F-numbers and Textured Concrete Surface Finishes

Parking structures and parking lots with swirl and broom finishes

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Textured finishes are typically specified for working surfaces of parking structures, parking lots, commercial pavements, and walkways. A swirl finish (Fig. 1(a)) is sometimes specified for parking structures and is recommended for that use by ACI Committee 362, Parking Structures (ACI 362.1R[1]), and others (Chrest et al.[2]). A broom finish (Fig. 1(b)) is commonly specified for parking lots and other exterior concrete and is recommended for that use by ACI Committees 330, Concrete Parking Lots and Site Paving, and 302, Construction of Concrete Floors (ACI 330.1[3] and ACI 302.1R[4]), and others (Collins et al.[5]). Unfortunately, contractors are encountering construction documents that specify unachievable F-numbers for slabs also specified to have swirl and broom finishes. Adding to the confusion, various finishing techniques are required or recommended for these finishes. Therefore, we see a need to discuss the industry's confusion regarding F-numbers and achieving textured swirl and broom finishes.

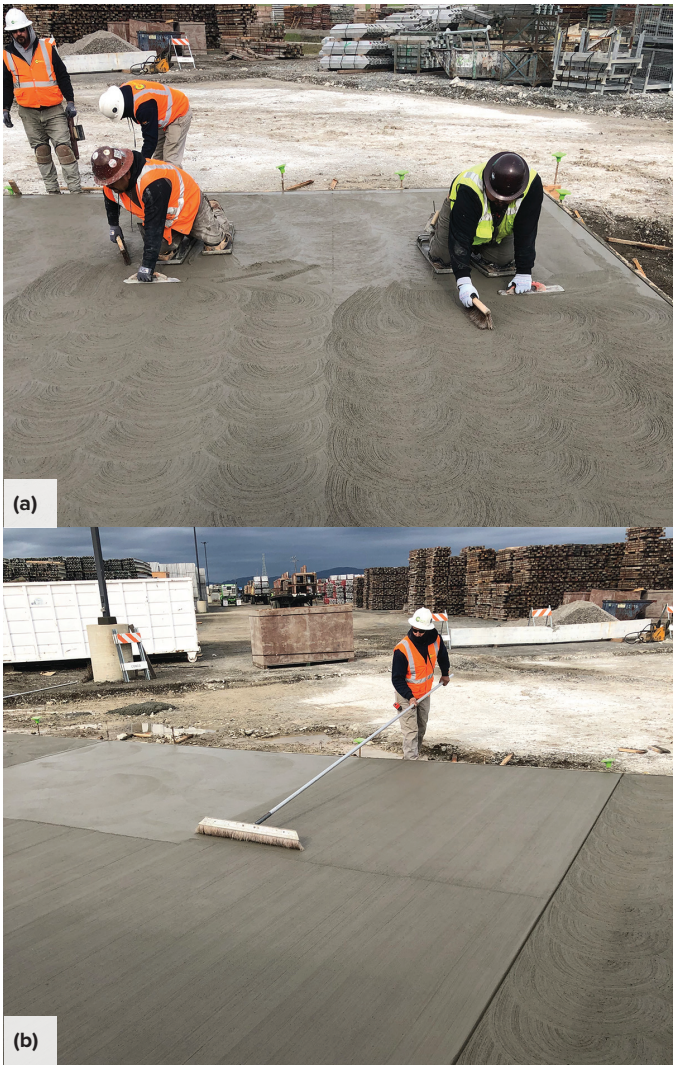


Fig. 1: Applying finishes to a test panel: (a) brush swirl finish; and (b) broom finish

Project Specifications

F-numbers

Some concrete contractors are encountering project specifications requiring floor flatness specified overall values (SOVs) as high as 50, with minimum local values (MLVs) of 35, for surfaces also specified to have a broom finish. One project specification required an MLV of 25 for a surface specified to have a swirl finish. The basis for these specified values is not clear.

Finishing

Required or recommended finishing techniques for textured finishes vary from project to project. The main issue is whether to machine float prior to applying a textured finish. This issue should be addressed separately for air-entrained and non-air-entrained concrete.

ACI Specifications and Recommendations

Several ACI documents include F-numbers and finishing methods for floor slabs. A summary of those documents is provided below.

ACI 117 specification

ACI 117-10(15)[6] provides requirements for the F-number system (Table 1 based on Table 4.8.5.1) and the manual straightedge method (Table 2 based on Table 4.8.6.1) based on the floor surface application. Commentary Section R4.8.4 provides guidance for defining the surface application:

- Conventional—Appropriate for mechanical rooms, nonpublic areas, surfaces under raised computer flooring or thick-set tile;
- Moderately flat—Appropriate for the carpeted area of commercial office buildings or industrial buildings with low-speed vehicular traffic;
- Flat—Appropriate for thin-set ceramic, vinyl tile, or similar coverings and warehouse employing conventional lift trucks and racks;
- Very flat—Restricted to high-end industrial applications such as high-speed lift trucks, air pallets, or similar equipment; and
- Super flat—Appropriate for limited applications such as TV production studios.

Unfortunately, the document offers no guidance for achieving textured surfaces.

ACI 302.1R guide

Section 10.15.1.1 of ACI 302.1R-15[4] recommends that: "The selection of proper F_F/F_L tolerances for a project is best made by measurement of a similar satisfactory floor. This measurement is then used as the basis for the F_F/F_L tolerance specification for the new project." When measurement of a similar floor is not practical or possible, ACI 302.1R, Section 10.15.1.1, indicates that the flatness/levelness quality levels provided in Fig. 2 (Fig. 10.9 in the document) are reasonable for the stated applications.

ACI 302.1R does not provide flatness/levelness recommendations for textured finishes. However, Tables 10.15.3a and 10.15.3b indicate that typical specification requirements for specified overall flatness (SOF_F) and specified overall levelness (SOF_L) are at least 20 and 15, respectively. Section 10.15.1.1 also recommends MLVs of 67% of SOVs, resulting in flatness and levelness MLVs of 13 and 10, respectively. The section further states that: "Minimum local values should never be less than F_F13/F_L10 because these values represent the minimum local results achievable by any concrete floor construction method."

ACI 310R guide

ACI 310R-19, Section 3.6.1,[8] provides information on the F-number system, indicating it is the preferred standard specification for measuring flatness and levelness of a concrete floor. However, the document provides conflicting information regarding the application of that system for evaluations of textured surfaces, stating: "It is difficult to evaluate the flatness and levelness of textured surfaces using traditional F-number testing techniques. Profiles measured using this testing will confirm surface characteristics meet the project requirements."

Table 1:
F-number system (ASTM E1155[7] method)

Floor surface classification	Specified overall flatness (SOF_F)	Specified overall levelness (SOF_L)
Conventional	20	15
Moderately flat	25	20
Flat	35	25
Very flat	45	35
Super flat	60	40

Table 2:
Manual straightedge method

Floor surface classification	Maximum gap 90% compliance Samples not to exceed	Maximum gap 100% compliance Samples not to exceed
Conventional	1/2 in.	3/4 in.
Moderately flat	3/8 in.	5/8 in.
Flat	1/4 in.	3/8 in.
Very flat	N/A	N/A
Super flat	N/A	N/A

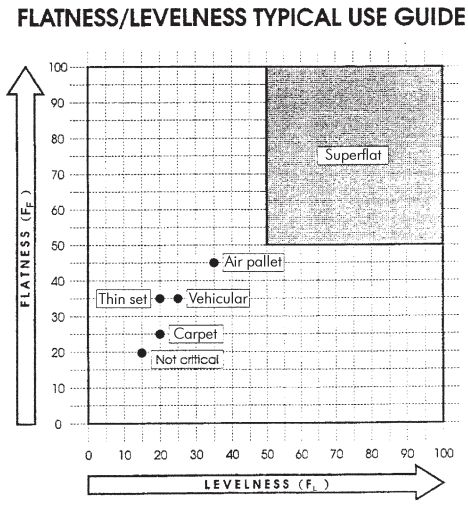
Note: 1 in. = 25 mm; N/A is not applicable

ACI 362.1R guide

ACI 362.1R-12, Section 7.2.2, recommends: "A light to medium broomed or float swirl finish be applied to driving and parking surfaces except where an alternate finish is required to install joint materials." The document refers to ACI 302.1R-04[9] for detailed information on finishing and provides no recommendations on surface flatness measurement.

ACI 330.1-14 specification

ACI 330.1-14, Sections 3.9.1 and 3.9.2, instruct: "Broom concrete surface with a steel or fiber broom to produce corrugations between 1/16 and 1/8 in. deep," and "Broom perpendicular to the nearest edge of the pavement. Broom all areas of a panel in the same direction." While ACI 330.1-14 does not provide a surface flatness requirement, ACI 330.1-03[10] and ACI 330.1-94[11] provided surface flatness tolerances based on the gap below a 10 ft (3 m) straightedge. The maximum gap was specified as 1/2 in. (13 mm) and 1/4 in. (6 mm) in the 2003 and 1994 editions, respectively.



SLABS ON GROUND

Composite Overall Flatness (F_F)	Composite Overall Levelness (F_L)	Typical Use	Typical Class
20	15	Noncritical: mechanical rooms, non-public areas, surfaces to have raised computer flooring, surfaces to have thick-set tile, and parking structure slabs	1 or 2
25	20	Carpeted areas of commercial office buildings or lightly-trafficked office/industrial buildings	2
35	25	Thin-set flooring or warehouse floor with moderate or heavy traffic	2, 3, 4, 5, 6, 7, or 8
45	35	Warehouse with air-pallet use, ice or roller rinks, gymnasium floors[4]	9
>50	>50	Movie or television studios	3 or 9

SUSPENDED SLABS

Composite Overall Flatness (F_F)	Composite Overall Levelness (F_L)	Typical Use	Typical Class
20	15[2] or N/A	Noncritical: mechanical rooms, non-public areas, surfaces to have raised computer flooring, surfaces to have thick-set tile, and parking structure slabs	1 or 2
25	20[1] or N/A	Carpeted areas of commercial office buildings or lightly-trafficked office/industrial buildings	2
35	20[2] or N/A	Surfaces to receive thin-set floorings	2, 3, or 4
45	35[3]	Ice or roller rinks, gymnasium floors[4]	3
>50	>50[1,3]	Movie or television studios	3 or 9

NOTES
1. Multi-directional quality of this level requires grinding of joints.
2. Levelness F-number only applies to level slabs shored at time of testing.
3. This levelness quality on a suspended slab requires a two-course placement.
4. All elevation samples should fall inside a 1/2 in. deep envelope.

Fig. 2: Typical use guide for flatness and levelness (Fig. 10.9 in ACI 302.1R-15[4])

ACI 330.2R and PRC-330 guides

ACI 330.2R-17[12] and PRC-330-21[13] recommend that the acceptability of the texturing technique and finish should be agreed upon by all parties, either through a mockup at a preconstruction conference or during the initial placement on the project. ACI PRC-330-21, Section 5.5.4.3, indicates that power floating "may help to produce a more consistent final finish." Neither document provides recommendations for measuring surface flatness.

ACI CCS-1(10) document

ACI CCS-1(10)[14] is used for training concrete finishers, and it provides the most detailed information on expected F-numbers for various finishing procedures for parking garages, parking lots, exterior concrete flatwork, floors, and industrial slabs (Table 3).

Industry Specifications and Recommendations

In this section, we discuss the contents of the AIA MasterSpec,[15] example specifications for projects constructed in Colorado and California, recommendations for parking structures made by Walker Consultants,[2] measured F-numbers on broomed surfaces (Malisch et al.[16]), and recommendations from the American Society of Concrete Contractors (ASCC) Finishing Committee.

AIA MasterSpec

AIA MasterSpec® is the most used project specification in the United States. Its Section 033000-Cast-in-Place Concrete requires F-numbers or gap-under-a-straightedge measurements only for a trowel finish or a trowel and fine-broom finish. It does not provide a flatness tolerance for a broom finish. Like ACI 301-20[17], MasterSpec requires a float finish prior to brooming. Unlike ACI 301, however, MasterSpec does not have a flatness tolerance for a float finish.

Parking structure, Colorado, USA, 2015

The specification for this project called for a maximum 1/2 in. gap under a 10 ft straightedge and stated that no

Table 3:
Finishing procedures, uses, and F-number expectation

Procedures	Use	F-number expectation*
Screed, bull float, broom	Parking garages, parking lots (concrete is air-entrained)	SOV F_F = 20 SOV F_L = 15
Screed, bull float, edge/joint, broom	Exterior concrete flatwork (concrete is air-entrained)	SOV F_F = 20 SOV F_L = 15
Screed, bull float/straightedge, waiting period, power float, power trowel	Retail, commercial, school floors (concrete is non-air-entrained)	SOV F_F = 35 SOV F_L = 25
Screed, bull float/straightedge, waiting period, power float, power trowel	Industrial slabs (concrete is non-air-entrained)	SOV F_F = 45 SOV F_L = 35

*SOV is the specified overall value

puddle areas should exist. However, these two requirements are contradictory, as the gap under the straightedge specification essentially defines a puddle no deeper than 1/2 in. This contradiction is found in many project specifications.

This project included a unique requirement for petrographic analysis of the concrete in areas where power trowels were used: "At the contractor's expense, a petrographic analysis is required in each area where a power trowel is used to verify the air content at the slab surface is within specified limits." Several ASCC contractors felt that the owner would not accept the final broom finish appearance unless the surface was power floated in advance of brooming, so they proceeded to power float the surface. While the appearance may have improved, the engineer enforced the petrographic requirement that cost the contractors more than $30,000. Based on this experience, the contractors all say they will not power float prior to broom finish ever again.

Parking structure, Los Angeles, CA, USA, 2020

The specification for this project had no flatness requirement. For a broom finish, it first required a float finish, then a light steel trowel, and then brooming. The swirl finish also started with a float finish and continued with hand floating to produce a swirl. It should be noted that the project did not require air-entrained concrete, and thus the specifications may be appropriate for this use.

Walker Consultants parking structures

Chrest et al.[2] provide recommendations from a well-known parking structure consultant. Note, they recommend a 1/2 in. gap under a 10 ft straightedge for floor flatness: "Finishing tolerance: That gap at any point between the straightedge and the floor (and between the high spots) shall not exceed 0.5 in." This would be equivalent to ACI 117 conventional floor classification.

Measured F-numbers on broomed surfaces

ACI PRC-330-21, Section 5.5.4, recommends the steps for finishing shown in Fig. 3.

Malisch et al.[16] summarized broom specifications, broomed surface finish techniques, broomed surface tolerances, and provided floor flatness (F_F) measurements for different textures of broomed surfaces. Table 4 lists the measured F_F in accordance with ASTM E1155 for different broom textures provided by three different finishing techniques. The F_F values range from a low of 14.0 to a high of 22.0.

ASCC Finishing Committee

The unanimous opinion of the ASCC Finishing Committee was not to have F-numbers specified on textured finishes. The major objection was that the surface texture was too variable, resulting in widely different F_F values. One concrete contractor reported surface measurements of a swirl finish achieving a maximum 1/2 in. under a 10 ft straightedge, and a couple of contractors reported measured F_F values ranging from 12 to 15 for a swirl finish.

Broom and Swirl Test Panel

Section 10.15.1.1 of ACI 302.1R recommends that: "The selection of proper F_F/F_L tolerances for a project is best made by measurement of a similar satisfactory floor." To accommodate this recommendation, a 6 in. (150 mm) thick, 20 ft (6 m) wide, and 80 ft (24 m) long slab-on-ground test panel (Fig. 1

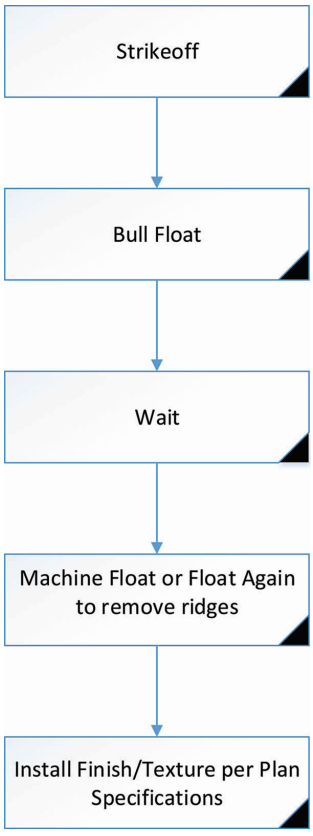


Fig. 3: Steps for finishing parking lots (Fig. 5.5.4 in ACI PRC-330-21[13])

and 4) was recently constructed at a contractors' facility in Martinez, CA. The 1600 ft² (150 m²) test panel was reinforced with No. 4 bars at 14 in. (356 mm) on center, each way, at middepth of the slab. Four truckloads of concrete (32 yd³ [25 m³] total) were delivered from a plant in Oakland, CA, located 30 miles (48 km) from the site. A 28 m (92 ft) pump placed concrete in two strips in the long direction, requiring the transverse broom and swirl finish to cope with the concrete variations in two truckloads. The ambient air temperature was 45°F (7°C) on an overcast day.

Test panel finishes

The 20 x 80 ft test panel was divided into four 20 x 20 ft sections, each with a different finish:

- Swirl finish (Fig. 1(a));
- Broom finish (Fig. 1(b));
- Pan float finish (used prior to swirl); and
- Bullfloat (used pan floating).

The test panel was constructed in this manner to evaluate the effect the swirl or broom finish had on the surface flatness prior to application. F-numbers were measured and evaluated on each surface separately.

Concrete mixture

The concrete mixture used (Table 5) was appropriate for post-tensioning slabs and beams. The design compressive strength was 3000 psi (21 MPa) at 3 days for post-tensioning and 5500 psi (38 MPa) at 28 days. Slump was specified as 6 ± 1.5 in. (152 ± 38 mm), air content at less than 2%, and a maximum water-cementitious materials ratio (*w*/*cm*) of 0.45.

Placing and finishing procedures

Concrete was placed with a boom pump, vibrated with a backpack vibrator, and screeded by hand with a 16 ft (5 m) straightedge using a 3 ft (1 m) overlapping pass. Next, a 6 ft (2 m) channel float was used to smooth the screeded concrete (Fig. 4(b)). After waiting until the bleed water disappeared and the concrete stiffened, a 36 in. (914 mm) walk-behind machine with a

Table 4:
Measured F_F for different broom textures

Finishing technique	Light broom	Medium broom	Heavy broom
Type A	19.9	22.0	21.3
Type B	16.3	19.7	14.0
Type C	17.6	16.5	20.7

Type A—hand screed with 16 ft (5 m) long magnesium straightedge, 4 ft (1.2 m) wide magnesium bullfloat, 3 ft (1 m) wide broom.
Type B—12 ft (3.7 m) long handheld vibrating screed, 4 ft wide magnesium bullfloat, 3 ft wide fresno, 3 ft wide broom.
Type C—12 ft handheld vibrating screed, 4 ft wide magnesium bullfloat, 3 ft walk-behind machine with float shoes, 3 ft wide fresno, 3 ft wide broom.

Table 5:
Materials, quantities, and volumes for the test panel concrete

Material	Description	Design quantity, lb/yd³	Volume, ft³
Cement	ASTM C150/C150M[18]	415	2.11
Slag cement	ASTM C989/C989M[19]	178	0.98
Total cementitious materials		593	3.09
Coarse aggregate, No. 57	ASTM C33/C33M[20]	1600	8.90
Intermediate aggregate		350	2.12
Fine aggregate		1414	8.06
Total aggregates		3364	19.08
Water	ASTM C1602/C1602M[21]	267	4.28
Target air content of 2.0%	—	—	0.54
Sum		4224	27.00

Note: 1 lb/yd³ = 0.6 kg/m³

Fig. 4: Initial steps in the construction of a 20 x 80 ft (6 x 24 m), 6 in. (150 mm) thick test panel used to evaluate the effects of swirl and broom finishes on F-numbers: (a) formwork, reinforcement, pump, and crew are in place; and (b) concrete placement nears completion. Concrete was pumped, internally vibrated, struck off using a 16 ft (5 m) long screed, and smoothed using a 6 ft (2 m) channel float

pan was used (Fig. 5). A swirl finish was then applied to the panned surface with a small hand brush (Fig. 1(a)).

Following panning, finishers on kneeboards used a hand float and trowel (Fig. 6), after which a 3 ft wide broom made of a 50/50 mixture of horsehair and plastic was used to finish the surface of an adjacent panel (Fig. 1(b)). The surface was purposefully broomed halfway from each side to illustrate a typical broom mark.

Flatness measurements

A technician from ATLAS used a Dipstick® to measure F-numbers (Fig. 7) on diagonal measurement lines within 24 hours after the concrete placement. The F_F numbers for each run and the overall combined are shown in Table 6.

Project F_F for swirl finish

The workers that provided the swirl finish on the test panel also provided a swirl finish on a parking garage project. The project requirements included measured F-numbers to meet a specified MLV F_F of 25. F-numbers were measured on two different placements with the swirl finish. The engineer stopped the F-number measurements after receiving the first two F-number reports and deleted the F-number requirement for the swirl finish. Table 7 provides the measured F_F for each test area and the combined F_F for each placement. Note that the two combined F_F values were 17.90 for Placement 1 and 15.84 for Placement 2. The test area F_F values ranged from 11.25 to 22.85. All F_F values were below the initial specification requirement.

Summary and Analysis

Table 8 provides a summary of the information presented for flatness measurement methods and values and finishing techniques. It is easy to see that there is no consensus among the different sources of information.

Broom finish

Flatness—Two major construction documents, ACI 301-20 and AIA

Fig. 5: After the channel float and waiting time, workers used a 36 in. (914 mm) walk-behind machine with a pan

Fig. 7: Technician uses a Dipstick® to measure F-numbers on parallel measurement lines for each test panel section: swirl, broom, pan float, and bullfloat finish

Fig. 6: For a broom finish, after panning, finishers on kneeboards used a hand float and trowel to prepare the surface for brooming. The swirl finish was placed on the panned surface

Table 6:
Measured F_F for the test panel

Section finish	Area, ft²	Run 1	Run 2	Run 3	Run 4	Combined
Bullfloat	400	19.63	27.06	17.28	15.88	19.33
Machine float	400	26.53	24.74	22.03	17.97	22.82
Broom	400	32.50	30.20	30.39	28.25	30.51
Swirl	400	24.28	21.99	25.22	18.50	22.29

Table 7:
Project-measured F_F numbers for swirl finish

Placement	Swirl finish	Area 1	Area 2	Area 3	Area 4	Combined
1	F_F	22.85	12.72	16.56	—	17.90
	Area, ft²	1677	1147	1760	—	5432
2	F_F	15.94	17.46	11.25	19.37	15.84
	Area, ft²	3876	480	1512	1638	7506

Table 8:

Summary of flatness measurement methods and values and finishing techniques for broom and swirl finishes

Information source	Flatness method	Flatness value	Finishing broom	Finishing swirl
ACI 117-10(15)	F-number Gap under straightedge	Requires engineer to specify	N/A	N/A
ACI 301-20	Defaults to F-numbers	No requirements for broom, but requires SOF_F of 20 prior to broom	Requires float finish prior to broom	No statement
ACI 302.1R-15	Prefers F-numbers	Recommends SOF_F of 20 for parking structure slabs	For fine broom, broom freshly troweled surface. For coarse broom, broom after floating. For silica fume parking garages, bullfloat then broom	For smooth swirl, use steel trowel in a swirling motion. For coarse swirl, use hand float after machine float
ACI 310R-19	Prefers F-numbers	Provides no recommendations	No statement	No statement
ACI 330.1-03	Gap under straightedge	Requires 1/2 in. for broom finish	Bullfloat, then broom. Do not use steel trowels or power finishing equipment	N/A
ACI 330.1-14	No requirement	N/A	Bullfloat, then broom. Do not use trowels	N/A
ACI 330.2R-17	No requirement	N/A	Bullfloat, then broom. Power floating or troweling not recommended for air-entrained concrete	N/A
ACI PRC-330-21	No requirement	N/A	Bullfloat, then broom. Power floating not recommended but is optional and may produce more consistent final finish	N/A
ACI 362.1R-12	No requirement	N/A	Follow ACI 302.1R-04	Follow ACI 302.1R-04
ACI CCS-1(10)	F-numbers	Recommends SOV F_F of 20 for parking garages, parking lots, and exterior concrete for broom finish	Bullfloat, then broom	N/A
AIA MasterSpec, Cast-In-Place Concrete	F-numbers Gap under straightedge	No requirement for broom finish	Requires float finish prior to broom	No statement
Parking structure, Colorado	Gap under straightedge	1/2 in. for broom finish	Bullfloat then broom. Power floating not recommended but if done, cores must be examined to prove air content at the surface	N/A
Parking structure, Los Angeles, CA	No requirements	N/A	Float, light trowel, then broom	Float prior to swirl
Chrest et al.[2]	Gap under straightedge	1/2 in. for swirl finish	N/A	Bullfloat, wait, then swirl
Malisch et al.[16]	Measured F-numbers	F_F ranges from 14 to 22 for broom finish	Three methods: (1) bullfloat, broom; (2) bullfloat, fresno, broom; and (3) bullfloat, machine float, fresno, broom	N/A
Test panel, Martinez, CA	Measured F-numbers	Broom F_F 31 Swirl F_F 22 Machine float F_F 23 Bullfloat F_F 19	Machine float, then hand float and trowel prior to broom	Machine float prior to swirl
Parking garage project	Measured F-numbers	Six test areas: F_F ranges from 11 to 23 for swirl finish	N/A	Machine float prior to swirl

Note: 1 in. = 25 mm; N/A is not applicable

MasterSpec, did not require flatness measurements for a broom finish. ACI 302.1R-15 recommends F-numbers for parking structure slabs, and ACI CCS-1(10) recommends F-numbers for parking structure slabs, parking lots, and other exterior concrete.

While ACI 330.1-14 is silent, the previous edition, ACI 330.1-03, required a 1/2 in. maximum gap under a 10 ft unleveled straightedge. A project specification in Colorado also used this requirement. Tipping and Smith[22] used 100 individual measurement profiles, each 100 ft (30.5 m) long, to analyze the relationship between flatness and gap under a straightedge. They reported corresponding F_F values ranging from 17.4 to 27.7. This is also reported in ACI 117-10(15) commentary.

Malisch et al.[16] reported flatness values of light, medium, and heavy broomed surfaces ranging from 14 to 22. Surprisingly, the test panel broom surface flatness measured 31. This high value is likely due to the hand float and trowel application prior to the brooming. While the test panel was for non-air-entrained concrete, this finishing procedure is unlikely to be used on air-entrained concrete. In addition, hand finishing is expensive.

As expected, and shown with the test panel, the flatness for the bullfloat was 19, and the machine float was 23. ACI 117 and ACI 302.1R indicate that a bullfloat flatness will be about 20. For a bullfloat and broom finish, the flatness expectation should be about 20 or below. This also matches the test results from Malisch et al.[16]

Is a flatness requirement necessary for a broomed surface? That is the approach of ACI 301 and AIA MasterSpec and certainly deserves more discussion. However, if a flatness requirement is deemed necessary, the authors prefer using F-numbers because of the procedural approach in ASTM E1155. While there is a straightedge measurement procedure approach in ACI 117, it doesn't appear to be in use. The authors would recommend SOV for flatness between 15 and 20, but certainly not over 20.

Finishing procedure—The surprising finishing procedure was the hand float and trowel used prior to the brooming of non-air-entrained concrete for the test panel and the resulting flatness of 31. Section 5.5.4.3 of ACI PRC-330-21 includes an interesting statement that power floating "may help to produce a more consistent final finish" but also notes that: "Typically, power floating is not recommended for exterior pavements...."

ASCC contractors say they frequently can't get the owner or architect to accept the broom finish appearance unless they power float or use a fresno to remove the ridges left by bullfloating. This is especially difficult when a 2 ft square broom reference sample is used as a comparison because this sample size isn't representative of the difficulty of brooming a 15,000 ft^2 (1390 m^2) placement.

Malisch et al.[16] also discuss the issues associated with small sample references versus expectations for a broom finish on large concrete placements. The authors recommend that brooming for both non-air-entrained and air-entrained concrete be bullfloat and broom, both accomplished prior to any bleed water appearing on the surface. For a 15,000 ft^2 placement, this allows the finish to be completed without having to wait and step back into, or on, the concrete to perform further work. Finally, the durability of the top surface should govern the required finish, not the appearance.

Swirl finish

Flatness—Except for the 1/2 in. gap under a 10 ft straightedge used by Chrest et al.,[2] all other documents are silent on a flatness requirement for a swirl finish. The project specification for which the test panel was created required a minimum local flatness of 25. The contractor didn't believe this was going to be possible and constructed a test panel to determine what was feasible. As often occurs, the flatness of 22 measured for the test panel was at the high end of that measured for the six project test areas, ranging from 11 to 23.

Is a flatness requirement necessary for a swirl surface? There is likely a lot of swirl finish that exists that was never measured for flatness. However, if a flatness requirement is deemed necessary, the authors prefer using F-numbers because of the procedural approach in ASTM E1155. The authors would recommend a specified overall flatness value between 15 and 20, but certainly not over 20.

Finishing procedure—There are different ways to produce a swirl finish. However, applying the finish must wait until the concrete is stiff enough to place a swirl that will hold its shape. Thus, we don't see a swirl being provided immediately after bullfloat, but rather waiting until the concrete stiffens. As was done in the test panel, we anticipate a machine float prior to hand applying a swirl finish.

Recommendations

The authors believe that a consensus can't be achieved by individual ACI committees but requires coordination between ACI Committees 302, 330, and 362, and Joint ACI-ASCC Committees 117, Tolerances, and 310, Decorative Concrete. We recommend that representatives from each committee have a separate meeting at an ACI convention or at an ASCC-sponsored workshop to discuss flatness requirements.

We present these five questions for discussion:

1. Do textured finishes need a flatness requirement? This includes not only broom and swirl finishes but also architectural finishes, such as embossing, imprinting, stenciling, and stamping.
2. If a flatness requirement is necessary, what procedures and criteria are appropriate?
3. How should finishing procedures be accomplished for air-entrained and non-air entrained exterior concrete with textured surfaces?
4. The balancing act—what is number one: appearance, durability, or flatness?
5. How does the need for drainage impact the flatness requirement? What drainage slopes are compatible with what flatness values?

Project credits

The Conco Companies, Concrete Contractor, and Hector Campos-Diaz, ATLAS, Testing Agency.

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