Tech Brief

National Concrete Pavement Technology Center

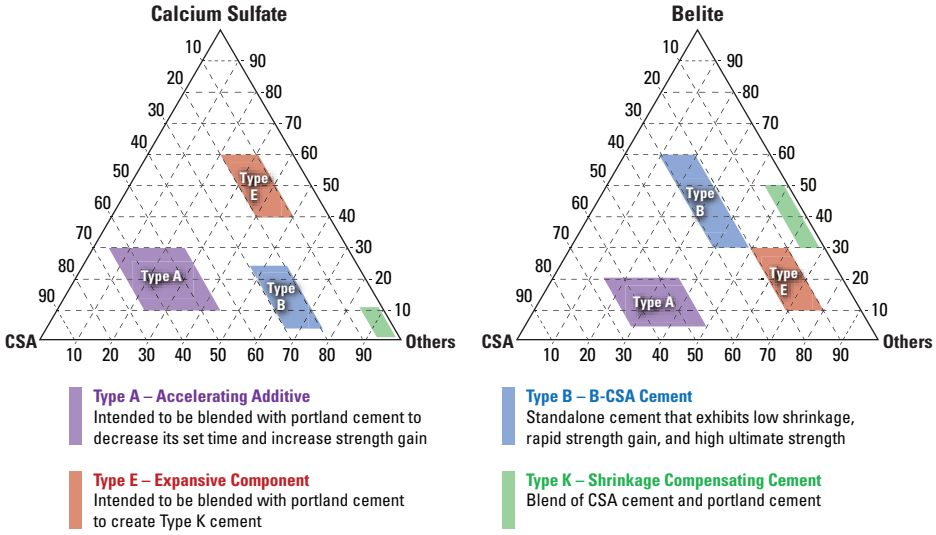
Tech Center

DECEMBER 2024

CALCIUM SULFOALUMINATE CEMENTS

INTRODUCTION

Calcium sulfoaluminate-containing cements were developed in the late 1950s following work by Alexander Klein at the University of California, Berkeley. The main active compound in these cements is Ye'elimite, sometimes called calcium sulfoaluminate (CSA). CSA cements are a class of alternative cements exhibiting a wide range of characteristics, from rapid strength gain to low shrinkage and, perhaps most importantly, a low carbon footprint (Bescher and Kim 2019). Several types of CSA cements are available on the market and are classified based on the CSA content, as illustrated in Figure 1.



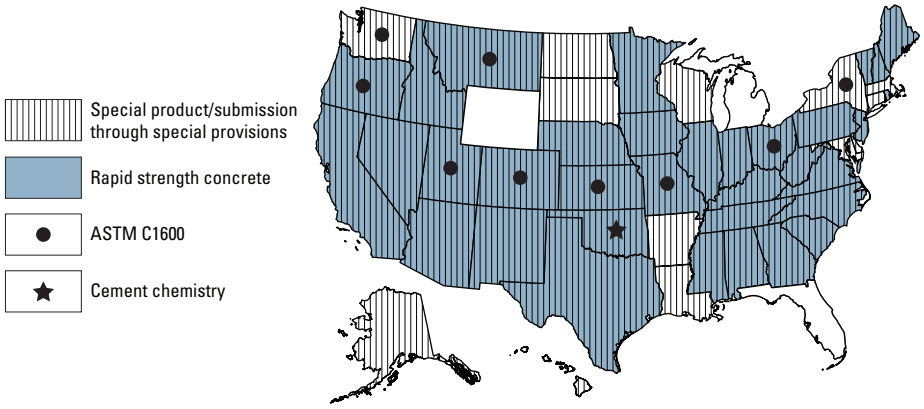
Recreated from Eric Bescher, University of California, Los Angeles, used with permission

Figure 1. Classification of types of CSA cement according to composition

SPECIFICATIONS

Rapid-setting CSA cement can be specified using the ASTM C1600 specification for rapid-hardening hydraulic cements. Shrinkage-compensating CSA cement can be classified using ASTM C845. ASTM C1600 is a performance-based specification for mortar that allows a range of early strengths. It is similar to ASTM C1157 but allows a shorter setting time of 15 minutes instead of 45 minutes. ASTM C1600 also includes basic mortar performance specifications such as alkali-silica reactivity and sulfate resistance.

Agencies can also provide for the use of concrete made with CSA cements through concrete performance specifications (typically high early strength) and/or as part of rapid-strength concrete pavement specifications. This is the approach taken by more than 70% of State departments of transportation (DOTs), such as Colorado (CDOT 2021) and Missouri (CTS 2023). A smaller proportion of DOTs, such as Washington State (WSDOT 2024), allow the use of concrete made with CSA cement through special provisions. Figure 2 shows how CSA cements are specified by different DOTs in the United States.



Adapted from Eric Bescher, University of California, Los Angeles, used with permission

Figure 2. CSA cement specifications in the United States

SPEED OF CONSTRUCTION

CSA cements yield high early strength concrete without the need for organic accelerators. Typical compressive strengths of 4,000 lb/in.^{2} (flexural strengths of approximately 400 lb/in.^{2}) at 3 hours can be obtained with a typical 7.5 sack mix (Bescher et al. 2021, Aguilar Rosero et al. 2023). (Note that with CSA cement, especially Type B, a mix with a high cement content is not required.) This high early strength gain has been successfully used by agencies to accelerate construction schedules and minimize closures.

LOW SHRINKAGE

The shrinkage exhibited by concrete mixtures containing CSA cements is typically 20% of the drying shrinkage observed in ordinary portland cement (OPC) mixtures. This property has been successfully used by agencies in high-restraint environments, such as middle-lane pavement patches. The reduced cracking propensity resulting from this property can lead to lower maintenance costs and increased durability, ultimately resulting in increased longevity in critical applications.

DURABILITY

If properly designed and constructed, concrete containing CSA cement undergoes a level of carbonation comparable to that measured in portland cement-based concretes. Freeze-thaw requirements are addressed in a manner similar to that used for OPC concrete, through air entrainment. A target air content between 6% and 8% is recommended. Chloride diffusion coefficients are sometimes higher in CSA-based concrete than in other types of concrete and are addressed with the use of a pore-blocking additive. Epoxy or metal dowels can be used in CSA-based concrete, just as they are in portland cement-based concrete. CSA-based concrete can also be used successfully for dowel bar retrofit (DBR) purposes. Alkali-silica reactivity is mitigated in CSA-based concrete due to the presence of aluminum (and/or lithium) in the mix and the internal desiccation of the concrete.

SUSTAINABILITY

The carbon footprint of CSA cements is approximately 70% that of ordinary portland cement. The global warming potential (GWP) reported in the Environmental Product Declarations (EPDs) for CSA cements and the industry average GWP values for OPC and portland limestone cement (PLC) are compared in Table 1. It is important to note that these GWP values are obtained without the addition of optional supplementary cementitious materials (SCMs). In many cases, SCMs can be used in the concrete mixture to further reduce the GWP. Another sustainability consideration is the higher albedo of CSA cements (0.44) compared to that of portland cements (0.30). This increased albedo means that more of the sun's incoming energy is reflected back out into the atmosphere and into space, which in turn can contribute to a reduction of the urban heat island effect (Mateos et al. 2020).

Table 1. Global warming potential values for four types of cement

Material	GWP (kg/CO_2 eq / 1,000 kg material)
OPC	919
PLC	844
Type B cement	673
Type K cement	726

APPLICATIONS

CSA cement is used worldwide for overnight rehabilitation of large concrete pavement infrastructure such as highways, taxiways, and runways. It is also used for smaller projects such as spall repairs, partial-depth repairs, dowel bar replacement, and bridge deck repairs. The first large-scale use occurred in 1997 on I-10 in Pomona, California (Figure 3), though other reconstruction projects since the mid-1980s have included the Mexico City–Queretaro highway; runway reconstruction projects at the Seattle, Melbourne, Chicago, and Taiwan airports; and many highway rehabilitation projects in various climates in the United States. The concrete can be produced from ready-mix trucks and volumetric mixers.

Full-depth overnight replacement of highway pavement

Bridge hinge reconstruction in San Francisco

Overnight replacement of taxiway/runway pavement

Eric Bescher, University of California, Los Angeles, used with permission (top and center) and ©2024 Google Earth (bottom)

Figure 3. Applications of CSA concrete

AVAILABILITY

Several CSA-based bagged mortar and concrete products meeting DOT specifications for concrete repairs have been developed in the United States. CSA cement is available in bulk (via supersacks, trucks, and railcars) from several manufacturers in the United States, such as CTS Cement and Buzzi Unicem USA, so that contractors and DOTs can design or specify their own concrete.

CONCLUSION

CSA cement is a useful material for low-carbon, rapid rehabilitation of concrete pavements and concrete structures that meets or exceeds most performance specifications for these applications. It has been implemented successfully in cases involving accelerated opening and high-restraint environments and in patching applications.

REFERENCES

Aguilar Rosero, I., E. Soriano Somarriba, B. Farivar, and C. D. Murray. 2023. Effects of mixture design parameters on the properties of belitic calcium sulfoaluminate concrete. *Magazine of Concrete Research*, Vol. 76, No. 5, pp. 217–228. https://doi.org/10.1680/jmacr.23.00067.

Bescher, E., and J. Kim. 2019. Belitic calcium sulfoaluminate cement: History, chemistry, performance, and use in the United States. *1st International Conference on Innovation in Low-Carbon Cement and Concrete Technology; London 24–26 June 2019*. University College London, London, UK.

Bescher, E., J. Kim, and M. McNerney. 2021. On the differences in chemistry and performance between types of rapid strength concretes (RSCs). *Proceedings of the 12th International Conference on Concrete Pavements*. International Society for Concrete Pavements, Minneapolis, MN. https://www.doi.org/10.33593/83main8q.

CDOT. 2021. Revision of Sections 601, 701 & 711 Accelerated Pavement Repair Concrete. Project Special Provision [PSP]. Colorado Department of Transportation, Denver, CO.

CTS. 2023. *Environmental Product Declaration for Cement Products Produced by CTS Cement Manufacturing Corporation at their CTS Cement Plant Facility in Ciudad Juarez*. CTS Cement Manufacturing Corporation, Garden Grove, CA. https://www.labelingsustainability.com/_files/ugd/5fea69_194c1328e455459eb480116773149a5e.pdf.

Mateos, A., J. Harvey, R. Wu, F. Paniagua, and J. Paniagua. 2020. *Development of Improved Guidelines and Designs for Thin Whitetopping: Environmental Response of Full-Scale BCOA Sections*. UCPRC-RR-2017-03. University of California Pavement Research Center, UC Davis, Davis, CA. https://escholarship.org/uc/item/5hx556j4.

WSDOT. 2024. *2025 Standard Specifications for Road, Bridge, and Municipal Construction*. M 41-10. Washington State Department of Transportation, Olympia, WA. https://www.wsdot.wa.gov/publications/manuals/fulltext/m41-10/ss.pdf.

AUTHOR
Éric Pascal Bescher, Professor
University of California Los Angeles

SPONSOR
Federal Highway Administration
Part of Cooperative Agreement 693JJ31950004, Advancing Concrete Pavement Technology Solutions

NOTICE
The mission of the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University is to unite key transportation stakeholders around the central goal of developing and implementing innovative technology and best practices for sustainable concrete pavement construction and maintenance.

NATIONAL CONCRETE PAVEMENT TECHNOLOGY CENTER
2711 South Loop Drive, Suite 4700 • Ames, IA 50010-8664
cptechcenter.org • 515-294-5798

National Concrete Pavement Technology Center
CP Tech Center
IOWA STATE UNIVERSITY
Institute for Transportation