Applications of Sulfoaluminate Cements

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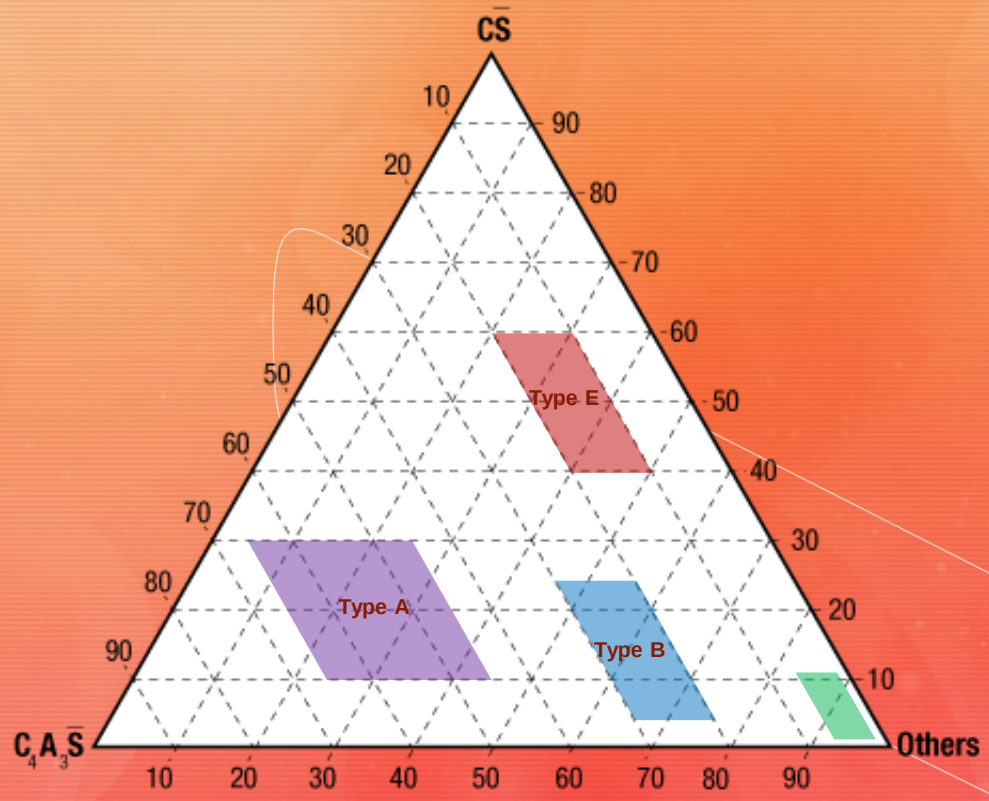
Agenda

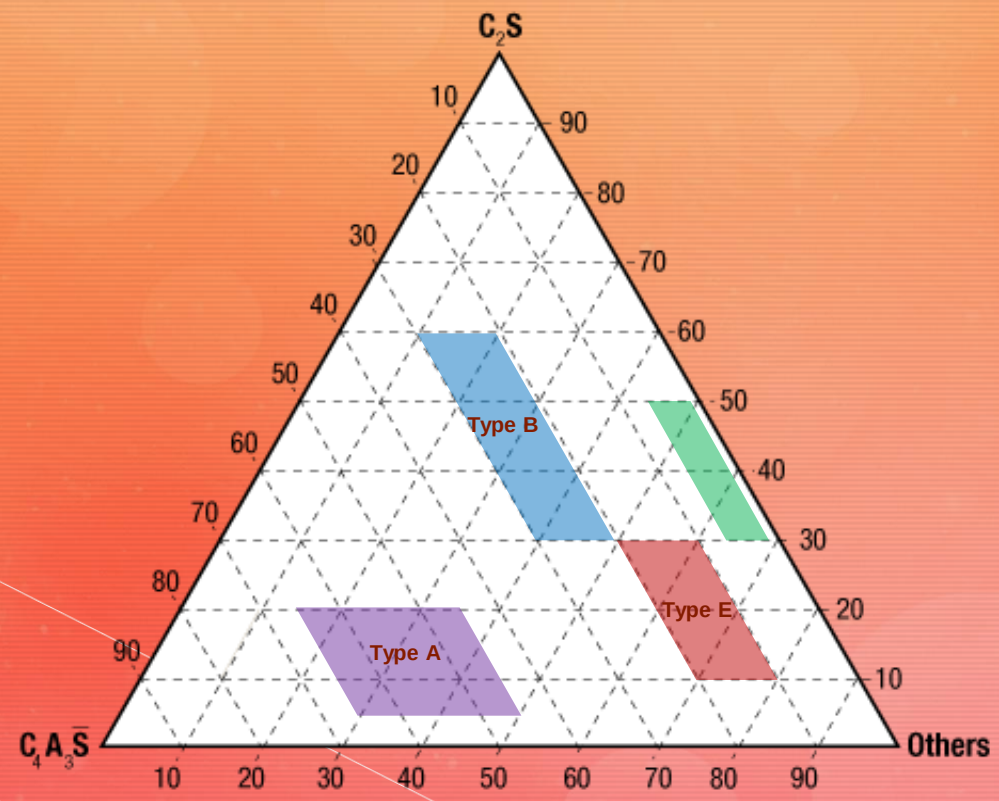
- History
- Highway Pavement
- Bridges
- Airfield Pavement
- Performance Engineered products
- Bagged products

History: Calcium Sulfoaluminate (CSA) Cement

- Developed in the late 1950s by Professor Alexander Klein at UC Berkeley
- Originally designed to compensate for drying shrinkage in Portland cement
  - Type K Cement
- In mid 1970s, CSA chemistry was altered to create a fast-setting cement
  - OST Patent
- Subsequent development of different classes of CSA cements

In Murten in 2018, I proposed a nomenclature for “CSA Cements”- Now with ACI 242





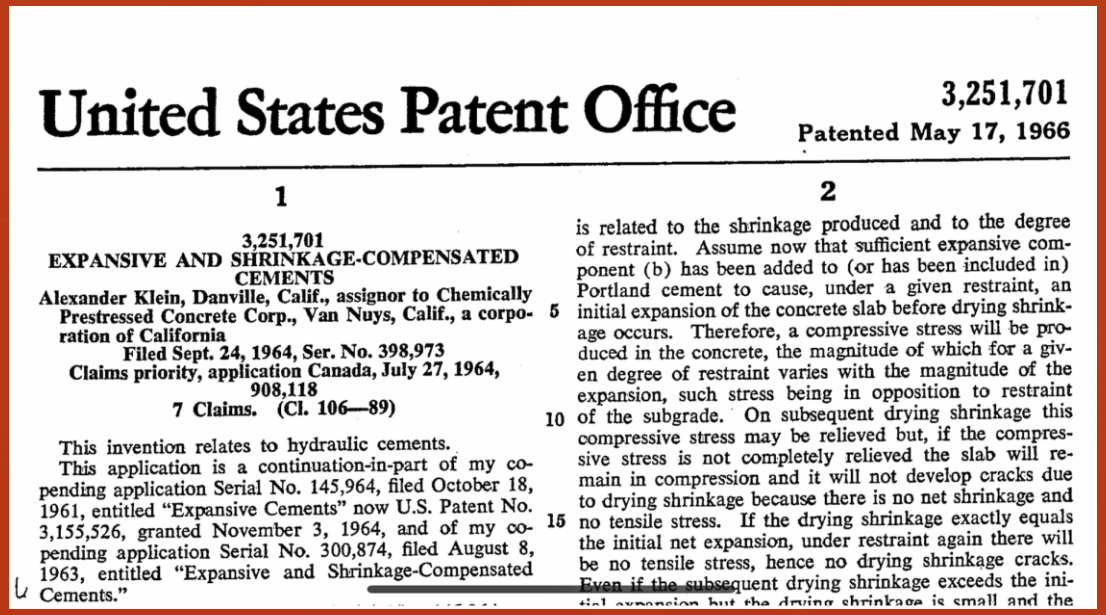
Type A – Accelerating Additive
To be blended with portland cement to decrease set time and accelerate strength gain.

Type B – BCSA Cement
Standalone cement that exhibits low shrinkage, rapid strength gain, and high ultimate strength.

Type E – Expansive Component
To be blended with portland cement to create Type K cement.

Type K – Shrinkage Comp Cement
Blend with portland cement. A slightly expansive, net zero drying shrinkage cement.

1964: The Klein Patent on CSA (K cement)



United States Patent Office

3,251,701

Patented May 17, 1966

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3,251,701

EXPANSIVE AND SHRINKAGE-COMPENSATED CEMENTS

Alexander Klein, Danville, Calif., assignor to Chemically Prestressed Concrete Corp., Van Nuys, Calif., a corporation of California

Filed Sept. 24, 1964, Ser. No. 398,973
Claims priority, application Canada, July 27, 1964, 908,118
7 Claims. (Cl. 106—89)

This invention relates to hydraulic cements.

This application is a continuation-in-part of my copending application Serial No. 145,964, filed October 18, 1961, entitled "Expansive Cements" now U.S. Patent No. 3,155,526, granted November 3, 1964, and of my copending application Serial No. 300,874, filed August 8, 1963, entitled "Expansive and Shrinkage-Compensated Cements."

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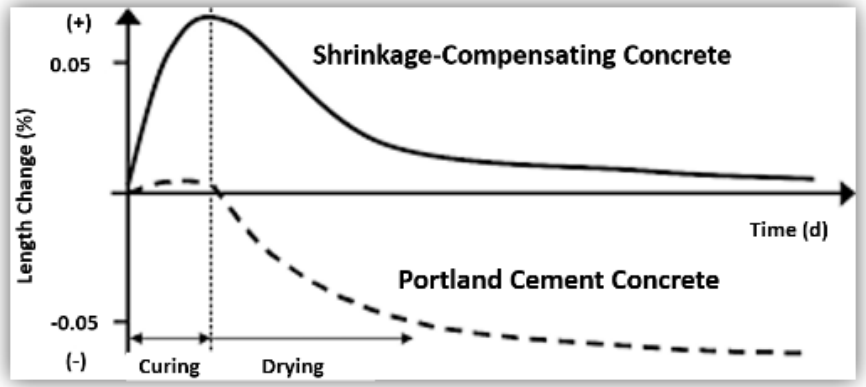
is related to the shrinkage produced and to the degree of restraint. Assume now that sufficient expansive component (b) has been added to (or has been included in) Portland cement to cause, under a given restraint, an initial expansion of the concrete slab before drying shrinkage occurs. Therefore, a compressive stress will be produced in the concrete, the magnitude of which for a given degree of restraint varies with the magnitude of the expansion, such stress being in opposition to restraint of the subgrade. On subsequent drying shrinkage this compressive stress may be relieved but, if the compressive stress is not completely relieved the slab will remain in compression and it will not develop cracks due to drying shrinkage because there is no net shrinkage and no tensile stress. If the drying shrinkage exactly equals the initial net expansion, under restraint again there will be no tensile stress, hence no drying shrinkage cracks. Even if the subsequent drying shrinkage exceeds the initial expansion but the drying shrinkage is small and the

1963 – First CSA (Type K) Highway Pavement

Palmdale, California – Still in Service

Lodi, California – Still in Service

Shrinkage Compensating Cement: Komponent



- ACI 223 Type K Concrete
- Blended with Portland cement
- Expansion compensate for drying shrinkage
- Uses: warehouse, super-flat floors, bridge rehabs, concrete dams, bridge decks, water tanks.

F.W. Webb Company, Londonderry, N.H.
40,000 joint-free slabs

CTS

KOMPONENT

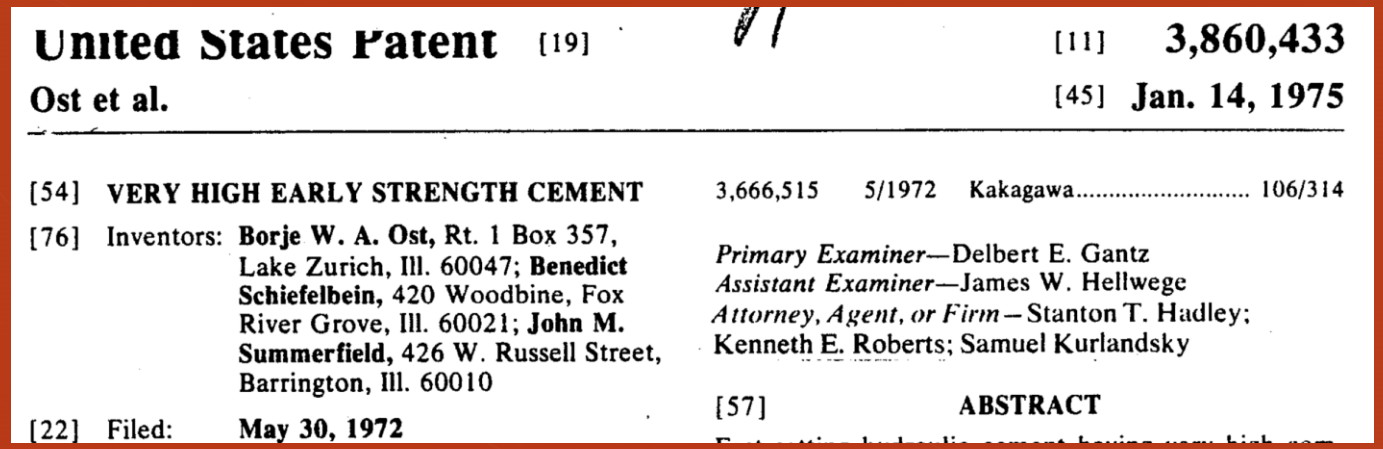
FOLSOM DAM | GROUTING

Auxiliary Spillway Control Structure

February 2014

- $900M Project
- US Army Corps of Engineers, US Dept. of the Interior, US Bureau of Reclamation Cooperative
- 1,100 ft approach channel, 3,027 ft spillway chute, 6 submerged gates
- Type K SCC **Grout** specified for steel gate supports
- **Prevent shrinkage, volume change and movement that would compromise the control structure**
- 16% dosage rate of Komponent (ASTM C878) and fly ash
- 7000 psi compressive strength

1972: The Ost patent on BCSA Cement



United States Patent [19]

Ost et al.

[11] 3,860,433

[45] Jan. 14, 1975

[54] VERY HIGH EARLY STRENGTH CEMENT

[76] Inventors: **Borje W. A. Ost**, Rt. 1 Box 357, Lake Zurich, Ill. 60047; **Benedict Schiefelbein**, 420 Woodbine, Fox River Grove, Ill. 60021; **John M. Summerfield**, 426 W. Russell Street, Barrington, Ill. 60010

[22] Filed: **May 30, 1972**

3,666,515 5/1972 Kakagawa 106/314

Primary Examiner—Delbert E. Gantz
Assistant Examiner—James W. Hellwege
Attorney, Agent, or Firm—Stanton T. Hadley; Kenneth E. Roberts; Samuel Kurlandsky

[57] ABSTRACT

A calculated composition of this material shows 45.7% C_2S, 27.0% $C_3A_3C\bar{S}$, 18.95% $C\bar{S}$, 0.62% free CaO, and 7.7% unallocated CaO. The strength development of

TWO-MINUTE GUIDE

The Great Chicago Flood of 1992

Three decades after the rainless Loop deluge, it remains one of the weirdest emergencies in Illinois history.

Workers prepare to pour cement into a shaft leading to a flooded tunnel to block the flow from the Chicago River on April 18, 1992, days after a leak caused the Loop Flood of 1992. | Charles Bennett / AP

In the end, the flood cost almost $2 billion – a bit higher than a $75,000 contractor bid. An estimated 250 million gallons of river water flooded the tunnel system and building basements. While many were able to return to their offices after a few days, some couldn't return for weeks. Water damage repairs took time.

1994 - Northridge Earthquake

- Collapse of Interstate 10 Overpass
- Approach Slabs Rehabilitation
- Re-opened 74 days ahead of schedule
- Catalyst Project for California Dept of Transportation

Pavements

California Department of Transportation → Since 1995

Freeway Closes at 10 pm, re-opens at 5 am

Specifications:
400 psi Flexural Strength at 4 hours
600 psi Flexural Strength at 28 days

+2,000 lane-miles of rapid-setting CSA pavement

Between 2000 and 2022: RSC placed for pavements: +2,356,629 cy

Project: MO I-35

- **Concrete Producer:** Geiger Ready Mix
- **Contractor:** Clarkson Construction
- **Client:** Missouri DOT
- **Application:** Pavement Rehab**.**
- **Product:** Rapid Set Cement
- **Spec:** 4000 psi @ 4hrs.
- **Volume**: +3000 cy

Maintenance and Rehabilitation of pavement projects using BCSA

- **Mexico, Queretaro**
  - 2019
  - Mexico City – Queretaro highway
  - Built in 1997
  - 600 feet sections per night closure
  - **Ready mix production**
  - +25,000 cy at a rate of 400 cy/day
  - Haul time, traffic and weather
  - 100% MR increase in 6 years.

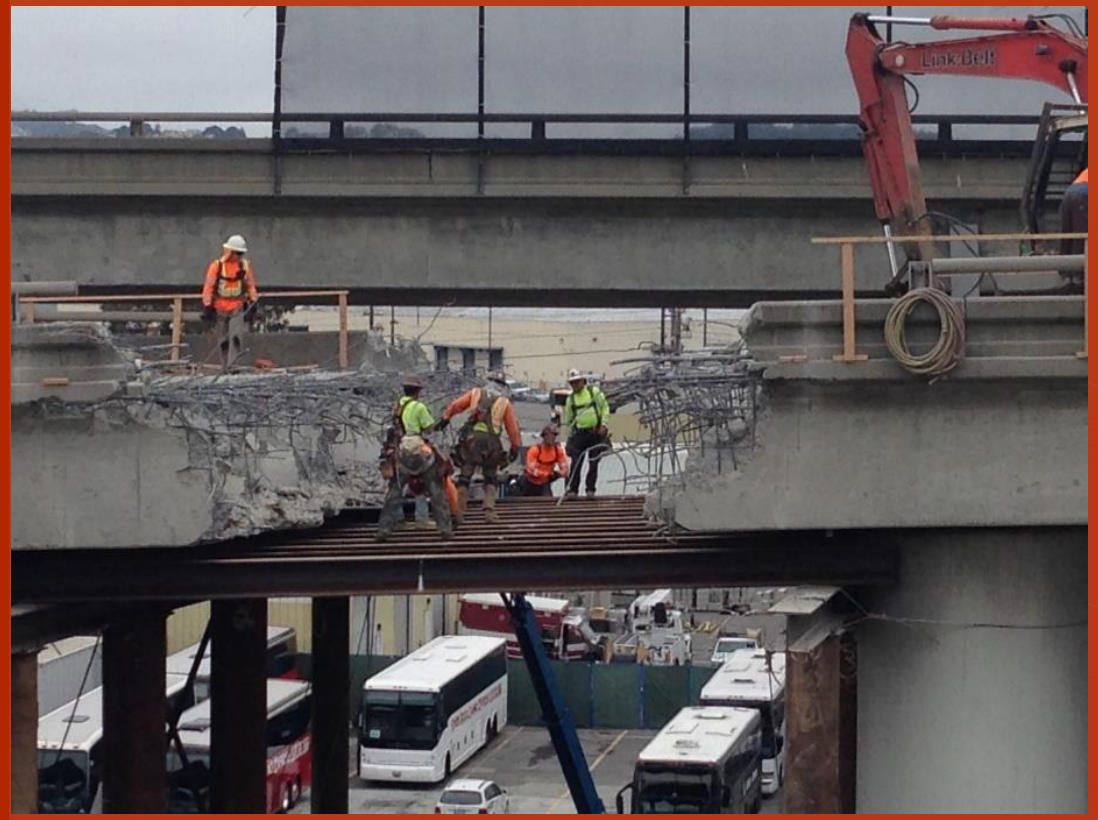
Bridge Applications

- Structural hinges
- Link slabs
- Bridge decks
- Pavement overlays
- Full/Partial slab replacement
- Approach slabs
- Patching

The high-speed interchange at State Route 8 and Interstate 84 in Connecticut

90-hr Bridge Hinge Reconstruction

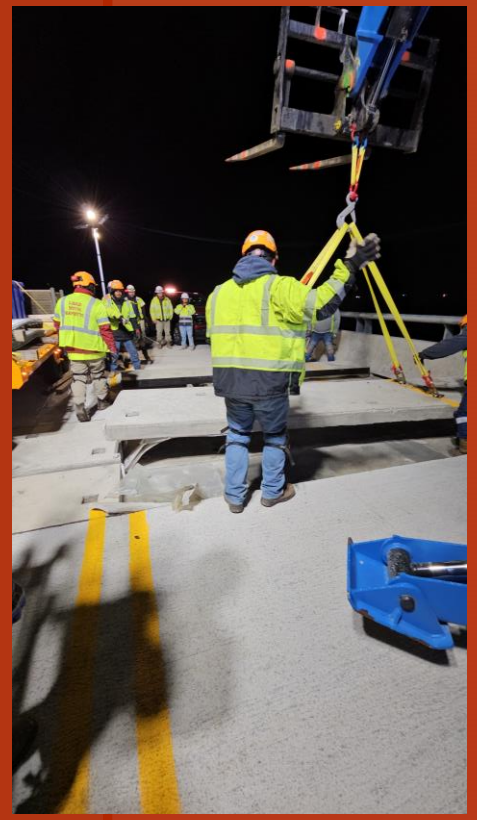
Highway 280, San Francisco, California Department of Transportation

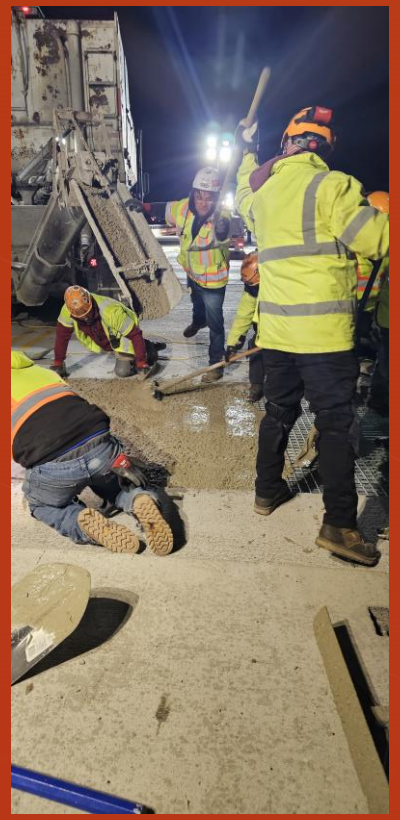
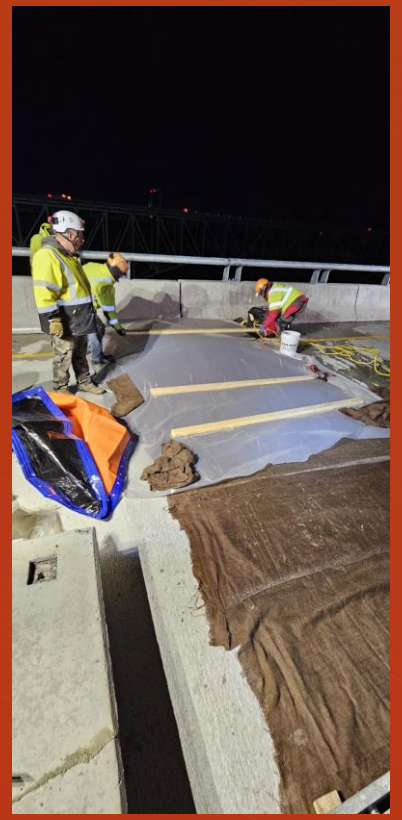
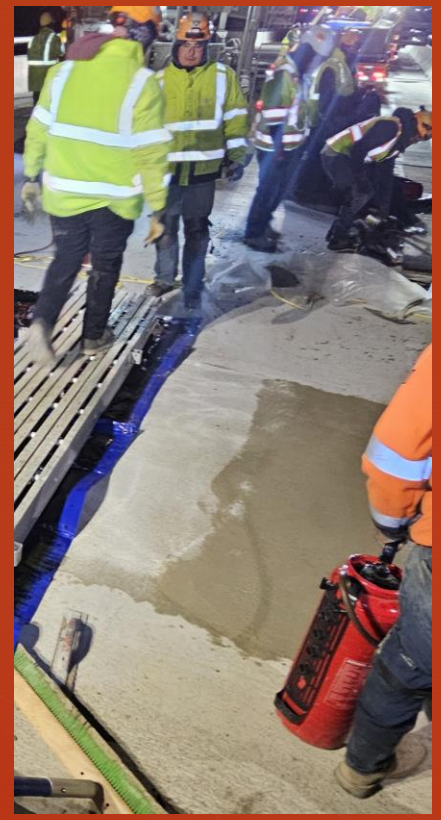


8.2 MPa (1000 psi) Flexural Strength in 3 hours, self-consolidating concrete

Maryland Bay Bridge Link Slabs

Highway 280, San Francisco, California Department of Transportation

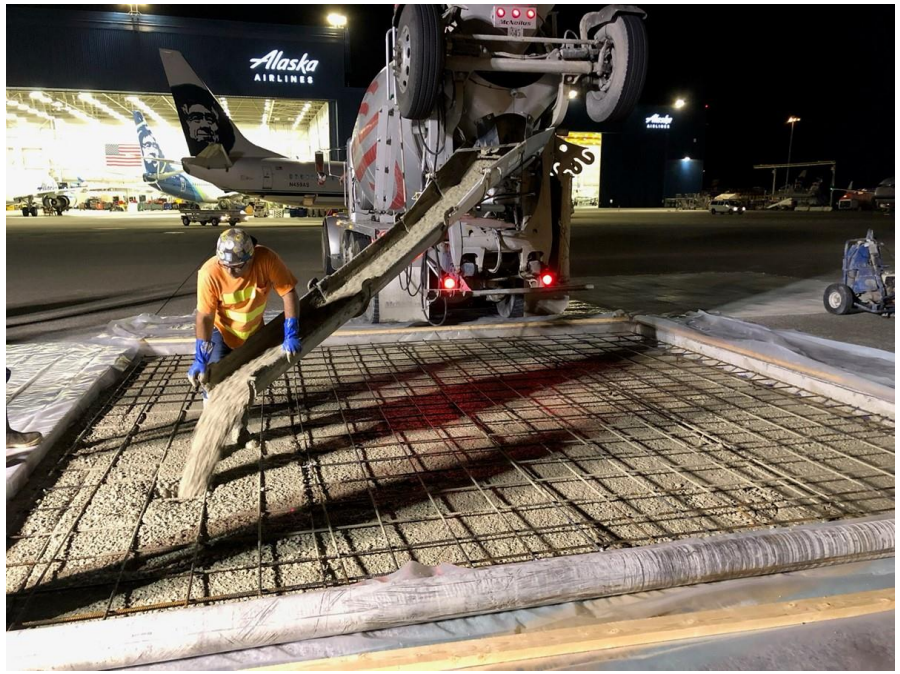


3000 psi Compressive Strength in 3 hours, Rapid Set – LLP concrete

Airfield Pavements

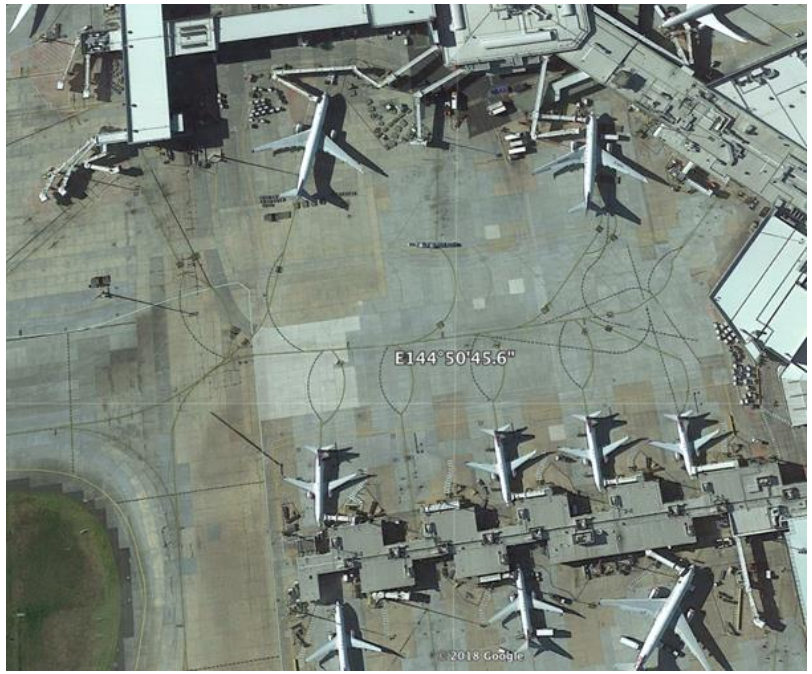
Chicago Midway Airport



Seattle International Airport

Airfield Pavements

Taiwan, Lanyu Runway



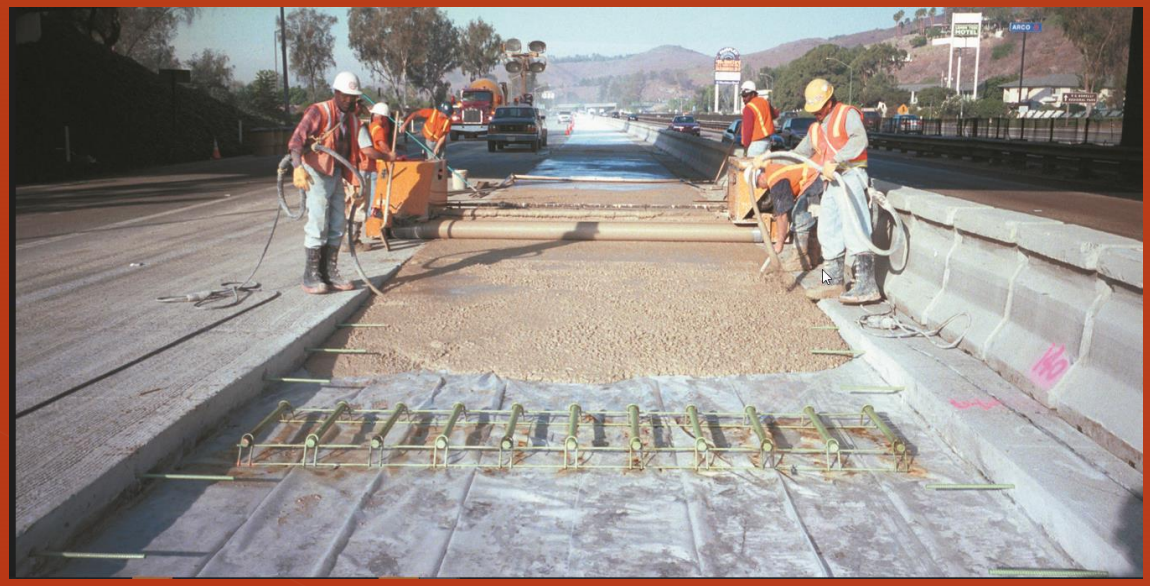
Melbourne Tullamarine Airport

Pavements – Long Term Performance

Burbank Airport – CA, 1997

Design Strength at 4 Hours
MOR: 2.76 MPa (400 psi)

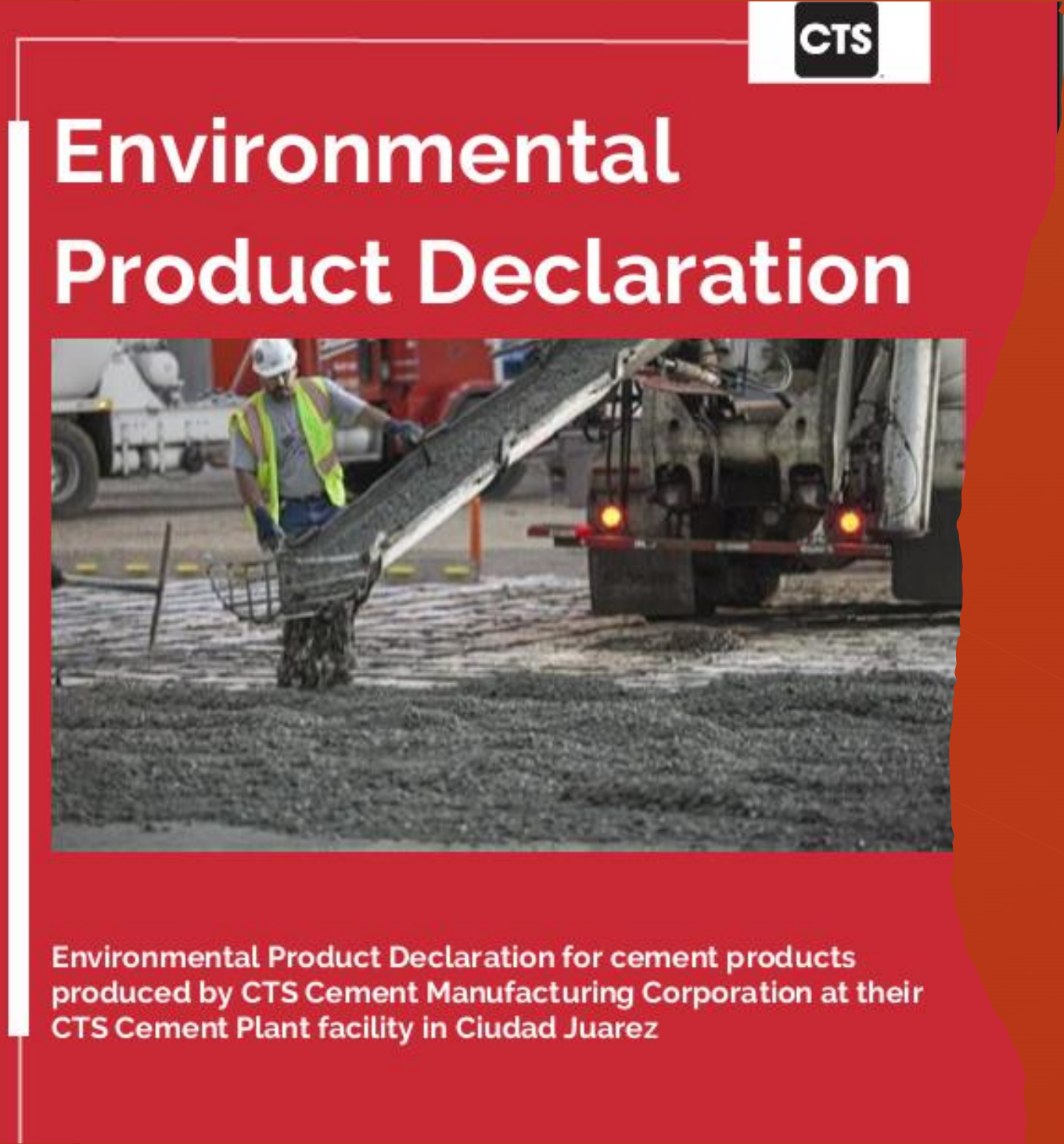
Calculated Flexural Strength
MOR: 8.45 MPa (1,225 psi)



Highway 10, Pomona – CA, 1998.

Design Strength at 4 Hours
MOR: 2.75 MPa (400 psi)

Calculated Flexural Strength
MOR: 8.5 MPa (1,236 psi)



EPDs

- Environmental Product Declarations in 2021 for Rapid Set Cement and Komponent
- Rapid Set's GWP of 673 kg-CO2e/ton is 27% lower than portland cement
- Komponent's GWP of 461 is 50% lower than portland cement

Performance Engineer Products: UHPC

- CSA UHPC Mortar
- Ready for traffic and loading in 2 hours (+6000 psi)
- Over 17,000 psi in 28 days
- Freeze-thaw resistant
- Very low permeability (500 coulombs)
- High bond strength
- Uses: concrete repair, pre-cast bridge connections, industrial floors, waste transfer stations, pavement repairs, etc.

The Dulles Bridge, OR
Deck Connections

Performance Engineer Products: LLP

- Protective barrier for embedded steel
- Reduces chloride permeability
- Versatile in bulk concrete production
- Typical Resistivity: 50-60 kOhms*cm
- Typical RCPT: 400-600 Coulombs
- Uses: bridge deck repairs, bridge overlays, elevated deck repairs, tunnels, marine and coastal structures

CSA-based Products

Conclusions

- CTS have been producing sulfoaluminate cement since 1960s
- CTS is the largest producer of alternative and low carbon cement in USA.
- Application includes:
  - Pavement
  - Airfields
  - Bridges
  - Structural Concrete
  - Flooring
  - Patching and repairs
- Durability and long-term performance is well proven

Thank You

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