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Ward R. Malisch Concrete Construction Symposium

SP-338

Editors:
Bruce A. Suprenant and Oscar R. Antommattei

American Concrete Institute
Always advancing

Ward R. Malisch
Concrete Construction Symposium

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PREFACE

Ward R. Malisch Concrete Construction Symposium

Ward R. Malisch spent most of his 50-year career addressing issues related to concrete construction, specifically to problems that concrete contractors deal with daily. His civil engineering training began at the University of Illinois at Urbana-Champaign where he received his BS, MS, and PhD in 1961, 1963, and 1966, respectively. During his time at Illinois he also carried out research on concrete durability and taught courses on plain concrete. Following that, he taught courses in concrete construction at the University of Missouri-Rolla (now Missouri University of Science and Technology) where he received several awards for outstanding teaching. During his time there he took a leave of absence to work in quality control for the prime contractor building Missouri's first nuclear power plant. This experience spurred his interest in how specification requirements and tolerances affected contractors' abilities to build both simple and complex structures.

Malisch was able to reach the construction industry more directly when he joined the staff of the World of Concrete seminar program and later became editor of Concrete Construction magazine. He was then able to teach at a national level by further developing a seminar program and editorial content that featured how-to-do-it information on concrete technology, with an emphasis on contractor-related topics. During his tenure with the magazine, he began answering questions on a telephone hotline service offered by the American Society of Concrete Contractors (ASCC), and gave advice on problems related to unrealistic concrete tolerances, inadequate knowledge about plastic concrete properties, ambiguous specifications, and a wide range of other construction-related topics.

In subsequent years, Malisch served as director of engineering and later as senior managing director at the American Concrete Institute. There, while supervising the engineering, marketing, and education departments, and serving as publisher of Concrete International magazine, he also interacted with other concrete-related organizations, serving on the Research, Engineering, and Standards Committee of the National Ready Mixed Concrete Association and on the ASCC Board of Directors. Along with the ACI Strategic Development Council, ASCC, and Construction Technology Laboratories, he helped to organize an Inter-Industry Working Group on Concrete Floor Issues that brought together leaders from several construction and flooring industry groups. One outcome of this group's activity was publication of ACI 302.2R-06, "Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials."

Upon retirement from ACI in 2008, he was named technical director of ASCC. He was active again in forming an Inter-Industry Working Group on Reducing the Cost of Tolerance Compatibility Problems along with eight other co-sponsoring groups. He later served as principal investigator on two construction related research projects dealing with contractor-related problems.
Dr. Malisch's awards include:

- 1986— Elected Fellow of the American Concrete Institute
- 2004— Arthur Y. Moy Award, ACI Greater Michigan Chapter
- 2006— Silver Hard Hat Award, highest award given by the Construction Writers Association

- 2008— Richard D. Gaynor Award, Highest technical award given by the National Ready-Mixed Concrete Association
- 2009—One of Concrete Construction magazine's Most Influential People
- 2010— Arthur R. Anderson Medal, ACI, given for outstanding contributions to the advancement of knowledge of concrete as a construction material
- 2011— ACI Construction Award, given to the author of any paper of outstanding merit on concrete construction practice
- 2011— ASCC Lifetime Achievement Award, ASCC's highest honor, acknowledging recipients for their body of work within the industry and their service to ASCC
- 2013— ACI Honorary member, given to a person of eminence in the field of the Institute's interest or one who has performed extraordinary meritorious service to the Institute
- 2019—Roger H. Corbetta Concrete Construction Award, ACI, given to an individual that has made significant contributions to progress in methods of concrete construction.

For his dedication to the concrete construction industry, this Special Publication is a tribute to his work and is sponsored by the ACI Construction Liaison Committee. Sixteen presentations, distributed in four sessions named "Ward R. Malisch Concrete Construction Symposium," were given at the 2017 ACI Fall Convention in Anaheim, CA. The quality of the presentations was highlighted by the participation of four former presidents of ACI: David Darwin, Terry Holland, Ken Hover and Mike Schneider.

The nine manuscripts presented in this Special Publication are significant in that each paper represents authors that have been previously published in ACI. Thanks are extended to the many ACI members who reviewed the manuscripts and provided helpful technical and editorial comments which enhanced the authors' papers.
This Special Publication is but one small token of appreciation and gratitude to the more than 50-year service of Ward R. Malisch to concrete construction. He has been a source of inspiration to many as well as an example of honesty, integrity, and dedication. He has built the foundation for others to build upon in serving the concrete construction industry.

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Can Bugholes Be Evaluated Objectively on As-Cast Concrete Surfaces?

Ward R. Malisch, PhD, P.E. Hon. Member ACI and Heather Brown, PhD, FACI

Synopsis: Bugholes on as-cast surfaces are an aesthetic issue, not a performance issue related to strength, durability, or serviceability. Because they are an aesthetic issue, attempts to evaluate bugholes objectively, with measurements, are not useful. Measuring bugholes using an evenly divided scale or other instrument can reveal their number, individual area, and total area as a percentage of a sample area. But there is no scale or instrument for aesthetic judgments. Thus, matching a mock-up surface with the as-cast surface, although subjective, is a better method for acceptance of surface appearance.

Keywords: aesthetics; bugholes; forms; surfaces; performance; rating systems

Ward Malisch is the Concrete Construction Specialist for the American Society of Concrete Contractors. He has taught civil engineering materials courses at several universities, worked in quality control for a major contractor, and previously served as ACI's senior managing director. He is a current member of ACI Committee 301 on specifications and an Honorary Member of ACI.

Heather Brown is a professor and director of the School of Concrete and Construction Management at Middle Tennessee State University. Her technical experience includes five years of material testing and research for the Tennessee Department of Transportation. An ACI Fellow, she is a current member of SCI Committee 522 on pervious concrete and of the ACI Board of Direction.

INTRODUCTION AND BACKGROUND

In 1972 Reading[1] stated that bugholes (also called surface air voids) in as-cast concrete surfaces were of concern to most owners and architects—a statement that is still true today. He was struck by the wide differences in the numbers of bugholes from job to job, and even in different parts of the same placement when conditions seemed to be identical. This led him to suggest that it should be possible to better control bugholes if the controlling factors could be established and the knowledge of these factors could then be applied in the field**.** In summary, he said: "We need a yardstick for rating concrete surfaces with respect to bugholes, and more know-how on how they can better be controlled."

SUBJECTIVE RATING SYSTEMS

One such yardstick is a subjective rating system. The systems compare an as-cast concrete surface with standard photographs of surfaces exhibiting bugholes of varying size, number, and concentration. The number of standard photographs used can range from 0 to 7 increments, with the larger numbers indicating a higher incidence of bugholes. A specifier could thus require a lower number for architectural concrete and higher numbers for less important structures.[2,3,4] One system of this type appears to still be in use in Australia.[5] Subjective rating systems can be affected by personal opinions, interpretations, points of view, emotions, and judgment. This is a major detriment of such systems' bias.

OBJECTIVE RATING SYSTEMS

Objective information is fact-based, measurable, and observable. Several objective rating systems for bugholes have been proposed. [6,7,8] Some of the most recent are included in ACI 301-16[9] and in ACI 347.3R-13.[10] The former is a specification that defines three surface finishes (SF-1.0 through SF-3.0), based upon several measurements that include patching surface voids that exceed specified dimensions. The lowest quality surface—SF-1.0—requires patching of voids larger than 1½ in. wide or ½ in. deep, presumably including both bugholes and honeycomb as voids. SF-2.0 is the default finish, and SF-3.0 is the highest quality finish, with both requiring patching voids larger than ¾ in. wide and ½-in. deep. A mock-up is optional unless otherwise specified for an SF-2.0 and is mandatory for an SF-3.0 finish. There is no limit on the number of bugholes smaller than ¾ in. wide and ½-in. deep, but differences in appearance between the mock-up and as-cast surfaces would reflect differences in the number of bugholes. ACI 301-16 is a mostly objective specification for bugholes, although matching an as-cast surface with a mock-up surface is clearly subjective.

ACI 347.3R-13 defines four formed concrete surface categories (CSCs). The lowest classification is CSC1 (the Guide gives basement walls as an example) and the highest classification is CSC4 (the Guide gives monumental or landmark structures for examples). This Guide is claimed to provide objective methods for evaluation of formed surface characteristics such as porosity,[11] which is measured and expressed as a surface void ratio (SVR), defined as the total area of bugholes in a 2x2-ft (610 x 610 mm) square sample expressed as a percentage of the sample area. There are four SVR categories ranging from SVR1 (the lowest quality surface) to SVR4 (the highest quality surface). Recommended SVRs for the four categories are shown in Table 1, along with a footnote and additional note.

Table 1 Surface void ratios recommended (SVR) for as-cast formed surfaces

SVR1	SVR2	SVR3	SVR4
Max. area = 6.9 in.^{2} (4452 mm^2); *Dmax* = 3/4 in. (19 mm)	Max. area = 5.8 in.^{2} (3742 mm^2); *Dmax* = 5/8 in. (16 mm)	Max. area = 3.5 in.^{2} (2258 mm^2); *Dmax* = 3/8 in. (9.5 mm)	Max. area = 1.7 in.^{2} (1095 mm^2); *Dmax* = 1/4 in. (6 mm)
Void area* not to exceed 1.2 percent of the test area.	Void area not to exceed 1 percent of the test area.	Void area not to exceed 0.6 percent of the test area.	Void area not to exceed 0.3 percent of the test area.

*Void area is the summation of the areas of all voids within the sample space of 24 x 24 in. (610 x 610 mm). Voids with an average diameter of d < 3/32 in. (2.4 mm) are excluded from the calculation of the void area.

Note: If these criteria are made applicable to the project, then the mock-up should demonstrate the ability of the contractor to meet the surface void ratio expected for these surfaces. The general appearance of the final structure should be compared with the general visual appearance of the mock-up.

A CLOSER LOOK AT ACI 347.3R-13

Section 3.2 of ACI 347.3R-13 states that: “The surface void ratio is only required to be determined if the entire impression of the surface does not meet the contract expectation.” But the “entire impression” is a subjective judgment that can overrule the objectively measured SVR.

Section 3.2 also describes a procedure for measuring SVR on a single sample, with no indication of how the sample is chosen. A rectangle is superimposed over each void in the sample space such that about as much void area falls outside the rectangle as non-void area falls inside. The area of each rectangle is measured, then the areas are summed and expressed as a percentage of the sample area. Another option is measuring each void area with a circle or square template superimposed over the bughole in the same manner as the rectangle.

The final report of a research project that examined and evaluated ACI 347.3R-13[12] cited two concerns:

- The SVR determination is made on one sample from the building unit under consideration, but with no details given as to how the sample is chosen.
- Repeatability and reproducibility of the suggested method for measuring SVR were not reported and no data were presented regarding variability of results using the method.

Sampling is critical, and the “sample-of-one” approach recommended in ACI 347.3R-13 was shown in the research report to lead to either rejection or acceptance of the same wall, depending on sample location. Thus, the use of more than one sample was studied, with several different measuring methods. Students in Concrete Industry Management programs at three universities made measurements on different walls. Further, three independent testing laboratories made measurements on each of three different walls constructed in three different states by different contractors. Shown in Fig. 1 is a shear wall with an as-cast finish in the garage portion of a high-rise condominium. Nine randomly chosen, non-overlapping sample locations were marked. Fig. 2 shows results of SVR measurements by a testing laboratory manager and two technicians on all nine samples. They used a square template, which they found to be a faster method for void measurement. Note that the average SVR was 0.4%, which would place the wall in the SVR3 category. But note also that individual results for the three measurements of each sample, due to differences in reproducibility, could have placed the wall in any of the four SVR categories.

Thus, the average of several samples is needed to categorize a wall, and reproducibility of the proposed void measurement methods is suspect.

Photographic methods are being developed using software programs to precisely and accurately measure the surface void ratio of samples and relate them to photos of the same surface.[13] Some researchers also suggest two "visual impact ratios" with *ratio one* being the same as the SVR, and *ratio two* obtained by dividing the SVR by the total number of voids. This second ratio is an indicator of whether or not the number of bugholes visible from a distance is significant. A small *ratio two* indicates that the number of bugholes visible from a distance is insignificant. Thus, they state that the smaller these two ratios are, the higher the quality of the surface.[14] Eventually, it may be possible to rapidly and accurately measure the two ratios for an entire wall. But would the results of such measurements give us an objective measurement of the wall's aesthetic qualility?

PERFORMANCE AS OPPOSED TO AESTHETICS

Bugholes are listed as defects in AIA MasterSpec©[15] and as "negative surface effects" in ACI 309.2R-15.[16] These two documents can be applied to any structural concrete surfaces exposed to view—not just architectural concrete surfaces. But the term "defect," when applied to structural concrete usually refers to performance issues related to strength, durability, or serviceability. Performance of vertical as-cast surfaces that receive no coatings or other surface treatments is rarely, if at all, affected by bugholes. So this is not a performance issue.

Thus, considerations of aesthetic appeal or pleasing appearance seem to be the major reason for attempting to limit the size and number of bugholes on formed surfaces.[17] But how does one quantify aesthetics? What quantifiable features of bugholes make a surface beautiful or ugly?

IS QUANTIFICATION OF AESTHETICS USEFUL?

Any concept can be quantified, but such attempts at quantification are not necessarily useful. Many methods for quantifying art or aesthetics have been proposed, all with flaws that make them imperfect. A good discussion of the reasons is presented by Naukkarinan [18] in his paper "Why Beauty Still Cannot be Measured." He states that aesthetic judgments based on the same measurements can vary to a great extent if the evaluator is changed. Further, in measuring, one normally uses an evenly divided and hierarchical scale. The numbers indicate if something is bigger than something else and by how much. But there is no scale or instrument for aesthetic judgments.

As an example related to bugholes, measurements reveal their number, individual area, and total area as a percentage of a sample area, expressed as the SVR. But the four SVR categories in ACI 347.3R-13 suggest that there is an aesthetic difference among the categories based on SVR, thus implying for a given range in SVR, the aesthetic qualities are similar. Consider the three drawings in Fig. 3. They are drawn to scale and represent concrete surfaces with bugholes of three sizes and with identical surface void ratios. The SVR for each is just under 1.0%, the borderline between an SVR2 and an SVR3. The only difference in the three drawings is the concentration or areal distribution of the bugholes. Which of the three is most pleasing to the eye? The SVR measurements are of no help in making such a decision, because qualities such as symmetry, proportion, balance, and other such factors vary even though the SVR remains constant. It is also likely that differing owners or architects would have differing opinions as to the acceptability of any of the three bughole distributions.

Finally, in Fig. 4, examine the two photographs from the interior of the Herbert F. Johnson Museum of Art on the Cornell University campus. This monumental structure won an AIA New York honor award in spite of the rather large bugholes seen in photos of the board-finished surface for a stairway. These bugholes were cited specifically by a panel of architects as an aesthetic feature of the museum's interior. The surface was described as: "richly textured" with a "porous surface that resembles a sea-tossed shell."

HOW TO BEST EVALUATE BUGHOLES

If appearance of vertical concrete surfaces is not of concern, there is little need for detailed restrictions on bughole size, number, or concentration. Using the ACI 301-16 default surface finish of SF-2.0 should be satisfactory for most surfaces. An exception is for surfaces to be painted or coated, which may require a grout-cleaned rubbed finish as described in Section 5.3.3.4(a) of ACI 301-16. This makes paint or coating failures less likely.

Based on the information in this paper, do not evaluate bugholes as a separate aspect of formed surface appearance for architectural concrete surfaces. Instead, construct a mock-up and compare the general appearance of the final structure with the general visual appearance of the mock-up as is suggested in ACI 347.3R-13. As noted in the ACI Guide: "The surface void ratio is only required to be determined if the entire impression of the surface does not meet the contract expectation."

Using a mock-up to evaluate formed surface appearance is admittedly subjective. But it is superior to basing an evaluation on objective measurements that don't necessarily relate to aesthetics.

Section 6.1.4.4 of ACI 301-16 contains detailed instructions for field mockups as follow:

> **"6.1.4.4.a** Construct field mockups using same procedures, equipment, and materials that will be used for production of architectural concrete. Accepted field mock-up shall serve as the reference to which architectural concrete will be compared for periodic and final acceptance. Construct field mockups at an acceptable location on site. Provide a simulated repair area to demonstrate an acceptable repair procedure. Repair procedure shall be suitable to provide an acceptable color and texture match. Protect from physical damage and retain the mockups until final acceptance of architectural concrete."
>
> **"6.1.4.4.b** For formed architectural concrete surfaces, include vertical, horizontal, rustication joints, and any sculptured features. Demonstrate, color and texture. Cure the mock-up as intended with the structure. If required, apply sealers and coatings to only a portion of the mock-up. Construct mockup to include at least-two lifts having heights planned for placement of architectural concrete."

When building mock-ups, contractors can't duplicate all of the variables that affect the size, number, and concentration of bugholes.[12] They can, however, reduce effects of some of the variables when building the mock-up by avoiding the following mistakes:

- Using different personnel and production procedures for the mock-up than those to be used during building construction. Using a hand-picked crew of the best workers and telling them to take extra care on the mock-up is self-defeating. Given enough skills, time and money, most contractors can build an outstanding mock-up with some bugholes. But the goal is to achieve the architect/owner's desired appearance for the completed structure, and nothing more.
- Using new forms for the mock-up, when it's known that reuse of forms is planned for the structure. Constructing the mock-up with used forms is more realistic, because form facing materials have a major effect on bughole formation.
- Using only one truckload of concrete in the mock-up. Concrete from two truckloads will help to highlight any effects of batch-to-batch variations on bugholes.

Finally, architects and owners need to approve the whole mock-up rather than parts of it.[19] If parts of it are not satisfactory, a new mock-up should be built. Contractors are first fully introduced to the specifier's expectations when the mock-up is evaluated. Specifications can't adequately describe the desired end result because acceptance is subjective. There is then a need to provide for fair compensation of the contractor when more than one mock-up is required.

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FIGURES

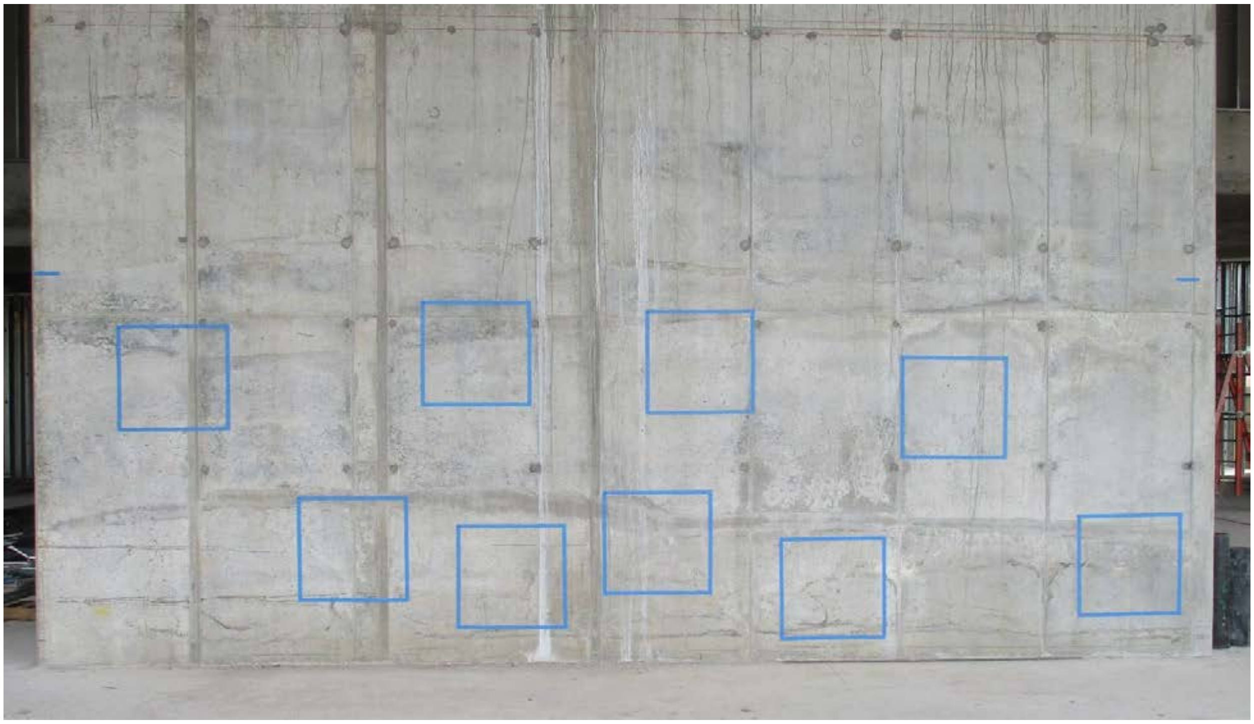

Fig. 1 Nine randomly chosen, 24 x 24-in. (610 x 610 mm) non-overlapping samples for measuring surface void ratio on a shear wall with an as-cast finish. (Credit: Paradigm Consultants, Inc.)

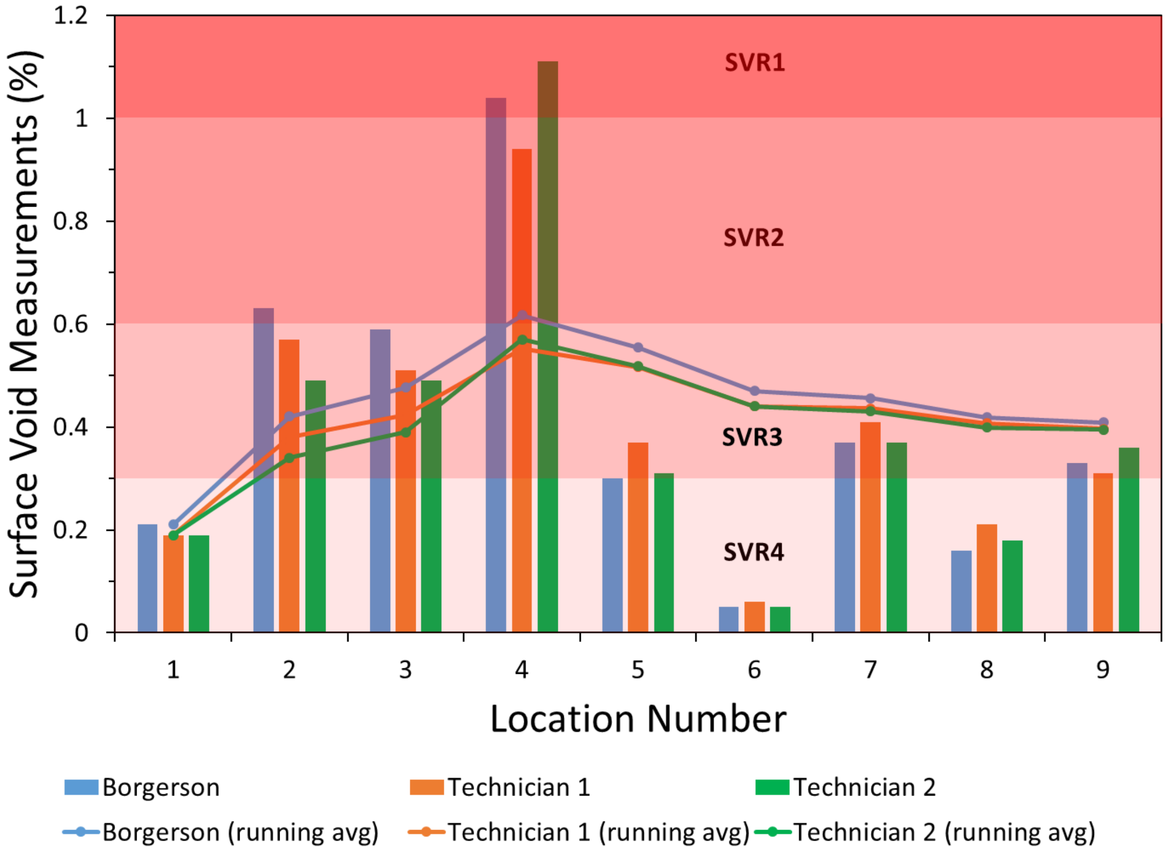

Fig. 2 Results of SVR measurements by three different testing laboratory employees. Note that the average SVR was 0.4%, which would place the wall in the SVR3 category. But also note also that individual results for the three measurements of each sample, due to differences in reproducibility, could have placed the wall in any of the four SVR categories.

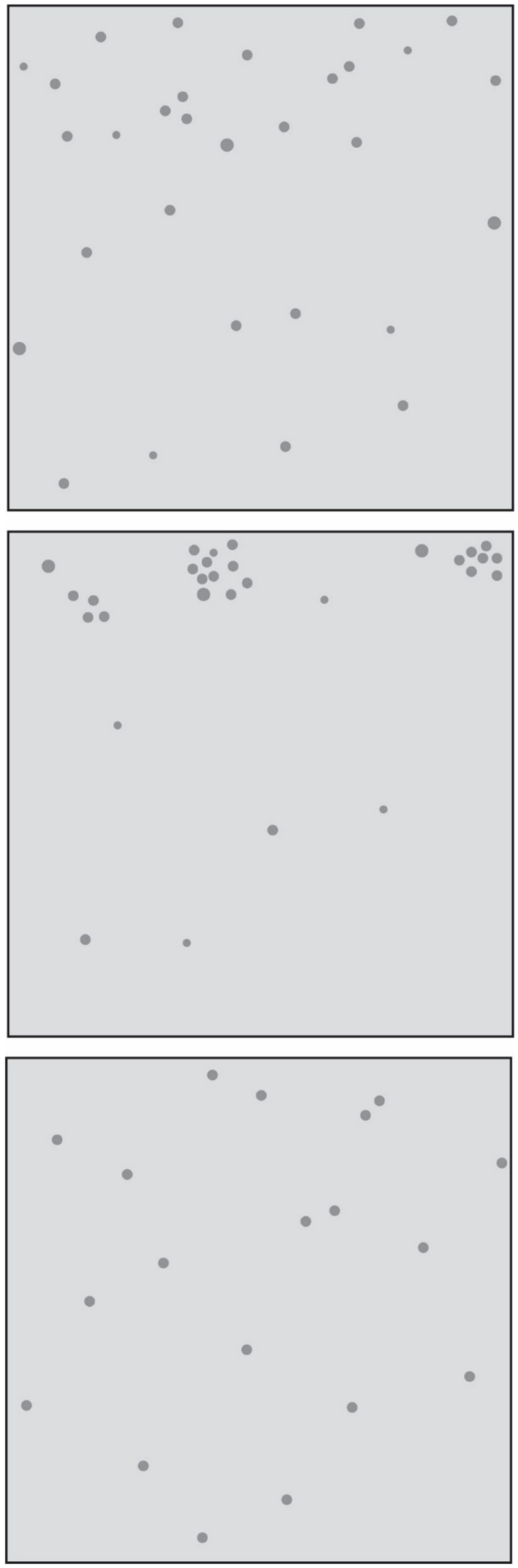

Fig. 3 Scale drawings for three patterns of varying size bugholes with identical ratios of void area to total surface area. SVR equals approximately 1.0%. Due to difference in symmetry and concentration of the bugholes, it is doubtful that all three patterns would be judged to be of equal aesthetic value.

Fig. 4 Photos of board-finished walls in an award-winning museum. Note the number and size of bugholes, which were considered by a panel of architects to be a pleasant aesthetic feature of the museum’s interior.
(Photos courtesy of the Herbert F. Johnson Museum of Art, Cornell University)