

Guide to Decorative Concrete

Reported by Joint ACI-ASCC Committee 310



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Guide to Decorative Concrete

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Guide to Decorative Concrete

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This guide describes techniques for imparting aesthetic finishes to concrete flatwork, of which many can be combined for unique effects. The owner and architect/engineer will acquire detailed, practical guidance for achieving aesthetic effects using proven techniques. Recommendations are made for the production of cast-in-place decorative concrete flatwork, decorative stains, and overlays. In addition to attention to the specified materials, mixture designs, concrete placement, curing, protection, sealing, and other treatments, this guide also considers the effects of these treatments on the overall aesthetics of the project.

Keywords: cementitious overlays; dry-shake hardeners and release agents; embossing; engraving; etching; inlays; polishing; stains; stamping; tooling.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Decorative concrete has been in existence since approximately 70 A.D., when concrete was used for defining affluent or important areas of living space in communal cultures (ConcreteNetwork.com 2019). Early examples of this type of adornment are the streets and paving throughout the city of Pompeii near Naples, Italy. Early decorative concrete used colored aggregates and varying shapes or natural materials embedded in concrete paving.

Traditionally, concrete has been specified more for its functional characteristics than as an enhancement to the aesthetics. Landscape architects were leaders in using concrete flatwork to enhance the visual appeal of hardscapes. Using color and texture introduced concrete as a landscape feature in addition to its functionality. An example is flatwork textured and colored to replicate the look of slate, brick, or natural stone, as shown in Fig. 1.1a and 1.1b.

The use of decorative concrete has been well received and considered as an alternative to other building materials for durable, versatile, and economical finishes. Designers are creating greater aesthetic appeal in projects by using one or more combinations of special concrete placement techniques, including integral concrete colors, color hard-



Fig. 1.1a—Stamped, colored concrete with slate and brick patterns in landscape setting (courtesy of Decorative Concrete Resources).



Fig. 1.1b—Concrete slab enhances design aesthetic with mimic of stone slab (courtesy of L. M. Scofield Company).

eners, chemical stains, pigments and dyes, surface texturing, jointing, exposed aggregate, surface embossing, polishing, and the use of sealants and coatings. The combinations of techniques and mediums described in this guide are exclusive; they cannot be replicated by any other durable medium.

1.2—Scope

This guide describes several techniques for imparting aesthetic finishes to concrete, many of which can be combined for unique effects (Fig. 1.2a and 1.2b). The guide provides detailed practical guidance for achieving aesthetic effects

using proven techniques, both within and beyond the context of **ACI 302.1R**, which also governs these concrete elements.

Recommendations for the production of cast-in-place decorative concrete, stains, and overlays are presented. In addition to attention to specified materials, mixture proportions, concrete placement, curing, protection, sealing, and other treatments, consideration of the effects of these treatments on the overall aesthetics of the structure is also addressed.

CHAPTER 2—DEFINITIONS

Please refer to the latest version of “ACI Concrete Terminology” for a comprehensive list of definitions. Definitions provided herein complement that resource.

color hardener—similar to traditional one-component hardeners, having additional constituent materials formulated to color the concrete surface.

concrete dye—colorant for concrete that is applied to the concrete while it is in solution and results in a stained appearance; concrete dyes do not produce color via chemical reaction.



Fig. 1.2a—Cast-in-place decorative concrete combining treatments during and post placement to achieve aesthetic effects (courtesy of Concrete Mystique Engraving).

crack chaser—rotary tool using a v-shaped diamond blade to enlarge cracks in concrete to facilitate repair.

decorative aggregate—specially selected aggregates chosen for their artistic contribution to the project; examples of materials used as decorative aggregate include colored stone, intrinsically valuable gathered stone, semiprecious stone, or colored glass.

decorative overlay—mixture of cementitious materials installed over an existing concrete substrate.

densifier—combination of silicate and water-based compounds that react in the surface of the concrete to produce additional calcium silicate hydrate (C-S-H).

embossing—creating a raised print or reverse replication of an object in the concrete surface.

engraving—cutting with a mechanical rotary or impact tool to texture a concrete surface.

etch—textured surface produced by cutting with a mechanical impact tool or by chemical etching by use of acid.

grinding—intentional removal of a visually apparent amount of the surface paste to create a profile on the surface.

integral color—iron oxide pigments that are added to the concrete during the mixing process to change the color of the paste.

microtopping—bonded decorative overlay usually 1/8 to 3/16 in. (3 to 5 mm) in thickness.

needle scaler—reciprocal impact tool that uses single or multiple thin rods to strike a surface.

polished concrete—post-placement architectural finish or texturing technique where concrete undergoes sequential mechanical abrasion resulting in full surface refinement.

polished overlay—bonded decorative overlay 3/8 to 1 in. (10 to 25 mm) in depth cast over an existing concrete substrate designed to accept diamond abrading for a polished concrete appearance.

reactive stain—reactive solution of one or more metal salts stabilized by acid that produce coloration in a concrete substrate by neutralization of acid followed by precipitation of metal hydroxides or oxides.



Fig. 1.2b—Decorative concrete applications such as post placement colorant or staining complement or enhance the overall aesthetics of a project (courtesy of PROSOCO).

stain (v)—use of a chemical stain or a concrete dye to change the color of the concrete surface that can be a penetrant or a low-build coating that does not appreciably change the concrete's texture.

stamping—process of applying a surface pattern to decorative concrete by using impact pressure to emboss texture, patterns, or faux joints into the surface of plastic concrete.

stencil patterned concrete—texture created by use of preprinted pattern stencils or freeform using alternate texturing materials.

surface release agent—temporary powder or liquid, usually pigmented, that is applied to plastic concrete surface immediately prior to imprinting or texturing that performs as a bond breaker between texturing tools and the concrete surface.

surface split—separation in the paste usually 0.005 to 0.060 in. (0.13 to 1.52 mm) wide and less than 1 in. (25 mm) in length appearing on top surface, which is normally near a joint or corner of imprinted surface.

weeding—process of removing portions of a stencil to allow decorative treatment or protection of specific areas to produce a desired pattern of contrasting color and or texture.

CHAPTER 3—GENERAL AND DESIGN CONSIDERATIONS

3.1—General

Decorative concrete is a durable building media providing artistic choices and flexibility for the designer. Combinations of techniques (Fig. 3.1) offer variations for adaptability and sustainability unmatched by other building materials.

3.2—Process development

Although concrete is one of the most popular and versatile construction materials, it has not always been known for its beauty. Creative and technical improvements in the concrete industry have resulted in better-quality concrete and led to techniques that allow the contractor to manipulate concrete to resemble other building materials such as brick, slate, marble, granite, or other decorative stone. These techniques have been used to produce unique visual effects not possible with other materials. Aesthetic effects can be added to concrete so that it combines with the structural landscape to create a landscape that meets the aesthetic requirements of the owners and architects. As more color palettes, texturing systems, and post-placement processes become available, more owners are considering the addition of decorative concrete elements to their projects (Fig. 3.1).

Decorative concrete is subject to cracking and scaling common to all concrete construction when proper construction and maintenance procedures are not followed. Properly designed concrete mixtures and joints and proper installation procedures will mitigate many unwanted imperfections. Feature strips incorporated into a design can help avoid mismatched patterns and break up pattern fields into easily managed areas. Contractors installing decorative concrete should be experienced and possess the expert knowledge and skills necessary to work with it. Requiring contractors to use



Fig. 3.1—Decorative concrete used to create visual effects not possible with other materials (courtesy of L. M. Scofield Company).

ACI-certified flatwork finishers and or decorative flatwork finishers should ensure that the quality is consistently high.

3.2.1 Communication—A critical element among all participants of a project is to ensure the design intent of the owner, architect/engineer, or both, is achieved. Job-site meetings and mockups are helpful and allow those involved to share information and discuss their expectations, limitations, questions, and concerns (Fig. 3.2.1).

Some designers/engineers incorporate decorative designs and coloration into the structure; care should be taken to ensure tolerance requirements for the structural installation are consistent with those of the final decorative finishes. Where multiple contractors are responsible for end results of two distinctly different building mediums, tolerance incompatibility between phases of the work will dictate additional work or preparation by one of the contractors. Although similar materials and trades are needed to install the concrete, different levels of knowledge, care, and planning are required. Issues that arise that can compromise achieving the intended design should be addressed with the owner and architect/engineer and those involved, and an alternate solution or plan formulated.

3.2.2 Sample panels—Just as historical data and trial batches demonstrate a material supplier's ability to produce concrete suitable for a given project, sample panels demonstrate a contractor's ability to produce the required decorative effects. Sample panels are typically small enough to be placed in a room and are often used as a tangible exhibit of a contractor's work.



Fig. 3.2.1—Good communication ensures the design intent is achieved (courtesy of L. M. Scofield Company).

They give the owner, architect/engineer, or both, a first look at what is achievable for a given application or process.

Sample panels should use locally produced materials for the project and be prepared under conditions similar to those anticipated during production. If the sample panel appearance and mixture are approved prior to developing project specifications, then the procedures and methods used by the contractor to produce the approved panel can be incorporated into the project specifications. If the sample panel appearance and mixture are approved after developing project specifications, then the procedures and methods used by the contractor to produce the approved panel should be incorporated into the contractor's quality control plan for this portion of the project. During new construction, some repairs are often needed to be done to the decorative concrete work. The sample panel can be used to identify appropriate repair materials and methods that will match the sample panel finish prior to starting work. Then, if repair of the decorative concrete is needed, an approved repair process is already in place.

In-place work that has been in use for at least 2 years can serve as a practical sample, provided that the placement conditions and maintenance are properly documented. Color and durability are the most important variables affected by production and post-production elements. Weather conditions, deicing, and wear and tear due to traffic and snow or ice removal affect coloring over the first few years of service.

3.2.3 Mockup panels—A properly constructed mockup panel could be the single most useful component when establishing expectations for a project, especially when

incorporating treatments affected by job-site conditions such as topical application of reactive stain or dye.

Mockup panels can give the owner, architect/engineer, and contractor an accurate example of the finished floor before construction begins. Adjustments in the methods or products can be made easier during the mockup phase than during the project. The mockup panel(s) should be sized to accurately display the surface treatment under consideration. Typical mockup panels range in size from 2 x 2 ft to 12 x 12 ft (0.6 x 0.6 m to 3.7 x 3.7 m). Some specifications or bid documents call for a specific size for the mockup panels and for the number of panels required. During a pre-job conference or bid meeting, participants should discuss the size and number of panels required as well as the scheduling consequences, construction costs, and financial responsibility for construction of the panels if any of these considerations are not clearly specified.

The type of mockup to be constructed will depend largely on the project requirements. A valid mockup should be produced with the same materials and methods as the finished work. Ideally, the mockup will be incorporated into the project in a noncritical room or isolated section of the work. This approach generates maximum flexibility and efficiency for the owner and installer.

Mockups are used as an achievable monument (referee panel) for prebid inspection by contractors, as a postbid sample produced by the contractor awarded the project, or both, to verify the contractor can achieve the required appearance. Mockup panels should be kept in good condition on site for reference by the installer, contractor, owner, or architect until project closeout. Mockup panels cast, cured, or aged differently from the main work will not have the same characteristics as the final work.

3.3—Substrate preparation

The substrate can be the ground below a slab, existing uncolored concrete paving, or a structural slab designed to carry vehicle loads in addition to the dead load of the decorative concrete.

Properly compacted, slightly moistened, well-graded subgrades are important to the proper performance of most decorative installations. Conduct proper testing of the subgrade density and compaction to avoid unnecessary and costly corrections to work that has cracked or settled. Soil drainage or added layers of porous material are recommended in areas that experience freezing-and-thawing cycles. Moisture control is an important design consideration, as moisture transmission through colored concrete can cause efflorescence.

Subbase preparation is commonly overlooked in a specification, but is critical to the slab aesthetics, quality, durability, and flatness. The subbase should be prepared in accordance with ACI 302.1R and should be free of any standing water or organic material. The subbase should be compacted properly and be designed to support the intended weight of the concrete and structure.

Soil reports should be obtained and referenced in the specification. The base should be graded evenly to

provide consistent support for the concrete during placement, finishing, and curing. An uneven or inconsistent subbase can introduce additional stresses to the concrete during early stages of curing and strength gain. If these stresses exceed the tensile strength of the concrete during these stages, cracking will occur.

3.4—Jointing

Jointing patterns and locations play an important role in designing a functional, durable, and constructible installation for decorative concrete. During the curing period, concrete tends to shrink proportionately in all directions, and selection of contraction and isolation joint location is critical. Refer to **ACI 360R** for isolation joint placement details and recommended contraction joint spacing. While square or rectangular patterns for contraction joints are most commonly used, other shapes can be employed, provided they do not result in isolated design elements that cannot shrink as a contiguous element.

Contraction joint cutting should be completed within 24 hours of initial concrete set to be fully effective. Early-entry, dry-cut saw-cutting can be achieved without damaging the slab but requires supplemental joint protection during cutting.

Contraction joint layout and installation in decorative concrete should be done with consideration for the appearance of the overall pattern in the final work while maintaining appropriate joint spacing. Incorporating contraction joints into artistic work can help hide the joint pattern. Specifiers should note that allowing the contractor control of joint placement can enhance the final appearance. The option of allowing contractor flexibility in joint placement should be considered and addressed in the design stage.

3.5—Joint filling and sealing

All joints should be filled or sealed as recommended by **ACI 360R**. Joint sealants are typically used to prevent the accumulation of moisture, dirt, or debris in saw-cut contraction joints or formed isolation or construction joints. If the joint edges are at risk of deterioration under impact by wheeled traffic (lift trucks, pallet jacks, or shopping carts), a semirigid joint filler is recommended per **ACI 360R**. Fillers and sealants should ideally be colored to match or complement the finished floor.

Common joint sealants include one- or two-part elastomeric products such as polyurethanes or silicones. Joint sealants should be installed over a backer rod or other bond breaker. These products are designed for use where continual or occasional lateral joint movement is expected, such as a result of thermal changes in a concrete slab. These products will not provide structural protection of the joint where hard wheeled traffic is present.

Joint grouts are typically cementitious based and include a mixture of sand, cement, water, and a coloring agent. Joint grouts can also be modified with epoxies or polymers to enhance performance characteristics such as flexural strength and chemical resistance. In general, grouts are used in decorative or scored joints where joint surfaces do not move independently of each other.

Semirigid joint fillers are two-part resinous epoxy or polyurea products designed for use where wheeled traffic is present. Semirigid joint fillers should be 100 percent solids and have a minimum Shore A hardness of 80 when measured in accordance with **ASTM D2240** per **ACI 360R**. Semirigid fillers should be installed full-depth in saw-cut joints. On floors where material handling vehicle traffic will be minimal, the use of semirigid fillers with Shore A hardness between 60 and 80 are often acceptable. Such lower shore hardness fillers are typically installed over a backer rod or other bond breaker per manufacturer's instructions rather than to the full depth of the joint.

Joints should be suitably cleaned to remove saw-cut residue, debris, curing compound, or other contaminants that would affect complete filling or adhesion of the filler to the walls of the joint. Saw cleaning of the joint with a dry-cut diamond or abrasive blade slightly wider than the joint is an effective means of cleaning saw-cut joints. Saws equipped with a shroud attached to a dust collection system are preferred for best joint cleaning and to minimize airborne particulates.

Joints should be vacuumed a second time to remove dust and additional debris. Cured semirigid fillers should be shaved flush with the floor surface to protect the joint edges and to create a serviceable floor surface.

Prior to using a joint sealant or semirigid joint filler in floors to receive a nonbreathable covering or to be ground and polished, confirm suitability of the product with the manufacturer. Care should be exercised to avoid staining concrete surfaces with sealant or joint filler overfill, especially where the floor is to receive a reactive stain or dye.

3.5.1 Time of joint filling and sealing—Per **ACI 360R**, newly placed concrete slabs-on-ground continue to shrink for years; shrinkage takes place primarily within the first 4 years. The most significant shrinkage takes place within the first year, especially in the first 60 to 90 days. It is advisable to defer joint filling and sealing as long as possible to minimize the effects of shrinkage-related joint opening on the filler or sealant. If the floor is in a building that will ultimately be temperature- or climate-controlled, it is recommended that joint filling work be deferred until HVAC systems are activated and the building is stabilized at the ultimate operating condition for a period of 7 days or more because HVAC can affect concrete shrinkage rates.

Observing these recommendations is especially important where semirigid fillers are used in traffic-bearing joints; such fillers have minimal flexibility.

If the construction schedule requires filling the joint before most of the shrinkage has occurred, separation should be expected between the joint edge and the joint filler or sealant, or within the joint filler or sealant itself. In the case of semirigid joint fillers, these slight openings can subsequently be filled with low-viscosity filler recommended by the same manufacturer as the original filler. In the case of polyurethane or silicone sealants, removal and replacement of the sealant may be required.

When early filling is called for, provisions should be made to require the contractor return at a preestablished time to complete any necessary joint reworking using the same manu-

facturer's products. Earlier filling will result in greater separation and will lead to the need for more substantial correction; this separation does not indicate a failure of the filler or sealant.

3.6—Proper installation and quality control

Contract documents typically require closer inspection and fewer blemishes with decorative concrete than with normal concrete. Special consideration should be given to:

- (a) Materials and textures used during the design stage to ensure that the process and desired effect chosen will perform well in service in the climate where it will be used; the use of color and topical sealers sometimes exaggerates minor flaws, which would be overlooked in uncolored concrete
- (b) Scheduling decorative work so that it is planned well in advance, allowing for adequate time to properly complete the production work according to the steps used in developing an approved sample
- (c) Anticipating weather conditions during the scheduling process
- (d) Properly installing vapor retarders to avoid efflorescence, which is particularly problematic on colored concrete because it is more visible than on uncolored concrete

Properly installing the slab is critical to the final appearance and performance of the finished product. Refer to **ACI 301** and **ACI 302.1R** for guidance.

Maintain consistency in application methods, as it is paramount to a uniform finish. For example, adding water to the surface of decorative concrete in any amount will change the finished appearance.

Size of placements should be based on experience, limiting the size to one the contractor can safely accomplish while producing a uniform finished surface. Placements should maintain proper grades and pitch to encourage proper water drainage flow off the slab or to drains. Protect surrounding surfaces so that fresh concrete from any new placement does not reach and damage previously finished sections.

Basic knowledge of concrete use and performance is of primary concern; installers should be carefully chosen based on previous performance. A recommended minimum requirement is that the crew leader should be certified as an ACI Decorative Concrete Flatwork Finisher.

3.6.1 Tolerances: F-Numbers—The F-Number system, which is the preferred standard specification for measuring the flatness and levelness of a concrete floor, is designated by **ACI 117**. The testing method is specified in **ASTM E1155**. This system includes two measurements:

- (1) F_F —Floor flatness; a higher number indicates a flatter surface
- (2) F_L —Floor levelness; a higher number indicates a more level surface

The F_F number gives an indication of the bumpiness of the surface and is evaluated for overlapping distances of 2 ft (600 mm) at 1 ft (300 mm) increments. The F_L number relates directly to the pitch or tilt of a slab surface and is evaluated for overlapping distances of 10 ft (3 m) at 1 ft (300 mm) increments.

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. F_F is an important characteristic for concrete intended to be polished. While there is no direct correlation between the older gap-under-a-straight-edge method of evaluating floor flatness, **ACI 117-10(15)** Sections 4.8.4 through 4.8.6 provide some guidance on the topic.

ASTM E1155, which governs the evaluation of surfaces using the F-number system, lists numerous acceptable measuring options. A properly trained and certified operator/technician can typically collect sufficient data to evaluate the F-numbers of a surface in 60 to 90 minutes, depending on the size of the area. Most testing labs offer this service locally. Some testing labs offer dipstick rental for use by experienced contractors. All **ASTM E1155** measurements for record should be performed by a technician certified in the use of the equipment required to collect the data.

3.6.2 Concrete mixture designs—Concrete mixture designs, also known as mixture proportions, are important to successful decorative concrete placement and execution. Mixture designs detail what fine and coarse aggregate; cement, supplementary cementitious materials (SCMs), or both; pigments; and admixtures are combined with a specific amount of water to produce a workable mixture capable of achieving the desired structural and aesthetic goals of the project.

Concrete mixtures used previously with positive long-term results should be used as the basis for an initial trial batch design. In the absence of experience with a given mixture, field trial batches are necessary for the supplier to demonstrate their ability to deliver concrete that meets project requirements.

The use of clean, sound, hard aggregates that are free of any organic materials is recommended for decorative concrete applications. Do not use aggregate sources that contain more than 2 percent materials passing a No. 100 (150 μ m) sieve. Select aggregates of the proper size for intended use meeting **ASTM C33/C33M** for the primary concrete mixture. Avoid gap-graded aggregates and optimize aggregate gradation for lower water demand and greater stability. Do not use aggregate known to be reactive.

Suppliers offer a variety of seeded aggregates in different colors and sizes that are used for creating specific looks. Properties such as gradation, density, surface characteristics, and percentage of nonstandard or decorative aggregates that are used to replace normal aggregate should be known and considered in the custom mixture design process. Crushed glass should be coated, nonreactive, or both, to prevent the possibility of alkali-silica reaction (ASR) from occurring. (Jin et. al. 2000; Du and Tan 2014).

Concrete mixtures that achieve a minimum 28-day compressive strength of 3500 psi (24 MPa) are considered normal for decorative concrete installations. Special attention should be given to the water-cementitious materials ratio (w/cm) to achieve dense, properly consolidated concrete that is less susceptible to cracking and other problems such as efflorescence.

cence. For interior floors, w/cm ranges of 0.47 to 0.55—the same as recommended in [ACI 302.1R](#)—are generally used. For exterior slabs, w/cm ranges of 0.40 to 0.45 are usually necessary to meet Code durability requirements. Reduced water content can decrease porosity and bleeding, which can increase moisture retention and reduce shrinkage.

Supplementary cementitious materials can enhance the sustainability of the finished product and improve hardened properties of the concrete, such as its resistance to chemical attack, reduced porosity, and improved strengths; however, they have an effect on concrete's color and on a mixture's plastic and hardened properties. These effects should be considered when deciding if to include them in decorative concrete mixture designs. Supplementary cementitious materials such as fly ash, slag cement, silica fume, metakolin, ground reactive glass products, and other materials react with calcium hydroxide ($\text{Ca}(\text{OH})_2$) to form calcium-silicate hydrate (C-S-H). This reaction can negatively affect the effectiveness of decorative concrete materials such as densifiers or reactive stains.

As with any concrete mixture, the workability of a given decorative concrete mixture will be affected by the amount of water in the mixture and the use of chemical admixtures. The workability of the mixture, often measured by slump, should be selected for the given project application and conditions. Chemical admixtures can be effectively used to minimize water or compensate for increased water demand resulting from the use of pigments or decorative aggregates, and they can also affect other plastic and hardened properties, such as set times and permeability. Calcium chloride and admixtures that contain chloride can yield unpredictable effects on concrete color and are, therefore, typically not recommended for use in decorative concrete mixtures ([ACI 302.1R](#)).

3.7—Climate

Decorative concrete is used in all climate conditions and is not limited to warm climates. Durability concerns require consideration of materials and the final service requirements of the concrete. Concrete in warmer climates rarely experiences the abrasion of a snowplow or shovels. Warmer climates require temperature considerations for expansion and retaining moisture in the early-age concrete matrix. Refer to [ACI 305R](#) and [ACI 306R](#) for guidance on environmental considerations for concrete mixture designs. Climate also affects appropriate curing methods. Warmer arid climates often require more aggressive moisture-retention methods than cooler humid regions.

3.8—Curing

The quality and durability of a decorative concrete surface can be greatly affected by curing procedures. Every effort should be made to maintain moisture on the surface for the first 3 to 7 days to allow for the hydration of the cementitious materials. Loss of moisture from the surface zone of a concrete slab can cause cement hydration to slow or stop, leaving a weaker surface that can be more susceptible to scaling and loss of the finish surface by abrasion and other

forms of damage. Using wind breaks, misting to increase humidity, applying evaporation retardant, and early morning or late evening placement help mitigate loss of surface moisture; these and other options are among the procedures detailed in [ACI 308R](#).

Special construction techniques involved with the installation of decorative concrete can require the use of curing procedures that, while producing durable decorative concrete with proven historical performance, differ from the ones addressed in [ACI 308.1](#). Some recommendations of [ACI 308.1](#) interfere with production of the decorative effects that are the primary consideration for decorative concrete. For example, membrane-forming curing compounds should be used with special care to avoid interference with subsequent post-color treatments, penetrating sealers, and some polishing processes.

Decorative concrete curing procedures should be planned well in advance of application. Best practice is to consult weather forecasts and prepare for predicted conditions and have contingency plans for changing circumstances. If standard curing methods as outlined in [ACI 308.1](#) cannot be followed, then the decorative concrete contractor should discuss planned curing practices at the preconstruction or preplacement meeting and submit a plan outlining the curing procedures that will be followed. The contractor crew should take steps to prevent rapid surface drying. All required materials, such as curing blankets, fogging equipment, or surface release agents should be on the job site and used when the bleed water dissipates and the concrete can be walked on. If little or no bleed water is present, begin curing procedures as soon as placement is complete and there is potential for plastic shrinkage cracking or surface drying to occur.

Curing techniques required for decorative concrete applications, including stamping, trowel finish, float finish, colored floors, or floors expected to receive post-placement texturing or coloring, are critically dependent on anticipated weather conditions during and 24 hours after the initial installation. Improper choices of techniques can have detrimental effects on the final finish of the decorative concrete. When possible, concrete placements should be avoided during periods of low humidity, wind, and very hot weather, as these conditions increase the rate of bleed-water evaporation.

To determine appropriate methods of curing, each decorative material and curing method, or combination of materials and curing methods, should be considered for their ability to prevent moisture loss in the cure-affected zone. Manufacturers of materials such as liquid and powder release agents, color pigments, and integral and surface hardeners should be contacted for their recommended methods of curing and compatibility of cure methods.

Figure 3.8 ([ACI 305R](#); [Menzel 1954](#)) is based on research to predict water loss from reservoirs ([Uno 1998](#)). It has been widely used to estimate water evaporation rates on concrete surfaces early in the bleeding process. The chart provides a graphic method of estimating the loss of surface moisture for various weather conditions. When the evaporation rate is greater than the concrete's bleed rate, little or no bleed water can accumulate on its surface, which can lead to rapid

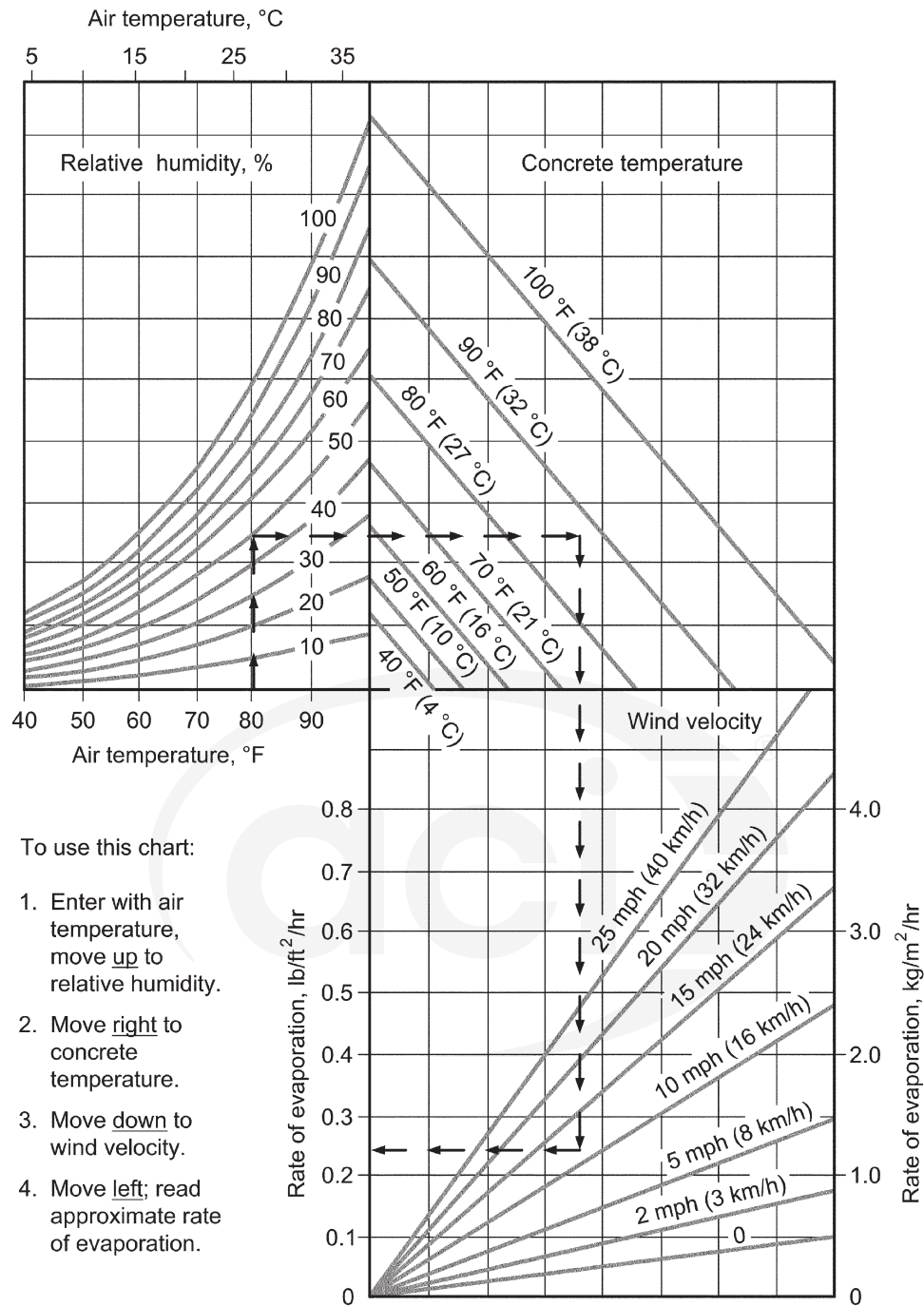


Fig. 3.8—This National Ready Mixed Concrete Association (NRMCA)-Portland Cement Association (PCA) nomograph for estimating evaporation rates depicts the effect of concrete and air temperatures, relative humidity, and wind speed on the rate of evaporation of surface moisture from concrete (ACI 305R).

drying and greater risk of plastic shrinkage cracking. The traditional rule of thumb says that if the rate of evaporation approaches $0.2 \text{ lb/ft}^2/\text{h}$ ($1 \text{ kg/m}^2/\text{h}$), precautions against plastic shrinkage cracking are necessary (Lerch 1957). It is important to recognize that most commercial concrete mixtures have a much lower bleeding rate than $0.2 \text{ lb/ft}^2/\text{h}$ ($1.0 \text{ kg/m}^2/\text{h}$), which in turn dictates a markedly lower tolerable evaporation rate. Bleeding rate can be measured by ASTM C232/C232M (Hover 2006). With this in mind, the

nomograph should be seen only as a useful tool for alerting the contractor to adverse conditions that are likely to cause rapid drying of the concrete surface. There are several online calculators that incorporate Menzel's (1954) nomograph to predict if rapid drying is likely. When in doubt, take precautions to protect the concrete surface from rapid drying.

To use Fig. 3.8, follow the four steps as listed. Wind speed is the average horizontal air speed in m/h (km/h) and should be measured at a level approximately 20 in. (510 mm) higher

than the evaporating surface. When measuring wind speed consider the effect that buildings, stacks of material supplies, construction equipment, parked cars, and trucks or other obstructions may cause uneven drying of the surface. Air temperature and relative humidity should be measured at a level approximately 4 to 6 ft (1.2 to 1.8 m) higher than the evaporating surface on its windward side shielded from the sun's rays (Lerch 1957). ACI 305R provides detailed equations and discussion for determining evaporation rates and evaporation control measures.

Evaporation retarders applied to the surface of concrete reduce the evaporation rate of water by forming a monomolecular film over the water layer. They should not be used as finishing aids. Consult with the manufacturer for application details and discuss their application during preconstruction or preplacement conferences to establish proper usage.

Do not place plastic film in direct contact with the concrete surface, as it will leave a darkened mottled pattern that appears as stripes or blotches on the surface where it comes in contact with the concrete. The pattern left by this method will be accentuated by color pigments or stains applied to the surface. Specially designed plastic-backed wet curing blankets will aid in proper curing without leaving differential curing marks on the surface when properly installed. Concrete textured in a plastic state should not be cured using conventional or the aforementioned wet curing blankets, as the texture will be altered by the blanket contact.

Note that wind measurements should be taken at approximately 20 in. (510 mm) above the surface of the concrete (Hover 2006).

3.9—Sealers

Sealers are surface coatings that perform various functions on decorative finishes. They can protect the concrete from contaminants and staining, add gloss, and enhance the color of the decorative surface being sealed. Some sealer application methods may produce unwanted appearance or texture to the finished installation. They vary in sheen or gloss intensity, including matte, semi-gloss, and high-gloss. The use of sealers may preclude further modification of the concrete, including application of water-based colors, membrane-forming protective coatings, densifiers, or hardeners. The choice of sealer type may vary depending on application and the practical experience of the contractor doing the work. A sealer's resistance to deterioration or damage from UV exposure is important for exterior applications and interior areas exposed to sunlight or high-UV-emitting interior lighting. Exercise care when selecting coatings for sheen level, clarity, resistance to yellowing and oxidation, and durability.

3.9.1 Surface or topical sealers—Depending on ambient conditions and permeability, newly placed concrete may continue to have high moisture content that can migrate to the surface as vapor or salt solutions for as long as 6 to 9 months after placement. Surface coatings and sealers applied to concrete reduce the natural moisture vapor transmission rate (MVTR). Excessive moisture below the coating can result in coating discoloration, delamination, or blistering.

Apply sealers with good MVTR properties in one or more thin applications, overapplication may reduce the MVTR. Some sealers may darken the concrete surface and require following the manufacturer's recommendations on application and testing before use.

3.9.2 Penetrating sealers—Concrete tends to readily absorb water because of its pore and capillary structure. Penetrating sealers are typically silicate-, silicate-, silane-, or siloxane-based compounds that chemically bond with materials in the concrete surface to fill or create water-repellent characteristics within pores of the concrete matrix. They help prevent damage due to moisture and chloride ion ingress of salt solutions by reducing concrete absorbency. Some sealers may darken the concrete surface and require careful reading of product literature and recommended testing before use.

3.10—Safety

Dust is a common hazard in the concrete industry. Some of the coloring chemicals are caustic and proper precautions should be followed. Establish health and safety practices appropriate to the specific circumstances involved with the use of each product. Determine the applicability of all regulatory limitations and comply with all applicable laws and regulations, including the U.S. Occupational Safety and Health Administration (OSHA) health and project-specific or local safety standards.

3.11—Reinforcement

Structural reinforcing should be considered for substrates that historically move or settle to avoid unsightly settlement cracking and misalignment of surface planes along cracks or joints. Subgrade preparation per ACI 302.1R will provide adequate support for decorative slabs-on-ground. Local building codes often address required thicknesses of pavements for their intended use and some specify reinforcement materials or none at all. Refer to ACI 318 and local building code requirements.

3.12—Sustainability

Decorative concrete delivers all the sustainability benefits of normal concrete with the added benefit of not having to be coated or covered with another material to achieve an architectural finish. Material optimization is a sustainable benefit of using decorative concrete. It delivers aesthetic benefits, so the use of products such as less-durable floor or wall coverings can be eliminated or decreased. Careful attention to documentation associated with surface treatments and coatings used in conjunction with decorative operations will ensure compliance with volatile organic compound (VOC) regulations and green-building indoor air-quality goals.

Many pigments and coloring agents have some recycled content that can contribute to an owner's green building targets. Supplementary cementitious materials, including slag cement and fly ash, are made from recycled industrial by-products. When their use is appropriate, they reduce the portland-cement clinker content in the paste required to achieve the design strength and durability of the concrete, which in

turn reduces the embodied energy and greenhouse gas emissions associated with a given mixture, while also diverting the SCM product from landfills. The use of SCMs should be carefully evaluated and coordinated with the decorative concrete installer and concrete material supplier, as many products will change the color of the finished surface and or inhibit desired reactions with decorative treatments. In many cases, it is more feasible to achieve a desired aesthetic using no SCMs rather than applying more material and labor resources to concrete that contains these products.

Decorative concrete typically requires less maintenance than other building systems. Brightly colored decorative concrete is more reflective than dark surfaces. Highly reflective concrete requires less illumination and can be used to reduce the amount of artificial lighting required to meet illumination goals. Reflective decorative concrete can contribute to the reduction of urban heat island effect, which results from dark materials absorbing heat and can contribute to other green building goals, such as providing durable, low-maintenance products.

Existing concrete that is improved, reused, or remodeled is a true example of sustainability. It takes far fewer resources to reuse an existing concrete surface than to construct a new one. Concrete can be reused and repurposed more than once before the end of its service life.

CHAPTER 4—PLASTIC CONCRETE COLOR TECHNIQUES

4.1—General

The color of concrete is initially determined by ingredients in the mixture. Concrete color depends on the color of the:

- (a) Cement
- (b) Other cementitious materials, such as fly ash or slag cement
- (c) Aggregates, especially the fine aggregate
- (d) *w/cm*
- (e) Coloring agents, including surface treatments

Color selection charts offered by manufacturers are for general consideration of hues only and do not indicate what a final color will be. Pigments are subject to regional variations, so proper color specification and preconstruction sample approval is crucial.

4.2—Integral color

Decorative concrete using coloring agents added to the concrete during the mixing process to achieve a desired color is called integrally colored (Fig. 4.2). The coloring agents can be added to cement or concrete mixtures as fine powder or in liquid form. Integral color is incorporated into the mixture by the concrete producer or added on site. Consistency is paramount regarding the addition of color to the mixture, the quantity of color added, and the time allowed for it to mix completely with the concrete. Use coloring products in accordance with the manufacturer's recommendations.

Except for coloring agents, the color of the cement has the greatest effect on the concrete color. Integral coloring agents combine within the cement paste to coat the aggregate. The



Fig. 4.2—Pigments added to concrete mixtures as dry powders or as liquid solutions offer a wide range of color options (courtesy of Davis Colors).

effectiveness of integral coloring agents depends greatly on how dark the cementitious materials are in the mixture. In many cases, integral coloring agents have the effect of hiding the color of the cement. Consequently, some colors are easier and much less expensive to achieve than others. For example, earth tones are easier and less costly to achieve than pastels or light colors.

White cement is a good choice when developing colored concrete in applications where the need for color consistency is high, where the color is more difficult to achieve, or to reduce the amount of pigment added to the mixture. Some lighter hues require the use of white portland cement and cannot be achieved by using gray portland cement.

Traditionally, when integral color is used, the cement is tinted. Colored cements are available in some markets in standard colors and custom blends. Integral coloring is generally muted and less vibrant than other coloring techniques. In some cases, the desired color will not be achieved with integral color, and a different coloring method is required to supplement or modify the integral color after placement. In accordance with **ASTM C979/C979M**, the amount of coloring agent added to the mixture should be limited to not more than 10 percent by mass in relation to the amount of cementitious materials in the mixture.

4.2.1 Advantages—Integrally colored concrete is batched and placed like uncolored concrete (Fig. 4.2.1a and 4.2.1b). With the few exceptions noted herein, standard concreting practices for batching, transporting, placing, and finishing are used (Fig. 4.2.1c).

No special surface finishing techniques are required; however, the surface texture imparted to integrally colored concrete can dramatically change the apparent color due to light refraction. Projects are sometimes designed to have color changes depending on the time of day and how sunlight or artificial light plays on the textured surface. Any surface finish that is applied to uncolored concrete can be applied to integrally colored concrete.

Integral color is permanent and extends the full depth of the slab. Chips or spalls should not reveal a different underlying color, and exposed interior color will eventually oxidize to the same hue as the surrounding color.

4.2.2 Disadvantages—Integral color can only be used for newly placed concrete. Depending on the color of the



Fig. 4.2.1a—Integrally colored concrete is batched and placed like uncolored concrete (courtesy of Davis Colors).



Fig 4.2.1b—Integrally colored concrete is batched and placed like uncolored concrete (courtesy of Davis Colors).

cementitious materials and the color admixtures produced, they tend to be in the softer, earth-tone range. Very light or intense colors are difficult to obtain using integral color in common gray cement mixtures. Integrally colored mixtures also cost more than uncolored concrete.

For thicker paving, surface color treatments could be a more affordable option. Compare costs for pavements over 4 in. (100 mm) thick against a similar color achieved with a color hardened surface. Another alternative is to use a topping slab or two-course slabs. The thinner top slab would be colored full depth rather than the overall slab depth.

Research local concrete plants for their color agent capabilities; one may have limited facilities for handling special cement or coloring agents while another may have liquid-injection systems.

Patching integral color is a trial-and-error effort and often takes several trial batches to achieve a similar color to the surrounding area.



Fig. 4.2.1c—Integrally colored concrete is placed using standard practices (courtesy of Davis Colors).

4.2.3 Special procedures and tools—Standard concreting tools such as vibrators, screeds, floats, and trowels are required in the first stages of finishing integrally colored concrete. Plan finishing operations to achieve the desired color and appearance as different techniques, troweling equipment, the number of passes taken, trowel blade pitch, and finish blade type will all affect the final outcome. When using power trowels, choose specific blade types based on their properties, the type of finish required, and the manufacturer's recommendations. Plastic finishing blades and/or hand troweling are often recommended for integrally colored concrete to minimize darkening the surface (burn marks) due to the transfer of iron from steel or combination finishing blades to the top of the slab. However, finishers using steel or combination blades can, through careful monitoring and proper blade selection, time the troweling process to reduce differential finishing defects. When choosing between plastic, combination, or steel finishing blades, consider any required post-placement texturing such as the specified class of grind the slab will receive (refer to [Chapter 7](#)).

Specialty tools for an integrally colored concrete may include rocker handles, bull floats, highway straightedges, bump cutters, and pans for power trowels ([3.6](#)). Special tools can be used independently to emboss texture or in conjunction with other patterning tools ([Chapter 5](#)). Where different colors are placed adjacent to each other, construction joints should be coordinated for efficient placement (Fig. 4.2.3).

4.2.4 Products—Integral color is available in powdered or liquid form. The coloring agent dosage rate is typically expressed in pounds per cubic yard (kilograms per cubic meter), in number of prepackaged bags per cubic yard (meter), or in ounces per hundred weight (mL per 100 kg) of cement. The dosage rate should be determined in advance of mixing and pigment quantities premeasured based on approved samples or previously installed work using the same mixture design. Because the color should be introduced at the time of mixing, detailed preplacement coordination with the concrete producer, the contractor, and the specifying agent in agreement with the owner is crucial. Integral



Fig. 4.2.3—Integrally colored concrete places with alternating sections delineated by construction joints (courtesy of L. M. Scofield Company).

coloring agents can be used in conjunction with texturing processes such as stamping; stencil patterns; traditional tooling; post-placement texturing; grinding or polishing; and other coloring agents such as shake-on color hardeners, colored release agents, pure pigment, and chemical stains or dyes.

Representative job-site samples made in conditions similar to production are a highly recommended practice to assure a positive final result and attainment of expectations.

4.3—Color shake-on hardeners

Color hardeners are introduced to the plastic concrete surface as soon as bleed water begins to escape from the concrete matrix at the surface. Care to evenly distribute color is essential to color uniformity. Hand broadcasting and mechanical spreaders are usually used for this purpose.

As with integral color, color hardeners can be used in conjunction with texturing processes such as stamping, stencil patterns, traditional tooling, texturing mats and rollers, post-placement, and texturing (Fig. 4.3a and 4.3b). They can also be used with other coloring agents such as integral color, colored release agents, pure pigments, and reactive stains. Because they are applied at the surface, they do not penetrate deeply into the matrix (Fig. 4.3c).

Dry-shake or broadcast color hardeners are a mixture of coloring agents or pigment, cement, and fine natural aggregate or metallic particles that are worked into the top layer of plastic concrete flatwork, becoming a monolithic part of the surface. Although fine aggregates can be mineral or metallic,



Fig. 4.3a—Color hardeners are often used in combination with texturing techniques such as stamping (courtesy of Patterned Concrete of Pennsylvania Inc.).



Fig. 4.3b—Color hardeners are often used in combination with texturing techniques such as stamping (courtesy of Patterned Concrete of Pennsylvania Inc.).



Fig. 4.3c—Delamination of color shake-on hardener illustrating depth of coloration (courtesy of Patterned Concrete of Pennsylvania Inc.).

those most commonly used in architectural concrete are silica sand; fine quartz aggregate; or, for increased slip resistance, angular aggregates such as emery and trap rock. Color hardeners should produce uniform, streak-free color and conform to **ASTM C979/C979M** for color stability.

4.3.1 Advantages—Hardener colors are generally more vibrant than integral colors and depend less on the concrete mixture components. Repairing spalls and defects is less challenging than a trial-and-error process with integral color. Careful attention to detail allows applicators to place multiple colors with the same truckload of concrete. Color hardeners create a dense, hardened surface that is normally more resistant to wear than the concrete beneath it. Widely used manufacturer's color charts help establish expectations, but will not exactly match the finished concrete. Using a generic coloring chart to establish a color range allows a wider range of choices among different manufacturers. Color and texture selection should be closely coordinated with the contractor during the sample production process. Samples and adjustments to color selections are easier and less costly than integral color samples.

Surface colored and hardened concrete can be polished successfully if appropriate F-numbers (F_F) are specified and achieved.

4.3.2 Disadvantages—The large number of color choices can lead to difficulty in color selection. Only the top 1/8 to 3/16 in. (3 to 5 mm) of the concrete surface is colored. Exposed edges may need to be colored after concrete is rigid enough to remove formwork and still plastic enough to accept working the color into the surface. Saw-cut joints will reveal the uncolored concrete below the colored surface and require additional treatment, grout filler, or joint sealant or filler. Grinding and polishing operations performed on a colored surface removes a portion of the concrete surface. This will expose the base color if the concrete surface color is not built up sufficiently or if grinding beyond Class A is necessary (7.2.5).

4.3.3 Special procedures and tools—No special tools or equipment are needed for installing shake-on color-hardened concrete. Special tools are used to emboss texture in conjunction with color hardeners, including patterning tools such as stamps, texture mats and rollers, and stencil pattern techniques. Broadcast and work color hardener into the surface using only wooden finishing tools while the surface is damp to preclude a too-rapid closing of the surface. Refer to **ACI 302.1R** for guidance.

4.4—Exposed aggregate

Exposed aggregate can be produced by one of two single-course methods:

- (1) Exposing decorative aggregate from within the concrete matrix
- (2) Seeding decorative aggregate into the surface of a normal concrete design mixture

Exposed aggregate can also be produced through techniques that require two courses:

- i. Using an aggregate topping mixture over a normal concrete base course



Fig. 4.4.1—Examples of exposed aggregate achieved on identical slabs with surface retarders rated for different exposure levels (courtesy of Nick Sorrentino).

- ii. Applying a polymer mortar decorative aggregate topping

4.4.1 Exposed decorative aggregate from within concrete matrix—Exposing aggregate within the concrete can be accomplished by using the following methods: surface retarders (Fig. 4.4.1), sandblasting, acid etching, grinding, or water-washing (with pressure or without) the cement matrix away from the aggregate before final set.

4.4.2 Seeded exposed aggregate—Aggregates can be broadcast into fresh concrete or topping mortars and embedded into the mixture with vibration or floating. Exposure is accomplished by either a surface retarder or washing to expose the aggregate before final set. Recycled crushed, graded, and acid-etched glass produced for this purpose may be used as exposed aggregate. Seeded aggregate into the surface typically yields a more uniform appearance than can be attained by depending solely on the aggregate in the matrix of the mixture. A jitterbug tool is helpful to consolidate the added aggregate into the surface, bringing additional cement paste to the surface to coat the added aggregate to lock it into the concrete matrix.

Distribution of the seed aggregate can be accomplished either by broadcasting equipment or by manual distribution with shovels. Prewash the aggregate to assure removal of detrimental contaminants. Dampen before broadcasting over the slab surface, after bull floating, and near the end of bleed water evaporation. It is important that no one walks through the fresh concrete, but rather broadcasts the seed aggregate to avoid foot tracks in the final finish. The seeded aggregates can then be worked into the surface; accepted practice calls for using a Fresno trowel or functionally similar tool at multiple angles until the aggregates are cleanly seated in the surface. No additional finishing is required if the surface is to be ground and polished.

4.4.3 Two-course decorative aggregate topping—This mixture design is used for topping courses typically containing different aggregates from the base course to impart a decorative appearance. Using a two-course topping