3.1.6 Chemical attack—sulfates, acids, chloride
     - 3.1.7 Abrasion, erosion, cavitation, impact
     - 3.1.8 Electric currents
     - 3.1.9 Deicing chemicals that contain chloride ions
     - 3.1.10 Heat from adjacent sources

- 3.2 Drainage
  - 3.2.1 Flashing
  - 3.2.2 Weepholes
  - 3.2.3 Contour
  - 3.2.4 Elevation of drains
- 3.3 Loading
  - 3.3.1 Dead
  - 3.3.2 Live
  - 3.3.3 Impact
  - 3.3.4 Vibration
  - 3.3.5 Traffic index
  - 3.3.6 Other
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  - 3.4.6 Water table (level and fluctuations)

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5. Materials of construction
- 5.1 Hydraulic cement
  - 5.1.1 Class or classes—(portland, blended, high alumina, ground granulated blast-furnace slag)
  - 5.1.2 Type or types, and source
  - 5.1.3 Chemical analysis (obtain certified test data if available)
  - 5.1.4 Physical properties
- 5.2 Aggregates
  - 5.2.1 Coarse
    - 5.2.1.1 Type, source, and mineral composition (representative sample available)
    - 5.2.1.2 Quality characteristics
      - 5.2.1.2.1 Percentage of deleterious material
      - 5.2.1.2.2 Percentage of potentially reactive materials
      - 5.2.1.2.3 Coatings, texture, and particle shape
      - 5.2.1.2.4 Grading, soundness, hardness
      - 5.2.1.2.5 Other properties as specified in ASTM Designation C 33 (C 330 for lightweight aggregate)
      - 5.2.1.2.6 Service record on other projects
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    - 5.2.2.2 Quality characteristics
      - 5.2.2.2.1 Percentage of deleterious material
      - 5.2.2.2.2 Percentage of potentially reactive materials
      - 5.2.2.2.3 Coatings, texture, and particle shape
      - 5.2.2.2.4 Grading, soundness, and hardness
      - 5.2.2.2.5 Other properties as specified in ASTM Designation C 33 (C 330 for lightweight aggregate)
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  - 5.4.1 Air-entraining admixtures
    - 5.4.1.1 Type and source
    - 5.4.1.2 Composition
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    - 5.4.1.4 Manner of introduction
  - 5.4.2 Mineral admixtures
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6.3.5.1 Type—slabs, floors, pavements, appurtenances
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6.3.7.1 Vertical
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CHAPTER 3—DEFINITIONS AND ASSOCIATED PHOTOGRAPHS

Distress manifestations have been categorized and illustrated by photographs. Their severity and extent of occurrence have been quantified where possible. Their purpose is to attempt to standardize the reporting of the condition of the concrete in a structure. Those performing the survey should be thoroughly familiar with the various types of distress and the rating scheme before starting the survey.

A.1 *Crack*—A complete or incomplete separation, of either concrete or masonry, into two or more parts produced by breaking or fracturing.

A.1.1 *Checking*—Development of shallow cracks at closely spaced but irregular intervals on the surface of plaster, cement paste, mortar, or concrete.

A.1.2 *Craze cracks*—Fine random cracks or fissures in a surface of plaster, cement paste, mortar, or concrete.

Crazing—The development of craze cracks; the pattern of craze cracks existing in a surface.

A.1.3 *D-cracking*—A series of cracks in concrete near and roughly parallel to joints, edges, and structural cracks.

A.1.4 *Diagonal crack*—In a flexural member, an inclined crack caused by shear stress, usually at about 45 degrees to the axis; or a crack in a slab, not parallel to either the lateral or longitudinal directions.

A.1.5 *Hairline cracks*—Cracks in an exposed concrete surface having widths so small as to be barely perceptible.

A.1.6 *Pattern cracking*—Fine openings on concrete surfaces in the form of a pattern; resulting from a decrease in volume of the material near the surface, or an increase in volume of the material below the surface, or both.

A.1.7 *Plastic cracking*—Cracking that occurs in the surface of fresh concrete soon after it is placed and while it is still plastic.

A.1.8 *Shrinkage cracking*—Cracking of a structure or member due to failure in tension caused by external or internal restraints as reduction in moisture content develops, or as carbonation occurs, or both.

A.1.9 *Temperature cracking*—Cracking due to tensile failure, caused by temperature gradient in members subjected to external restraints or by temperature differential in members subjected to internal restraints.

A.1.10 *Transverse cracks*—Cracks that develop at right angles to the long direction of the member.

A.2 *Deterioration*—1) Physical manifestation of failure of a material (for example, cracking, delamination, flaking, pitting, scaling, spalling, straining) caused by environmental or internal autogenous influences on hardened concrete as well as other materials; 2) Decomposition of material during either testing or exposure to service.

Disintegration—Reduction into small fragments and subsequently into particles.

A.2.1 *Abrasion damage*—Wearing away of a surface by rubbing and friction.

A.2.2 *Blistering*—The irregular raising of a thin layer, frequently *25* to 300 mm in diameter, at the surface of placed mortar or concrete during or soon after completion of the finishing operation; blistering is usually attributed to early closing of the surface and may be aggravated by cool temperatures. Blisters also occur in pipe after spinning or in a finish plastic coat in plastering as it separates and draws away from the base coat.

A.2.3 *Cavitation damage*—Pitting of concrete caused by implosion, that is, the collapse of vapor bubbles in flowing water that form in areas of low pressure and collapse as they enter areas of higher pressure.

A.2.4 *Chalking*—Formation of a loose powder resulting from the disintegration of the surface of concrete or of applied coating, such as cement paint.

A.2.5 *Corrosion*—Destruction of metal by chemical, electrochemical, or electrolytic reaction with its environment.

A.2.6 *Curling*—The distortion of an originally essentially linear or planar member into a curved shape such as the warping of a slab due to creep or to differences in temperature or moisture content in the zones adjacent to its opposite faces.

A.2.7 *Deflection*—Movement of a point on a structure or structural element, usually measured as a linear displacement transverse to a reference line or axis.

A.2.8 *Deformation*—A change in dimension or shape.

A.2.9 *Delamination*—A separation along a plane parallel to a surface as in the separation of a coating from a substrate or the layers of a coating from each other, or in the case of a concrete slab, a horizontal splitting, cracking or separation of a slab in a plane roughly parallel to, and generally near, the upper surface; found frequently in bridge decks and other types of elevated reinforced concrete slabs and may be caused by the corrosion of reinforcing steel; also found in slabs on grade caused by development, during the finishing operation, of a plane of weakness below the densified surface; or caused by freezing and thawing, similar to spalling, scaling, or peeling except that delamination affects large areas and can often be detected by tapping.

A.2.10 *Distortion*—See *Deformation*.

A.2.11 *Dusting*—The development of a powdered material at the surface of hardened concrete.

A.2.12 *Efflorescence*—A deposit of salts, usually white, formed on a surface, the substance having emerged in solution from within either concrete or masonry and subsequently been precipitated by evaporation.

A.2.13 *Erosion*—Progressive disintegration of a solid by the abrasive or cavitation action of gases, fluids, or solids in motion.

A.2.14 *Exfoliation*—Disintegration occurring by peeling off in successive layers; swelling up and opening into leaves or plates like a partly opened book.

A.2.15 *Exudation*—A liquid or viscous gel-like material discharged through a pore, crack, or opening in the surface of concrete.

A.2.16 *Joint spall*—A spall adjacent to a joint.

A.2.17 *Pitting*—Development of relatively small cavities in a surface; in concrete, localized disintegration, such as a popout; in steel, localized corrosion evident as minute cavities on the surface.

A.2.18 *Peeling*—A process in which thin flakes of mortar are broken away from a concrete surface, such as by deterioration or by adherence of surface mortar to forms as forms are removed.

A.2.19 *Popout*—The breaking away of small portions of a concrete surface due to localized internal pressure that leaves a shallow, typically conical, depression.

A.2.19.1 *Popouts, small*—Popouts leaving holes up to 10 mm in diameter, or the equivalent.

A.2.19.2 *Popouts, medium*—Popouts leaving holes between 10 and 50 mm in diameter, or the equivalent.

A.2.19.3 *Popouts, large*—Popouts leaving holes greater than 50 mm in diameter, or the equivalent.

A.2.20 *Scaling*—Local flaking or peeling away of the near-surface portion of hardened concrete or mortar; also of a layer from metal.

A.2.20.1 *Scaling, light*—Loss of surface mortar without exposure of coarse aggregate.

A.2.20.2 *Scaling, medium*—Loss of surface mortar 5 to 10 mm in depth and exposure of coarse aggregate.

A.2.20.3 *Scaling, severe*—Loss of surface mortar 5 to 10 mm in depth with some loss of mortar surrounding aggregate particles 10 to 20 mm in depth.

A.2.20.4 *Scaling, very severe*—Loss of coarse aggregate particles as well as mortar, generally to a depth greater than 20 mm.

A.2.21 *Spall*—A fragment, usually in the shape of a flake, detached from a larger mass by a blow, by the action of weather, by pressure, or by expansion within the large mass.

A.2.21.1 *Small spall*—A roughly circular depression not greater than 20 mm in depth nor 50 mm in any dimension.

A.2.21.2 *Large spall*—May be roughly circular or oval or, in some cases, elongated, more than 20 mm in depth and 150 mm in greatest dimension.

A.2.22 *Warping*—A deviation of a slab or wall surface from its original shape, usually caused by either temperature or moisture differentials or both within the slab or wall.

A.3 *Textural features and phenomena relative to their development*

A.3.1 *Air void*—A space in cement paste, mortar, or concrete filled with air; an entrapped air void is characteristically 1 mm or more in size and irregular in shape; an entrained air void is typically between 10 μm and 1 mm in diameter and spherical or nearly so.

A.3.2 *Bleeding*—The autogenous flow of mixing water within, or its emergence from, newly placed concrete or mortar; caused by the settlement of the solid materials within the mass; also called water gain.

A.3.3 *Bugholes*—Small regular or irregular cavities, usually not exceeding 25 mm in diameter, resulting from entrapment of air bubbles in the surface of formed concrete during placement and consolidation.

A.3.4 *Cold joint*—A joint or discontinuity resulting from a delay in placement of sufficient time to preclude a union of the material in two successive lifts.

A3.5 *Cold-joint lines*—Visible lines on the surfaces of formed concrete indicating the presence of joints where one layer of concrete had hardened before subsequent concrete was placed.

A.3.6 *Discoloration*—Departure of color from that which is normal or desired.

A3.7 *Honeycomb*—Voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse aggregate particles.

A.3.8 *Incrustation*—A crust or coating, generally hard, formed on the surface of concrete or masonry construction or on aggregate particles.

A.3.9 *Joint*—A physical separation in concrete, whether precast or cast-in-place, including cracks if intentionally made to occur at specified locations; also the region where structural members intersect such as a beam-column joint.

A.3.10 *Laitance*—A layer of weak and nondurable material containing cement and fines from aggregates, brought by bleeding water to the top of overwet concrete; the amount is generally increased by overworking or over-manipulating concrete at the surface by improper finishing or by job traffic.

A.3.11 *Sand pocket*—A zone in concrete or mortar containing fine aggregate with little or no cement.

A.3.12 *Sand streak*—A streak of exposed fine aggregate in the surface of formed concrete, caused by bleeding.

A.3.13 *Segregation*—The differential concentration of the components of mixed concrete, aggregate, or the like, resulting in nonuniform proportions in the mass.

A.3.14 *Stalactite*—A downward-pointing deposit formed as an accretion of mineral matter produced by evaporation of dripping water from the surface of concrete, commonly shaped like an icicle.

A.3.15 *Stalagmite*—An upward-pointing deposit formed as an accretion of mineral matter produced by evaporation of dripping water, projecting from the surface of concrete, commonly conical in shape.

A.3.16 *Stratification*—The separation of overwet or over-vibrated concrete into horizontal layers with increasingly lighter material toward the top; water, laitance, mortar, and coarse aggregate tend to occupy successively lower positions in that order; a layered structure in concrete resulting from placing of successive batches that differ in appearance; occurrence in aggregate stockpiles of layers of differing grading or composition; a layered structure in a rock foundation.

A.3.17 *Water void*—Void along the underside of an aggregate particle or reinforcing steel that formed during the bleeding period; initially filled with bleed water.

Fig. A.1.1—Checking

Fig. A.1.4—Diagonal cracks

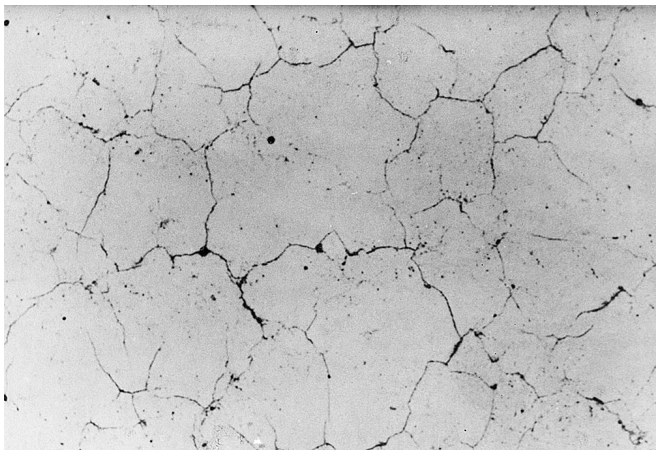

Fig. A.1.2—Craze cracks

Fig. A.1.6a—Pattern cracking (fine)

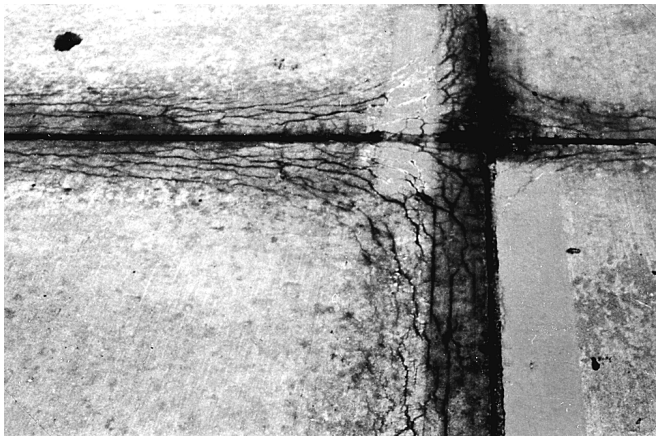

Fig. A.1.3—D-cracking (fine)

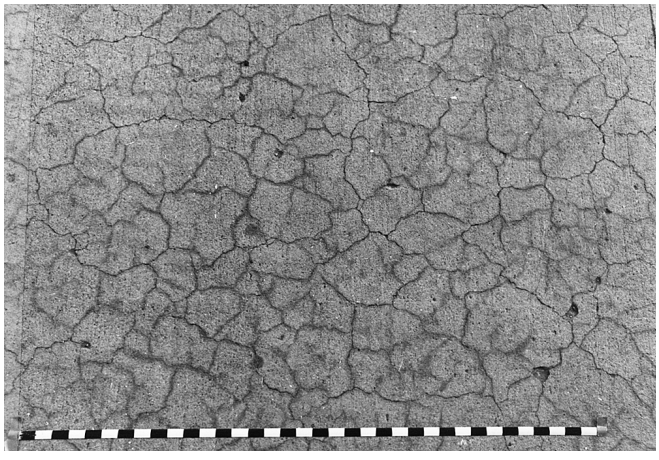

Fig. A.1.6b—Pattern cracking (medium)

Fig. A.1.6c—Pattern cracking (wide)

Fig. A.1.6e—Pattern cracking (restraint of volume change)

Fig. A.1.6d—Pattern cracking (alkali-silica reaction)

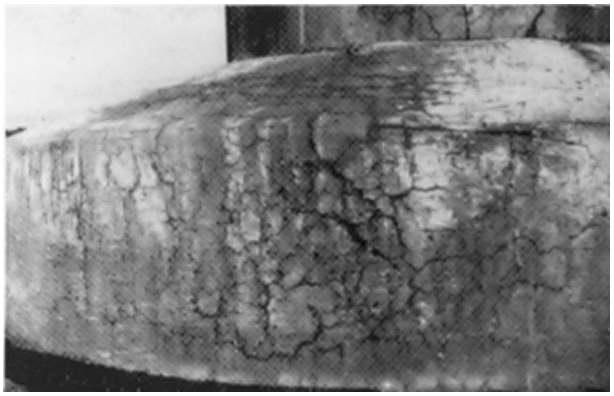

Fig. A.1.6f—Pattern cracking (alkali-carbonate reaction)

Fig. A.1.7—Plastic cracking

Fig. A.1.8—Shrinkage cracking

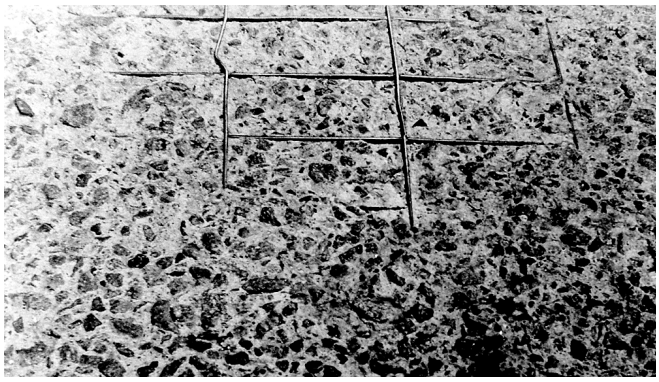

Fig. A.2.1—Abrasion damage

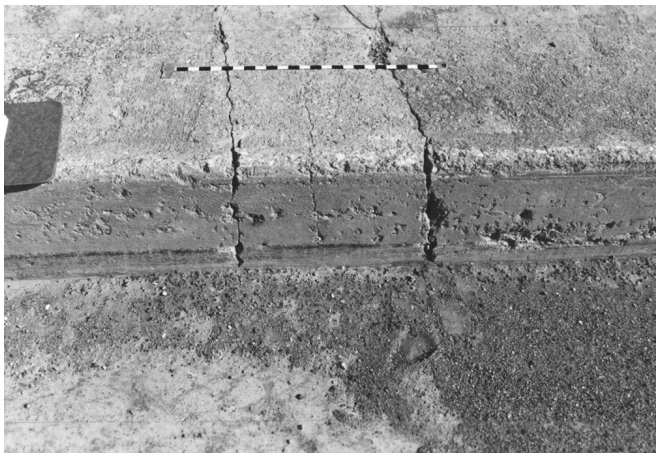

Fig. A.1.10—Transverse cracking (wide)

Fig. A.2.2—Shrinkage cracking

Fig. A.2—Disintegration

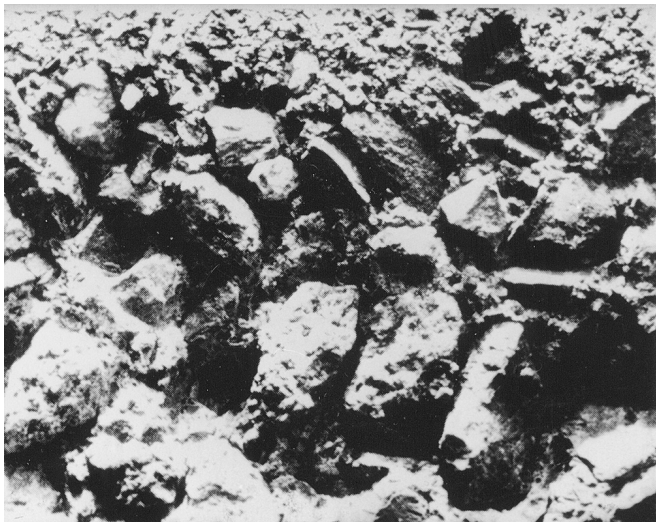

Fig. A.2.3—Cavitation damage

Fig. A.2.5—Corrosion damage

Fig. A.2.10—Distortion

Fig. A.2.9—Delaminations

Fig. A.2.11—Dusting

Fig. A.2.12—Efflorescence

Fig. A.2.16a—Joint spall

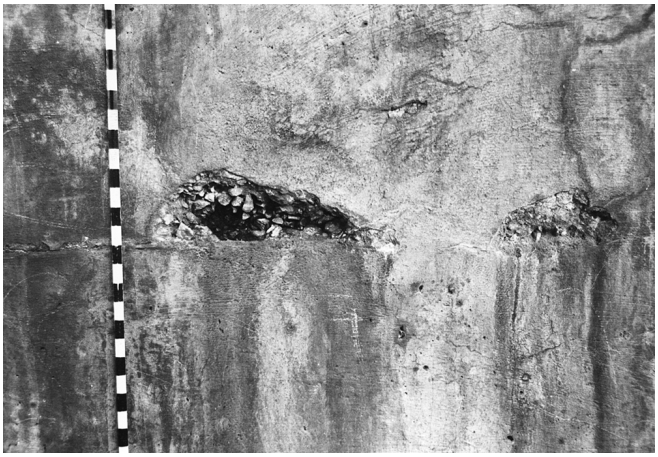

Fig. A.2.13—Erosion

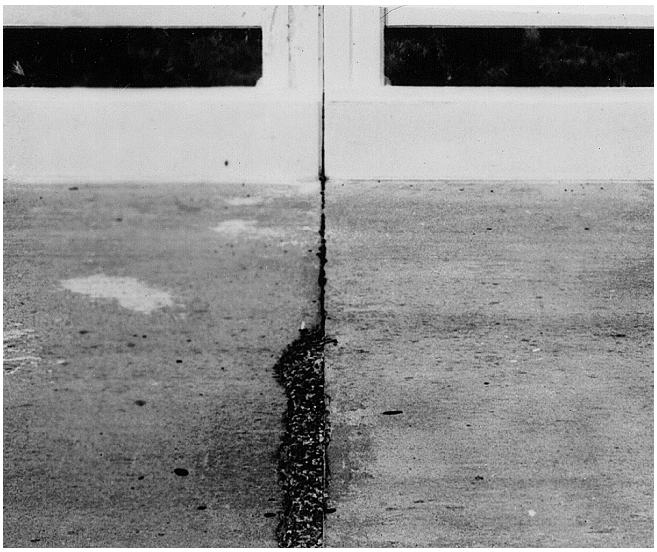

Fig. A.2.16b—Joint spall

Fig. A.2.15—Erosion

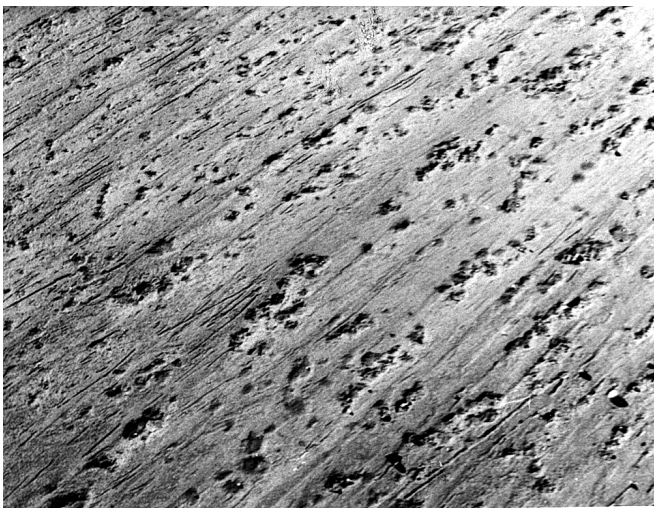

Fig. A.2.17—Pitting

Fig. A.2.18a—Peeling

Fig. A.2.18b—Peeling (close up)

Fig. A.2.19—Popouts

Fig. A.2.19.1—Popout (small)

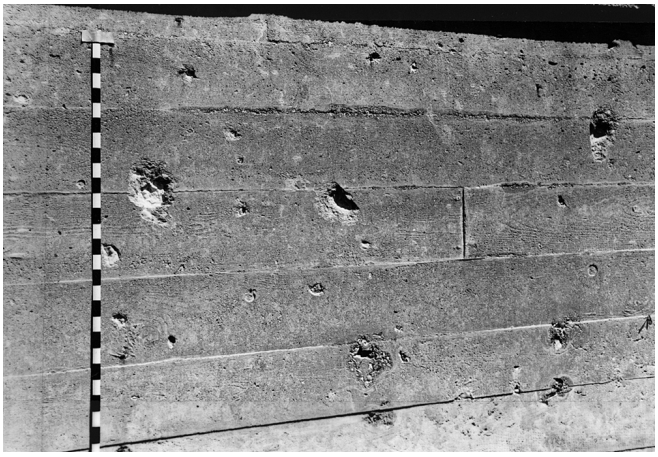

Fig. A.2.19.2—Popout (medium)

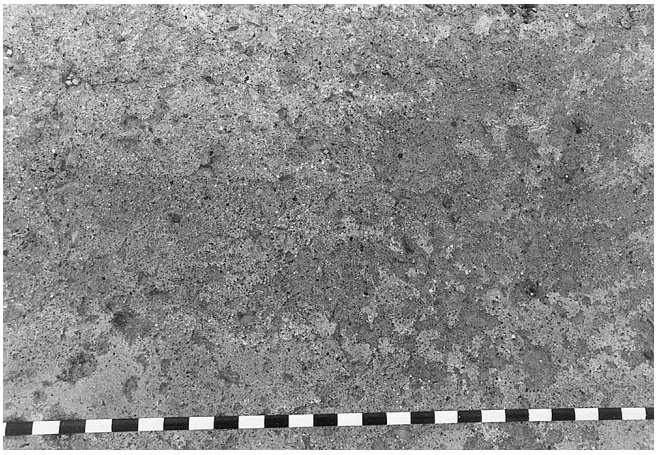

Fig. A.2.20.1b—Close-up scaling (light)

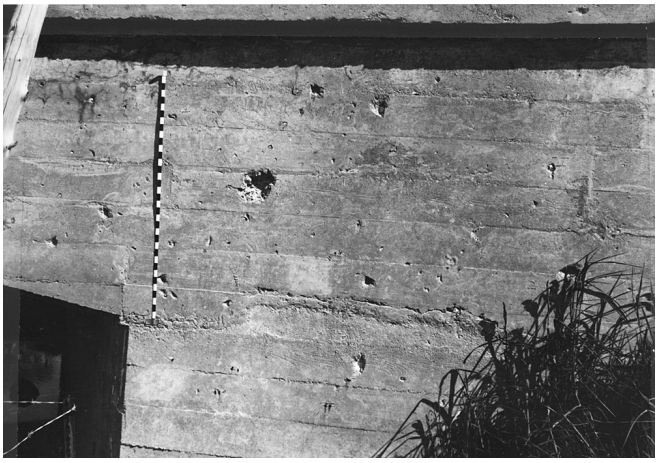

Fig. A.2.19.3—Popout (large)

Fig. A.2.20.2a—Scaling (medium)

Fig. A.2.20.1a—Scaling (light)

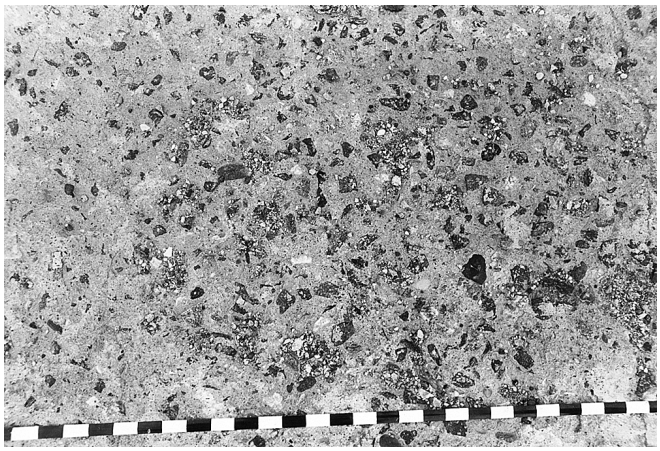

Fig. A.2.20.2b—Close-up scaling (medium)

Fig. A.2.20.4a—Scaling (very severe)

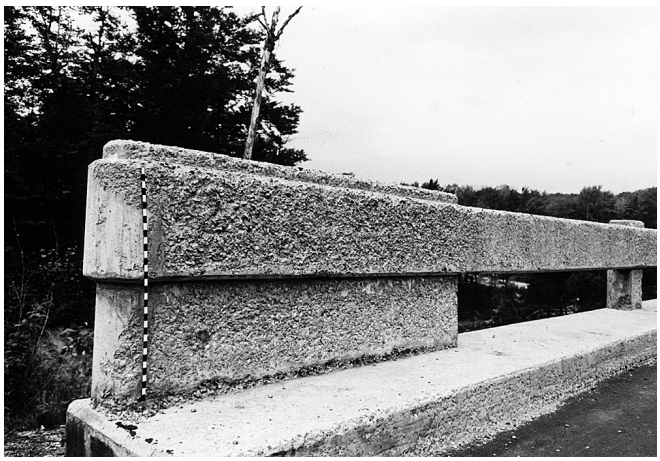

Fig. A.2.20.3a—Scaling (severe)

Fig. A.2.20.4b—Close-up scaling (very severe)

Fig. A.2.20.3b—Close-up scaling (severe)

Fig. A.2.21.1—Small spall

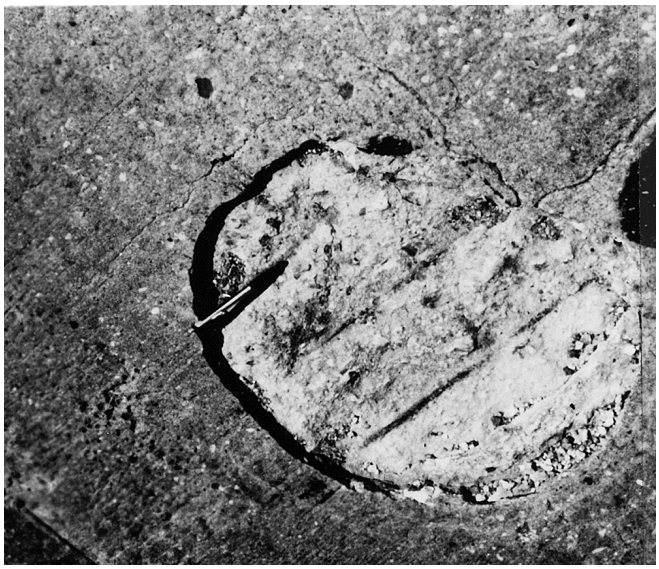

Fig. A.2.21.2—Large spall

Fig. A.3.5—Cold joint

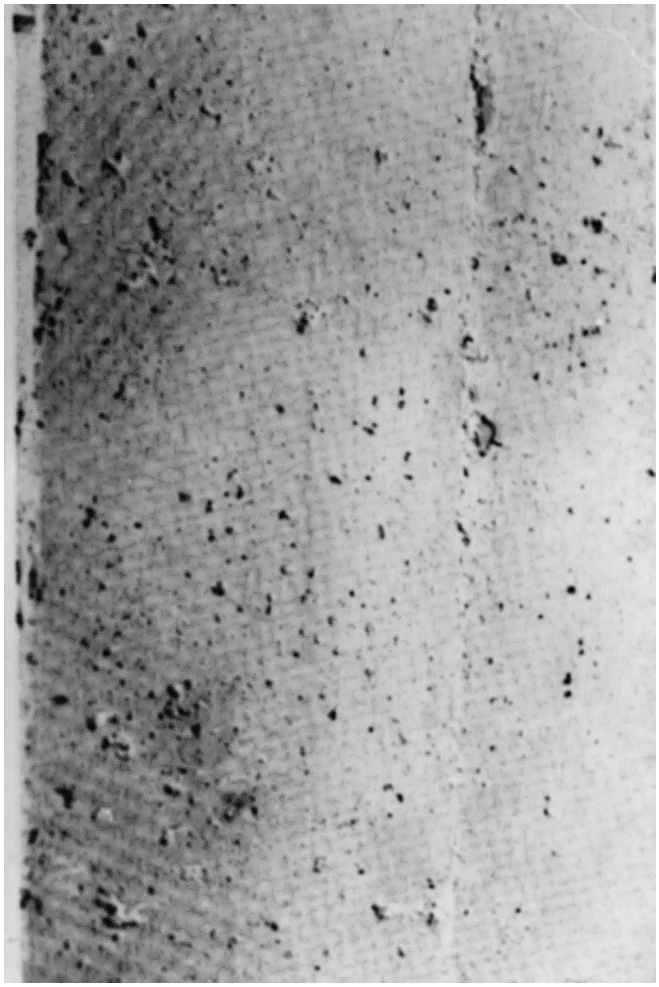

Fig. A.3.3—Bugholes

Fig. A.3.6—Close-up scaling (severe)

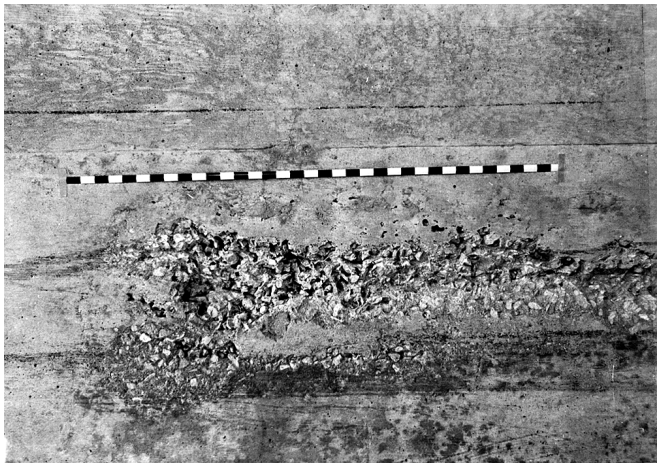

Fig. A.3.7—Honeycomb

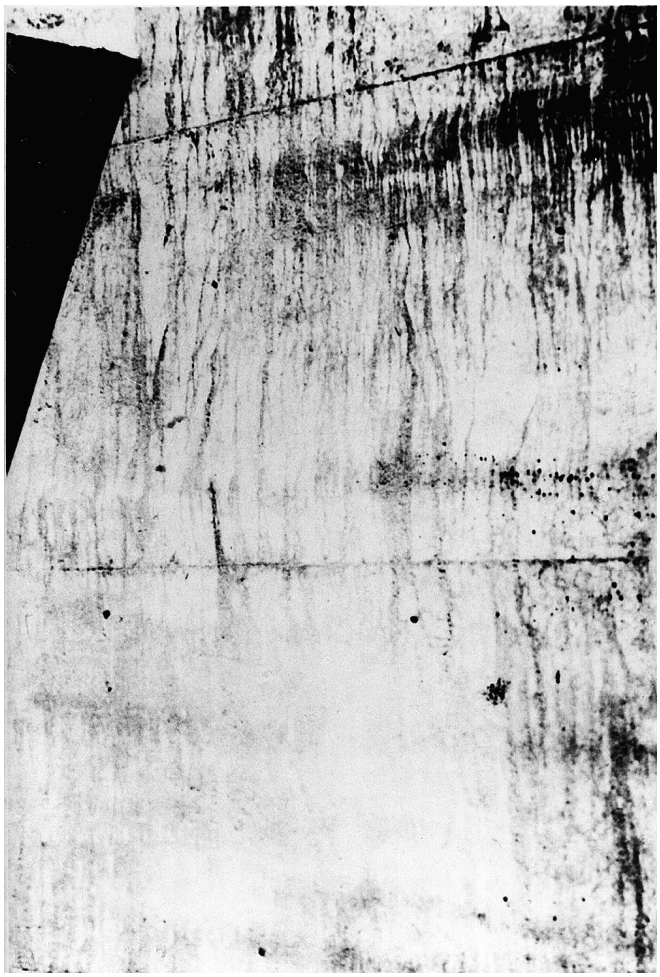

Fig. A.3.12—Sand streak

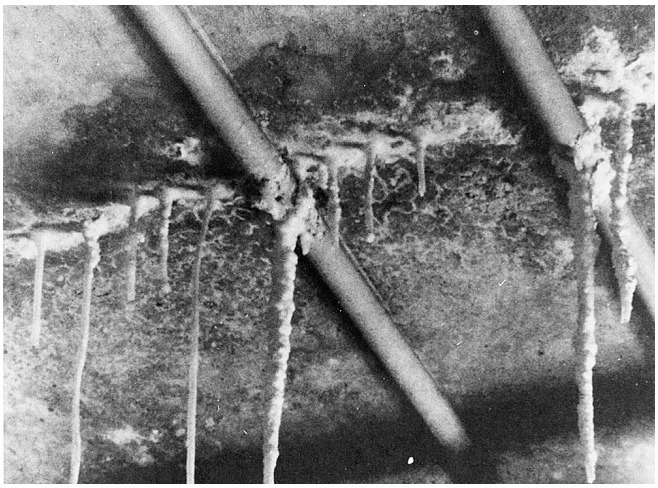

Fig. A.3.14—Stalactite

This report was submitted to letter ballot of the committee and approved according to ACI balloting procedures.