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Guide to Identification and Control of Visible Surface Effects of Consolidation on Formed Concrete Surfaces

Reported by ACI Committee 309

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This document provides guidelines for identifying and controlling visible effects on the surface of concrete as it relates to consolidation on precast or cast-in-place-formed concrete surfaces. A perfectly homogenous and blemish-free concrete element is difficult, if not impossible, to achieve. This document, therefore, does not define an acceptable level of quality, as this should be defined in the contract documents.

This guide explores the direct and indirect cause-and-effect relationships, as well as other factors, concerning concrete surface appearance. Photographs are included in this document to illustrate typical concrete surface finish effects that are a departure from absolute perfection. Negative surface effects in concrete can be minimized by proper planning during the design and specification stages. Significant consolidation factors that minimize undesirable concrete negative surface effects are also discussed.

Keywords: bugholes; consistency; consolidation; construction joints; discoloration; form offset; formwork (construction); layer lines; mixture proportioning; plastic settlement cracking; preplaced-aggregate concrete; quality control; sand streaking; surface air voids; surface defects; vibration; workability.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

This guide is a reference source for specifiers, design engineers, architects, contractors, and other professionals who work with concrete surface finish of formed surfaces. The ability to identify or categorize negative surface effects is the first step in detecting the root cause of them. The goal of this guide is to differentiate between various negative surface effects to improve the concrete process and subsequent concrete quality. The cause of negative concrete surface effects is sometimes not correctly diagnosed. For example, air voids are usually attributed to lack of vibration in circumstances where the correct source of the imperfection is ill-prepared formwork or improper selection of the form-release agent. With misdiagnosis, negative surface effects are likely to occur again because appropriate corrective actions have not been identified and taken.

This guide includes a summary of direct and indirect causes of negative surface effects in concrete surface finishes, along with photographs to illustrate them. The most serious effects resulting from ineffective consolidation procedures are also reviewed. They include honeycomb, cold joints, and excessive surface voids. A detailed description of these occurrences and their causes are provided. Of equal importance is the employment of properly trained and motivated supervisory and nonsupervisory construction personnel to achieve the intended concrete finishes and surface textures. Extreme negative surface effects do not always conform to the acceptable limits required by contract documents and might be considered defective work. Methods for minimizing surface effects are also discussed.

1.2—Scope

This guide does not define an acceptable level of quality, as this should be determined by the parties involved with the project. A perfectly formed concrete surface, uniformly smooth or deeply textured and essentially free of negative surface effects and color variation, is impossible to attain. Repairs to concrete surfaces are costly and difficult. The best repair work will not be as good as an original properly finished surface. Every effort should be made before and during construction to minimize repairs by establishing and maintaining quality concrete operations and adhering to acceptable consolidation procedures for producing formed concrete work. Concrete construction procedures and project costs do not always provide the conditions necessary to consistently obtain perfectly homogenous concrete free of all negative surface effects. Several negative surface effects discussed in this guide are tolerable and inherent in concrete production. Other potential causes of such negative surface effects may exist beyond those listed in this report. It is the responsibility of the specifier to indicate in the contract documents what constitutes acceptable and unacceptable negative surface effects for the various surfaces to be produced under the terms of a given contract. Surface tolerance specifications can be found in ACI 347.3R-13, Table 3.1.

To achieve any concrete finish, the designer and contractor should use the most appropriate materials and design and construction practices to minimize negative surface effects and keep them within acceptable limits. This guide should not be used as a standard for surface finishes, but rather as a guide for the identification of surface effects and their causes. Because concrete consolidation is considered an established field, current research is limited.

CHAPTER 2—DEFINITIONS

2.1—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology," http://www.concrete.org/tools/concreteterminology.aspx.

radius of influence—plan-view-area that a vibrator is able to produce sufficient impulses to consolidate concrete.

CHAPTER 3—FACTORS CAUSING NEGATIVE SURFACE EFFECTS

3.1—General causes of negative surface effects

Table 3.1 presents the primary causes of surface conditions that factor into the resulting negative surface effects for the following factors: member design, formwork, construction conditions, concrete properties, placement, and consolidation. Examples of common negative surface effects are illustrated in Fig. 3.1a through 3.1i. The causes of negative surface effects on formed concrete surfaces are described in Table 3.1.

3.2—Design considerations of structural members

Common problems requiring consideration during design and planning are congested reinforcement—in particular, splices, narrow sections, or complex form configurations. Conditions that require closed top forming, embedments, and battered forms also require consideration during design and planning. Figure 3.2 features a dense matrix of pipe inserts and illustrates the importance of having a consolidation plan well in advance of production.

To produce properly consolidated concrete with the desired appearance, placement and consolidation of concrete should be understood. The designer should have working knowledge of the concrete placement process. The designer and constructor should communicate during early phases of the concreting process. Early recognition of problem areas will allow enough time to take remedial measures, such as staggering splices, grouping reinforcing steel, modifying stirrup