PORTLAND CEMENT ASSOCIATION

CONCRETE TECHNOLOGY Today

What is White Cement?

Fig. 1. This white precast concrete building houses the ASTM International Headquarters in West Conshohocken, Pennsylvania. Architect: Diseroad Wolff Kelly Clough Bucher Inc., Hatfield Pennsylvania. Photographer: Peter Leach, Denver, Pennsylvania.

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Contents

Uses of white cement for architectural, safety, and specialty applications

White cement is a portland cement. Except for color, it has essentially the same properties as gray cement. A controlled manufacturing process—including selecting raw materials with low amounts of iron and manganese—is the primary method of ensuring that the finished product is white. With distribution centers from coast to coast, white cement is readily available throughout North America.

Specifying White Cement

Color is a very important quality control issue in the white cement industry, which maintains strict standards to meet customer needs. The color of white cement depends on raw materials and the manufacturing process. The metal oxides (iron, manganese, and others) influence the whiteness and undertone of the material.

Table 1. Chemical and Compound Composition and Fineness of Cements*

Type of portland cement	Chemical composition, %						Loss on ignition, %	Na_2O eq	Potential compound composition, %				Blaine fineness, m^2/kg
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3			C_3S	C_2S	C_3A	C_4AF	
White I	22.5	4.5	0.4	66.3	1.0	2.8	1.7	0.17	60	19	11	1	464
Gray I	20.5	5.4	2.6	63.9	2.1	3.0	1.4	0.61	54	18	10	8	369

*Values represent the mean of combined statistics. Air-entraining cements are not included. Adapted from Gebhardt, Ronald F., "Survey of North American Portland Cements: 1994," in *Cement, Concrete, and Aggregates*, Vol. 17, No. 2, ASTM, West Conshohocken, Pennsylvania, December 1995, pages 145-189.

White cement is manufactured to conform to ASTM C 150, *Specification for Portland Cement.** Types I, II, III, and V white cements are produced, although Types I and III are the most common. Table 1 compares the chemical compositions of white and gray cements.

White cement or a mixture of white and gray cement can be specified to provide a consistent color of choice. Mockups should be constructed at the job site to serve as reference panels for comparison.

Mix designs with white or colored cement must consider the effects of all ingredients on the resulting color. These include:

- type and color of cement
- type and dosage of pigment
- type, gradation, color, and cleanliness of fine and coarse aggregate
- type and dosage of admixtures

Cement of the same type and brand from the same mill should be used throughout the entire job to minimize color variation. For uniform color, adequate quantities of all materials—cements, supplementary cementing materials, and aggregates—should be stockpiled to ensure a single source. If a change is needed, test panels should be fabricated.

White High-Performance Concrete (White HPC)

High-performance white concrete (such as high-strength or very low permeability concrete) is now possible by incorporating materials like calcined clay (such as metakaolin), slag, or white silica fume into white cement concrete. Applications for HPC may include high-rise buildings, bridges, and parking structures.

*A typical specification for white cement could read as follows: Cement shall be white portland cement conforming to the requirements of the *Standard Specification for Portland Cement*, ASTM C 150, for Type __ portland cement.

Panels, Paints, Patches and More

White cements produce clean, bright colors, especially for light pastels. Two or more pigments can be combined to achieve a wide range of colors. White cement can be used wherever white or colored concrete or mortar is desired:

- terrazzo surfaces (see Fig. 2)
- floors and pavements (see Fig. 3)
- architectural panels, precast or cast-in-place (see Figs. 1 and 4)
- stucco (see Figs. 5 and 6)
- swimming pools (see Fig. 7)
- cement paint
- tile grout
- patching material
- transportation projects: traffic barriers, railroad crossings (see Fig. 8)
- decorative and ornamental concrete (see Fig. 9)
- concrete masonry and mortar.

For a long time, the more common uses for white cement were for stucco, terrazzo, paints, and tile grouts. In the 1960s, extensive work was done on architectural panels to show the wide variety of surface colors and finishes possible. Improvements in form liners have simplified the casting of both precast and cast-in-place architectural concrete. In the last two decades, colored, pattern-stamped concrete has become popular for both indoor and outdoor applications (see Fig. 3).

Prepackaged patching compounds or job mixed patches often contain a blend of white and gray cement. Blending the cements makes it possible to color match the patch to the concrete substrate. Typical patching material contains about 25% white and 75% gray cement.

Though the use of white cement is most often for aesthetic purposes, the resulting white concrete can provide enhanced performance for the finished structure. For instance, white concrete floors require less building lighting due to high reflectance. This reduces energy costs and improves the safety of operations such as warehouse storage.

White or colored concrete can also be used to improve the safety of other concrete construction. Transportation projects incorporating white or colored concrete have a strong visual aspect. Cast-in-place or precast concrete elements can be used. For example, at-grade rail crossings can be made from colored, stamped concrete. This delineates the crossing from the rest of the pavement for pedestrians while providing a uniform surface for motorists. As another example, median ("Jersey") barriers made of white concrete not only physically separate vehicles from hazards, but have the added benefit of improved safety because they are highly visible, even at night (see Fig. 8).

Ornamental concrete pieces—statuary, bird baths, architectural shapes—are used in gardens and as building accents (see Fig. 9). These figures can be copies of carved stone artwork. White concrete also enhances the visibility of surface detail. Architectural precast pieces can be color-matched to the building by using a combination of white cement and pigments.

Because it has a low iron content, white cement can be used for non-magnetic concrete, which is used in hospitals, research centers, and anywhere magnetic interference must be minimized.

Related PCA Publications

Color and Texture in Architectural Concrete, SP021

(continued on page 4)

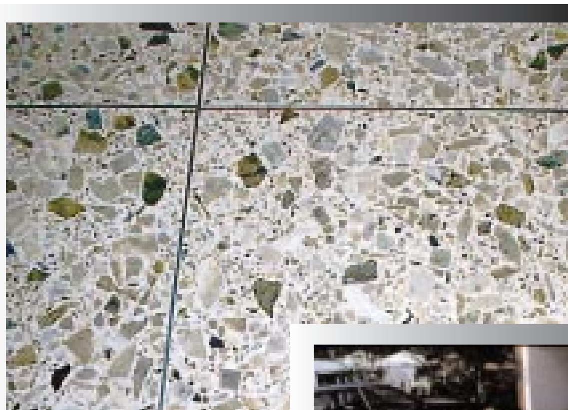


Fig. 2. White cement complements any color. This polished terrazzo floor is made with white cement and green granite aggregate (#68923).

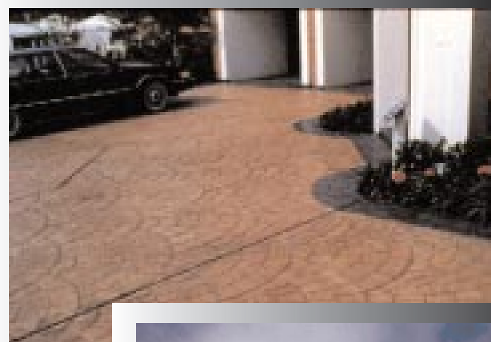
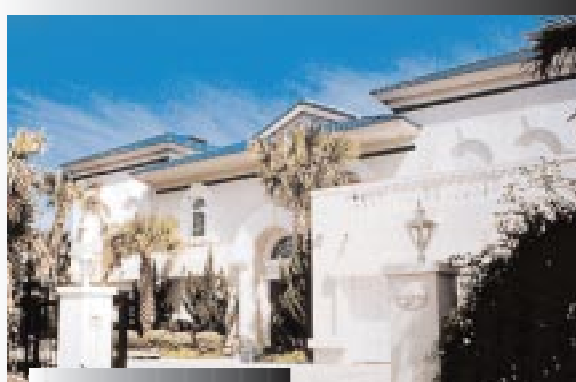


Fig. 3. Intense color is possible on cast-in-place pattern-stamped concrete made with white cement and pigments (#60012).

Fig. 4. The San Francisco Marriott is built with precast panels made with white cement and a pink pigment. The upper floors are all glass fiber reinforced concrete. GFRC panels provide an attractive finish and are lightweight, strong, and durable. Architect: Zeidler Roberts Partnership, Toronto Canada. Photographer: Peter Leach, Denver, Pennsylvania.



Figs. 5 and 6. Portland cement stucco is a versatile material. As shown here, white cement plaster can provide a bright finish for a home (#67897). Plaster also serves as an artistic medium for a 20-m (67-ft) tall statue of Sam Houston in Huntsville, Texas. Statue Sculptor and Photographer: David Adickes.

Fig. 7. Plaster finish coats for swimming pools offer many benefits: long life and low maintenance. They are readily available and can take on a wide variety of appearances including both white or colored surfaces.

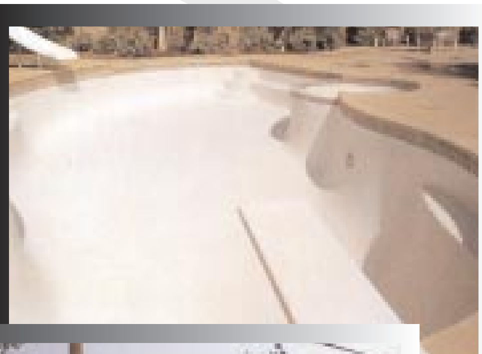


Fig. 8. White traffic barrier sections are bright and highly visible to drivers.

Fig. 9. The white balustrades on the balcony of this residence add architectural detail to the house and surrounding garden. Photo courtesy Haddonstone, Pueblo Colorado.

(continued from page 3)

Finishing Concrete Slabs with Color and Texture, PA124
Portland Cements, IS004
Portland Cement Plaster (Stucco) Manual, EB049
Durability Studies of Exposed Aggregate Panels, RX158
Masonry Mortars, IS040

Other Related Publications

Architectural Precast Concrete (MNL 122), PCI
Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products (MNL 117), PCI
Collection of Ideas on the Production of Architectural Precast Concrete (APC-1), PCI
Standard Specification for Cast Stone 04720-98, CSI
Terrazzo Ideas and Design Guide, NTMA
Guide to Cast-in-Place Architectural Concrete Practice, Committee 303 Report, ACI
Guide to Portland Cement Plastering, Committee 524 Report, ACI
Guide for Precast Concrete Wall Panels, Committee 533 Report, ACI
Guide for the use of Polymers in Concrete, Committee 548 Report, ACI
Installation of Exterior Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster, ASTM C 1063
Application of Portland Cement-Based Plaster, ASTM C 926

Organizational Resources

ACI: American Concrete Institute, 38800 Country Club Drive, Farmington Hills, Michigan 48331; phone: 248-848-3700; fax: 248-848-3701; web site: aci-int.org

APA: Architectural Precast Association, P.O. Box 08669, Fort Myers, Florida 33908-0669; phone: 941-454-6989; fax: 941-454-6787; web site: archprecast.org

ASTM: American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959; phone: 610-832-9500; fax: 610-832-9555; web site: astm.org

CSI: Cast Stone Institute, 10 West Kimball Street Winder Georgia 30680-2535; phone: 770-868-5909; fax: 770-868-5910; web site: caststone.org

NPC: National Plasterers Council (swimming pools), 30575 Trabuco Canyon Road, Suite 104, Trabuco Canyon, California 92678-3002; phone: 949-459-8735; fax: 949-858-9607

NTMA: National Terrazzo & Mosaic Association Inc., 110 East Market Street, Suite 200-A, Leesburg Virginia 20176-3122; phone: 703-779-1022; fax: 703-779-1026; web site: ntma.com

PCA: Portland Cement Association, 5420 Old Orchard Road, Skokie, Illinois 60077-1083; phone: 847-966-6200; fax: 847-966-8389; web site: portcement.org

PCI: Precast/Prestressed Concrete Institute, 175 West Jackson Boulevard, Chicago, Illinois 60604; phone: 312-786-0300; fax: 312-786-0353; web site: pci.org

Developments in Alkali-Silica Gel Detection

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Using petrography and staining methods to evaluate alkali-silica reactivity in existing structures

Alkali-silica reaction (ASR) can sometimes result in cracking and expansion of concrete structures. This occurrence often necessitates investigation of the concrete condition and evaluation of the ASR gel.

For many years, petrographic examination has been the standard practice for detecting gel from ASR. Recently staining techniques have been developed to identify ASR gel in the laboratory and field. The Cornell University Staining Method or Gel Fluorescence Test was introduced in 1988 as a tool for detecting the presence of ASR gel and studying its distribution.[1] The Los Alamos National Laboratory Staining Method was introduced in 1997 as a simple, rapid tool for identifying ASR gel and determining degree of degradation.[2] This article reviews these methods and illustrates how to use them properly.

Petrographic Examination

Petrographic examination of concrete (ASTM C 856, *Standard Practice for Petrographic Examination of Hardened Concrete*) is the most widely accepted means of determining the presence and distribution of ASR gel and interpreting the extent of damage caused by expansion related to ASR. A concrete petrographer uses various microscopes to examine samples (usually cores) from the field. The quality of the samples and information from the field investigation are vital to the interpretation of the petrographic results.

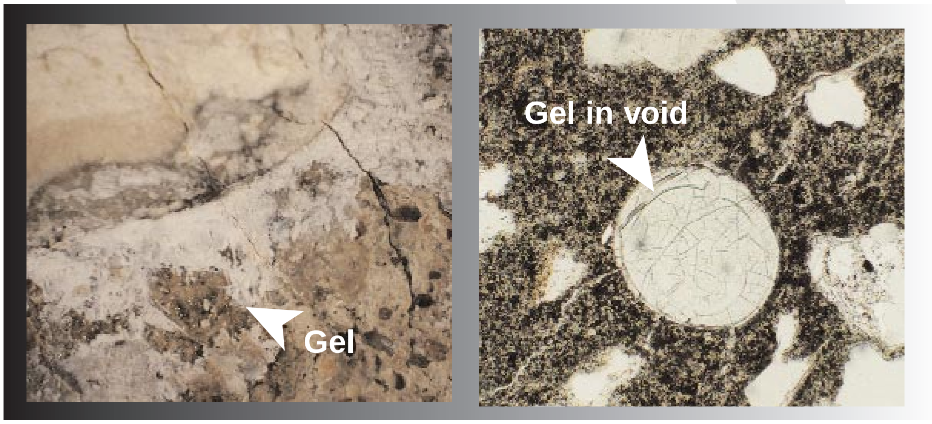

Fig. 1. ASR gel as viewed using (left, #68937) a stereomicroscope (10 x) and (right, #68938) a polarized-light microscope (100x).

The identification of gel, the product of alkali-silica reaction, is based on visually and microscopically distinctive optical and physical properties of fresh and aged gel. The petrographer also studies the association of gel with specific aggregate rock types and notes the distribution and location of gel in order to establish the significance of ASR in the concrete. The petrographer recognizes that the presence of ASR gel does not always signal distress in concrete as some aggregates produce only meager amounts of gel. The petrographer also looks for other distress mechanisms beyond ASR. Figure 1 shows alkali-silica gel viewed with a stereomicroscope and with a polarized-light microscope.

Cost and turnaround time may limit the number of samples that can be examined. These often-cited drawbacks to the use of concrete petrography are the principal reasons for the development of rapid alternative procedures.

Cornell University Staining Method - Gel Fluorescence Test

The Cornell Method was developed as a rapid procedure to identify alkali-silica gel and determine its distribution within concrete. The Cornell Method is standardized in the annex to ASTM C 856. The Strategic Highway Research Program (SHRP) promulgated the method as a field procedure to aid in screening rapid diagnosis of concrete displaying cracking characteristic of expansion.[3]

Using the method, a uranyl acetate solution is applied to a broken or roughened concrete surface that has been rinsed with water. After several minutes, the solution is rinsed off and the treated surface is viewed under ultraviolet light. Areas of gel fluoresce bright yellow-green.

It must be recognized, however, that several materials not related to ASR in concrete can fluoresce and mislead the novice user. Potential interference from naturally fluorescent minerals can be readily determined by using the ultraviolet light to view the same area before and after treatment with uranyl acetate. Weaker yellow-green fluorescence is sometimes seen in areas of carbonated paste. Reactions from fly ash, silica fume, and other pozzolans can fluoresce, along with harmless secondary deposits, such as secondary ettringite. Opal, and some other rock ingredients, fluoresce appearing as ASR gel. With practice it is possible to judge the intensity of the fluorescence and link the distribution of gel with fractures and specific aggregates. Without this knowledge and expertise, a false indication of ASR can easily be made. ASTM C 856 considers this test ancillary to more definitive petrographic examinations and other tests. Figure 2 shows a uranyl-acetate treated surface photographed first with normal laboratory lighting and then with ultraviolet light.

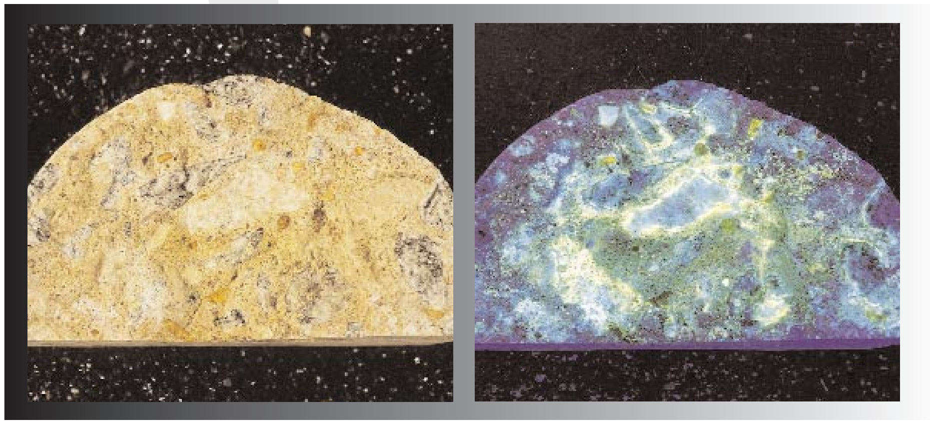

Fig. 2. The view (left, #68941) shows a uranyl acetate treated concrete surface as seen with normal laboratory lighting and (right, #68942) as it appears under ultraviolet light.

The toxicity and radioactivity of uranyl acetate are cited as drawbacks to the use of this procedure. Instruction in the proper preparation, use, and disposal of the solution (and perhaps of the treated concrete) is warranted. Use of an ultraviolet light source also merits some attention due to the potential for eye damage. Because daylight obscures the fluorescence, it is usually necessary to use an enclosed light box in the field. The laboratory environment is well suited to the routine use of the method. Users of the procedure must purchase the uranyl acetate as a powder and must also acquire an ultraviolet light source of the appropriate wavelength.

Los Alamos National Laboratory Staining Method

The Los Alamos Method was developed by the Los Alamos National Laboratory as a simple means for detecting gel in the laboratory or field. The chemical reagents are considered safe for the user and the environment.

It is a modified staining procedure traditionally used to identify potassium feldspar in rocks using a solution of sodium cobaltinitrite. Potassium feldspar stains yellow.

In this method, the reagent is applied to a fresh concrete surface and viewed for yellow staining, which indicates gel containing potassium.

A second reagent, rhodamine B, provides contrast for the yellow stain. The rhodamine B solution is applied to the rinsed surface and allowed to react. The surface is again rinsed with water. The rhodamine B stain produces a pink background with darker pink stain in the vicinity of the yellow stain. The darker pink stain corresponds to calcium-rich ASR gel. According to test developers, the dark pink stain indicates an advanced or advancing state of degradation. Figure 3 shows concrete before and after application of the stain solutions.

This test is not in any ASTM standard and little information is available on interferences or limitations as it is so new. Additional research is needed to find interferences and evaluate the method's ability to indicate the degree of ASR deterioration.

Appropriate Use of Staining Methods

Staining techniques can assist in studying and reporting the presence and extent of ASR gel. Staining methods should never be used as the sole technique to determine the cause of concrete deterioration or to establish a concrete's condition and expected life. Misuse of staining methods often occurs in field applications where petrographic examinations and proper field surveys are not performed. Many individuals do not understand the limitations of these methods. Observations of materials that stain like gel (interferences) are often misreported as the cause of ASR when ASR is actually not present. The staining methods will also show the

Fig. 3. Concrete as it appears before (left, #68939) and after (right, #68940) staining with solutions from the Los Alamos Method.

presence of any ASR gel, no matter how small or harmless.

It is often not realized that ASR can produce gel without causing damage to concrete. ASR gel can also be present as a consequence of damage caused by other destructive mechanisms. Sometimes users of staining methods overlook the influence of frost action, sulfate attack, and other deterioration mechanisms once ASR is perceived as the problem.

Another misuse of staining methods is the field examination of concrete structures not exhibiting signs of distress. In this instance, ASR is sometimes found by staining methods. The perceived threat of ASR causes unnecessary repair or specification changes when in reality the ASR has no potential for detrimental effects on the structure. It should be realized that most aggregates contain some siliceous components that can react, often harmlessly, after being in moist concrete for many years.

Staining methods used in the field frequently only test the near-surface concrete, whereas, petrography is usually performed on the full cross section depth of the concrete element. As gel can migrate from the area it was produced and concentrate at the surface or in fractures, the surface staining test result can exaggerate the level of ASR in a structure.

When analyzing distressed concrete in the field with a rapid staining method, samples (cores) should be taken near the stained location for further laboratory analysis whether or not the test indicates the presence of ASR. Only after a laboratory analysis (petrography and physical and chemical testing) and a field survey can a decision be made regarding the kind or extent of deterioration. For this reason, investigators sometimes opt to skip the expense of the staining investigation and go directly from a detailed field survey to coring and a laboratory analysis.

If there is no indication of ASR gel by staining and it is certain that the staining procedure was done properly, then ASR is not present in the test area. When ASR gel is indicated by a staining method, petrography and other testing must be performed.

Users should be cautioned that the staining tests are best performed as part of an overall test program:

- To spot check specific deteriorated locations for gel presence
- To help verify if a suspect material is ASR gel and show its distribution
- To identify if and where petrographic or other examination is needed.

Conclusions

The rapid methods for detecting the presence of ASR gel are useful in the field and in the laboratory as long as their limitations are understood. Both require an initial investment in training, equipment, and supplies. Neither of the rapid procedures is a viable substitute for petrographic examination coupled with proper field inspection. Only a thorough examination of a structure in the field and in the laboratory can provide sufficient information for rational decisions regarding the true factors causing distress and for making recommendations on repair and rehabilitation.

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3. Stark, D., *Handbook for the Identification of Alkali-Silica Reactivity in Highway Structures*, National Research Council, Washington, D.C., 1991.

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