

WHITE CEMENT CONCRETE AND COLORED CONCRETE CONSTRUCTION

Owners and developers seeking dynamic architectural results demand the benefits that only white or colored concrete can deliver. Informed designers rely on careful selection of materials and attention to mixing and placement details to achieve eye-catching architectural and decorative finishes.

Because of its versatility, concrete offers endless design possibilities. A wide variety of decorative looks are achieved by using colored aggregates and pigments, and by varying surface finishes, treatments, and textures. Combining white cement with pigments and colored aggregates expands the number of colors available to discerning customers. Colors are cleaner and more intense because pigments and specialty aggregates don't have to overcome the grayish paste of common concrete.



Figure 1. The Condell Medical Center is built with load-bearing precast concrete panels with an architectural finish achieved by using white cement. Courtesy of Condell Medical Center.

Mix Designs

From a structural design perspective, white cement-based concrete mixes are identical to gray cement-based mixes. Mix designs for white or colored concrete differ from common concrete in that they are formulated based on each ingredient's effect on concrete color. Listed in order of decreasing importance these effects are:

- color of cement and cementitious materials
- type and dosage of pigment gradation, color, and cleanliness of fine and coarse aggregates
- type and dosage of admixtures
- batch consistency of proportions, especially water-cement ratio uniformity

Once a mix design has been developed, sample panels (mock-ups) should be built as references for color and overall surface appearance for every architectural project.

Selecting Cement

Cement of the same type and brand from the same mill should be used throughout the entire job to minimize color variation (see Fig. 2). At precasting plants and other projects where early strength gain is critical, Type III or High Early Strength cement provides for fast form stripping and turnaround. For other construction, Type I or General Use cement is specified. Gray and white portland cements are manufactured in accordance with American Society for Testing and Materials ASTM C 150, Standard Specification for Portland Cement, Type I, II, III or V. Other cement designations include:

- CSA A3000 cements that conform to the Canadian Standards Association standards for Cementitious Materials
- American Association of State Highway and Transportation Officials, AASHTO M85 Standard Specification for Portland Cement
- ASTM C595 Standard Specification for Blended Hydraulic Cements
- AASHTO M240, Standard Specification for Blended Hydraulic Cement
- ASTM C1157 Standard Performance Specification for Hydraulic Cement



Figure 2. White cement is subject to exacting quality control procedures that minimize color variation during manufacturing.

Selecting Pigments

Pigments for coloring concrete are natural or synthetic metal oxides conforming to ASTM C 979, Specification for Pigments for Integrally Colored Concrete. Combining two or more pigments provides a wide range of color choices (see Fig. 3).

Common addition rates for white portland cement-based mixes are ½ % to 2 % by mass (weight) of cement. Carbon-based pigments once commonly used for achieving dark colors are not recommended. Pigment



Figure 3. Concrete pigments are available in a wide range of choices. Courtesy of Davis Colors.

manufacturers often use gray cements to establish the standards in their reference charts, but white cement-based color charts are typically available on request. Whether or not a chart is available, best results will be achieved by relying on actual (physical) samples for color selection.

A lot of colored concrete work is done with gray cement and pigments. To produce pastel or bright concrete colors, however, better results may be obtained with white cements and pigments. White concrete requires white cement.

Selecting Aggregates

The paste (cement, supplementary cementitious materials, ultra-fine aggregate, water, and pigments, if any) coats the aggregate particles, giving the predominant color to concrete, especially for smooth finishes. Light-colored or white aggregates are recommended for light-colored or white concrete because dark aggregates can shadow through the thin layer of surface paste and produce a darker or spotted appearance.

Aggregates account for the largest volume of the concrete, so the overall color and appearance can be influenced by the color of the fine and/or coarse aggregates (depending on the depth of exposure) (see Fig. 4). Pigments of similar color can be used to tint the cement paste and enhance the basic concrete color established by the aggregates.

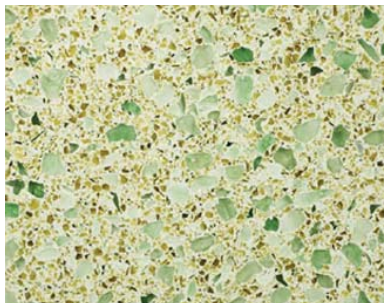


Figure 4. Colorful aggregates stand out even more when used in a white cement-based concrete. Courtesy of IceStone, LLC.

Alternatively, purposely choosing aggregates and pigment with dramatic color differences can create striking appearances, such as a salt-and-pepper appearance achieved by a white paste with white sand and black or very dark medium and/or large aggregate (see Fig. 5).

Concrete mixes can be formulated with either natural (sand) or manufactured fine aggregates which are made by crushing larger stone, or a blend of the two can be used for colored

concrete. When natural sands lack the required whiteness for white concrete, crushed limestone or quartzite sands may be a good option. Manufactured sand often adds valuable color tone and can be made to a uniform color appearance. Since color is strongly affected by the fine aggregate, the gradation should be carefully controlled, especially for the finest portion of the material.

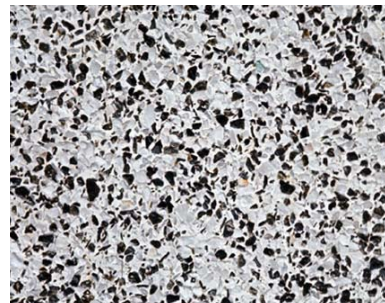


Figure 5. This panel is a good example of white cement and white and black aggregate (milky quartz and black obsidian) used to create a salt-and-pepper appearance.

Coarse aggregates are selected for color, durability, size, shape, and gradation. Exposed aggregate finishes offer a variety of textures and colors. While natural aggregates from a given region may only be available in a limited range of color choices, manufactured aggregates from natural stone and/or recycled and manmade materials provide essentially unlimited color choices.

To prevent discoloration, the guidelines of ASTM C 33 Specification for Concrete Aggregates should be followed to limit impurities in aggregates. Coarse aggregates should be free from iron oxides and other minerals that can stain the concrete matrix. Aggregates should not contain injurious amounts of organic impurities.

Selecting Admixtures

Common admixtures, such as water reducers and air-entraining agents, usually have little effect on color. Some early generation lignosulfonate-based admixtures, however, can turn white concrete slightly yellow. Every effort should be made to maintain a constant water to cementitious materials ratio in a mix for a given project as variations in water content may result in a visible shift in concrete color.

Research has shown the use of calcium chloride as an accelerating admixture can delay the hydration of ferrite compounds in gray portland cement concrete, resulting in sections of darker color when compared to non-chloride dosed concrete. This condition is not applicable to white cement concrete because it contains essentially no ferrite phases so as to maintain the white color of the product.

Care in Mixing

Mixing equipment should be free of oil, grease, rust, and dirt. To avoid discoloration, white and colored concrete should be mixed and placed with equipment that has been thoroughly cleaned. This includes concrete mixing drums, hoppers and chutes. During mixing, extra attention should be given to maintaining:

- the cleanliness of equipment
- consistent batch weights and sequencing
- control of water added after batching
- uniform mixing time

These factors should be consistent from batch to batch to minimize color differences. Guidelines for batching tolerances are provided in ASTM C 94 Specification for Ready-Mixed Concrete.

Forming, Finishing, and Curing

Formwork for white or colored concrete requires attention to detail. Joints must be tight to prevent leakage. All white or colored concrete should be cast against nonabsorbent surfaces. Suggested materials include steel, rubber, treated or overlaid (plastic-coated) plywood, fiberglass reinforced plastic, or plastic form liners. Some common form oils can cause staining; however, there are many non-staining form release agents commercially available. Diesel or waste petroleum products should never be used as form release agents. Stripping time should be consistent to avoid color variations.

Clean placing and finishing tools (shovels, floats, and trowels) should be used with both white and colored concrete. The overuse of metal tools on flatwork can “burn” concrete surfaces, causing dark spots or other surface discoloration. Thus, tools made of wood, fiberglass, polyethylene, or other plastic are often employed in final finishing techniques. Unlike interior flatwork, exterior flatwork, in most cases, requires no troweling, since a floated or broomed finish can provide a uniform appearance and texture, and results in a durable, non-slip finish.

Following finishing, concrete should receive uniform curing. Nonstaining curing compounds or faced curing blankets designed for use with white or colored concrete are the preferred method of curing. Use of waterproof paper sheets or unfaced plastic sheets (“visqueen”) for curing can lead to surface discoloration.

Following curing, white or colored surfaces may require cleaning. The cleaning method depends on the surface finish and aggregate type. Broom-finished or floated surfaces usually do not need to be cleaned. Cleaning methods include lightly sandblasting the surface (see Figs. 6 and 7), which dulls the aggregate, and acid etching, which can brighten the aggregate. Cleaning methods should first be tested on an inconspicuous area to assure the treatment will not affect the desired finish and color. Proprietary chemical cleaners are available that have a proven track record of predictable performance. Manufacturers’ recommended safety precautions should always be used when working with acids or chemical cleaners.

Figure 6. Lightly sandblasting over a pattern created using rubber inserts results in a surface with color, texture, and relief. A white cement matrix anchors the green aggregate (cordierite), whose color predominates.

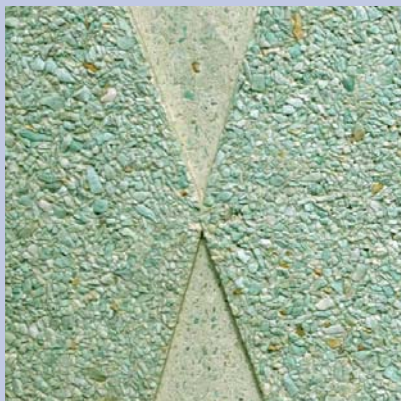
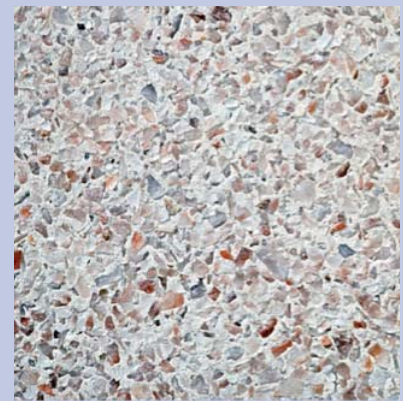


Figure 7. A concrete surface cleaned by acid etching. The rose quartz aggregate stands out on a white cement background.



Following cleaning, surface sealers can be used to protect white or colored surfaces from the effects of water and atmospheric staining. Non-yellowing formulations of acrylic sealers or penetrating water repellents are good choices.

Specifying and Measuring Color

By specifying materials, mix proportions, and construction methods, reasonably uniform color should be obtained throughout the job. As with any natural material, concrete has an inherent amount of color variation, which gives it its characteristic appearance. For projects with colored concrete, the common method of specifying color is to first reference a color chart* (color strips) or sample panels and then develop a mix design using available materials. Following this, a mockup is built and its color is measured to provide a basis for comparison during the job.

* Color chart source: *The Munsell Company, 800-622-2384 or www.munsell.com*

References

1. *Architectural Precast Concrete*, Precast/Prestressed Concrete Institute, Chicago, 1989.
2. *Guide to Cast-in-Place Architectural Concrete Practice*, ACI Committee 303 report, American Concrete Institute, Farmington Hills, Michigan, 1991.
3. *ASTM Standards on Color and Appearance Measurement*, ASTM, West Conshohocken, PA, 1991.
4. *Federal Color Standard 595 A*, U. S. Government Printing Office, 1989.
5. "Ensuring the Quality of Colored Concrete Finishes," *The Construction Specifier*, Construction Specifications Institute, Alexandria, Virginia, December 1998, pages 39-44.
6. "Suggestions for Improving Coloured Concrete Products," *Betonwerk Fertigteil-Technik*, Bauverlag GmbH, Wiesbaden, Volume 60, No. 11, 1994, pages 92-100.

Related PCA Publications

"What is White Cement?" *Concrete Technology Today*, PL991

"Factors Influencing Color," *Concrete Technology Today*, PL992

Color and Texture in Architectural Concrete, SP021

Finishing Concrete Slabs with Color and Texture, PA124

Portland Cement Plaster (Stucco) Manual, EB049

Clear Coatings for Exposed Architectural Concrete, DX137

Other Resources

APA: Architectural Precast Association, 6710 Winkler Road, Suite 8, Fort Myers, Florida 33919; phone: 239.454.6989; fax: 239.454.6787; web site: archprecast.org

DCC: Decorative Concrete Council, 2025 S. Brentwood Blvd., Suite 105, St. Louis, Missouri, 63144; phone: 314.962.0210; web site: asconline.org/DecorativeConcreteCouncil/Overview.aspx

PCI: Precast/Prestressed Concrete Institute, 200 W. Adams St. #2100, Chicago, Illinois 60606; phone: 312.786.0300; fax: 312.786.0353; web site: pci.org



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