

Do Hand-Held Vibrating Screeds Affect Surface Air Entrainment?

Original research
by CONCRETE
CONSTRUCTION looks
at the effect of
these handy tools
on air entrainment

By Joe Nasvik

Across the Midwestern states last December, there was a much greater accumulation of snow-fall than usual. Ground temperatures, as a result, tended to remain around freezing. With little snow in January and temperatures frequently fluctuating above and below freezing, exterior concrete slabs experienced more freeze/thaw cycles than usual. By spring of this year, the number of reports of spalled and scaled concrete, especially for residential driveways, was skyrocketing. Concrete installed during the 2000 construction season had the most damage.

Why residential driveways were more susceptible to these problems than other concrete installations raises questions about mix designs, installation methods, and adequate curing. Problems in residential construction sometimes arise because inexperienced contractors are left to install as they wish—with no specification to guide them. Ready-mix producers sometimes let economics dictate the percentage of cement and pozzolans in their performance mixes, and contractors sometimes order 3000-psi mixes for exterior residential use. (ACI's "Guide to Residential Cast-in-Place Concrete Construction," ACI 332R-84 [Table 2.2] recommends a minimum of 3500 psi for driveways in severe weather regions but notes that 4000-psi concrete will provide superior durability.) Concrete is sometimes poured with slumps as high as 8 inches, and proper curing is often neglected.

While all of these factors could account for the problems, we also wondered if the increasing use of hand-held vibrating screeds for striking off concrete flatwork could reduce air-entrain-



It's easy to see why hand-held vibratory screeds are becoming very popular. They take all the work and back-breaking effort from "striking-off" concrete, and they save labor.

ment levels at the surface of the concrete enough to contribute to the scaling. After checking with two leading companies that do petrographic analysis, and learning that they hadn't performed any air void studies on the effect of screeding concrete with these tools, we decided to conduct our own study.

How vibrating screeds work

One worker operates the screed, which consists of a small gasoline engine mounted on a handlebar, a vibrator positioned near the screed bar, and a 4- to 16-foot-long screed bar made from extruded aluminum. By controlling the angle of the screed bar, the operator can create the surface plane of the concrete. A recommended engine speed is usually marked on the throttle of these tools. Manufacturers recommend that the screed be run at this

speed to create the proper frequency vibration for placing concrete. Manufacturers recommend use of the screeds for slumps ranging from 2 to 9 inches.

Our research program

We cast four concrete slabs 4 feet wide by 10 feet long using a concrete mix design commonly used in the Chicago area for residential construction (see Table 1). The slabs were cast from two separate batches in the yard of a local ready-mixed concrete producer (a short distance from the batch plant). We placed 2½-inch slump concrete for the first two slabs and 6-inch slump for the remaining two. The 2½-inch batch was considered to be strong, durable concrete, and the 6-inch batch was considered to be closer to what is actually installed in the field. Slabs were cast as follows:

- Slab #1: 2½-inch slump concrete, manually struck off
- Slab #2: 2½-inch slump concrete, struck off with a vibrating screed
- Slab #3: 6-inch slump concrete, manually struck off
- Slab #4: 6-inch slump concrete, struck off with a vibrating screed

Frequency of vibrators

Frequency, amplitude, and time of vibration are the factors that most af-

fect concrete. Of the three, frequency and time have the most impact on air entrainment. High frequencies remove smaller bubbles in concrete, such as those manufactured by air-entraining admixtures. There's a difference of opinion about the frequency and time of vibration required to cause air-entrained bubbles to leave concrete. Estimates range from 6000 to 15,000 vibrations per minute (vpm). Differences in concrete mix designs, slump, and the length of time vibrators stay in the same location all affect the amount and type of

air removed from fresh concrete. The hand-held vibrating screed used for our slabs ranged from 6250 vpm to 7500 vpm. With no changes to the vibrating screed's engine speed, the frequency of the vibrator increased when the slump of the concrete decreased (see Table 2). For example, a frequency of 4500 vpm was measured recently on a jobsite where a contractor was placing concrete with a slump of approximately 8 inches.

Procedure

A leading manufacturer supplied a new hand-held vibrating screed for our study. The recommended speed for operating the unit was marked as an indent on the throttle. It's possible to operate at a higher speed, but we chose the recommended position on the throttle (increasing engine speed increases the frequency of the vibrator).

After initial temperature, plastic air content, and slump were determined, concrete was placed in the slab forms. One slab in each set was manually struck off with a wooden 2x4 and the other with a hand-held vibrating screed—that is, Slabs #1 and #3 with wood and Slabs #2 and #4 with the vibrating screed. We struck off the slabs with the vibrating screed in one smooth motion—not stopping or keeping the screed at any one location. The surface of each slab was then bull floated and broom finished—as in typical driveway construction.

We included an additional test (Specimen #5)—a small section of Slab #2 that was hand floated, steel troweled, and broomed, similar to the once-recommended installation procedure for exterior concrete. The timing of this finishing process corresponded to the time when finishers would get out on a slab with knee boards for final finishing.

On the morning after concrete placement, we cut 1-foot-square sections from each slab and delivered them to Construction Testing Laboratories (CTL), Skokie, Ill., for air-void analysis of the hardened concrete. Each specimen was labeled with the same number as the slab from which it was cut. The specimens were standard cured, and then full-depth sections were cut in order to study the air-void structure in the body of each specimen. An additional section was cut from the top of each specimen, and the top 0.06 inch (approximately

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We cast four slabs for this study: two at a 2½-inch slump and two at a 6-inch slump. Two were “struck-off” with a 2x4 in the time-honored way, and a vib-screed was used on the other two.



The petrographer cut samples like these from each slab. The sample at the left shows the body of the slab, and the one at the right shows the top surface area.



At the right is the surface of sample #2 after bull floating and brooming. At the left is sample #2 after hand floating, troweling, and brooming (specimen #5). Notice the darker color and absence of all large aggregate.

Table 1: Mix designs

(pounds/cubic yard, unless otherwise noted)

	Slabs #1 and 2	Slabs #3 and 4
Portland cement	564	564
Sand	1345	1345
Stone (#57—nominally passes 1-inch screen)	1740	1740
Water	267	283
Air-entraining admixture (ounces/cubic yard)	7	6
Water-cement ratio	0.47	0.50



With the sample mounted on a moving table, the petrographer is able to count each air bubble—entrained and entrapped.

$\frac{1}{16}$ inch) was removed and polished to study the surface air-void structure. If hand-held vibrating screeds removed entrained air, the damage would be most visible at the top surface.

Results

To protect concrete from freeze/thaw damage, specifications usually call for plastic entrained-air content to range from 4.5% to 6%. This is the sum of entrapped air (which has little ability to provide protection) and entrained air. In general, the entrained-air portion of the total air should be not less than 3%. But the size of the bubbles and how they are distributed throughout the concrete are more important factors. The parameter generally accepted for the size of air bubbles in hardened concrete is

0.006 inch or less in diameter; spacing between bubbles shouldn't exceed 0.016 inch, and specific surface should be 600 in.²/in.³ or higher.

In all, 2 petrographic studies were performed on each of the 5 specimens for a total of 10 tests. The results, which are reported in Table 3, show that all the specimens met or exceeded the above criteria and have acceptable entrained air levels. There were no significant differences in entrained air in the body of Specimens #1 through #4. Nor were there any significant differences between the body and the surface region of Specimens #1 through #4.

Specimen #5 is particularly interesting. Scrubbing the concrete surface with a hand float after bleeding ceased, followed by steel troweling, further den-

sified the surface. Fine aggregate and cement paste were the only ingredients left within the top 0.06 inch, and the color of the cement paste was noticeably darker than in the other specimens. The change in color indicates more unhydrated portland cement due to a lower water-cement ratio—the result of densifying the surface by hard troweling. The entrained air dropped from 5.5% to 2.3%—a percentage not generally regarded as sufficient to provide protection. But the void spacing factor is 0.006 inch and the specific surface is 1202 in.²/in.³, indicating that the larger air bubbles were removed, leaving the smaller ones and thus providing adequate freeze/thaw protection for the concrete. In fact, this concrete probably would perform better under freeze/thaw conditions than the others.

Looking at differences between entrained air in the specimens' body and surface, we noted fewer large aggregates at the surface. This is due to the action of both the bull float and the hand-held vibrating screed pushing down larger aggregate, forcing more sand and cement paste into the surface region.

Often the air content measured in hardened concrete is higher than in plastic concrete, as is the case in this study. Dave Vollmer, the CTL petrographer who performed this study, says there are at least two current theories as to why this happens—either the small air bubbles tend to be incompressible and thus are not measured in the fresh concrete using a pressure-type air meter, or the formation of entrained air bubbles continues for some period of time after plastic air readings are determined.

Table 2: Concrete placement records

	Specimen #1	Specimen #2	Specimen #3	Specimen #4	Specimen #5
Strike-off method	Hand	Vibrating	Hand	Vibrating	Vibrating
Finishing method	Bull float/broom	Bull float/broom	Bull float/broom	Bull float/broom	Steel trowel/broom
Vibrator frequency (vpm)		7500		6250	7500
Slump (inches)	2.5	2.5	6.0	6.0	2.5
Entrained air (plastic %)	6.2	6.2	6.2	6.2	6.2
Ambient temperature (° F)	78	78	78	78	78
Concrete temperature (° F)	79	79	85	85	
Concrete arrival to placement (minutes)	17	22	19	25	
Start placement to completion (minutes)	26	22	31	50	
Total time (minutes)	43	44	50	75	125

All concrete work was completed between 3:00 p.m. and 5:05 p.m. on July 27, 2001.

Table 3: Entrained air characteristics determined by petrographic analysis

Specimen	Air Content (%)				Void Spacing Factor (in.)	Specific Surface in. ² /in. ³
	Total	Entrained	% of Total	Entrapped		
#1 Surface	7.0	5.6	80%	1.4	0.005	960
Body	7.8	5.5	71%	2.3	0.004	680
#2 Surface	5.7	4.8	84%	0.9	0.004	1300
Body	8.4	5.3	63%	3.1	0.004	775
#3 Surface	7.3	6.5	89%	0.8	0.004	1080
Body	7.0	5.8	83%	1.2	0.003	1020
#4 Surface	7.3	6.6	90%	0.7	0.004	1320
Body	7.0	5.4	77%	1.6	0.003	975
#5 Surface	3.3	2.3	70%	1.0	0.006	1210
Body	7.5	5.5	73%	2.0	0.004	795

Conclusions

On the basis of this study we conclude that hand-held vibrating screeds, under the conditions used for this study, did not damage the entrained air bubble structure in the hardened concrete

Current guidelines are designed to avoid problems that occur when the proper timing of finishing operations isn't adhered to. But as demonstrated by Specimen #5, finishing procedures that densify the surface after bleeding has ceased actually can improve the freeze/thaw durability of concrete.

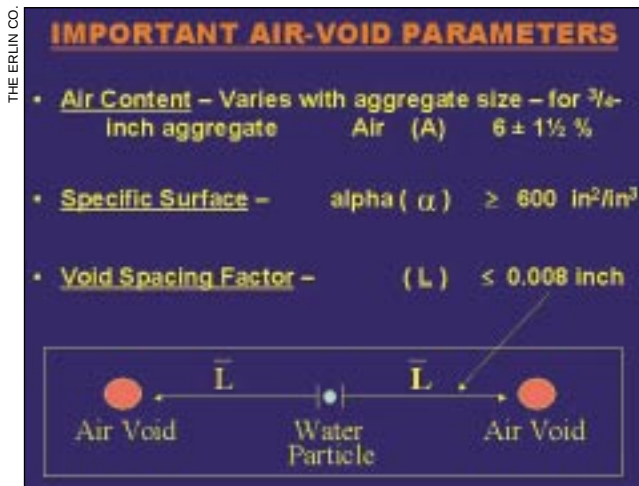
The instances of concrete scaling experienced in the Midwest last winter may be simply due to unusual weather. Other possibilities are less than adequate concrete mixes delivered to job-sites, poor placement practices, and a lack of proper curing. It's also possible that work performed at the end of the season didn't have sufficient time to

dry out sufficiently to survive freeze/thaw cycles. ■

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- Vans Material for supplying ready-mixed concrete and space in their yard to cast the slabs
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- Construction Technology Laboratories and The Erlin Co. for petrographic analysis and interpretation

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This is what is needed to provide good concrete durability regarding air entrainment.

enough that the slabs would have had freeze/thaw scaling problems. One study, however, does not imply significant proof, and further testing should be performed to ensure the reliability of these results.

It's possible that keeping a hand-held vibratory screed in one place too long while striking off concrete could cause significant loss of entrained-air bubbles—enough to cause freeze/thaw problems. And running the engines at rates of speed other than the manufacturer recommends could raise vibrator frequencies to a dangerous level.