An ACI Technical Publication

SYMPOSIUM VOLUME

Ward R. Malisch Concrete Construction Symposium

Editors:
Bruce A. Suprenant and Oscar R. Antommattei

SP-338

American Concrete Institute
Always advancing

Ward R. Malisch
Concrete Construction Symposium

Sponsored by
Construction Liaison Committee (CLC)

The Concrete Convention and Exposition
October 15-19, 2017
Anaheim CA, USA

Editors:
Bruce A. Suprenant
and Oscar R. Antommattei

American Concrete Institute
Always advancing

SP-338

First printing, February 2020

Discussion is welcomed for all materials published in this issue and will appear ten months from this journal's date if the discussion is received within four months of the paper's print publication. Discussion of material received after specified dates will be considered individually for publication or private response. ACI Standards published in ACI Journals for public comment have discussion due dates printed with the Standard.

The Institute is not responsible for the statements or opinions expressed in its publications. Institute publications are not able to, nor intended to, supplant individual training, responsibility, or judgment of the user, or the supplier, of the information presented.

The papers in this volume have been reviewed under Institute publication procedures by individuals expert in the subject areas of the papers.

Printed in the United States of America

Editorial production: Gail L. Tatum

ISBN-13: 978-1-64195-092-3

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.

TABLE OF CONTENTS

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 ACI 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.

After Two Hundred Years of Estimating Evaporation, It Is Still a Mystery

Kenneth C. Hover

Synopsis: PCA researchers interested in the problem of evaporation of bleed water from concrete surfaces borrowed an equation developed by hydrologists to predict evaporation from Lake Hefner in Oklahoma. PCA's graphical representation of that equation, subsequently modified to its present form by NRMCA, was later incorporated into multiple ACI documents, and is known by concrete technologists world-wide as the "Evaporation Rate Nomograph." The most appropriate use of this formulation in concrete construction is to estimate the evaporative potential of atmospheric conditions (known as "evaporativity"). Since the difference between actual and estimated evaporation rate can be in the range of ± 40% of the estimate, best use of the equation as routinely applied is as a semi-quantitative guide to estimate risk of early drying and inform decisions about timing and conduct of concrete placing and finishing operations. Use of the "Nomograph" and related "Apps" in specifications is more problematic, however, given: 1.) the inherent uncertainty in its underlying equation, 2.) the difficulty in obtaining input data that appropriately characterize jobsite microclimate, and 3.) establishing a mixture-specific criterion for tolerable evaporation rate.

Keywords: Bleeding, Cracking, Curing, Drying, Evaporation, Finishing, Shrinkage, Weather

A Comparison of Floor Tolerance Measuring Approaches F-Numbers, 10-Foot (305 cm) Straightedge, and Waviness Index

By: Eldon Tipping and Rick Smith

Synopsis: Two characteristics are of primary interest to those using floor surfaces – the surface bumpiness (flatness) and the levelness. Prior to publication of the 2006 cycle of the ACI 117 document, the ACI 117 committee completed an exhaustive study of the floor surface characteristics evaluated by the F-Number System, The 10-Foot (3 m) Straightedge approach, and the Waviness Index System. The purpose of the study was to evaluate each of the methods and to develop tables that establish a small degree of uniformity among the various tolerance approaches. The F-Number System and Waviness Index use data taken at regular intervals along lines located in random locations on the test surface. The 10-Foot (3 m) Straightedge approach uses a straightedge placed in any location on the floor surface. The largest gap between support points is then measured. Each of the methods utilizes different criteria to evaluate data, so it is important for the specifier to understand the specific surface characteristics controlled by each of the methods. The ACI 117 committee evaluated a set of 600 floor surface profiles. Each of the profiles was 100 feet in length. Six groups of F-number pairings were developed as follows: F_F 20/F_L 15; F_F 25/F_L 20; F_F 35/F_L 25; F_F 45/F_L 35; F_F 60/F_L 40; F_F 100/F_L 60; each of the groups contained 100 profiles. Both the Flatness F-number and Levelness F-number for each of the profiles in each group were within 5% of the respective target values. For each of the 600 profiles, the gap-below-the-straightedge and waviness index statistics were calculated. Results from the study are presented.

Keywords: flat, gap, level, tolerance

Concrete Surface Void Ratio: Perspective from the Testing Laboratory

Jacob L. Borgerson and Woodward L. Vogt

Synopsis: ACI 347.3R-13 provides guidance on the measurement and classification of surface voids (i.e., bug holes) in as-cast formed concrete surfaces. This paper will provide perspective from a testing laboratory on the challenges encountered when asked to perform surface void ratio measurements. Measurements were performed by field technicians and an engineer using the method as described in ACI 347.3R-13, in addition to a modified approach. Based on measurements performed on test areas of a cast-in-place shear wall for a high-rise condominium, it was determined that the between-operator variation and the selected test area significantly impact the classification of the surface. Because the test method does not specify methods for test area location selection or the number of test areas to sample, test results can vary greatly. Specifically, two 24 in. x 24 in. (610 mm x 610 mm) areas that are within 12 in. (300 mm) of each other may possess the highest and lowest classification. Based on field test results, an alternative method is proposed that provides better repeatability between operators and is more time efficient. In addition, based on measuring several different test areas on the same concrete surface, the number of test areas needed to accurately represent the void area of a surface was estimated.

Keywords: aesthetics, bug holes, concrete, formed surfaces, surface void ratio, surface voids

Effect of Cold Curing Water on Hot Concrete Flatwork: Field Study

Ronald Kozikowski and Kevin Rowswell

- **Synopsis: Several documents have indicated that applying curing water cooler than the concrete surface by more than 20º F (11º C) can produce a strain of about 100 millionths, exceeding the concrete's strain capacity, and resulting in cracking. Earlier work by the senior author and others has questioned the origin and applicability of the 100 millionths strain capacity for early-age concrete. Tests on small-scale specimens demonstrated that using curing water as much as 55º F (34º C) cooler than the concrete surface did not result in crazing or cracking. This paper describes a study in which cold curing water was used on a large concrete slab under field conditions. Experimental results suggest that at least a 50°F (32°C) temperature difference between curing water and a concrete slab can be withstood without causing surface crazing or cracking.**

<u>Keywords</u>: curing, cooling, cracking, slabs

Ronald Kozikowski ACI member **Ronald L. Kozikowski** is Vice President of North S.Tarr Concrete Consulting, P.C., Dover, NH, specializing in troubleshooting of concrete construction issues. He has over 20 years of experience as a construction and materials engineer and is a member of ACI Committees 207, Mass and Thermally Controlled Concrete; 213, Lightweight Aggregate and Concrete; 301, Specifications for Structural Concrete; 306, Cold Weather Concreting; 308, Curing Concrete; Joint ACI-ASCC Committee 117, Tolerances; and Joint ACI-CRSI Committee C680, Adhesive Anchor Installer Certification. He received his BS and MS in civil engineering from the University of New Hampshire, Durham, NH.

Kevin Rowswell is a Project Executive for Baker Concrete Construction, Inc., Monroe, OH, and has been in the concrete construction field with Baker for nearly 35 years. His past accomplishments include overseeing Baker's Midwest Commercial Division and the Central Florida Division. Currently, Rowswell works in the South East Region as the Pump Place Finish Manager for Baker's Concrete Services. He is the Past President of the Greater Miami ACI Chapter. Rowswell holds a BS degree in construction management from the University of Cincinnati, Cincinnati, OH, and an associate degree in civil and construction engineering technology from the Ohio College of Applied Science, Cincinnati, OH.

Implementing Best Practices to Improve Quality and Constructability of Hot Weather Concreting

Oscar R. Antommattei, MS, PE, FACI

Synopsis During hot weather concreting, contractors have several options for dealing with slump loss and rapid drying of concrete surfaces. Limiting slump loss requires cooperation between the concrete producer and contractor, especially with respect to reducing truck waiting time. Several options for minimizing surface drying are compared, based on effectiveness and cost. Finally, providing for adequate initial curing of concrete test cylinders can reduce the possibility of schedule delays and increased costs related to low strength-test results.

Key words Weather, Curing, Drying, Evaporation, Wind, Crusting, Cracking, Finishing, Testing

INTRODUCTION

During hot weather concreting, contractors must anticipate potential problems and prepare a plan to deal with them. High ambient and concrete temperatures, affect contractors' ability to place, consolidate, and finish concrete, with finishing problems being accentuated by high wind velocity and low relative humidity near the concrete surface. Results may include:

- Slump loss that results in placing and consolidation problems
- Rapid slab surface drying that reduces the time available for finishing

Due to rapid setting, high temperatures can also reduce the 28-day strength of cylinders cast for acceptance testing. Test cylinders must be stored so drying and temperature effects can be controlled.

SLUMP LOSS

Slump loss refers to the loss of fluidity or increase in stiffness of the concrete from the time of batching to the discharge time. This loss is usually caused by depletion of free water due to absorption by aggregate, cement hydration, and evaporation during hot weather. This slows placement rates and increases the time needed for vibration.

Concrete producers can reduce slump loss by:

- Sprinkling aggregate stockpiles to cool the concrete and reduce water absorption by lightweight and porous aggregates.
- Monitoring ambient and material temperatures and adjusting proportions as needed.
- Using water reducing, retarding, or workability retaining admixtures.
- Avoiding use of types or quantities of supplementary cementitious materials that increase slump loss.

Set retarders should be used with caution in hot, dry, and windy weather for reasons stated later. It is also important to note that slump loss does not necessarily coincide with a change in the setting characteristics of concrete. Contractors requesting longer setting times may actually need longer slump life only for placing and consolidation.[1]

Contractors can reduce slump loss by[2]:

- Scheduling placements in the early morning or at night when temperatures are lower
- Realistically scheduling concrete placement rates to shorten truck waiting times.
- Ensuring that site access roads to the discharge point(s) are as direct as possible and maintained in good condition.
- When concrete will be pumped, providing access for two trucks—one on each side of pump—and a staging area for testing and slump adjustment.
- Establishing person(s) responsible for directing/backing trucks to the placement area

Delays in placement and finishing caused by equipment breakdowns or insufficient crew size should be promptly reported to the concrete producer so truck waiting time can be reduced

RAPID SURFACE DRYING

This is primarily a problem for slabs. Evaporation rates that exceed bleeding rates cause rapid surface drying that reduces the time available for finishing. They can also cause problems such as surface crusting, plastic cracking, and surface tearing during finishing when the underlying concrete has not yet set (Figure 1). In addition, bleedwater may be trapped below the crusted surface and cause surface delaminations.

The Un-Shored Composite Slab on Metal Deck
Part I, Construction and Behavior

By: Eldon Tipping and Bryan M. Birdwell

Synopsis: This is the first of a three-part series, the goal of which is to provide the designer and contractor with tools necessary to produce deflected slabs on metal deck that are essentially level. This first part provides a general description of the components of a composite slab on metal deck including the behavior of each of the components prior to concrete placement and after the concrete hardens. Elements impacting the ability of the design/construction team to produce level deflected floors are presented and discussed. Fabrication tolerances for structural steel are published by the American Institute of Steel Construction (AISC) and impact the relative elevation of erected beam/column connections prior to concrete placement. Deflection of the erected floor frame under the weight of fresh concrete is impacted by choices made by the designer regarding the use of Allowable Strength Design (ASD) and Load and Resistance Factor Design (LRFD). Uncertain net deflections of the supporting structural steel frame provide challenges for the contractor in his efforts to provide sufficient concrete in the appropriate locations during initial strike-off to off-set the structural steel deflection. Implications of gauging up off the supporting structural steel versus using a rod and level for initial concrete strike-off are presented and discussed. The importance of construction joint location is addressed, and recommendations are presented.

Keywords: composite, deflection, gauging, level, metal deck

The Un-Shored Composite Slab on Metal Deck
Part II, Ineffective Contract Document Requirements

By: Eldon Tipping and Bryan M. Birdwell

Synopsis: This is the second of a three-part series, the goal of which is to provide the designer and contractor with tools necessary to produce level deflected slabs on metal deck. This second part explores the role ineffective and incorrect use of ACI and AISC documents plays in designer attempts to provide his client with level deflected slabs on metal deck. Project documents often incorrectly reference ACI guide documents such as ACI 302, attempting to make their content mandatory, when that is not intended by ACI. The ACI prohibition of using guide document content without restating in mandatory language is presented and discussed. Reference is often made in design documents to the AISC Code of Standard Practice for floor elevation when the Code is silent concerning the elevation of all elements excepting that of column base plate elevation. AISC tolerances impacting floor levelness are presented and discussed. Virtually all supporting structural steel floor framing systems are comprised of a collection of secondary members (beams) which transfer gravity loads to primary members (girders) which ultimately transfer these gravity loads to vertical elements and finally to foundations. The collection of floor framing members contains some combination of un-cambered steel beams/girders and those with fabricated camber to off-set anticipated deflection of the member when subjected to the weight of concrete. The deflection of those members will vary depending on member stiffness and the resistance of connections to end rotation. The ineffectiveness of the common designer requirement that concrete be added until “the floor is level” is presented and discussed in detail.

Keywords: beams, deflection, girders, level, mandatory, specification, metal deck

The Un-Shored Composite Slab on Metal Deck
Part III, Level Deflected Slab Strategies

By: Eldon Tipping and Bryan M. Birdwell

Synopsis: This is the third of a three-part series, the goal of which is to provide the designer and contractor with tools necessary to produce level deflected slabs on metal deck. This third part provides the designer and contractor with strategies for producing level deflected slabs on metal deck. An approach by which elevation tolerances can be successfully imposed on the erected steel frame is presented. The method requires that the designer first provide the contractor with desired relative elevation of splice points at each floor level and flexible column splice details. This information, provided by the designer, enables the contractor to establish desired relative elevations that can assist in achieving those tolerances. An effective cambering strategy that recognizes the differing behavior of members framing to columns and those that connect to girders is presented and discussed. The paper finally presents a floor construction/monitoring program that identifies frame behavior during construction and provides both the designer and contractor with the resources necessary to produce level deflected slabs. The program includes pre- and post-placement surveys of structural steel frame, utilization of a controlled method of striking off the concrete, a survey of the completed slab surface, and use of the collected data to respond to unexpected structural behavior. Other tools, including the selective use of "loose shores" or a secondary placement can enable the contractor to produce deflected slabs on metal deck with 80% or more of the surface within a 3/4 inch (19 mm) deep envelope.

Keywords: composite, deflection, elevation, gauging, level, metal deck