Visual Inspection of Architectural Concrete Surface Appearance

Commentary on current concrete industry practice

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It's 5 p.m. on a workday. Quitting time. Construction workers are packing their gear and heading to their trucks for the drive home—except for the concrete crew. This crew is positioned around the site, observing the surfaces of recently erected tilt-up panels. Some panels have features—lines correlating with the saw cuts in the slab that served as the casting surface for the panels—that are visible for only 1 hour a day, from 4 to 5 p.m. Although the crew patched the panel surfaces and found gaps beneath a straightedge of less than 1/32 in. (0.8 mm) across the saw-cut lines, these features are still visible.

From a construction contract administration perspective, are the lines imperfections? Concrete industry criteria for this situation aren't clear. If these features are considered imperfections, are they due to poor workmanship? Even if each line was repatched with a zero gap beneath a straightedge, would it still be visible? And why are these lines visible for only 1 hour in the afternoon?

Glancing Light

Glancing light is commonly used to describe a critical lighting condition that exists when light hits a surface at an acute or glancing angle (Fig. 1) and cast shadows that highlight surface imperfections. This critical lighting condition accentuates joints and variations in sheen, texture, surface uniformity, or other surface irregularities.

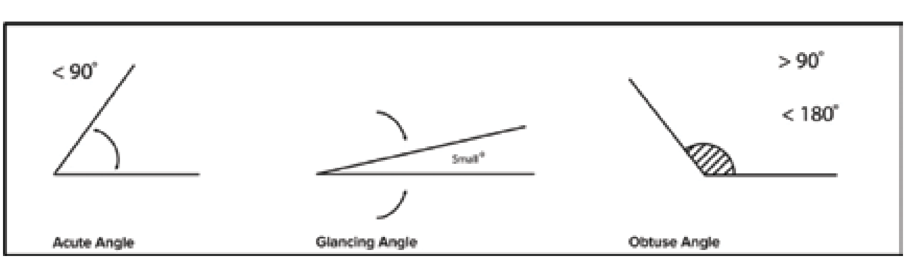

Fig. 1: Examples of acute, glancing, and obtuse angles. A glancing light angle is typically considered less than 15 degrees and can highlight surface irregularities of 1/32 in. (0.8 mm) or greater[1,2]

Light reflected from a surface is diffuse—it's scattered in many different directions—so a viewer may not perceive small imperfections when the angle of viewing to the surface is acute or obtuse relative. As the angle of viewing becomes more acute or critical, however, the amount of nonscattered light reflected to the eye is increased, and surface imperfections become more visible.[1] Surfaces that are very smooth (nontextured) or glossy will reflect more light rather than scatter it. The more the light is reflected, the more visible the surface imperfections.

Critical versus Noncritical Lighting

It's important to recognize what the terms "critical" and "noncritical" lighting mean. Critical lighting occurs when sunlight or another light source strikes a wall surface at or less than 15 degrees—the critical angle.[1,2] Visual inspection of wall or ceiling surfaces during critical lighting (Fig. 2) will cast a shadow for any irregularity that is 1/32 in. or greater.[2] Noncritical lighting occurs when the light strikes the surface at an angle greater than 15 degrees. If the specifications refer to viewing the surface when it is not critical lighting, or noncritical lighting, it indicates that this light condition should not be used to accentuate surface irregularities. Critical lighting exists for only a noticeably brief time, sometimes just a few minutes a day.

Although there are many sun angle

calculators (SunCalc®,[3] Omni Calculator,[4] and NOAA Solar Calculator[5]), there are more practical methods to determine when to visually inspect the surface. One recommendation is to visually inspect concrete surfaces between 10 a.m. and 2 p.m. when the daylight (sunlight) angle is greater than 15 degrees.[1] It should be noted, however, that critical lighting can also be an interior condition when windows or openings extend to walls or ceilings (Fig. 3).[6] In these cases, critical lighting may arise near dawn or dusk.

Artificial Lighting

Artificial lighting, which is any light that is not naturally occurring, such as construction or final project lighting, can also create glancing light. We can't find any recommendations for artificial lighting conditions to be used for visual inspection of interior surfaces during construction. However, placing inspection lighting at the same location as the final project lighting may highlight surface imperfections that could precipitate rejection when the final project lighting is in place.

Not Just an Exterior, Vertical Issue

Figure 4 illustrates the effect of glancing light on the interior slab of a parking garage. At 5:30 p.m., the glancing light through a wall opening highlights a washboard surface that is not as noticeable at 6 p.m. The visual washboard surface appearance diminishes with time when the glancing light ends.

Not Just a Concrete Issue

The effect of critical lighting on appearance based on visual inspection is an issue with other industries, including:

- Painted surfaces[1,8,9];
- Drywall[10];
- Exterior insulation and finish system (EIFS)[2];
- Stucco/plaster[2,11];
- Metal panels[12];
- Masonry[13]; and
- Cast stone.[14,15]

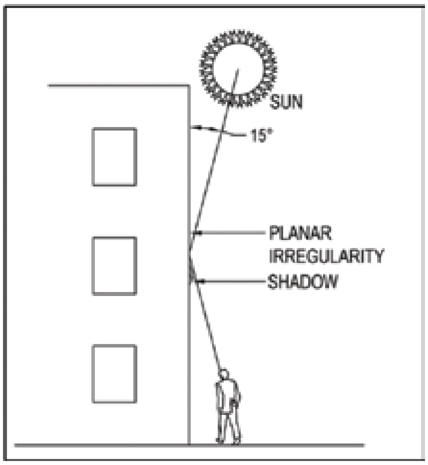

Fig. 2: During times of critical lighting, shadows cast by irregularities of 1/32 in. or greater can be seen. It is recommended that visual inspection be performed during noncritical lighting[1,2] (from Reference 2)

A review of the criteria for visual inspection of these surfaces illustrates the same confusion that exists in the concrete industry.

Basics of Visual Inspection

Visual inspection is the oldest form of quality control. While we are interested in visual inspection for surface

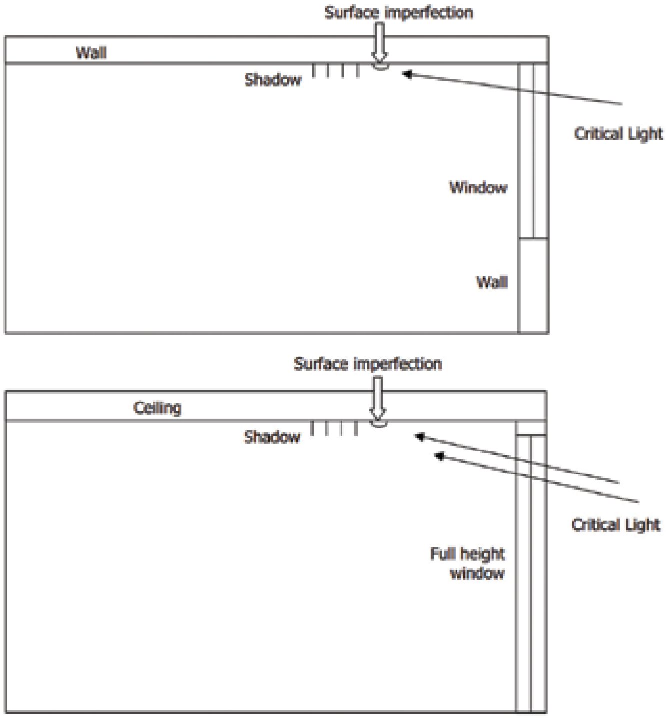

Fig. 3: Critical lighting can occur indoors when windows or openings extend to intersecting ceilings or walls (from Reference 6)

Fig. 4: Effect of exterior glancing light through wall openings in a parking garage. At 5:30 p.m., there is a washboard surface appearance that diminishes with time

appearance, it has also been used as a nondestructive testing (NDT) method to observe physical defects. While visual inspection is a method that offers numerous benefits, it's not without its limitations. One of the primary constraints is its dependence on the subjective judgment of inspectors, leading to potential inconsistencies in results.

Generally, the concrete industry uses comparative visual inspection: comparing an item against a reference or standard, often side-by-side, to spot any deviations or defects. However, when persons performing visual inspection are unable to remain objective and begin to introduce subjectivity (opinions and biases), the process is flawed.[16] It may become an issue when the appearance expectations are not clearly expressed in the specifications. When the inspector visually inspects a mockup or finished product, it's important to consider whether the evaluation is based on the workmanship according to the project specifications or the inspector's expectations of the mockup or completed project.

The "I know it when I see it" visual inspection approach creates difficulties. This colloquial expression is typically remembered as used by Arthur Conan Doyle and Supreme Court Justice Potter Stewart. In Doyle's *The Hound of the Baskervilles*, Sherlock Holmes comments on the quality of a portrait by saying: "I know what is good when I see it." Justice Stewart famously used the quote to describe his threshold test for obscenity. When this approach is used in visual inspection for construction, it creates great challenges for the contractor who bid on the project and provided a mockup based on project specifications.

See[16] provides a review of the literature on visual inspection, including the results of numerous inspection studies conducted over 6 decades on the factors that impact inspection performance as shown in Table 1. The Federal Highway Administration (FHWA) studied the reliability of visual inspection on highway bridges providing insight into the physical, environmental, and management factors affecting visual inspection.[17,18] The following summaries of the number of defects, standards for comparison, and factors for perfect inspection are edited versions from See.[16]

Table 1:
Factors that impact inspection performance (from Reference 16)

Task	Individual
• Defect rate • Defect type • Defect salience • Defect location • Complexity • Standards • Pacing • Multiple inspections • Overlays • Automation	• Gender • Age • Visual acuity • Intelligence • Aptitude • Personality • Time in job • Experience • Visual lobe • Scanning strategy • Biases
Environmental	**Organizational**
• Lighting • Noise • Temperature • Shift duration • Time of day • Vigilance • Workplace design	• Management support • Training • Retraining • Instructions • Feedforward information • Feedback • Incentives • Job rotation
Social	
• Pressure • Consultation • Isolation • Communication	

Number of defects

Megaw[19] observed that, regardless of the total number of potential defects, inspectors appear to search for a subset of about five. He points out that, without feedback, inspectors will not necessarily choose the most appropriate subset of defects. Along these lines, Rao et al.[20] concluded that six defects may represent the practical maximum for an inspector. In accordance with research findings regarding defect type, Gallwey[21] recommended searching for one type of defect everywhere on the product, then moving to the second defect type, rather than trying to search for all defect types concurrently in all areas of the product.

Standards for comparison

The way defects are defined can impact inspection performance. Defect definition includes both the literal definition of the defect (for example, a 2 in. [50 mm] long scratch) and any standards that may be used to define it in relation to good products.

First, with respect to literal defect definition, Jamieson[22] indicated that the absence of a clear specification of what constitutes a defect contributes to poor inspection performance. Specifically, the lack of clear definitions of defects prompted inspectors to form personal criteria, which led to variability in work quality during inspection. Such subjective criteria appear to drift over time as well, resulting in products that would have been rejected at one time but are accepted at another.[23] This phenomenon can be observed both between and within inspectors. Barring clear definitions, individual inspectors may revise their own work if, unknown to them, it is returned.

Second, the use of standards against which to compare a given item is generally beneficial. Using standards changes an absolute judgment task into a comparative judgment task, eliminating the need to rely on long-term memory of the standard. Therefore, inspection tasks that make use of standards for comparison tend to be associated with better defect detection.[22] However, the standards themselves must be simple and easy to interpret. Gallwey and Drury[24] showed that inspection performance was worse when different standards had to be used for different areas of the product as opposed to the condition in which the same standards for acceptance/rejection could be applied to any defect.

Perfect inspection

Individual factors refer to physical, mental, and personality characteristics of the inspector such as age, intelligence, and extraversion. Individual factors have been extensively investigated to identify the traits of the "perfect" inspector and to develop personnel selection techniques for inspection. In fact, perhaps the most consistent finding in inspection is the existence of large differences both between and within inspectors, in the way they perform the task and the overall level of accuracy they achieve.[25]

ASTM standards

ASTM International has standards for visual inspection of asbestos abatement projects, integrity of seals for flexible packaging, membrane switches, fabrics for inflatable restraints, clear transparent liquids, pharmaceutical equipment, steel castings, and diffusely illuminated opaque materials. These standards for visual inspection typically include requirements for:

- Inspector training;
- Lighting conditions;
- Viewing angle; and
- Viewing distance.

Three ASTM standards of interest include:

- ASTM E284-22, "Standard Terminology of Appearance"[26];
- ASTM E1808-96(2021), "Standard Guide for Designing and Conducting Visual Experiments"[27]; and
- ASTM E1499-16(2023), "Standard Guide for Selection, Evaluation, and Training of Observers."[28]

ASTM E284 defines terms used in the description of appearance, including but not limited to color, gloss, opacity, scattering, texture, and visibility of both materials (ordinary, fluorescent, and retroreflective) and light sources (including visual display units). The definition of terms has been made to achieve greater accuracy, brevity, clarity, precision, and internal consistency and to draw distinctions that are useful in the practical measurement and specification of appearance.

In addition, ASTM E284 defines the viewing conditions under which a visual observation is made, including: a) the angular subtense of the specimen at the eye; b) geometric relationship of source, specimen, and eye; c) photometric and spectral character of the source; d) photometric and spectral character of the field of view surrounding the specimen; and e) state of adaptation of the eye.

ASTM E1808, Section 5, provides recommendations for establishing viewing conditions, which include: a) light source; b) viewing geometry; c) surround and ambient field; and d) observers. Concrete industry recommendations for visual inspection would benefit greatly by using ASTM E1808 to establish viewing conditions.

ASTM E1499 provides guidance on the selection, evaluation, and training of observers that should be useful to all experimenters designing or using visual test methods to provide direct results in terms of the observation of appearance properties. The concrete industry is silent on the selection, evaluation, and training of observers or observer qualifications necessary to perform adequate visual inspection.

Concrete Industry Recommendations for Visual Inspection of Appearance

ACI 311.4R-05, "Guide for Concrete Inspection,"[29] provides "inspection for damage and visual appearance" for precast erection. Although the document provides no further specific advice on this task, it does comment on inspector training and the role of the architect/engineer (A/E) to provide additional requirements for speciality work such as architectural concrete:

> "All personnel performing concrete inspection and testing work should be certified and demonstrate a knowledge and ability to perform the necessary inspection and testing procedures equivalent to the minimum guidelines set forth for certification by ACI for the appropriate category listed." (Section 3.6)
>
> "*Specialty work*—Some construction projects may require items of inspection not listed in Table 3.1 or Appendix I. Such items can be added by the A/E to ensure adequate conformance to quality requirements. For this reason, the inspection items listed are intended to cover only those construction activities and materials most commonly encountered in concrete construction. Inspection items for specialty work, such as pressure grouting, shotcrete, high-performance concrete, self-consolidating concrete, two-course floors, super-flat floors, terrazzo, stucco, masonry, cast stone, tile, architectural concrete, painting, preplaced-aggregate concrete, tilt-up construction, underwater construction, vacuum concrete, and slipform construction are intentionally omitted from Table 3.1 and Appendix I. It is intended that the A/E will develop inspection criteria for specialty work that is appropriate to the specific needs of these activities." (Section 3.7.4.1)

ACI documents that include recommendations or requirements for visual inspection of cast-in-place, precast, and tilt-up concrete are:

- ACI 303.1-97, "Standard Specification for Cast-in-Place Architectural Concrete" (Withdrawn)[30];
- ACI 303R-12, "Guide to Cast-in-Place Architectural Concrete Practice"[31];
- ACI 301-20, "Specifications for Concrete Construction"[32]; and
- ACI 347.3R-13(21), "Guide to Formed Concrete Surfaces."[33]

ACI 303.1-97, Section 5.3.9.1, provides final acceptance requirements for architectural concrete:

> "Upon completion of architectural concrete, final acceptance is based upon the matching of the architectural cast-in-place concrete with the accepted

Field Mockups when viewed at the distance of 20 ft (6 m) in daylight."

ACI 303R-12 provides visual inspection recommendations for general and final acceptance and viewing the preconstruction mockup:

- "*General acceptance criteria*—Architecturally acceptable concrete surfaces should be aesthetically compatible with minimal color and texture variations and surface defects when viewed at a distance of approximately 20 ft (6 m) or more, as agreed upon by the architect, owner, and contractor, or as otherwise specified." (Section 3.1.1)
- "*Preconstruction mockup*—The preconstruction mockup (Fig. 3.5.4) is a full-scale sample of architectural concrete constructed on-site by the contractor with proposed equipment, materials, and construction procedures. The contractor should obtain written approval of the finished product from the specifying agency and the owner after viewing at the agreed-upon distance before constructing the main structure." (Section 3.5.4)
- "*Final acceptance*—If the procedures determined by the approved on-site mockup are continued throughout the project, final acceptance at the agreed-upon distance should not be a problem. Due to the inevitable nonuniformity of construction practices, some repairs will be required. Their final acceptability will depend on the contractor's blending technique and skill. Periodic review by the inspector and the architect/engineer to allow partial acceptance creates goodwill and confidence with all concerned. After final acceptance, the inspector's records should be completed and filed. If later additions are made or adjoining buildings constructed, these records will be helpful for construction." (Section 3.5.6.4)

ACI 301-20 provides visual requirements for acceptance of architectural concrete and architectural tilt-up panels, repairs on precast structural concrete, and surface color of thin bricks used for architectural precast concrete:

- *Periodic acceptance*—"Architect/Engineer will periodically observe completed portions of architectural concrete for conformance with accepted field mockup. The frequency of periodic acceptance and acceptance criteria will be established at preconstruction conference." (Section 6.1.4.5(a))
- "Architectural concrete declared unacceptable during periodic observation shall be repaired or replaced. Submit a revised method of producing acceptable concrete before proceeding with additional architectural concrete construction." (Section 6.1.4.5(b))
- "*Final acceptance of architectural concrete*—Upon completion of architectural concrete, including surface repairs and patching of tie holes, final acceptance is based on matching the architectural cast-in place concrete with accepted field mockup when viewed at 20 ft in daylight. Defective Work not conforming to Contract Documents, including repair areas not accepted, shall be removed and replaced." (Section 6.3.1.2)
- *Smooth Panel Finish-3 Architectural (SPF-3)*—"Upon completion of surface repairs and patching, for final acceptance, panels shall match the appearance of the accepted mockup panel when viewed from a distance of 10 ft in daylight." (Section 12.3.9(a)(d))
- *Repairs*—"Mix patching materials and repair members so cured patches blend with color, texture, and uniformity of adjacent exposed surfaces and show no apparent line of demarcation between original and repaired work when viewed in daylight from 20 ft." (Section 13.3.5(c))
- "*Surface coloring*—Brick specified with surface coloring, other than flashed or sand-finished brick, shall withstand 50 cycles of freezing and thawing in accordance with ASTM C67 with no observable difference in applied finish if viewed in daylight from 20 ft." (Section 14.2.6.2(j))

ACI 347.3R-13(21), Section 7.2, provides the following recommendation for visually evaluating the overall impression:

> "Make the evaluation under normal lighting conditions from a minimum distance of 20 ft (6 m) or greater, that is perpendicular to the concrete surface to be viewed. This viewing distance allows one to evaluate that the overall appearance of the structure has been achieved.
>
> Sunlight striking a concrete surface at an acute angle will amplify the appearance of irregularities, so evaluations under these conditions should be avoided. The appropriate viewing distance is equal to the distance that allows the entire building, the building's essential parts, or both, to be viewed in their entirety. The individual design features should be recognizable. For architectural concrete, refer to ACI 303R-12."

The Precast/Prestressed Concrete Institute (PCI) and the Tilt-Up Concrete Association (TCA) recommendations or requirements for visual inspection of precast and tilt-up concrete are included in:

- PCI MNL-117-13, "Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products"[34];
- PCI DN-22-11, "Designer's Notebook: Acceptability of Appearance"[35]; and
- TCA Guide Specification for Site-Cast Tilt-Up Construction.[36]

PCI MNL-117-13 provides the following recommendations on acceptance:

- Curing and Finishing Areas—"Lighting is extremely important in the finishing area and at the point where final inspection is made before transport to the storage area. This is where comparison to the approved samples is made for color and texture. Where possible, indoor lighting should compare to daylight as closely as possible." (Commentary Section 2.2.6)
- Acceptability of Appearance—"The finished face surface shall have no obvious imperfections other than minimal color and texture variations from the approved samples or evidence of repairs when viewed in good typical daylight

illumination with the unaided naked eye consistent with the viewing distance on the structure, but not less than 20 ft (6 m). Appearance of the surface shall not be evaluated when light is illuminating the surface from an extreme angle, as this tends to accentuate minor surface irregularities." (Section 2.10)

PCI DN-22-11 recommends that one person have final authority for the acceptability of color, finish, and texture, and that the contract documents clearly identify the accepting authority. The document also provides recommendations on acceptability of appearance and repairs and cracks viewed at a distance of 20 ft or greater:

- Acceptability of appearance—"Determining acceptable uniformity of color, finish, and texture is by visual examination, and is generally a matter of subjective, individual judgment and interpretation. Acceptable color and texture variations, surface blemishes, and uniformity should be determined at the time the sample, mockup, or initial production units are approved. Accordingly, it is beyond the scope of this publication to establish precise or definitive rules for product acceptability on the basis of appearance. However, a suitable criteria for acceptability requires that the finished concrete surface should have a pleasing appearance with minimal color and texture variations from the approved samples. The finished surface on the face should show no readily visible imperfections other than minimal color and texture variations from the approved samples or evidence of repairs when viewed in typical daylight illumination with the unaided eye consistent with the viewing distance of the structure but not less than a 20 ft (6 m) or greater viewing distance. Appearance of the surface also should not be evaluated when light is illuminating the surface from an angle, as this tends to accentuate minor surface irregularities due to shadowing."
- Repairs visible at 20 ft (6 m) or greater viewing distance—"A certain amount of product repair is to be expected as a routine procedure. Repair methods should ensure that the repaired area will conform to the balance of the work with respect to applicable requirements for appearance, structural adequacy, serviceability, and durability. Slight color variations may occur between the repaired area and the original surface due to the different age and curing conditions of the repair. The repair will generally become less noticeable over time (at least one month) with exposure to the environment and should blend into adjacent surfaces so it becomes less noticeable. Excessive variation in color and texture of repairs from adjacent surfaces may be cause for rejection until the variation is minimized." (Section 11)
- Cracks visible at 20 ft (6 m) or greater viewing distance—"The acceptability of cracks should be determined with respect to actual service condition requirements, structural significance, and aesthetics. Every effort should be made to promptly identify the cause of any cracking and to document the pattern, particularly when several units display similar cracking. Such cracking is often the result of a single design, manufacturing, or handling problem, which can then be rectified to prevent any recurrence. If crack repair is required for the restoration of structural integrity, cracks may be filled, or pressure injected with a low-viscosity epoxy. The acceptability of the crack repairs should be governed by the importance and function of the panel. The decision regarding acceptability must be made on an engineering basis as well as on visual appearance." (Section 13)

TCA Guide Specification, Section 034700, Site-Cast Tilt-Up Concrete states:

"3.7 PANEL FINISH

A. Finish exposed surfaces of panels as indicated on the Drawings including both the front and back of the panels as well as any exposed edges as defined below. Visible surfaces of the panels, when in place shall be free from surface defects as defined below.

B. Grade A - Architectural: Projects designed for the circulation of people within a distance of 10 feet to 25 feet.

1. Panel surfaces shall be free of voids, holes, pockets, and other surface deformations greater than 1/8 inch.
2. Surfaces of panels shall not project reinforcing patterns, floor joints or other projections or voids from the casting surface.
3. Cracks are not permissible in excess of 1/32 inch.
4. Surface repairs shall be performed in such a way as to prevent the projection of repair strokes through the intended finish.
5. Holes shall be filled with patching material to present a smooth surface ready for painting unless the designed finish is to result in exposed aggregates whereby the patching material shall match the intended color and texture."

Comments on Industry Recommendations/ Requirements

Formed and unformed surfaces can be specified as architectural concrete, which includes exterior and interior walls, floors, and ceilings. The visual inspection criteria—viewing distance and lighting—appear to apply only to exterior walls. It is unclear how to interpret a 20 ft viewing distance for a floor or ceiling and what daylight to use for an interior visual inspection. While ACI 301-20 requires a 20 ft viewing distance for cast-in-place architectural and precast concrete, it strangely requires a 10 ft (3 m) viewing distance for tilt-up panels.

The differences and discrepancies in visual inspection criteria shown in this article need to be evaluated, discussed, and revised in the next ACI 301 document. Other comments on industry recommendations or requirements for visual inspection of architectural concrete are provided.

Acceptability authority

Only Reference 35 discusses the problematic issue of visual inspection by different inspectors from the same company or inspectors from multiple companies such as the architect, engineer, construction manager, testing agency, or owner. PCI recommends that only one person have the final authority for acceptance, and that contract documents clearly identify that accepting authority. For cast-in-place concrete, one architect could approve the mockup, but a different architect might provide periodic approval, and then a third architect could give final approval. On some projects, the architect approves the work, only to find that the owner rejects the final work.

For precast, there are three approval stages: a) initial product at the plant; b) product as delivered; and then c) final product as erected. Interjecting multiple individuals or multiple organizations for approval by visual inspection leads to very real concerns about repeatability and reproducibility. Consider the "I know it when I see it" inspection approach by three different inspectors. This is fraught with considerable confusion, especially when the specifications don't adequately convey the architectural expectations, thus leading to each inspector's opinion and bias. This clearly needs more emphasis and discussion within the concrete industry.

Periodic inspection

ACI 301-20 allows for periodic inspection but unfortunately leaves the inspection intervals to be determined at the preconstruction meeting. ACI 301-20 does not provide for periodic inspection for architectural precast or architectural tilt-up. Periodic inspection, while in ACI 301-20, is often not performed, leaving the contractor's fate to the final inspection. Regarding periodic acceptance, ACI 301-20, Section 6.1.4.5(a), slips in that "acceptance criteria will be established at preconstruction conference." This is not appropriate, as the acceptance criteria should be clearly stated in the project specifications so the contractor can establish the bid. Acceptance criteria established at the preconstruction conference will likely lead to the contractor's request for a change order.

Viewing eye

The terms "naked" and "unaided" eye are used to describe visual inspection. A Merriam-Webster Dictionary definition says these terms are the same and mean "something that can be seen without any instrument that changes the apparent size or distance of an object or otherwise alters visual powers." Some specifications allow visual inspection as corrected by eyeglasses or contacts to a 20/20 vision. Is vision correction acceptable?

Viewing distance

A viewing distance of 20 ft for appearance is recommended. That distance is also considered appropriate for viewing repairs and cracks. Other viewing distances include 10 ft and an agreed-upon distance. There are no recommendations concerning how the viewing distance is applied to floors, ceilings, or interior walls with limited space for viewing.

Sunlight angle

The recommendation was not to view the appearance with the sunlight at an extreme angle as it would accentuate the surface irregularities. None of the recommendations or requirements, however, provided information on what would be "extreme." Some recommended that viewing should not occur when the sunlight is at an acute angle, which is any angle less than 90 degrees. Because critical lighting is defined as a glancing angle of 15 degrees, the viewing should only take place at that time. There is no guidance on calculating the viewing angle. Reference 1 recommends viewing surfaces from 10 a.m. to 2 p.m. as those times would avoid any glancing angles.

Viewing angle

The viewing angle should be perpendicular (90 degrees) to a concrete wall, and no information is provided for viewing floors or ceilings. If viewing is perpendicular to a wall, then the viewer's height determines what is observed. That recommendation seems to preclude looking up or down the wall, which limits the amount of observable area.

Illumination

Recommendations for illumination included daylight, sunlight, normal daylight, typical daylight, direct daylight, good typical daylight, typical lighting conditions, and indoor lighting that is comparable to outdoor lighting. Reference 37 indicates the illumination of a cloudy sky is about 500 footcandles, while for a clear sky it could be as much as 1500 footcandles. ACI PRC-228.4-23[38] indicates that the color temperature for visual inspection of physical defects should be 500 to 6500 K to simulate daylight. Illumination conditions for visual inspection during construction must be considered.

Age

Age is used as an indication of weathering and color changes due to drying and fading with time. This issue is of concern for viewing the mockup, periodic and final acceptance, and repairs. While PCI DN-22-11 recommended waiting at least 1 month to view repairs, there is no consistency with respect to the viewing age, an issue that plagues every project.

Inspector qualifications

Even though ACI 311.4R-05 discusses qualifications and certification of inspectors, there is no concrete industry document that addresses this issue for visual inspection of architectural concrete.

The Tilt-Up Conundrum—Conflict or Compatible

Table 2 provides a comparison of TCA Specification[36] and ACI 301-20 requirements. The TCA Specification cites ACI 301. Thus, it is interesting to evaluate whether the two specifications are compatible or in conflict. If the specifications contain a conflict clause that requires the most stringent apply, it would be interesting to see how the construction contract administrator would handle this.

Recommendations

The authors encourage ACI Committee 301, Specifications for Concrete Construction, to establish a task group to review and revise criteria for visual inspection of the appearance of formed and unformed concrete surfaces. Representatives of the American Society of Concrete Contractors (ASCC), PCI, and TCA should meet with this task group to assist in establishing criteria that are clear, concise, and stated in specification language that can't be misunderstood. An expert in illumination would also be of benefit to this task group.

One strategy, as shown in Table 3, is to summarize the visual inspection criteria for each architectural concrete item such as cast-in-place formed and

Table 2:
Comparison of TCA and ACI 301-20 specifications for architectural tilt-up panels

Formed surface	TCA Specification Architectural Panel Finish Grade A	ACI 301-20 Architectural Panel Finish SPF-3
Voids	Free	Not greater than 1/8 in.
Holes	Free	Not mentioned (likely included in voids)
Pockets	Free	Not mentioned (likely included in voids)
Other surface deformations	Not greater than 1/8 in.	Not greater than 1/8 in.
Projections	No projection of reinforcing patterns, floor joints, or other projections or voids from casting surface	Grind or patch floor flush surface defects that show on panel surface
Cracks	Not exceed 1/32 in.	Repair cracks that allow water to seep to interior
Repairs	Prevent projection of brush strokes through finish	Ground or patch voids and offsets greater than 1/8 in.
Acceptance	Maintain approved mockup for comparison with finish work	Match accepted mockup when viewed at a distance of 10 ft in daylight

Note: 1 in. = 25 mm

Table 3:
Criteria for visual inspection of architectural concrete

Visual Inspection for Acceptance—ACI 301-20 Section 6—Architectural Concrete (Formed Concrete Surfaces)	
Comparative standard	
Field mockup	Reference sample
Viewing conditions	
Viewing distance at 20 ft Viewed in daylight	
Visible surface anomalies	
Aesthetic anomalies	Physical anomalies* (SF-3)
• Color	• Voids larger than 3/4 in. wide or 1/2 in. deep
• Texture	• Projections larger than 1/8 in.
	• Tie holes
	• Class A surface tolerance
Acceptance	
Match accepted mockup or reference sample	
Periodic	Final
Repair	
Yes—unlimited but acceptance based on mockup repairs	

*Visual inspection then measured for conformance

Note: 1 in. = 25 mm

unformed surfaces and precast and site-cast tilt-up. The development and comparison of these tables should assist in maintaining consistency in developing visual inspection requirements for architectural concrete.

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Selected for reader interest by the editors.

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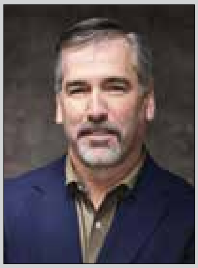

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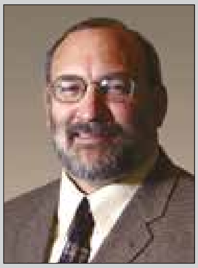

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