Protection of Concrete Work

ASCC Position Statement #40

Most project specifications, including ACI 301-10, "Specifications for Structural Concrete," contain provisions for protection of concrete work such as the following:

> "*Protection from mechanical injury*—During the curing period, protect concrete from damage by mechanical disturbances, including load-induced stresses, shock, and vibration. Protect concrete surfaces from damage by construction traffic, equipment, materials, running water, rain, and other adverse weather conditions."

The first sentence states, and the second sentence implies, that the required protection is during the curing period. This is reasonable because protecting the concrete during the curing period reduces the likelihood of failing to reach the specified strength. Since 1960, ACI 301 has included this statement regarding protection during the curing period. But some Owners and Construction Managers interpret this specification clause as requiring concrete contractors to protect the concrete until project completion.

For instance, on a sports stadium project, the concrete was required to have a broom finish. After two years of construction, during which the concrete was used by all trades as a working surface, the broom finish wore unevenly. The Owner believed that the specification clause required the concrete contractor to protect the surface from damage caused by all trades, even when the concrete contractor was no longer on site. A lawsuit resulted from this interpretation.

But do the two sentences cited require the concrete contractor to be responsible for work by other trades? "Guidelines for Authorities and Responsibilities in Concrete Design and Construction," prepared by the ACI Committee on Responsibility in Concrete Construction and published in *Concrete International*, April 2005, provides assistance in interpreting these two sentences. This document states two fundamental principles in determining responsibility:

- "One over-riding principle in these guidelines is the simple notion that responsibility and authority must be congruent"; and
- "The other principle is that every entity should be responsible for its own work."

Using these principles, the logical conclusion is that concrete contractors are not responsible for the work of other trades because they do not have the authority to control the other trades' work or limit their construction traffic. It is clear that concrete contractors have the responsibility and authority to protect the concrete they place by controlling their own work during the curing period for that concrete.

ASCC concrete contractors will work with Owner's Representatives, Prime Contractors, and Design Professionals in addressing protection of the concrete during the curing period. However, damage to the concrete by other trades is the responsibility of those trades. If you have any questions, contact your ASCC concrete contractor or the ASCC Technical Hotline at (800) 331-0668.

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Trowel Marks on Concrete Floors

ASCC Position Statement #4

Some specifications require concrete contractors to produce floor surfaces that are free of trowel marks. However, the specifications don't define the term "trowel marks."

Both ACI 301-99, "Specifications for Structural Concrete for Buildings," and ACI 302.1R-96, "Guide for Concrete Floor and Slab Construction," use the term "trowel marks" (Section 5.3.4.2c in ACI 301 and Section 11.9 in ACI 302.1R). Neither document defines the term, nor is the meaning clear from the context in which the term is used. ACI 116R-00, "Cement and Concrete Terminology," doesn't include a definition of trowel marks.

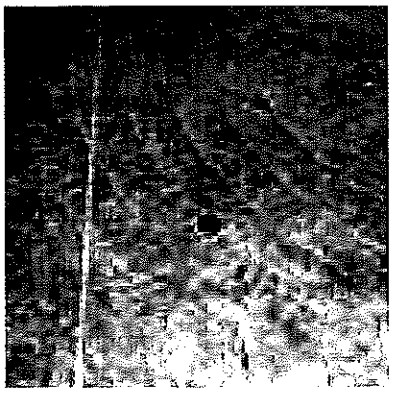

Fig. 1: Trowel pattern

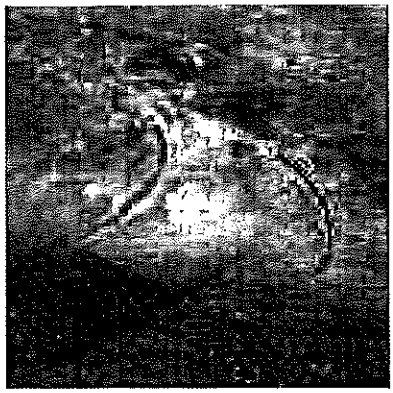

Fig. 2: Trowel marks

Because differing interpretations of this term can cause problems with acceptance of the finished floor, the American Society of Concrete Contractors (ASCC) seeks to establish a consensus definition for trowel marks that is applicable during both the bidding phase and execution/acceptance of the finished floor. Establishing a common industry definition provides all parties with a fair and equitable ability to judge the acceptability of a finished floor surface.

To provide a clear and specific understanding, this position statement includes a definition and photo for two terms: "trowel pattern" and "trowel marks."

Trowel pattern: A concrete surface feature (Fig. 1)–produced by troweling–that can be seen but can't be felt (has no vertical profile).

Trowel marks: Concrete surface features (Fig. 2)–produced by troweling–that can be seen and felt (have a vertical profile).

ASCC concrete contractors will remove trowel marks from concrete surfaces by rubbing, grinding, or other appropriate methods. A trowel pattern is not considered to be a surface defect and will not be removed from concrete floors.

If trowel patterns are unacceptable, the specifier must make a specific requirement in the specification.

If you have any questions, contact your ASCC concrete contractor or the ASCC Technical Hotline at (800) 331-0668.

Update: Reference to "trowel marks" has been deleted from ACI 301-10. ACI 302.1R-04 contains the same sentence from ACI 302.1R-96: "Similarly, if supervisors insist that a floor be finished by a certain time, whether it is ready or not, blisters, trowel marks, and poor surfaces can result." This statement was in Section 11.7 of both documents, but doesn't help to define the term "trowel marks."

(08-11 update replaces 03-03 original)

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Specifications for Crack Repair

ASCC Position Statement #5

Some specifications hold concrete contractors responsible for crack repair as shown by the following examples:

- Prior to filling any structure with water, cracks 0.01 in. (0.3 mm) in width or greater shall be "vee'd" as indicated and filled with specified sealant;
- Repair isolated random horizontal cracks:
  - Less than 0.01 in. wide, using specified silane sealer;
  - 0.01 in. to less than 0.03 in. (0.7 mm) wide, using specified methyl methacrylate; and
  - 0.03 to 0.06 in. (1.5 mm) wide, using rout and seal with specified sealant.

  Repair isolated random vertical cracks more than 0.01 in. wide using specified epoxy injection product; and
- Formed concrete surfaces requiring repairs shall include cracks in excess of 0.01 in. Unformed surfaces requiring repair shall include all surface defects such as crazing, cracks in excess of 0.01 in. wide, or cracks that penetrate to the reinforcement or through the member.

These specifications don't address how, where, and when the cracks will be measured. Because the warranty period is typically at least 1 year, contractors also can be held responsible for repairing cracks that grow to the specified width while the facility is in operation.

In bidding jobs with such specification requirements, it's difficult to estimate the total length of cracks that will require repair because the number and width of cracks are affected by the design and construction methods. The Commentary for ACI 318-02, "Building Code Requirements for Structural Concrete," states: "Crack widths in structures are highly variable. In previous codes, provisions were given for distribution of reinforcement that were based on empirical equations using a calculated maximum crack width of 0.016 in. The current provisions for spacing are intended to limit surface cracks to a width that is generally acceptable in practice but may vary widely in a given structure."

ACI 224R-01, "Control of Cracking in Concrete Structures," indicates that there are many specific causes of cracking and the document is "...designed to help the engineer and the contractor in developing crack-control measures." Designers and contractors can develop crack-control measures, but contractors are not responsible for, nor can they estimate, the amount of cracking that may occur as a result of design decisions.

Contractor compliance with the plans and specifications will produce a structure with a cracking potential that is determined by the designer's and specifier's decisions regarding reinforcement, joint spacing, concrete properties, and other variables. It is impossible for a prudent contractor to make a reasonable estimate of the amount of cracking of a certain width for a given contract and warranty period. Therefore, ASCC contractors will exclude provisions requiring such estimates from their bids.

Noncompliance with the project plans and specifications doesn't always cause cracks, but ASCC contractors will assume responsibility for cracks that are a direct result of such noncompliance. We suggest providing a project allowance for crack repair or requesting a unit price for horizontal, vertical, and overhead crack repair.

If you have any questions, contact your ASCC concrete contractor or the ASCC Technical Hotline at (800) 331-0668.

Update: The Commentary for ACI 318-10 differs slightly from the originally quoted ACI 318-02 Commentary.

(08-11 update replaces 06-03 original version)

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Birdbaths on Concrete Slabs

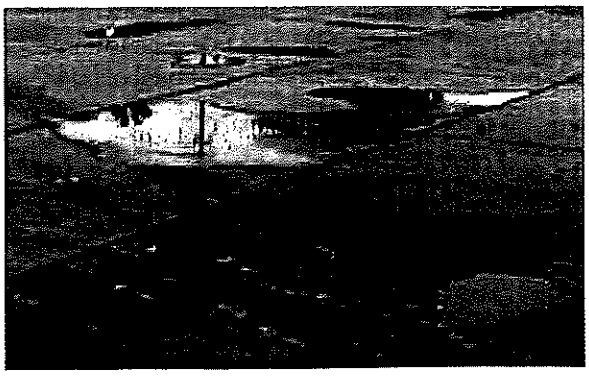
ASCC Position Statement #7

Owners, architects, and engineers have a variety of perceptions and expectations regarding birdbaths on concrete slabs. Birdbaths are small ponds or puddles of water that appear on a level or sloped concrete surface after a rain or washing the slabs (see photo). Many specifications attempt to eliminate birdbaths and often require a final water washing of the slab to check for birdbaths. The specifications require these birdbaths to be corrected by grinding or patching the slab surface.

Owners, architects, and engineers sometimes believe that birdbaths are a result of poor construction practices and can be eliminated. ACI 117-10, "Standard Specifications for Tolerances for Concrete Construction and Materials" doesn't address the issue.

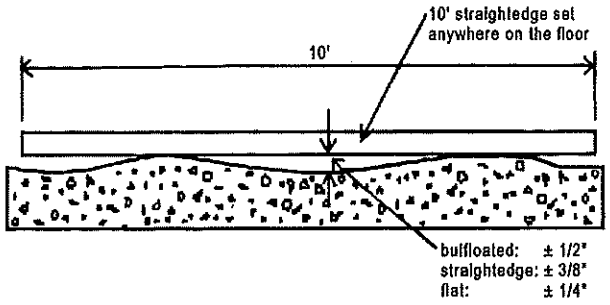
Eliminating birdbaths would require zero tolerances. The adjacent figure shows a birdbath at the valley of a slab surface profile under a 10 ft. straightedge. The tolerances shown are from ACI 117 and would indicate the maximum depth of the birdbath.

Expecting or requiring no birdbaths on level or sloped slabs is not compatible with ACI 117 tolerances. Specifying a relatively large permissible gap under a straightedge (low FF) results in numerous deep birdbaths. Specifying a small gap under a straightedge (high FF) results in a few shallow birdbaths.



Concrete contractors are responsible for meeting the flatness requirements of Division 3 in the specifications. Birdbaths are an unavoidable consequence of a flatness tolerance. ASCC contractors will meet the flatness requirements but will not be responsible for corrective action to eliminate birdbaths.

If you have any questions, contact your ASCC concrete contractor or the ASCC Technical Hotline at (800) 331-0668.



Update: ACI 117-10 does not address birdbaths or puddles. The drawing has been changed to reflect new staightedge tolerances in ACI 117-10:

Conventional	1/2 in.
Moderately flat	3/8 in.
Flat	1/4 in.

Values in the image have also been changed.

(08/11 update replaces 09-03 original)

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09/03

Bugholes in Formed Concrete

ASCC Position Statement #8

Bugholes, also called surface air voids, are small regular or irregular cavities, usually not exceeding ⅜ in. (16 mm), resulting from entrapment of air bubbles in the surface of formed concrete during placement and consolidation. They normally occur in vertical cast-in-place concrete surfaces. The photos show smooth-form-finish concrete with varying numbers and sizes of bugholes.

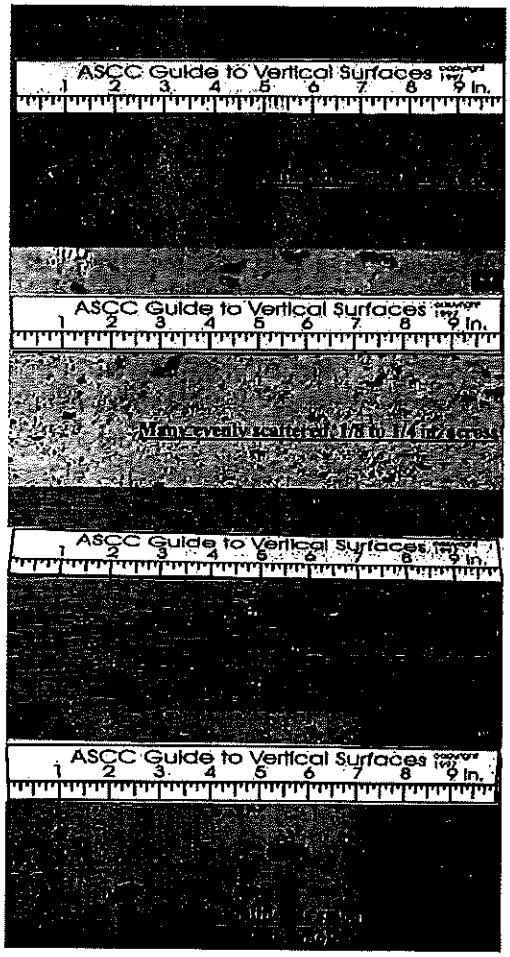
The permissible size or number of bugholes isn't defined for the smooth-form finishes described in ACI 301-99, "Specifications for Structural Concrete." Section 5.3.3.3.b for a smooth-form finish instructs the contractor to patch tie holes and defects. Section 5.3.7.3, Repair of surface defects other than tie holes, instructs the contractor to "Outline honeycombed or otherwise defective concrete with a 1/2 to 3/4-in. deep saw cut and remove such concrete down to sound concrete." If the term "surface defects" included bugholes, a saw cut would be required around each one, which is clearly an unreasonable and literally impossible task. This leads to the conclusion that bugholes aren't surface defects.

If bugholes aren't acceptable—because an architectural finish is desired or because the concrete surface is to receive paint or other coatings — ASCC concrete contractors recommend that the specifier select a rubbed finish as defined in ACI 301-10. The cost for a rubbed surface should be treated as a separate bid item, and is not included in the bid for a smooth-form finish.

For further information, consult "Guide for Surface Finish of Formed Concrete," a publication prepared by the ASCC Education and Training Committee. If you have any questions, contact your ASCC concrete contractor or the ASCC Technical Hotline at (800) 331-0668.

Update: Replace second paragraph with the following:

ACI 301-10 no longer uses the term *rough-* and *smooth-form finish*. The document instead describes three surface finish classes. SF-1.0 requires patching voids larger than 1 ½ in. wide or ½ in. deep. SF-2.0 and SF-3.0 both require patching tie holes and voids larger than ¾ in. wide or ½ in. deep. Section 1.2 of ACI 301-10 gives the following definition for surface defects:



"imperfection in concrete surfaces defined in Contract Documents that must be repaired."

This indicates that bugholes no deeper than ½ in. and no wider than 1 ½ in. for SF-1.0 or ¾ in. for SF-2.0 or 3.0 are not considered by ACI 301-10 to be defects, but may still be considered to be defects in some contract documents. Because bugholes are a natural feature of all as-cast vertical concrete structural components it is unrealistic to expect that surfaces will be free of bugholes.

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09/03

Cracks in Slabs on Ground

ASCC Position Statement #29

Random cracking caused by drying shrinkage or thermal contraction of concrete slabs on ground is a common complaint of facility owners. They often argue that faulty design, materials, or construction must have caused such cracks. But even when plans and specifications for slabs on ground are based on the best guidance in industry publications, some random cracking is likely. As stated in the Foreword to ACI 302.1R-04, "Guide for Concrete Floor and Slab Construction," published by the American Concrete Institute:

> *"Even with the best floor designs and proper construction, it is unrealistic to expect crack-free and curl-free floors. Consequently, every owner should be advised by both the designer and contractor that it is normal to expect some amount of cracking and curling on every project, and that such occurrence does not necessarily reflect adversely on either the adequacy of the floor's design or the quality of its construction."*

ACI 224R-01, "Control of Cracking in Concrete Structures," indicates that there are many specific causes of cracking and the document is "... designed to help the engineer and the contractor in developing crack-control measures." When designers and contractors develop crack-control measures, contractor compliance with the plans and specifications will produce a structure with a cracking potential that is determined by the designer's and specifier's decisions regarding reinforcement, joint spacing, concrete properties, and other variables. Alleged causes of random cracks are sometimes assigned to contractors based on conjecture: inadequate curing, joints sawn too late, or too much water added to the concrete. But unless such causes can be verified, they are guesses. ASCC contractors will assume responsibility for cracks that are a direct result of noncompliance with the project plans and specifications, even though noncompliance doesn't always cause cracks.

We suggest providing a project crack repair allowance, such as a unit price per lineal foot of cracking when fault can't be assigned for random cracks. Section 3.2.5.3 of the ACI 302.1R-04 states that random visible cracks might reasonably be expected to occur in 0 to 3% of the floor slab panels formed by saw-cutting, construction joints, or a combination of both. The 3% value could be used to cap the crack repair allowance.

The decision to repair, however, should be made with the knowledge that crack repair products and methods don't hide the cracks and may accentuate them. If aesthetics are the only concern, a use-as-is decision may be best. Removing and replacing cracked panels in a floor is often an economic waste that is counter to sustainability ideals. It is not likely to solve the aesthetics problem either, because replacement concrete usually doesn't match the color of the uncracked panels.

Under hard-wheeled traffic, spalling at the crack edges can affect floor performance and crack repair may be warranted. Crack repair is also warranted when faulting has occurred at the cracks or when cracks are wide enough to affect performance.

If you have any questions, contact your ASCC concrete contractor or the ASCC Technical Hotline at (800) 331-0668.

Structural

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Cracks in Structural Concrete

ASCC Position Statement #33

Some concrete professionals believe that reinforced concrete structures should not crack. With that belief, when cracking does occur, they often claim that the concrete contractor caused the cracks and should pay for repair. Cracks in reinforced concrete, however, are not a defect but are specifically included as part of the design process.

Design professionals using ACI 318-08, "Building Code Requirements for Structural Concrete," understand that meeting Code provisions for beams and slabs provides crack control. The Commentary (R10.6.1) states that "structures designed by working stress methods and low steel stress served their intended functions with very limited flexural cracking. When high-strength reinforcing steels are used at high service load stresses, however, visible cracks should be expected." The Commentary section below illustrates the typical crack width:

> **R10.6.4** Crack widths in structures are highly variable. In Codes before the 1999 edition, provisions were given for distribution of reinforcement that were based on empirical equations using a calculated maximum crack width of 0.016 in. The current provisions for spacing are intended to limit surface cracks to a width that is generally acceptable in practice but may vary widely in a given structure.

That section further states that:

> Research shows that corrosion is not clearly correlated with surface crack widths in the range normally found with reinforcement stresses at service load levels.

Thus, for structures designed in accordance with ACI 318-08, corrosion is not currently a concern when surface crack widths are in the range normally found with reinforcement stresses at service load levels.

In *Reinforced Concrete* (Prentice Hall, 2009), James K. Wight and James G. MacGregor echo ACI 318-08 by stating:

- "It should be noted that reinforced concrete structures normally crack when carrying service loads."
- "Corrosion of reinforcement has traditionally been related to crack width. More recent studies (3 references) suggest that the factors governing the eventual development of corrosion are independent of crack width."

ACI 224R-01, "Control of Cracking in Concrete Structures," indicates 0.016 in. as a reasonable crack width for reinforced concrete under service loads for a dry air exposure. The document also notes that a portion of the cracks in the structure will exceed these values. With time, a significant portion can exceed these values, and the width may double.

During the building process, the construction loads during reshoring, storing materials, and as a result of the work processes are limited by the engineer to the design service loads. As ACI 318 indicates, flexural cracks will occur and be visible under service loads. ACI 318 also indicates that the crack width is inherently subject to wide scatter (ACI 224R-01 indicates a coefficient of variation of 40%) and is influenced by shrinkage and temperature.

In addition to cracks due to service loads, cracks also result from restrained shrinkage and thermal contraction. Section 7.12 of ACI 318-08 includes requirements for shrinkage and temperature steel to control crack widths. ACI 224R-01 states that cracking due to drying shrinkage can never be eliminated in most structures.

ASCC concrete contractors will meet with the design team, construction manager, and general contractor to discuss crack expectations for the project. Concrete contractors want to ensure awareness by all parties that cracking will occur when the structure is built in accordance with the Contract Documents.

If you have any questions, contact your ASCC concrete contractor or the ASCC Technical Hotline at (800) 331-0668.

Update: Change the first sentence in 2nd to last paragraph to read: "ASCC concrete contractors will make themselves available to meet with the design team, construction manager, and general contractor to discuss crack expectations for the project." This change was made because concrete contractors can't force a meeting with the parties mentioned.

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