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Visual Condition Survey of Concrete—Guide

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Visual Condition Survey of Concrete—Guide

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Visual Condition Survey of Concrete—Guide

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This guide provides guidance on planning, performing, and documenting visual condition surveys of concrete structures. Chapter 1 defines the objective and scope of this guide and Chapter 2 covers terminology. Chapter 3 includes the process and tools one would use to plan and conduct a condition survey. Chapter 4 provides an image library and associated descriptions of the visual features that may be encountered when conducting the survey. Chapters 5

through Chapter 7 discuss the likely causes of the various features one might see when performing a visual condition survey.

Keywords: condition survey; construction defects; cracking; deterioration; durability-related distress; surface features; survey documentation; visual survey.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Generally conducted as part of a field investigation, a visual condition survey of concrete aids in assessing the condition and performance of the structure. A visual condition survey of concrete can be conducted throughout the life of a concrete structure.

Visual condition surveys performed at the completion of construction and routinely performed during the service life of a structure provide important information that can aid in assessing a structure's performance and durability. A single survey or a collection of surveys can aid in the early detec-

tion of distress conditions and deterioration, prompting repair or rehabilitation before replacement is necessary.

An individual conducting the visual condition survey should identify physical features observed and document their extent and location on the structure. This document provides guidance for conducting a visual condition survey and understanding the potential phenomena causing the visual features.

1.2—Objective and scope

Visual condition surveys involve visual examination of a concrete element for the purpose of identifying surface and geometrical features and documenting their physical extent. It is limited to the visible surfaces of the concrete.

This guide is intended to assist the person conducting the visual condition survey to plan and execute the survey, to understand common features that may be visible during a survey, and to document the results of the survey. **Chapter 3** presents methodologies to conduct the survey. **Chapter 4** defines common features that may be encountered in a condition survey and provides photographs to illustrate some of these features to aid in their identification. **Chapters 5 to 7** summarize the factors that can lead to the manifestation of various features related to construction, in-service conditions, and durability. The summaries are intended to assist the reader in better understanding and interpreting observations of a condition survey. References are provided to other published information to further aid the reader.

CHAPTER 2—DEFINITIONS

2.1—Definitions

Please refer to the latest version of ACI Concrete Terminology for a comprehensive list of definitions. Definitions provided herein complement that resource. Additionally, Chapter 4 of this guide provides a glossary of terms used to characterize visible features that may be encountered during a visual survey of concrete elements, many of which are defined in ACI Concrete Terminology. Some of the features listed in Chapter 4 are accompanied with illustrative photographs. The definitions provided in Chapter 4 also complement ACI Concrete Terminology.

CHAPTER 3—VISUAL CONDITION SURVEY PROCESS

A visual condition survey is a nondestructive evaluation using the human eye and basic supplemental tools as instruments. It is generally conducted as part of a field investigation. A field investigation may be requested by an agency or owner to document the type and extent of visible damage present in a structure. A field investigation can be divided into three primary tasks: 1) preparation and planning; 2) on-site verification of the accuracy of gathered information; and 3) conducting a visual condition survey of the structure. The visual condition survey includes: 1) identifying visible features; 2) documenting their location on the structure or element; and 3) documenting their approximate extent and severity (**ACI 364.1R**).

The person conducting the survey should be knowledgeable of concrete defects and distress conditions related to construction procedures, in-service conditions, unexpected concrete behavior, and durability issues. They should be competent in performing visual concrete condition surveys. The following section provides general guidance on the process of conducting a visual condition survey.

3.1—Planning and preparation

Planning and preparation increase the likelihood of a successful visual condition survey. Initial planning helps the person understand the requirements and scope of the survey to be performed. The person should take the opportunity to review project-related documents and conditions and communicate with the construction or maintenance team, or both, to determine pertinent information about the elements to be surveyed.

3.1.1 Project documents—Pertinent project documentation may include construction documents and records. These documents provide information about the applicable code and specifications for the project. Project documentation should include allowable construction tolerances for the project. Construction documents may consist of construction drawings, shop drawings, as-built construction drawings, historical inspection and testing reports, relevant documents for repairs or rehabilitation, concrete mixture design submittals, delivery tickets, quality assurance and quality control records, non-conformance reports, and construction photographs.

Construction drawings will indicate locations and physical details about the area to be surveyed. Similar to the construction drawings, shop drawings are supplied by manufacturers of prefabricated components used within a structure and may provide useful details of the members to be surveyed. Drawings can be used to verify in-place dimensions, map visible features, and record notes.

Relevant project documentation should be reviewed to provide sufficient background information to understand the design intent and as-built construction of the structure. If previous concrete surveys or repairs have been performed, documents pertaining to these activities should be requested for review to indicate changes the structure has incurred over time.

3.1.2 Interviews—Interviews with relevant parties can yield useful information that may not be reflected in the project documentation. This information includes the age of the structure at critical points in time (for example, removal of formwork and installation of joints), the environment in which the concrete is exposed, field changes to the concrete mixture design, unusual static and dynamic loading conditions, and information related to inspection history.

3.1.3 Precondition survey meetings—In certain circumstances, a precondition survey meeting should be held and include members of the construction or maintenance team, or both; the owner's representative; and the inspection agency, if applicable. They can provide the person with history and information about the area to be surveyed. Topics such as structure accessibility and required measures to safely

conduct a visual condition survey should be addressed during this meeting.

3.2—Conducting the visual condition survey

Ideally, the condition survey should start with a cursory walk-through to identify the different structural elements to be examined. Next, a methodical survey of the elements should be conducted, as required, to:

- Measure and record crack dimensions, location, and pattern
- Identify and record visible defects, damage, deterioration, and the presence of any foreign material such as paint or debris within defects (for example, crack openings)
- Record out-of-plumb elements, deformations, misalignments, and settlements
- Record loose or defective parts, connectors, and joints interfacing the elements in question
- Record water-related issues (leaks, ponding, drainage, infiltrations, and staining)

3.2.1 Crack mapping—Cracks are common indications of the presence of tensile strains within concrete that exceed the concrete's tensile strain capacity. There are a variety of crack attributes which can be recorded during a visual survey. Refer to [ACI 224R](#), [ACI 224.1R](#), and [ACI 224.2R](#) for further information on cracking and crack attributes. The process of measuring and recording cracks is called crack mapping. A crack map is a drawing indicating the width, length, patterns, and locations of cracks for the area surveyed.

Crack dimensions should be measured and recorded, along with location and orientation, on a scaled drawing or photograph of the element. Representative crack widths should be measured along the length of a crack, including the maximum crack width. Crack widths should be measured perpendicular to the crack faces. Distinction between actual crack width and spalling (or raveling) of the crack faces should be made. The straight-line distance between the start and end of a crack can be measured to give an approximate crack length. Crack depth cannot typically be determined visually; further nondestructive testing or invasive probing (for example, drilling or coring) may be needed.

A cracking index that summarizes the severity of cracking for the element surveyed can also be determined. One such cracking index was developed by the Laboratoire Central des Ponts et Chaussées (LCPC) in France ([LCPC 1999](#)) and is recommended by the Federal Highway Administration (FHWA) to assess the extent of cracking due to alkali-silica reaction (ASR) ([Fournier et al. 2010](#)), or other similar causes. The index indicates cumulative crack width per unit length. The index is determined by summing the width of cracks that intersect four perpendicular lines defining a 20 x 20 in. (500 x 500 mm) square on the surface of the element. Different reference grid dimensions may be adapted to suit the element being surveyed. Guidance on interpreting this type of cracking index data for structures with map cracking is provided in Fournier et al. (2010).

3.2.2 Rating visible deterioration—It is generally difficult to classify and quantify visible signs of deterioration

and damage; therefore, guidelines on descriptions or ratings should be established before conducting the survey to maintain consistency and better evaluate significance of deterioration or damage. **ACI 364.1R** provides further recommendations on the topic. When the survey is conducted in teams of persons, it is important that the individuals are aligned in their process of rating deterioration such that consistency is maintained among individuals. Surveying the same elements together and comparing results before splitting into teams can be beneficial.

3.2.3 Visible deviations and deformations—Deviations of elements from their intended location and size should be measured and recorded. Normally, deflections of horizontal and vertical elements exceeding $L/240$ should be visually detectable, where L is the span length. The slope of vertical and horizontal elements exceeding $L/50$ should also be visually detectable (**ACI 364.1R**).

3.3—Supplemental tools

A person should have the following tools to facilitate the visual condition survey: enhanced visibility tools, measurement tools, recording devices, and markers.

3.3.1 Enhanced visibility tools—The most common tool to enhance visibility is additional lighting. There are generally two forms of additional lighting—mobile or fixed. Examples of mobile lighting devices include handheld flashlights, and headlamps. Floodlights are an example of fixed lighting. The selection of the lighting type depends on the location and size of the area to be examined, and the available lighting when the survey is taking place. Lighting sources include incandescent, halogen, fluorescent, or light-emitting diodes (LEDs). However, the person should be aware of the effect of light color temperature on surface appearance. For instance, the color temperature of the light may affect the ability to observe and characterize staining on a concrete surface. Generally, color temperature corresponding to daylight (typically 5500 to 6500 K) provides suitable conditions for review of surface conditions.

Some surface conditions are difficult to survey due to narrow crack widths, rough surface conditions, or improper lighting. Surface wetting can be used to help identify surface cracks. The surface can be lightly sprayed with water. As the concrete surface dries, water retained within the crack will locally discolor the concrete and increase visibility of the cracks. This technique is especially useful when it is necessary to perform detailed crack mapping.

Other enhanced viewing methods include the use of binoculars, zoom lenses, drone-mounted cameras, flexible inspection cameras or borescopes, and crack comparator loupes. Binoculars and zoom lenses on cameras can be especially useful to provide more detailed observations if the survey must be conducted further than 5 ft (1.5 m) from the concrete surface due to access restrictions. Furthermore, advanced digital photography methods such as digital analysis of photographs and photogrammetry are becoming increasingly popular. These methods involve advanced processing or interpretation of high-resolution photographs. Use of drone-mounted cameras is becoming more common

to conduct visual surveys of tall buildings, rooftops, or other portions of a structure that are not readily accessible or otherwise present a high risk to the persons performing the survey. Drone-mounted high-resolution camera surveys are typically conducted by reviewing the aerial imagery in real time, collecting continuous video recordings, collecting still photographs, or a combination of the three methods. Drone surveys conducted for professional services must be performed in accordance with state and federal laws.

Flexible inspection cameras or borescopes can be helpful in viewing inaccessible areas. Often, these cameras include an integral light source, and the live video can be viewed from a connected device or an independent screen. A crack comparator loupe is an optical device that magnifies a portion of an element. The field of view is small, and the area can be viewed under natural daylight, or the loupe may have a built-in lamp to enhance the light level. The loupe contains a scale to measure crack width. Some loupes can be connected to an image-capturing device to record digital images.

3.3.2 Measuring devices—Distance-measuring devices include traditional tape measures and rulers or laser-based electronic devices. If detailed measurements are necessary for the visual survey, the same type of measuring device should be used throughout the survey. Other tools such as plumb bobs, levels, lasers, and squares can aid in evaluating deformations, misalignments, and settlements. A ruler, tape measure, or another well-known artifact, such as a coin, should be included in photographs to provide a reference scale for the image.

Crack comparator cards are handheld transparent plastic cards that include printed lines of varying widths. The line widths typically range from approximately 0.003 to 0.100 in. (0.10 to 2.5 mm). Crack comparator cards are used to determine approximate surface crack widths as shown in Fig. 4.1.1.

3.3.3 Recording devices—Notes and images of observed conditions and features can be handwritten or digitally recorded. These devices include paper, digital tablets, still cameras, video cameras, and voice recorders.

3.3.4 Markers—Markers are used to highlight or label features or areas on or adjacent to the concrete. Markers may include spray paint, chalk, crayon, soapstone, survey flags, survey tape, and survey stakes.

3.4—Documenting and reporting

Reporting the findings of the visual condition survey is critical to the overall evaluation of a structure. The reporting of the visual survey should typically include four main topics: general information, findings, conclusions, and supporting documentation.

3.4.1 General information—This section of the report provides the end-user with information that includes the name(s) of the person(s) conducting the survey, the date of survey, the scope of work, the structure surveyed, weather conditions at the time of the survey, equipment used, and client information. This section is usually at the beginning of the visual condition survey report. This section should include

include the procedure by which the survey was performed and the limitations of the visual survey.

3.4.2 Findings—The findings section of the report should provide the results of the condition survey. Generally, observed features can be identified, characterized, located, and dimensioned on a schematic drawing of the element surveyed. Features to be identified include, but are not limited to:

- (a) Surface conditions
- (b) Distress conditions
- (c) Observed misalignment
- (d) Presence of coatings or previous repairs

Construction or shop drawings can be used for this purpose. This section will include a discussion on observable features and their extent. Photos and sketches can be used to report findings.

3.4.3 Conclusions—This section of the report indicates the main findings and predominant features that were observed. Potential deterioration or damage mechanisms affecting the area examined can be provided if they can be deduced based on the survey results. The conclusions should include the limitations of the visual survey and should indicate, if appropriate, that some findings are subjective.

3.4.4 Supporting documentation—Supporting documentation used in planning, conducting, interpreting, and reporting the condition surveys can be added. The additional information may include work experience and certification of the person(s) who performed the survey, images, and other documentation to support findings and conclusions.

3.5—Limitations to visual surveys

Visual surveys of readily accessible surfaces of a concrete structure or element should not be considered comprehensive surveys that are inclusive of all potential concrete defects, damage, or deterioration. Visual condition surveys are limited to observations of visible concrete surfaces without using invasive or other nondestructive techniques. To gain more information about the mechanisms contributing to the observed surface conditions, visual surveys may be supplemented by concrete core sampling and petrographic analysis. In addition, other invasive probing techniques, or nondestructive testing methods, such as those discussed in [ACI 228.2R](#), can be used.

CHAPTER 4—DESCRIPTION AND VISUAL LIBRARY OF FEATURES

This chapter provides a glossary of terms used to characterize different visible features that may be encountered during the visual survey of a concrete structure. Included are photographs to illustrate the general appearance of some of the features. Refer to [ACI Concrete Terminology](#) for additional terms and definitions.

The glossary is divided into six general categories under which a feature may be assigned: cracks, geometric features, loss of material, accretion, staining, and placement features. For each category, a non-exhaustive list of terms is provided. The definitions are based on the visible characteristics of the feature for the purpose of identification during a visual

survey. [Chapters 5 through 7](#) provide potential causes of these observed features.

4.1—Crack

A crack is the visible separation on a concrete surface where the concrete surface is split into two or more parts. Cracks can be characterized in terms of their width and configuration. The term “cracking” refers to a series of cracks. This section describes different features that involve cracks.

4.1.1 Crack width—Distance between opposite faces of a crack measured perpendicular to the crack faces (Fig. 4.1.1).

4.1.1.1 Hairline crack—A crack that is barely visible to the naked eye, typically less than approximately 0.003 in. (0.08 mm) in width.

4.1.2 Crack configuration—Arrangement of a crack or multiple cracks in a particular form or pattern.

4.1.2.1 Cracking—Development of a network of narrow surface cracks with a random configuration, and typically spaced 1 to 2 in. (25 to 50 mm) apart.

4.1.2.2 D-cracking—A series of cracks near and roughly parallel to joints and edges resulting from use of coarse



Fig. 4.1.1—Measurement of crack width.

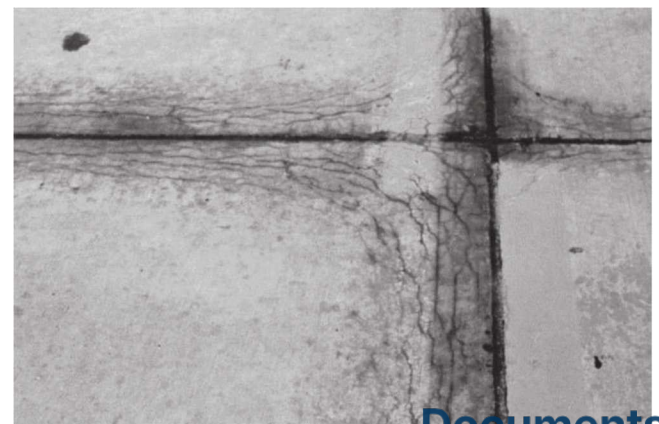


Fig. 4.1.2.2—D-cracking.

aggregate that is susceptible to damage during cycles of freezing and thawing (Fig. 4.1.2.2).

4.1.2.3 Diagonal crack—A crack: 1) in a flexural member caused by shear stress, usually at approximately 45 degrees to the longitudinal axis of the member (Fig. 4.1.2.3); and 2) that is not parallel to the lateral or longitudinal directions of the member.

4.1.2.4 Longitudinal crack—A crack parallel to the length of a member (Fig. 4.1.2.4).



Fig. 4.1.2.3—Diagonal crack.



Fig. 4.1.2.4—Longitudinal crack.



Fig. 4.1.2.5—Map cracking.

4.1.2.5 Map cracking—Formation of an irregular polygonal pattern of intersecting cracks (Fig. 4.1.2.5).

4.1.2.6 Pattern cracking—Cracking in the form of a repeated sequence.

4.1.2.7 Plastic shrinkage cracking—Formation of surface cracks before initial setting of concrete (Fig. 4.1.2.7).

4.1.2.8 Random cracking—Uncontrolled cracks that develop in randomly oriented directions.

4.1.2.9 Shrinkage cracking—Cracking due to external or internal restraints due to volume decrease of concrete (Fig. 4.1.2.9).



Fig. 4.1.2.7—Plastic shrinkage cracking.

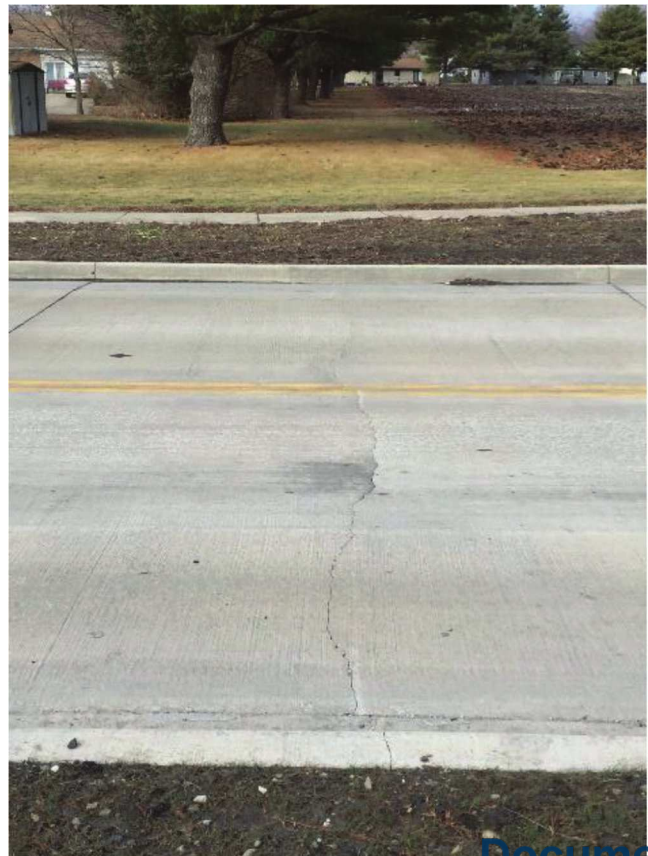


Fig. 4.1.2.9—Shrinkage cracking.



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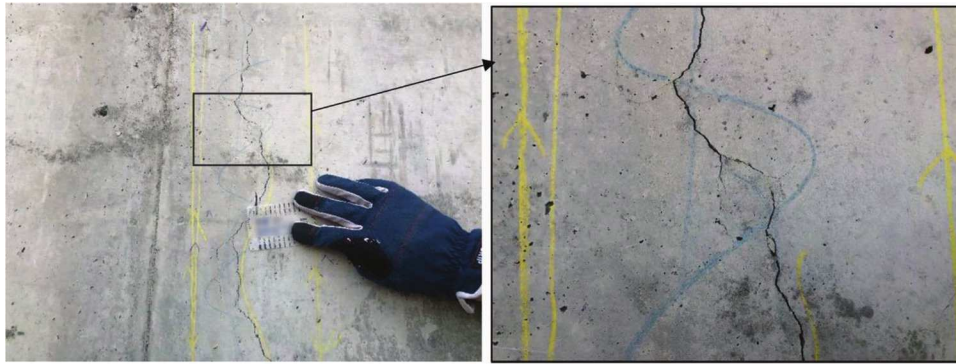


Fig. 4.1.2.10—Cracking in a mass concrete element, determined through further investigation, including review of temperature history and petrographic studies, to be thermal cracking.



Fig. 4.1.2.11—Transverse crack.

4.1.2.10 Thermal cracking—Cracking resulting from differences between interior temperatures and surface temperatures of concrete elements, also referred to as temperature cracking (Fig. 4.1.2.10).

4.1.2.11 Transverse cracking—Cracking that is approximately perpendicular to the longitudinal axis of a member (Fig. 4.1.2.11).

4.2—Geometric features

The following geometric features are related to the shape or geometry of an element:

4.2.1 Curling—Warping of a slab, pavement, or wall panel (refer also to *warping* [4.2.7]).

4.2.2 Deformation—A change in dimension or shape of a member due to internal or applied forces or loss of support.

4.2.3 Deflection—Movement of a point on a structure or structural member from its original or reference position, usually measured in a specific direction.

4.2.4 Distortion—Change in the shape of a member.

4.2.5 Faulting—Differential displacement of a slab or wall along a joint or crack (Fig. 4.2.5).

4.2.6 Swelling—An increase in volume (also referred to as expansion or volume change).

4.2.7 Warping—An out-of-plane distortion of a member from its original shape (refer also to *curling* [4.2.1]).



Fig. 4.2.5—Faulting.



Fig. 4.3.1—Chalking or dusting.

4.3—Loss of material

This section includes features that involve loss of material. In some cases, material loss is related to chemical activity and in other cases it results from physical actions.

4.3.1 Chalking—Development of a powdered material on a concrete surface that is easily rubbed off, also called dusting (Fig. 4.3.1).