# Rapid-Setting
# Non-Portland Cement Concrete Applications

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# Who We Are

***Leading manufacturer of belitic CSA cement technology in North America***

**INFRASTRUCTURE**
Highways, Roadways, Bridges and Viaducts

**GOVERNMENT**
Federal, State & Local Agencies, Public Works

**MIXED USE**
Urban Development, Multi-Family, Residential

**INDUSTRIAL**
Water/Wastewater, Power & Energy, Manufacturing

**MARINE**
Dams, Canals, Locks, Levees, Ports & Channels

**AVIATION**
Runways, Taxiways, Aprons, Hangars

**INSTITUTIONAL**
Schools, Universities, Healthcare, Correctional

**COMMERCIAL**
Retail, Hospitality, Recreation, Arenas, Convention Centers

**MINING & TUNNELING**
Shotcrete, Pumpable Grout, Cavity Fill, Pipe Liners

**100% Employee Owned**

*At the heart of CTS's success is our team of employee-owners whose integrity, commitment and willingness to go the extra mile stand behind everything we do. Every employee has a personal stake in helping you succeed.*

# Objectives

- **Review Industry Objectives & Key Challenges**
- **Introduce Calcium Sulfoaluminate (CSA) Cement Technology**
- **Understand the Performance Advantages of CSA**
- **Review Materials Available Based on CSA Technology**
  - Rapid Set® (ASTM C1600)
  - Komponent ® (ASTM C845)
- **Discover the Design Versatility CSA Offers**
- **Discuss the Sustainability Advantages of CSA**
- **Review Key Industry Standards, Best Practices & Specification Recommendations**

# Key Challenges

***Design, Construction & Development Teams are charged with…***

**Improving …**

- Project Efficiencies
- Long-Term Performance

**While …**

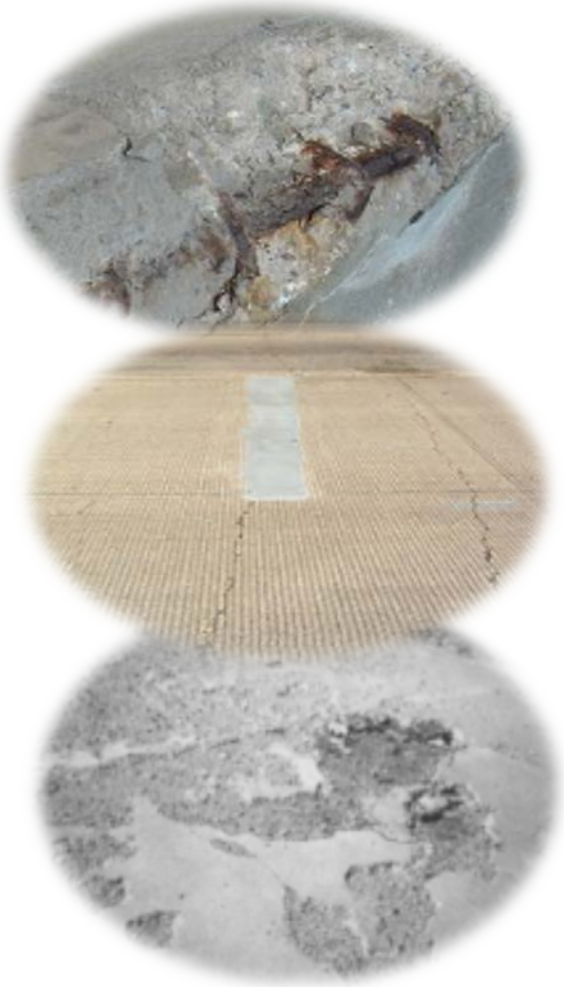
- Minimizing Downtime
- Reducing Project Costs
- Reducing Lifecycle Costs

# Key Challenges

***Primary theories on how deterioration & corrosion in concrete occurs:***

**Drying shrinkage cracking & porosity** of concrete allows…

- **Salts and other contaminants enter the concrete and cause corrosion.**
- **Corrosion of the metal leads to expansive forces that cause cracking of the concrete structure.**
- **Cracks in the concrete allow moisture and salts to reach the metal surface and cause corrosion.**



# Key Challenges

***Ultimately, Concrete Durability & Service Life  is Compromised by…***

- **Cracking & Curling**
- **Spalling & Abrasion**
- **Sulfates & Chlorides**
- **Alkali-Silica Reaction (ASR)**
- **Carbonation**
- **Corrosion**

## *How do We Achieve the Objective to Prevent Deterioration & Failure?*

**Prevent Deterioration Caused by Shrinkage Cracking** ✓

**Prevent Deterioration Caused by Chemical Attack** *(Sulfates, Chlorides)* ✓

**Lower Porosity & Permeability** ✓

**Maximize Durability & Asset Life** =

## Calcium Sulfoaluminate (CSA) Cement

- **Modified derivative of portland cement clinker**
- **Higher quality hydraulic cement**
- **Developed in the 1950's to overcome common shortfalls of portland cement**
  - *Excessive shrinkage*
  - *Susceptibility to chemical attack*
  - *Destructive reactions with certain aggregates*
  - *Negative consequences of traditional accelerating admixtures*

# Where Did It Come From?

*I wonder what the industry will look like in 200 years?*

- Joseph Aspdin is credited with the development of Portland Cement.
- Took out a patent in **1824** for "**Portland Cement**," a material he produced by firing finely-ground clay and limestone until the limestone was calcined.
- He called it **Portland Cement** because the concrete made from it looked like **Portland** stone, a widely-used building stone in England.

# History

**1950's** Alexander Klein discovers calcium sulfoaluminate (CSA) cement and focuses on chemical pre-stressing of concrete and shrinkage compensation of portland cement. **Type K Shrinkage-Compensating Cement Concrete** is invented. Ed Rice was instrumental in these early R&D efforts.

**1960's** Ed Rubin, Alexander Klein and Ed Rice develop **advanced CSA rapid hardening, high early strength cement**.
First industrial production of CSA at the Kaiser Cement Plant.

**1970's** CSA technology continues to develop and project uses grow. Including:

*Los Angeles World Trade Center, Washington, D.C. Subway, Chicago O'Hare Parking Structure, Dallas City Hall, and Ohio Turnpike Bridge Decks, The Pentagon.*

**1980's** Further growth and development of rapid setting technology & bulk products.

**1990's** Consumer-based product line developed (bag & box / retail & specialty distribution).

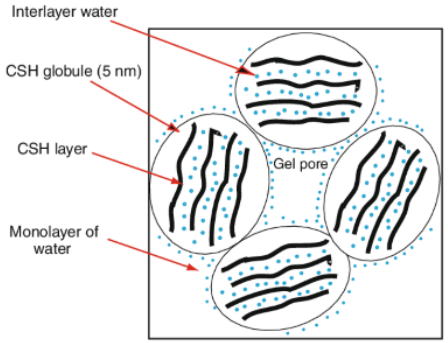
*CalTrans – 400 lane miles of concrete highway*

**2000's** International market expansion; product development continues (paint line, mining, self-leveling and polishable cements)


***Today, millions of cubic yards of CSA are placed worldwide each year.***

# Cement Technology Evolution

- Portland Cement
  - Ubiquitous, successful, 200 year-old.




- Calcium Sulfoaluminate (CSA) Cement
  - Developed out of UC Berkeley in California in the 1950s
  - Expansive material compensates drying shrinkage of portland cement. (Type K)

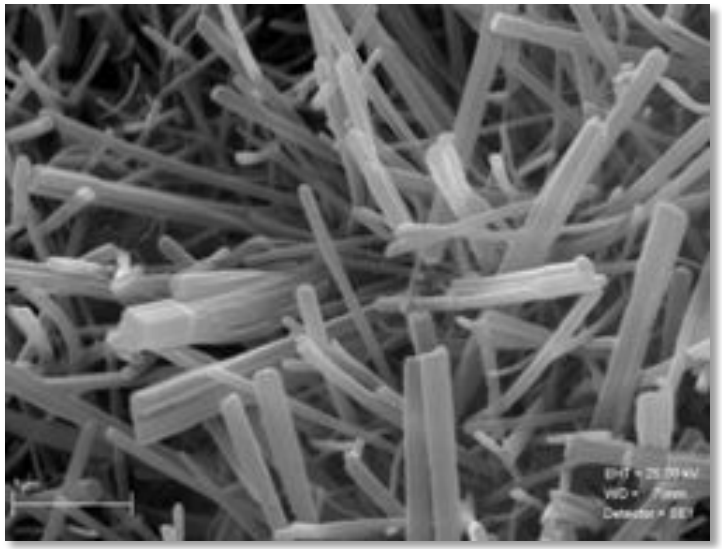
- Belitic Calcium Sulfoaluminate (BCSA) Cement
  - Standalone, rapid setting cement developed in the 1970s.
  - Does not exhibit the shortcomings of other Rapid Strength Concretes

# Portland Cement Concrete Limitations

| | | |
|---|---|---|
| **Strength Gain** | 4350 Psi in 7 days | - Slow Return of Infrastructure to Service<br>- Cost to traveling public and stakeholders, safety |
| **Shrinkage** | 600-700 Microstrains | - Cracking<br>- Slab Size (15-20 ft) - Distance Between Joints<br>- Cost of Joint Maintenance<br>- Service Life (25-40 years) |
| **Porosity** | 20-30% of Volume | - ASR, Ingress of Chlorides, Sulfates, etc.<br>- Service Life (25-40 years) |
| **Carbon Footprint** | 0.9 t $CO_2$/ t cement | - Sustainability |

# BCSA is a stand-alone rapid-setting cement.

No accelerating additive, No CaCl2, not Fondu, not of blends of CSA with portland, not a blend of Fondu with portland…..  no blending with other cements.



Ettringite

| | Calcium Sulfoaluminate | Dicalcium Silicate | Calcium Sulfate |
|---|---|---|---|
| **Belitic Calcium Sulfoaluminate Cement** | **25%** | **50%** | **15%** |

First commercialization of this cement: 1978 in the USA

1) Hydration of sulfoaluminate into ettringite $C_4A_3\$+8C\$+6C+96H \rightarrow 3C_6A\$_3H_{32}$

Followed by

2) Hydration of $C_2S$ $C_2S+xH \rightarrow C_ySH_{x+y-2}+(2-y)CH$

# Primary Differences

## Portland Cement Composition

| | Early Strength Gain | Long-Term Strength Gain | Attacked by Sulfates | | |
|---|---|---|---|---|---|
| ASTM C150 TYPE | $C_3S$ | $C_2S$ | $C_3A$ | $C_4AF$ | $\underline{CS}$ |
| I | 59 | 15 | 12 | 8 | 2.9 |
| II | 46 | 29 | 6-8 | 12 | 2.8 |
| III | 60 | 12 | 12-15 | 8 | 3.9 |
| IV | 30 | 46 | 5-7 | 13 | 2.9 |
| V | 43 | 36 | 4-5 | 12 | 2.7 |

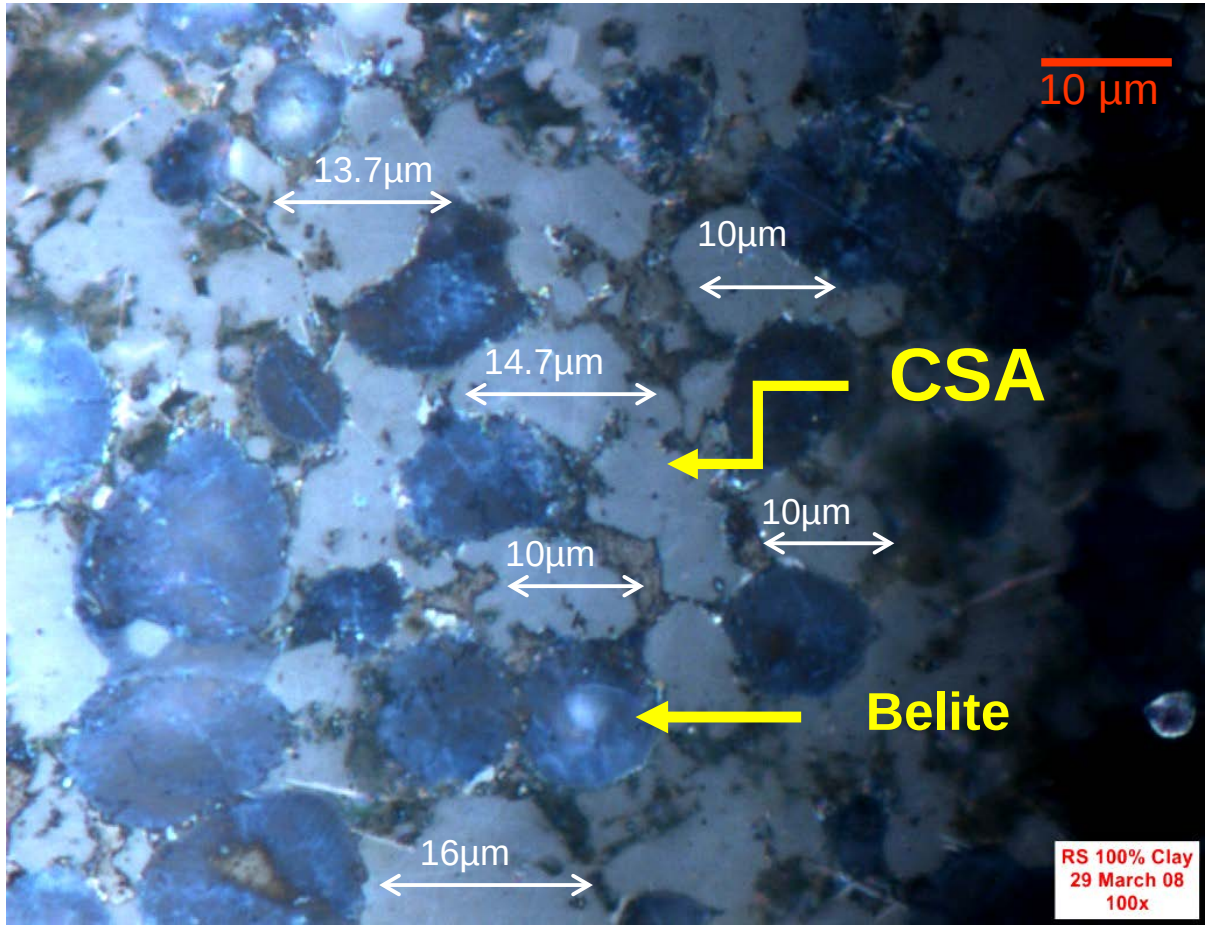
## Calcium Sulfoaluminate Cement Composition

| | Early Strength Gain | Long-Term Strength Gain | Attacked by Sulfates | | |
|---|---|---|---|---|---|
| ASTM C1600 | $C_4A_3S$ | $C_2S$ | $C_3A$ | $C_4AF$ | $\underline{CS}$ |
| CSA Cement | 30 | 45 | 0 | 2 | 15 |

*Quantities represent % composition*

- **Early Strength Gain Element Achieves a Significantly Different Performance**
- **Exceptional Long-Term Strength Gain**
- **Durability is not Compromised for Speed**
- **Negligible $C_3A$ Content Achieves Absolute Sulfate Resistance**

# BCSA has had a single-cement in use since 1978.



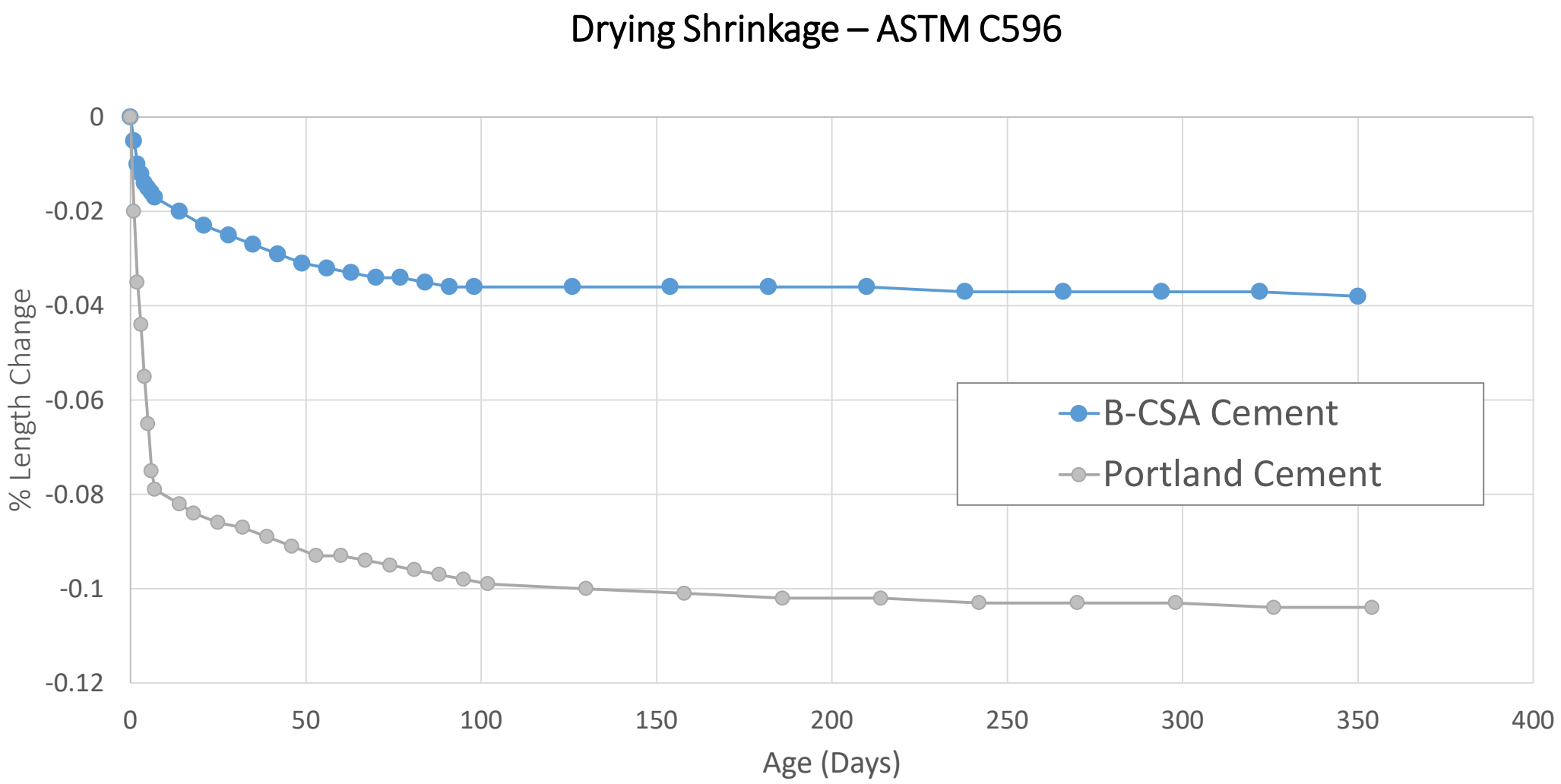

- Akin to Portland Cement
- 960375-09-1

Key: A SINTERED material, not a blend

# Key Characteristics of BCSA Concrete

- **Speed of Construction**
  - 1.5 Hour Compressive Strength  5070 Psi
- **Strength**
  - Ultimate compressive strength as high as 8700 PSI - Higher strength than Portland at equal w/c
- **Shrinkage**
  - As low as 200 microstrains at 28 days (without shrinkage-reducing admixtures)
- **Sulfate Resistance**
  - High sulfate resistance due to absence of $C_3A$
- **Sustainability**
  - 0.67 tons of $CO_2$ per ton of BCSA cement

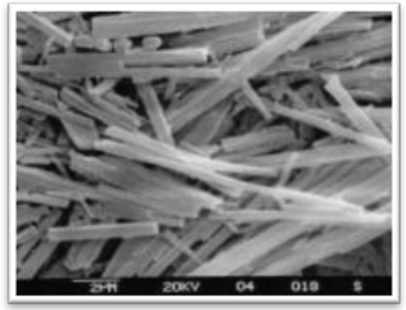
# Very Low Shrinkage: Increased durability



# Shrinkage-Compensating Concrete

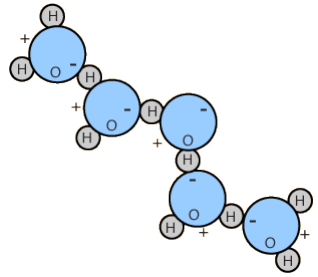
*ACI 223 Type K (ASTM C845, C878)*

- Designed to **IMPROVE THE CEMENT PASTE** within the concrete structure.
- Engineered to **COMPENSATE** for drying shrinkage – effectively achieving net zero shrinkage of the concrete.



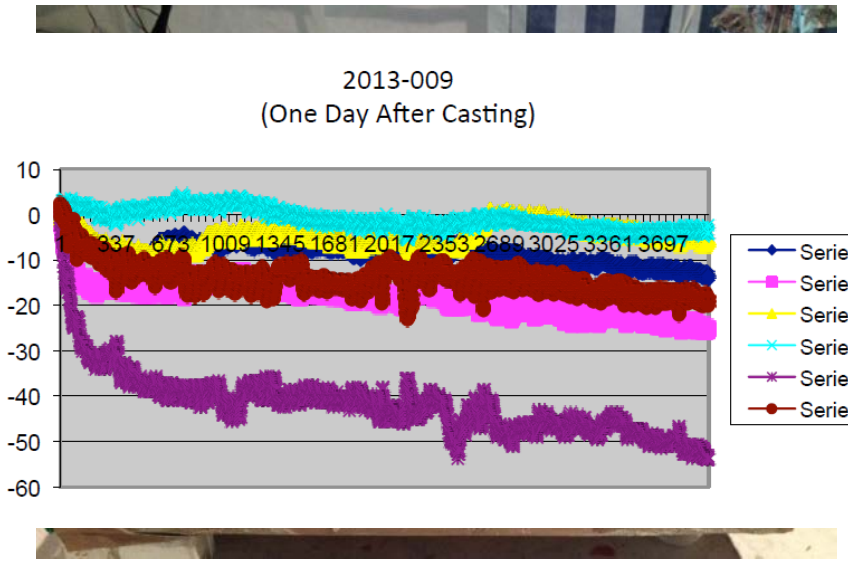
***Dimensional stability maintained for the designed service life of the placement.***

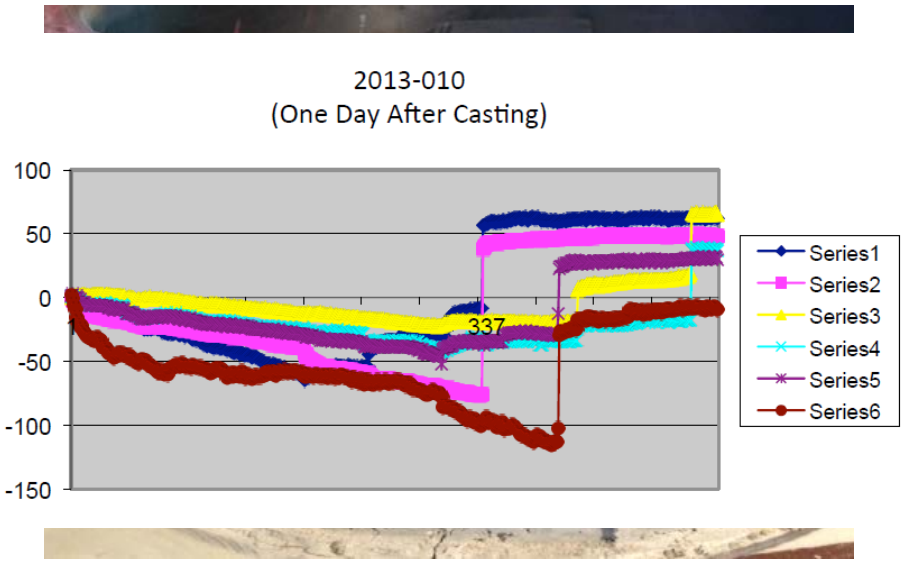

- CSA cement is **NOT** an SRA.
- SRAs affect the surface tension of the pore water.
- They are designed to **DELAY** shrinkage.
- Effects diminish over time.
- Compressive strengths can be affected.



Speed • Strength • Sulfate **Shrinkage** Carbon Footprint

## ASTM C1581: Restrained Shrinkage



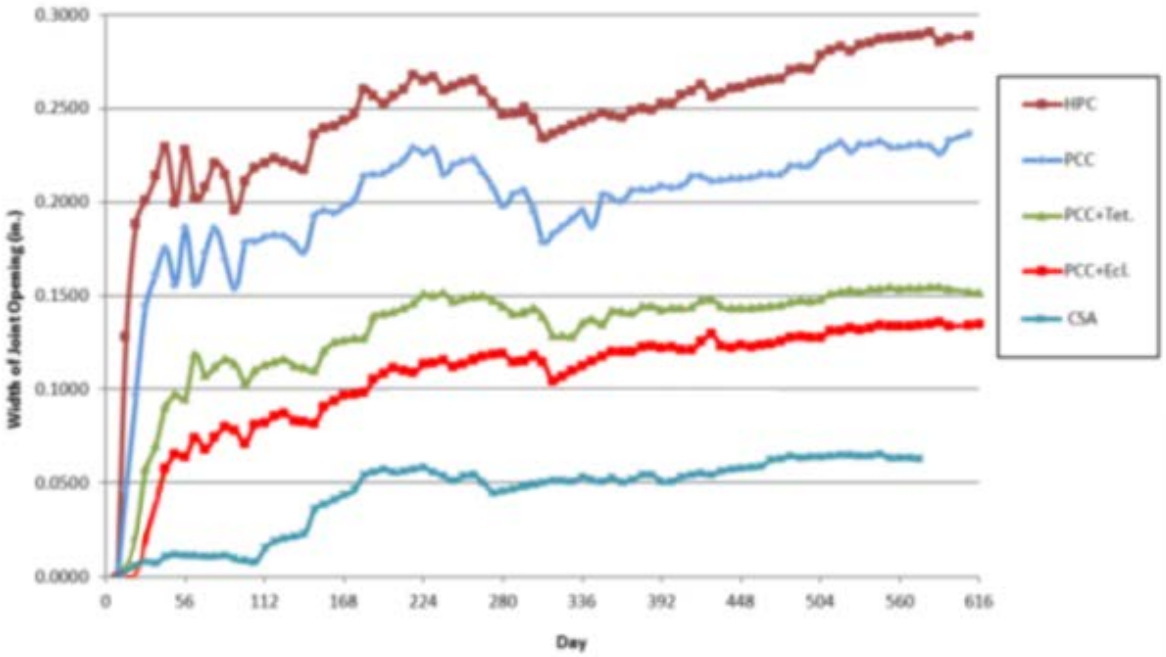




B-CSA Concrete:
No Cracks at 90 Days

Portland-based High Early Strength:
Failure at 8.9 Days (Avg.)

## Joint Width over Time

*The Wider the Joint, the Greater the Shrinkage of the Slab*

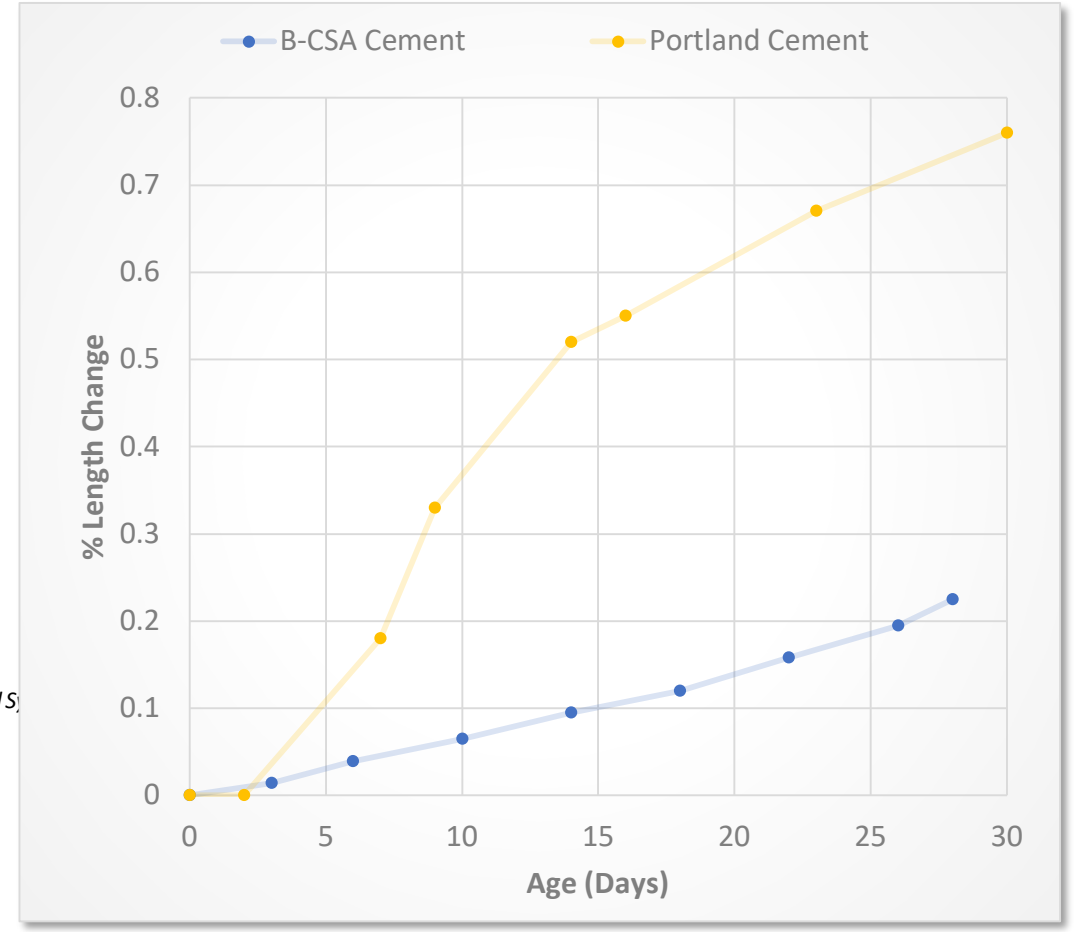



- Shrinkage Compensating Concrete (Komponent®) manufactured by CTS is extremely stable, with little to no long term shrinkage, control joint strain or warping. This stability is noted at both early age and at 10 months.
- Typical PCC and HPC continue to exhibit control joint growth at l0 months.
- Shrinkage Reducing admixtures have a minor impact at early age but do not impact long term sectional stability. Shrinkage, control joint strain and warping are nearly similar to typical PCC but slightly better than High Performance Concrete (HPC)

# Alkali- Silica Reactivity : A better cement matrix

Lower pH
Lower eq. Alkali
Internal dessication
Lower porosity

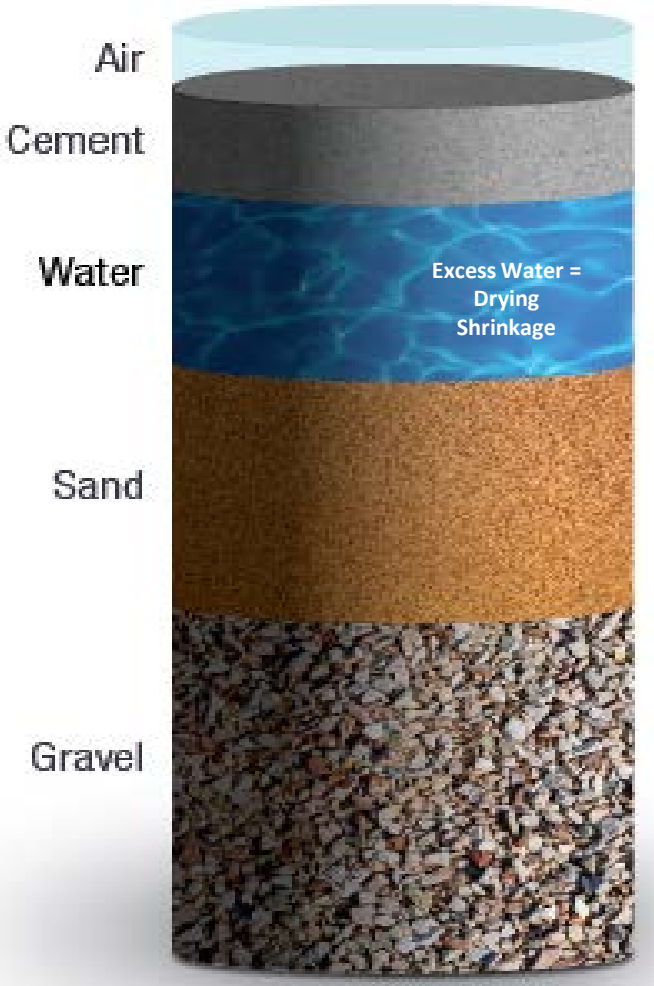
*13th International S*



# Performance

## PORTLAND CEMENT CONCRETE

Only hydrates approximately 55% (0.25 w/c) of the mix water leaving approximately 45% for evaporation

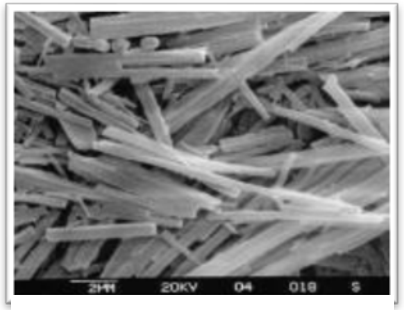



## CSA CEMENT CONCRETE

Hydrates approximately 98% (0.45 w/c) of the mix water leaving approximately 0-2% for evaporation

# Performance

1



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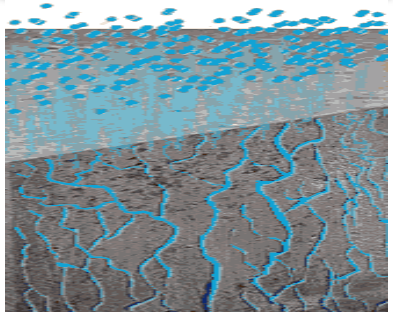

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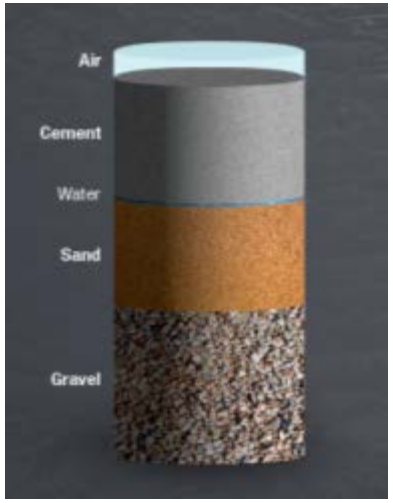


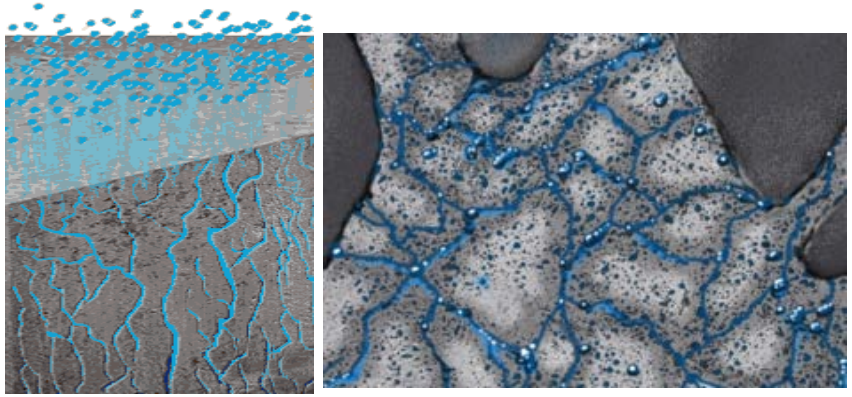

- **Maximum Utilization of $H_2O$ Used in Hydration**
  - Eliminate Capillary Channels and Voids
  - Low Shrinkage
- **Maximum Formation of Ettringite Crystals Achieves High 1 to 1.5 Hr. Strength (Up to 7,000 psi)**
- **Can Have Expansive Qualities (Type K)**
- **High Sulfate Resistance (No $C_3A$)**

- ✓ **Low Porosity = Low Chloride Diffusion**
- ✓ **Low Permeability**
- ✓ **Maximum Durability**

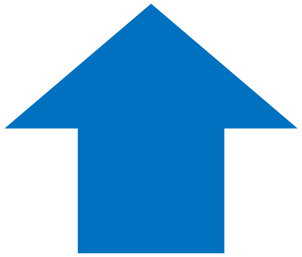
How?

# A Different Hydration Mechanism

- Mix water is chemically retained (“bound”) within the ettringite structure
- Eliminates bleed water (minimal water of convenience)
- Maintains integrity of the mix designed at the surface; w/c ratio is not compromised
- Improves abrasion resistance 30-40% (ACI 223)
- Prevents voids & capillary channels that lead to drying shrinkage
- Increases density
- Lowers porosity & permeability
- Prevents cracking & curling due to drying shrinkage & volume change
- Prevent laitance and other “debris” from being drawn to the surface



*Portland Cement Concrete Egress of Excess Water*



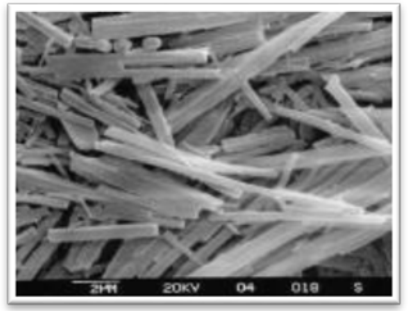
*Escape of convenience water in portland cement concrete creates voids & capillary channels that lead to shrinkage & contamination*

# How?

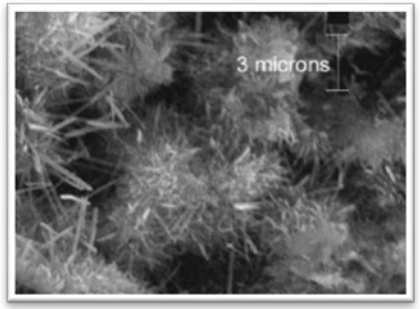
## Early Ettringite Formation

- **ASTM C1600**
  - Maximum formation during the first 24 hours
  - Rapid strength gain without sacrificing long-term performance
  - Fast return to service (1 to 3 hours)
- **ASTM C845**
  - Maximum formation during the first 7 days enhances strength gain
  - Minor controlled early expansion compensates for shrinkage
  - Rapid formation speeds setting time 20-30 minutes

*Full consumption of mix water and complete hydration of CSA cement during placement and cure maximizes performance of the placement and helps prevent detrimental delayed ettringite formation.*

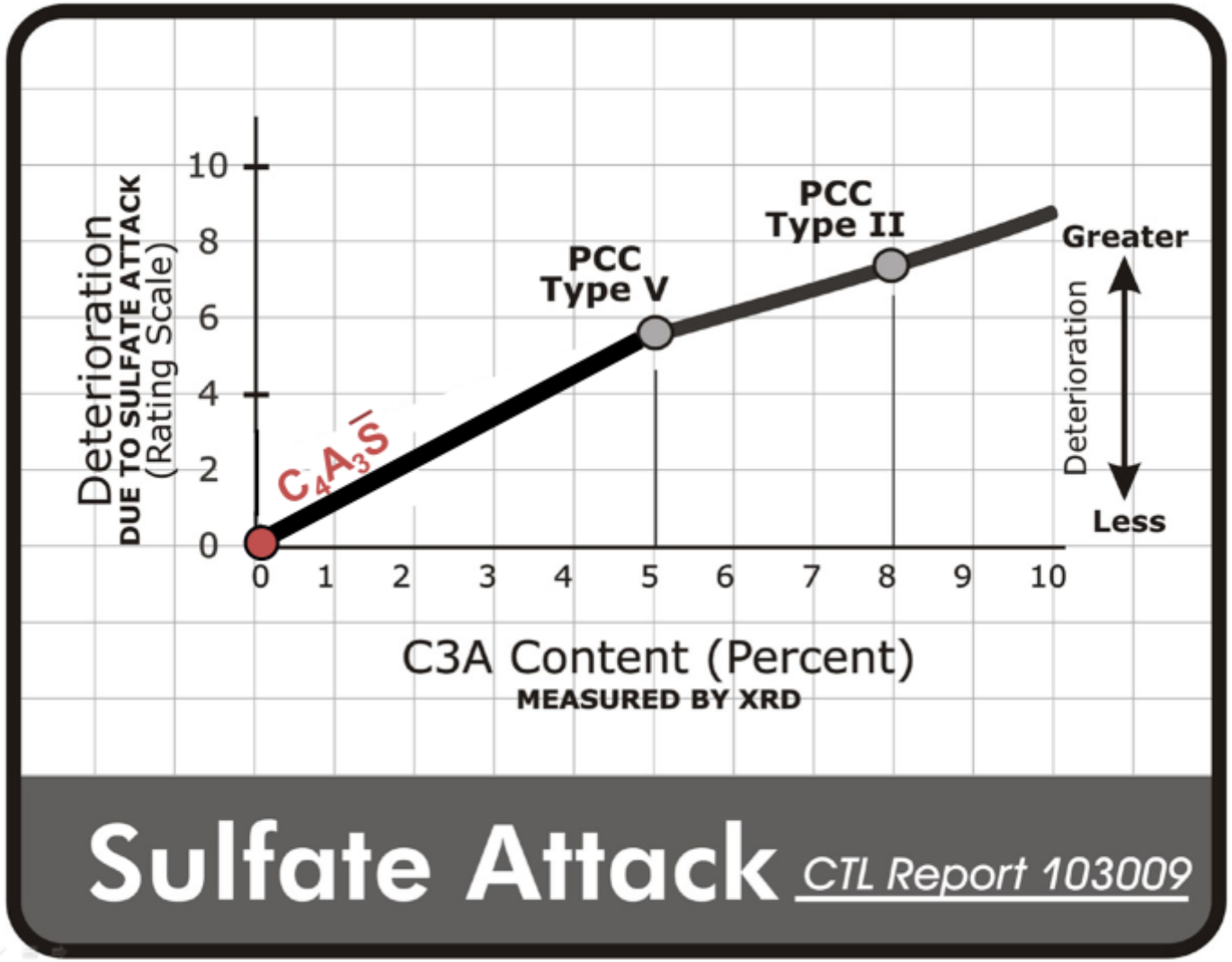


*CSA Cement Ettringite Crystals*




*Portland Cement Crystals & Gel*

# Performance

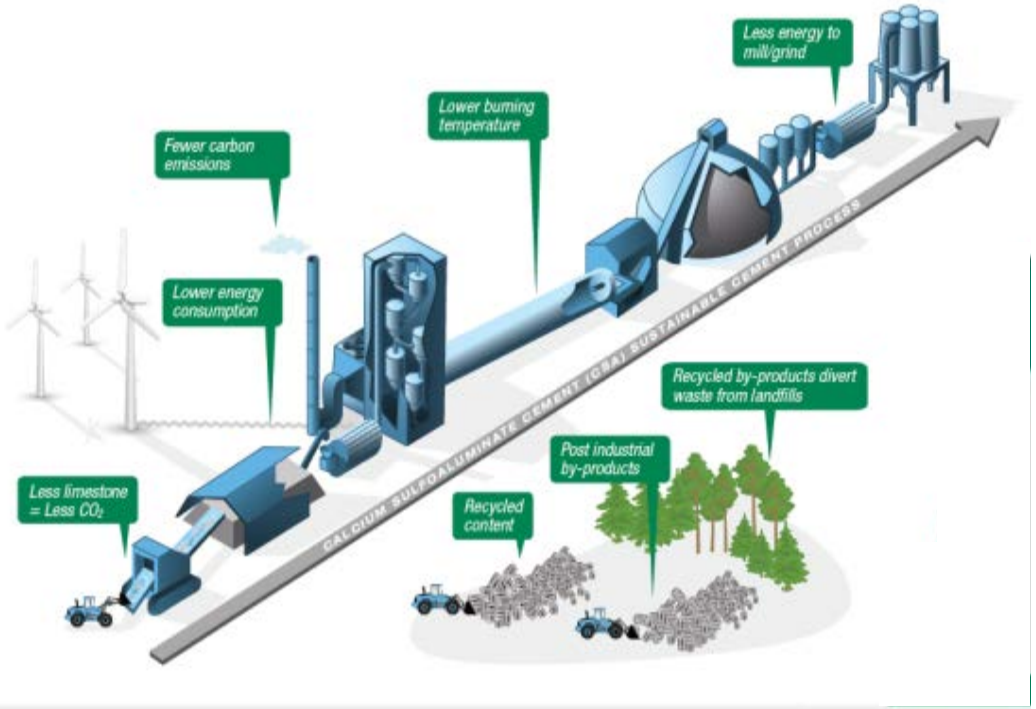


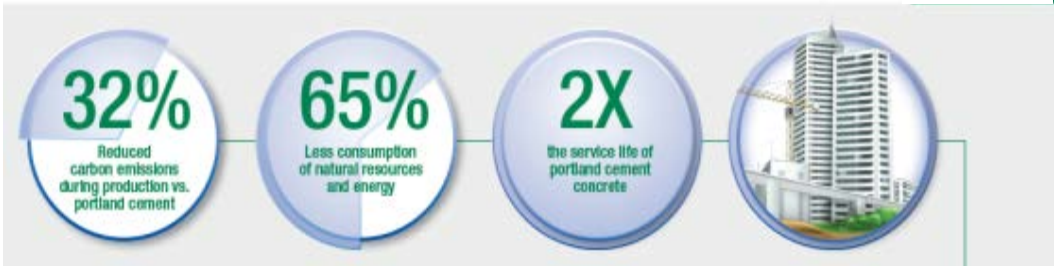

- **CSA cement** (ASTM C1600) **provides absolute sulfate resistance.**

- **CSA cement expansive additive** (ACI 223, ASTM C845) **enhances sulfate resistance for all OPC mix designs.**

# Sustainability

- **Less Limestone**
  - *Fewer Natural Resources*
  - *1/3 less $CO_2$ emissions*
- **Kiln Temperature is ~400°F Lower**
  - *Significant reductions in fuel and $CO_2$ emissions*
- **Easier to Grind than OPC Clinker**
  - *Less electricity/energy consumption*
- **Recycled & Post Industrial By-Products**
  - *Divert waste from landfills*



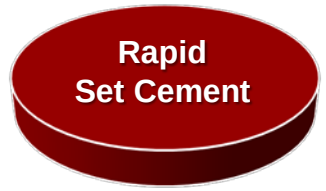



# Used In

## 1 Fast-Setting Hydraulic Cement Materials

*ASTM C1600*

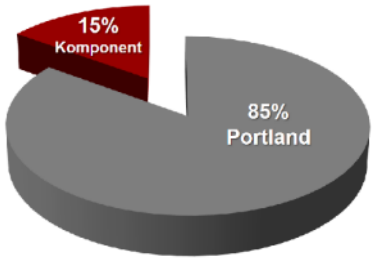
- High Early Strength
- Maximum Durability




## 2 Shrinkage Compensating Concrete

*ACI 223 Type-K (ASTM C845)*

- Expansive Additive
- Superior Durability



# Pavement

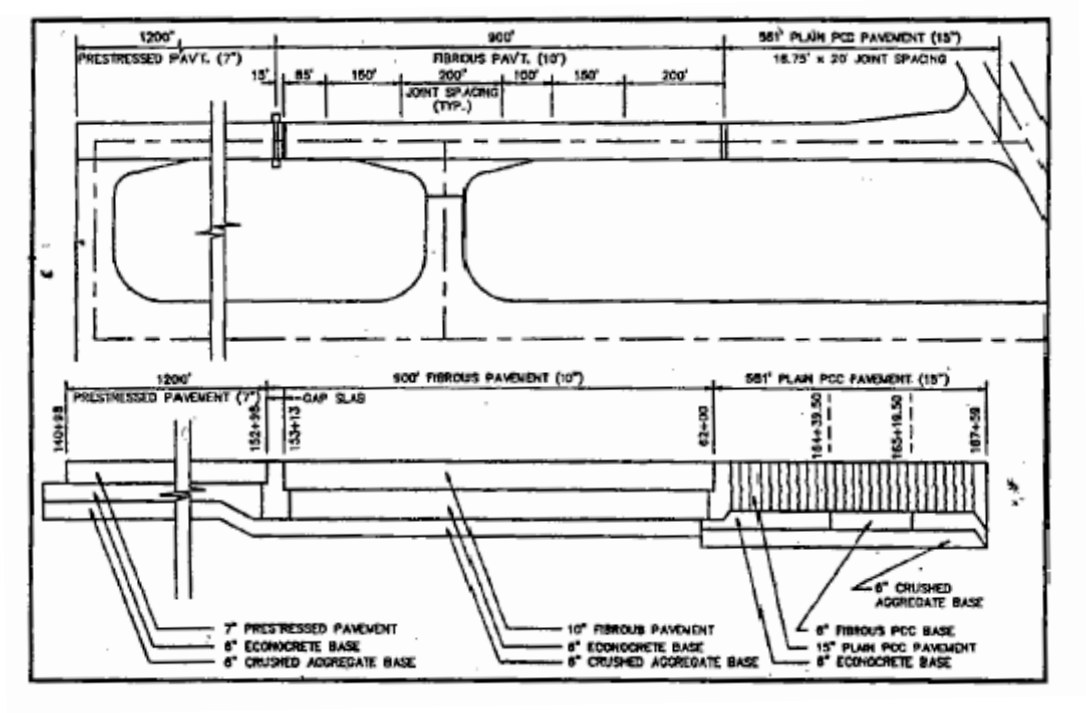
Palmdale, CA – Still in Service

Lodi, CA – Still in Service

**I-14 Palmdale, CA**
First Type K Shrinkage-Compensating Concrete Pavement
1963

**I-12 Lodi, CA**
Second Type K Shrinkage-Compensating Concrete Pavement
1963

# 1994 – Rockford Airport




The longest section: 1200 ft long and 7 inch thick without any transverse joints.

# Rockford IL Airport | FAA Research Project

*Evaluate durability and significant joint reduction – the location of spalling, a common source of foreign object debris, safety hazards, costly maintenance and repair projects.*

**Unique Pavement Designs**

- Type K Shrinkage-Compensating Concrete/ Steel Fibers
- Type K Shrinkage-Compensating Concrete/ Post-tensioned & Steel Fibers

| | Regular PCC | Type K + Steel Fibers | Type K + Post Tensioned + Steel Fibers |
|---|---|---|---|
| Length of Runway Section | 580’ | 900’ | 1200’ |
| Slab Thickness | 15” | 10” | 7” |
| Longitudinal Joint Spacing | 18.75’ | None | None |
| Transverse Joint Spacing | 20’ | 85’ to 200’ | None |
| PCI Rating (10 Years) | 67 | 82 | 98 |

# Rockford IL Airport | Constructability Report

10 Year Inspection

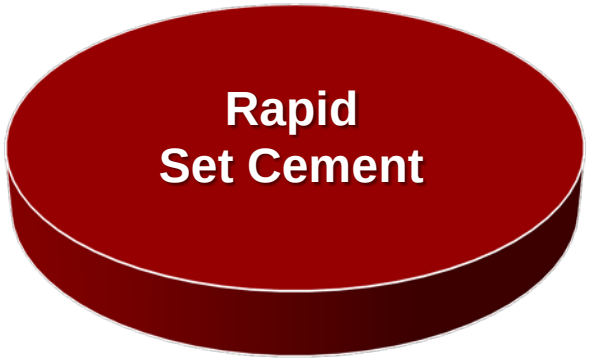
| | | |
|---|---|---|
| **$50.36** yd2 | Conventional PCC with Rebar<br>520’ long, 75’ wide, 15” thick<br>Joints: 18.75’ longitudinal & 20’ transverse | “Severely spalled” – many cracks & spalls<br>Performance Index: Good |
| **$50.72** yd2 | Steel Fibers and Shrinkage-Comp<br>900’ long, 75’ wide, 10” thick<br>Joints: no longitudinal, 85’ to 200’ transverse | “Performing very well” – a few tight cracks<br>Performance Index : Very Good Condition |
| **$46.29** yd2 | Post-Tensioned and Fibers and Shrinkage-Comp<br>1200’ long, 75’ wide, 7” thick<br>Joints: no longitudinal, no transverse | “Performing exceptionally”<br>Performance Index : Excellent Condition |

*“The use of Type K did not create handling, storing or delivery problems.”*

# When Time is Money

**1** **Fast-Setting Hydraulic Cement Materials**
*ASTM C1600*

- High Early Strength
- Maximum Durability



# 1994 - Northridge Earthquake

- Collapse of Interstate 10 Overpass
- Approach Slabs Rehabilitation
- Re-opened 74 days ahead of schedule
- Catalyst Project for CalTrans and FHWA

# 1995→ongoing: California Department of Transportation



Since 1994 Earthquake

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

**1,400 lane-miles of belitic CSA pavement.**

**Specifications:400 psi** ( 2.8 Mpa) Flexural Strength at 4 hours

**600 psi** Flexural Strength at 28 days

.

# Panel Replacement

**California Freeway System**
**(Caltrans)**

## Over 1,400 lane miles since 1995

**Caltrans Report**
**Evaluation of Rapid Strength Concrete Slab Repairs**
**Dated October 2008**
**Less than 1.4% distressed slabs found**
**Mostly construction related failers**

# Performance Goals Achieved

1. Maximum Formation of Ettringite Crystals
2. Eliminate Capillary Channels and Voids
3. Maximum Utilization of $H_2O$ Molecules
4. No $C_3A$ Content

- ✓ Prevent Deterioration Caused by Shrinkage Cracking
- ✓ Prevent Deterioration Caused by Chemical Attack *(Sulfates, Chlorides)*
- ✓ Lower Permeability
- ✓ Maximum Durability

# Used In

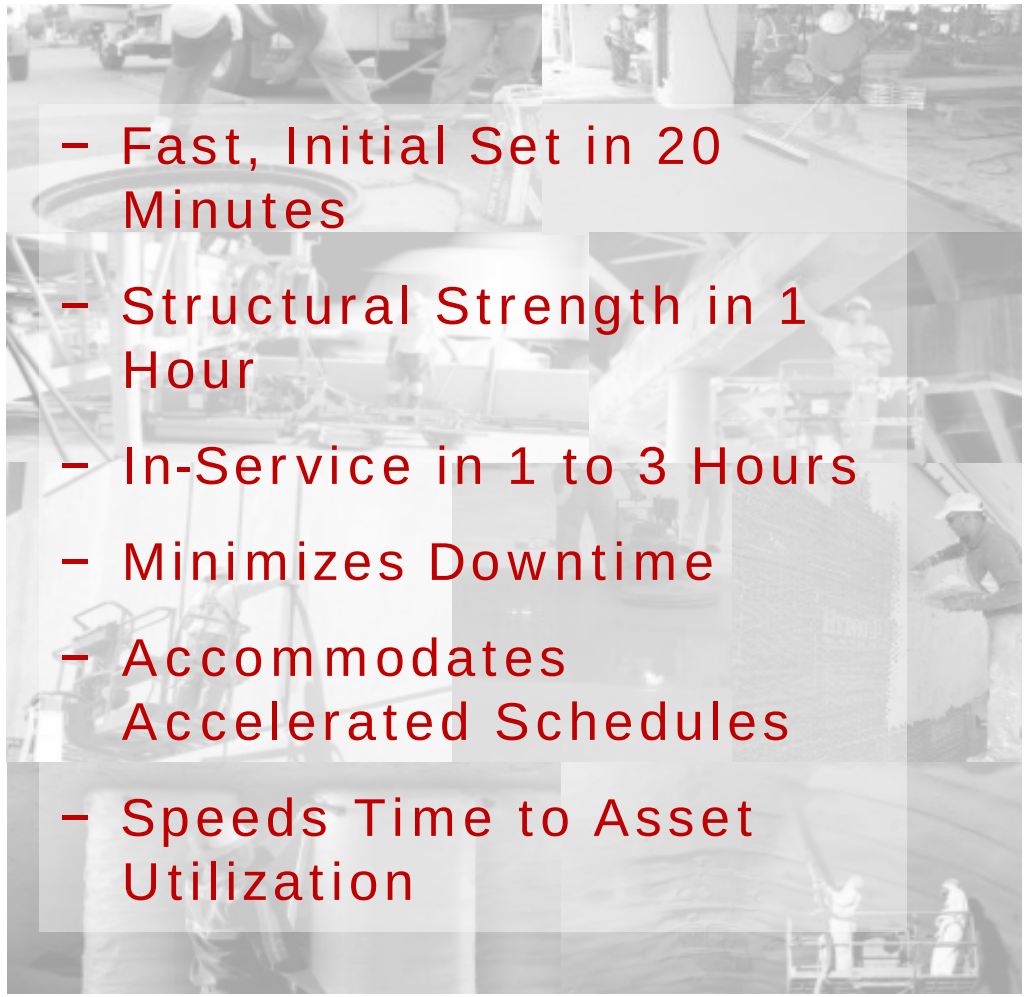
## Fast-Setting Hydraulic Cement Materials *ASTM C1600*

- Concrete Mixes
- Concrete Resurfacers & Underlayments
- Mortar Mixes & Repair Mortars
- Non-Shrink Construction Grouts
- Smoothing & Patching Compounds
- DOT & FAA Concrete Paving & Overlays
- Polishable Concrete Toppings
- Stucco Materials
- Tunneling & Mining Products
- Shotcrete
- Flowable Fill (CLSM)
- Cementitious Slurry
- Hardscape Mortars
- Tilt-Up Panels

# Fast-Setting Hydraulic Cement Materials *ASTM C1600*

**Advantages**

- CSA Technology
- Minimize Shrinkage
- Improved Durability
- Increased Abrasion & Impact Resistance
- Reduced Permeability
- Protection of Reinforcement
- Increased Service Life

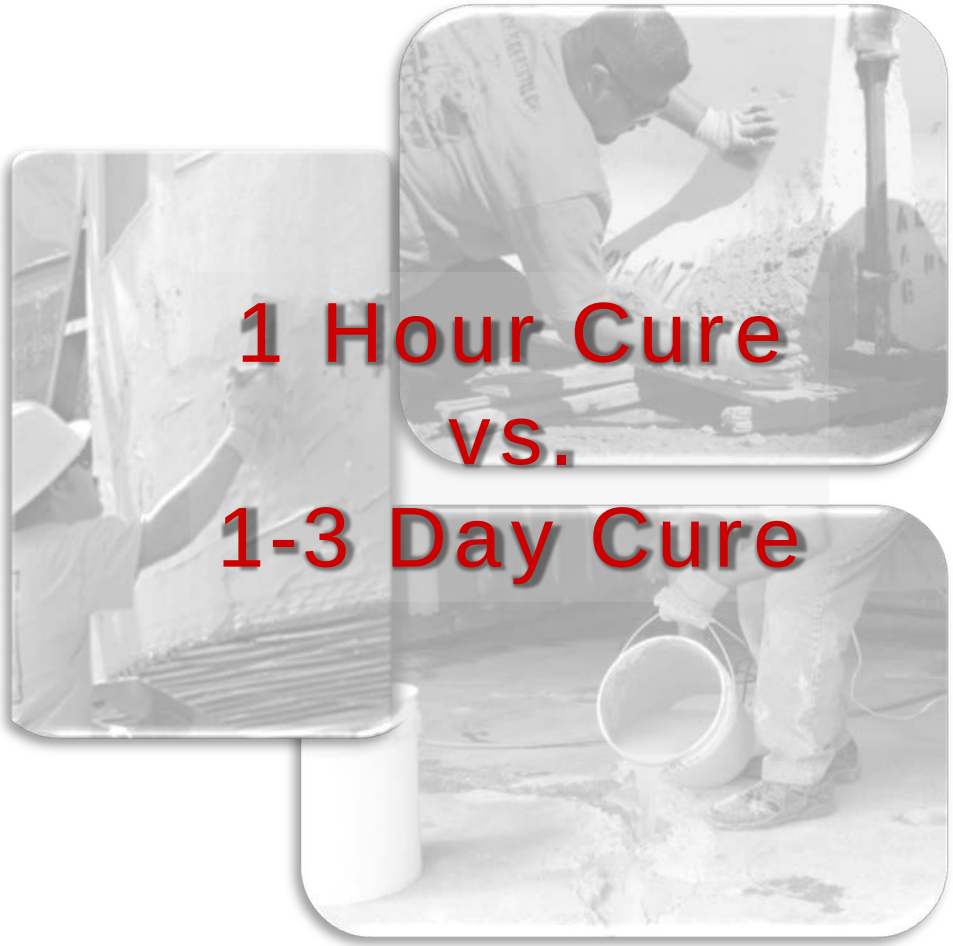


# Project Value

**CSA cement can be used wherever OPC is used**

- **Greatest Value is Realized…**
  - Anywhere Fast Strength Gain is Required
  - Where In-Service Time is Paramount
  - Re-Align Critical Path (Recapture Time)
  - When Project Schedules Fall Behind
  - When Delay Penalties are Impending
  - Opening On Time is Critical
  - Early Formwork Removal is Necessary or Beneficial
  - Revenue Generating Asset
  - Emergency Repairs
  - Fast-Track Projects

# Product Availability




## New Construction, Repair & Restoration

- Concrete Mixes
- Concrete Overlays & Sub-Bases
- Mortar Mixes & Repair Mortars
- Non-Shrink Construction Grouts
- Vertical & Overhead Materials
- Smoothing & Patching Compounds

# Product Availability


## Pavement & Overlays
## DOT Approved

- Concrete Mixes
- Concrete Overlays & Sub-Bases
- White Toppings (Bonded & Unbonded)
- Mortar Mixes & Repair Mortars
- Low Permeability Concrete
- DOT & FAA Concrete Paving
- Latex Overlays

# Product Availability


## Shotcrete, Tunneling, Mining, Geotechnical

- Shotcrete
- Cavity Fill
- Flowable Fill/Backfill
- Lean Base
- Structural Support
- Pipe Liner/Mine Roof Supports
- Underground Road Repair

# Rapid Strength Products


Set 45 Master Builders

Magnesium Phosphate based, not a hydraulic cement

Reg Set Ideal Cement Co.

High $C_3A$ – Subject to sulfate attack, no longer made

Pyrament Lone Star Cement Co.

Difficult to control, no longer made

PCC & Calcium Chloride Standard concrete mix with calcium chloride as an accelerator, subject to sulfate and chloride attack and high shrinkage rate

# Rapid Strength Products – cont.

Rockfast  Blue Circle Cement Co.

Mineral Admixture made in England, not competitive in the U.S.

Ultimax  Ultimax Corp.

Mineral Admixture has been used by Caltrans

Quickrete  Quickrete Corporation

Fast setting concrete products available for smaller "bag" sized projects

QUIKRETE®
CEMENT & CONCRETE PRODUCTS™

Type I-II Portland and Calcium Aluminate blend

High early strength gain, used in refectory industry high heat

CSA Cement blended with Type I-II or Type III Portland Cement,

Higher cement content need to obtain  for equal strength

Rapid Set Cement  100% CSA Cement CTS Cement Mfg. Corp.

Fast setting, high early strength available in bags or bulk

High early strength, minimal shrinkage, resistant to chemical attack

*All the above mentioned products are RAPID STRENGTH PRODUCTS*

*ONLY ONE RAPID SET!*

# Material Selection

| | Type III | BCSA | OPC | OPC + CSA | Type III + Accelerator | OPC + CAC |
|---|---|---|---|---|---|---|
| **Blended** | No | No | No | Yes | No | Yes |
| **Low Shrink** | No | Yes | No | Yes | No | No |
| **High Early Strength** | No | Yes | No | Yes | Yes | Yes |
| **Moderate Early Strength** | Yes | Yes | No | Yes | Yes | Yes |
| **Sulfate Resistance** | No | Yes | No | No | No | No |
| **Cost** | $$ | $$$ | $ | $$ | $$ | $$$ |

## CalTrans

1999

- In 1999, CalTrans replaced a two-mile section of freeway from the 57/210 interchange to Garey Avenue in Pomona, CA.
- This rehabilitation project placed 3,500 cubic yards of Rapid Set cement pavement, 9-in thick in 55 hours and completed the project on time.

*Crews Placing a Two-Mile Section of the 210 Freeway, 1999*

# Roads & Bridges

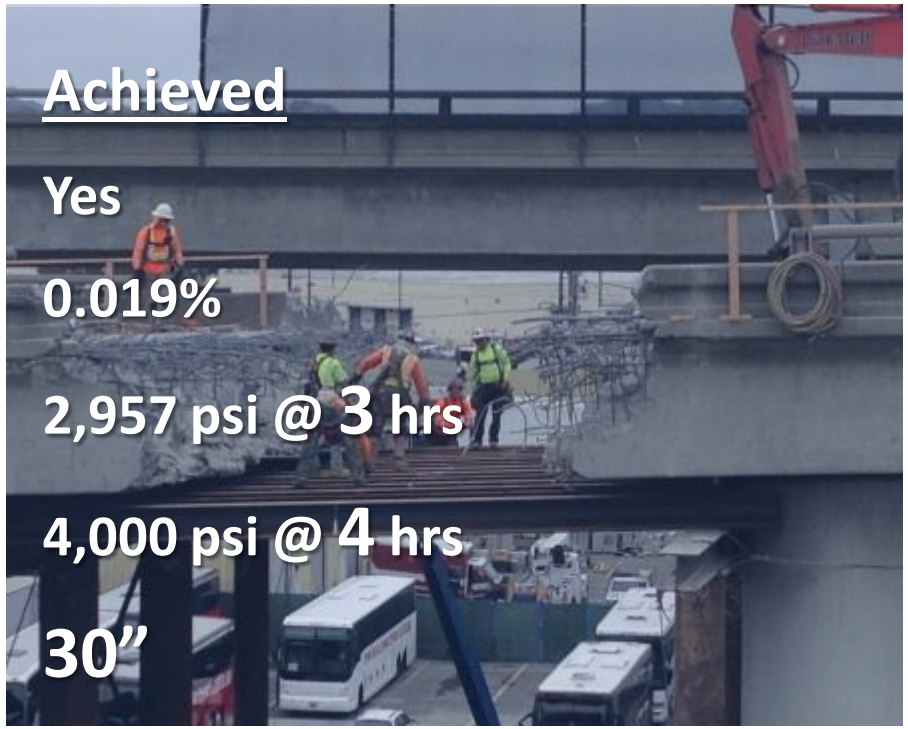
- Structural Repair of 4 Bridge Hinges
- 60’ W x 25’ L x 5’ Thick Sections
- Self-Consolidating Mix Design

## Highway 280
## San Francisco


*“Replacement work went without a hitch.”*
*- Joon Kang, Project Manager - CalTrans*

## Highway 280
## San Francisco


| Specification | | Achieved |
|---|---|---|
| 1 Hour Workability | ✓ | Yes |
| Max. Shrinkage 0.045% | ✓ | 0.019% |
| 1,200 psi @ 3 hrs | ✓ | 2,957 psi @ 3 hrs |
| 3,500 psi @ 4 hrs | ✓ | 4,000 psi @ 4 hrs |
| 28” to 35” Displacement | ✓ | 30” |



# Highway 280
# San Francisco

*"We used Rapid Set to improve efficiencies and meet the deadline at it is performing beautifully."*

*- Joon Kang, Project Manager/CalTrans*

## Remove & Replace Hinges

1 Hinge Memorial Day ✓ Opened 3 Hours Early

1 Hinge July 4th ✓ Opened 10 Hours Early

2 Hinges Labor Day Weekend ✓ Opened 7 Hours Early

# Pavement Rehabilitation I–10 Pomona CA

**Replacement of 9” Thick Concrete**
**3 hour Flex Strength 450 psi**

# Nevada DOT – PN# Q2-010-12

Remove & Replace Damaged PCCP - 2013

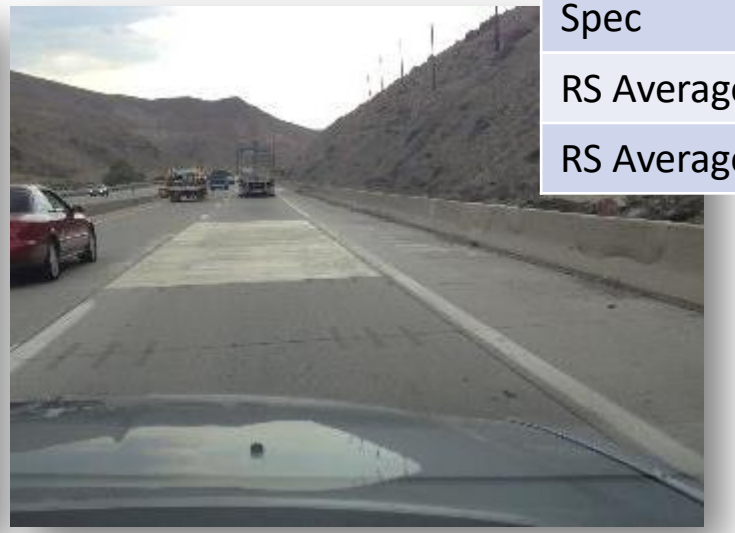
**Pavement damage on this main thoroughfare due to rock slide**

# Nevada DOT – PN# Q2-010-12

Remove & Replace Damaged PCCP - 2013

**RMA Group Test Results # 13-068-0/02**
**Strengths Requirements & Results**

| | | Compressive | Flexural |
|---|---|---|---|
| Spec | ½ Hour | 1700 psi | N/A |
| RS Average | 1 Hour | 3460 psi | 455 psi |
| RS Average | 10 Day | 5260 psi | 620 psi |



- **Rapid Set chosen for Cast-in-Place Panel Replacement**
- **The Most Cost Effective Solution with Minimal Impact on Commuters and Commercial Transportation**

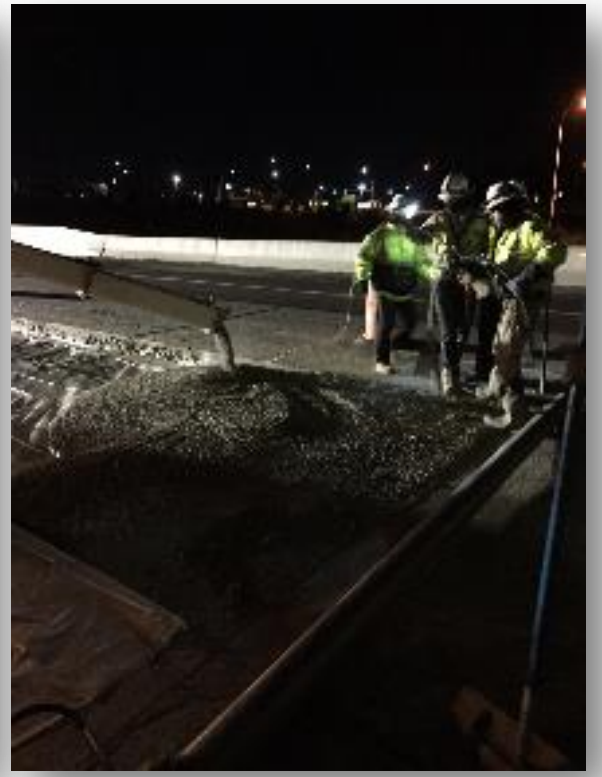
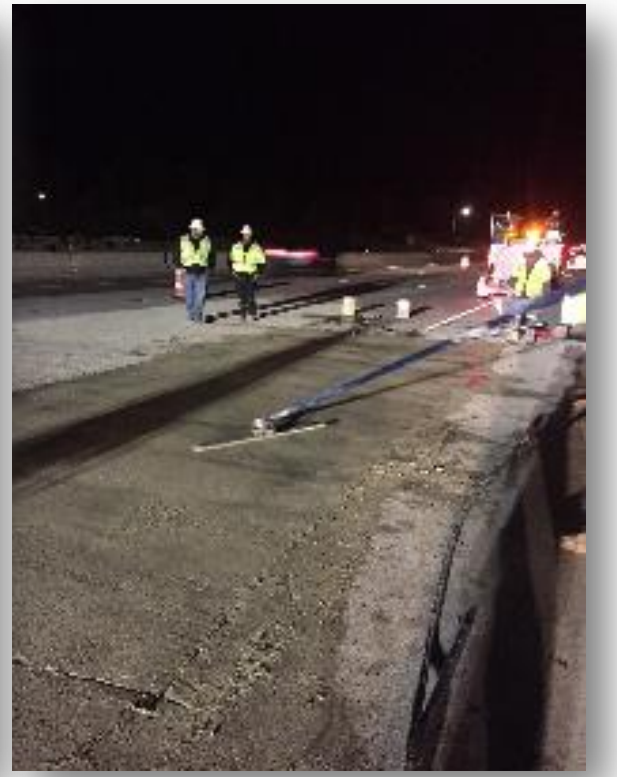
# Overlay

2” Thick Rapid Set® Concrete Used on Tulsa Streets Rehabilitation  Bid Competitively Against Asphalt On Life Cycle Basis

**Rehabilitating a damaged street in 4 hours (Overlay)**

# Utah DOT I-80 Patching

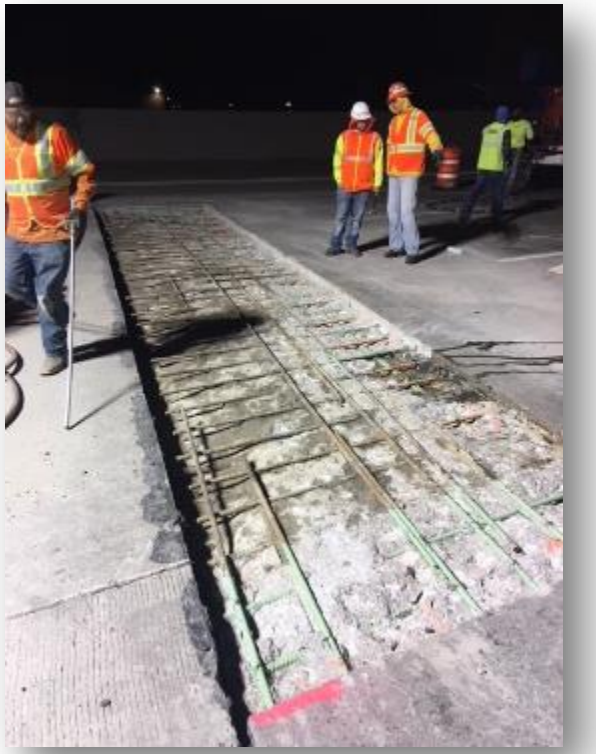


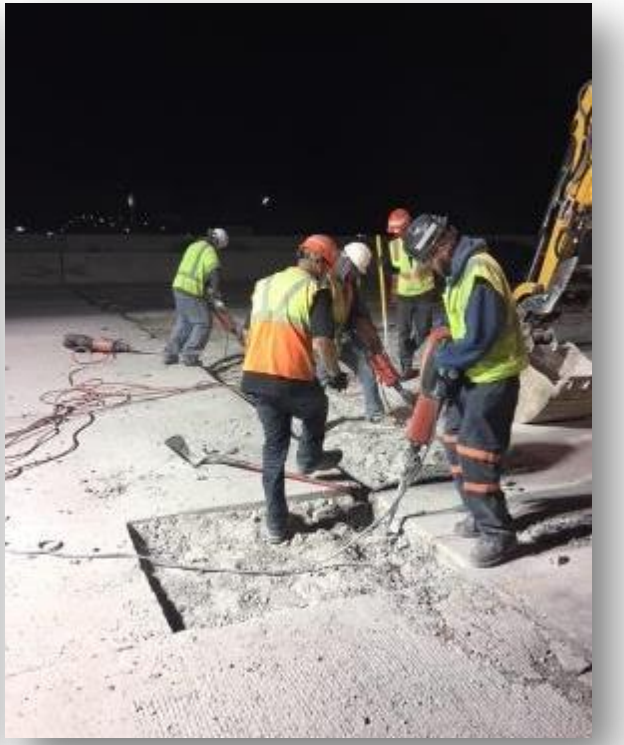



- Sub-Base repair with RS Lean Concrete Base
- Full Depth Panels, 10” Thick
- Ready Mix Production, 20-25 Transit Time
- Opening Strengths in 2 Hours (Retarded Mix for 1 Hour)

# Utah DOT I-15 Patching

Bridge Impact Panels | The “Spaghetti Bowl” I-15 and I-80 Intersection





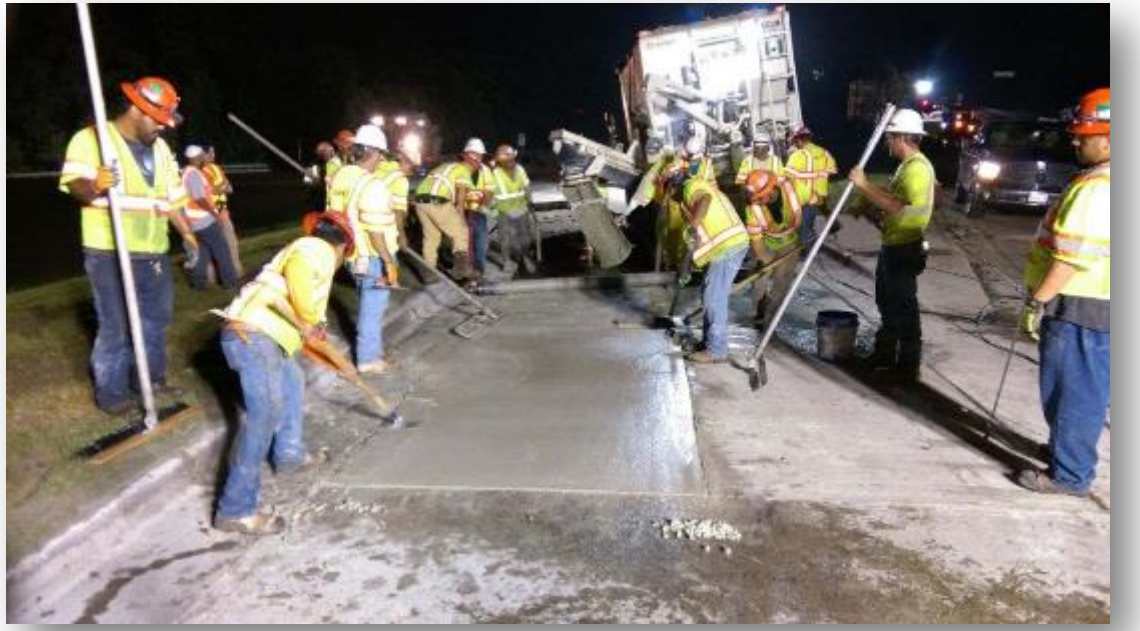
- High Traffic Thoroughfare
- Closures 6 Hrs/Night
- 3” to 6” Repair Depths
- Chipping Hammer Removal
- Ready Mix Production (w/retarder)
- Wet Burlap Curing

# I-40 NC DOT

Current Project | 4,000 cu. yd.

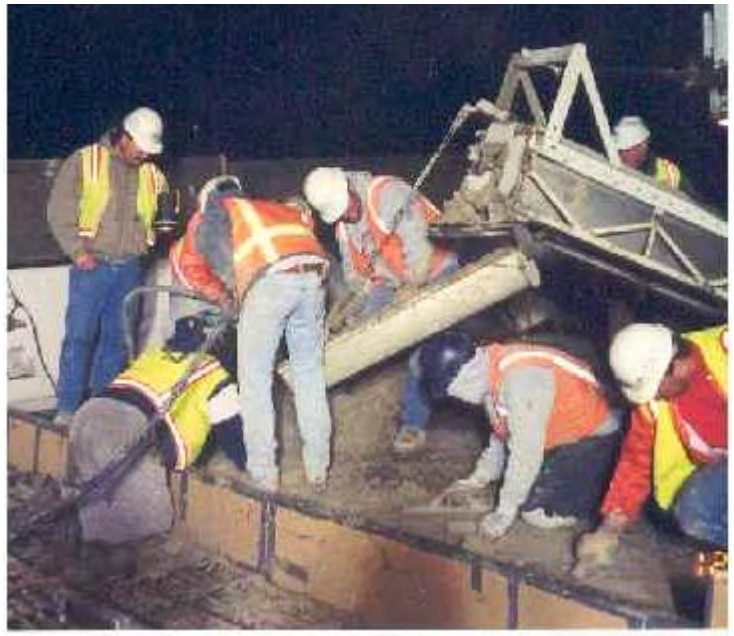

- **Flexural Spec: 400 psi in 4 Hours**
- **Breaking Flex Beams Nightly**
- **RS is meeting spec in 1.5 Hrs; Over 500 in 2 Hrs**
- **Curing Compound Used on Panels**

- **Volumetric Production**
- **Time Restrictions: 8:30pm to 6:30am**
- **Late Opening Penalties: $5,000/Hour**
- **Must meet Flexural (650 psi) AND Compressive (4500 psi) Strengths @ 28 Days**



# Emergency Repairs I-5 Sacramento

Rapid Set® Saved 7 Days of Repair Work
Required Low Shrinkage



Concrete Placement Using a Mobile Mixer

# SC DOT I-85 Patching

**2016, 8-Weekend Project**

- 150-180 cu. yd./weekend
- Opening Compressive Strength Spec: 1,600 psi
- Breaking Cylinders @ 24 Hrs and 28 Days

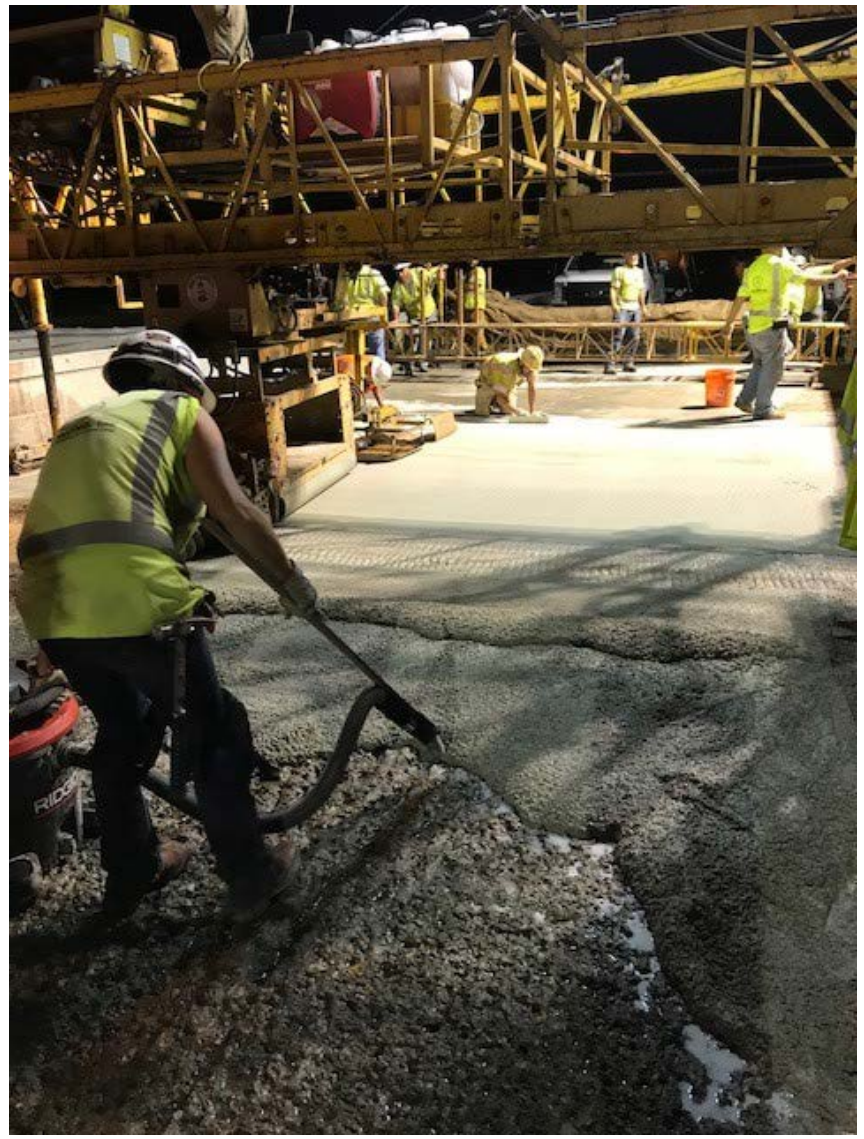
# Lincoln Tunnel

## Full Depth Repair

- Most traveled thoroughfare in the region
- Weekend pavement replacement
- Demo & prep completed on Saturday
- Poured at 6am Sunday
- Opened to traffic 6pm Sunday

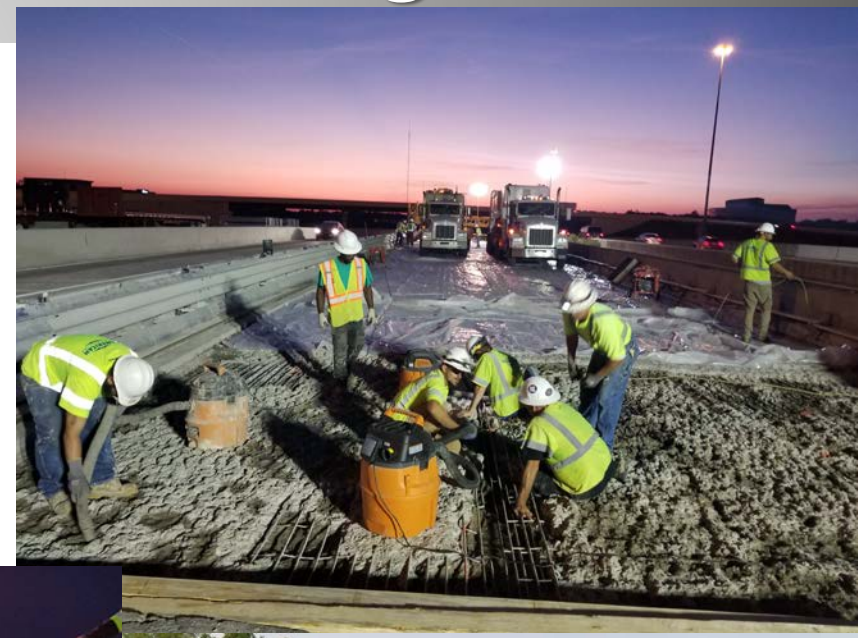
# RSLMC Bridge Decks

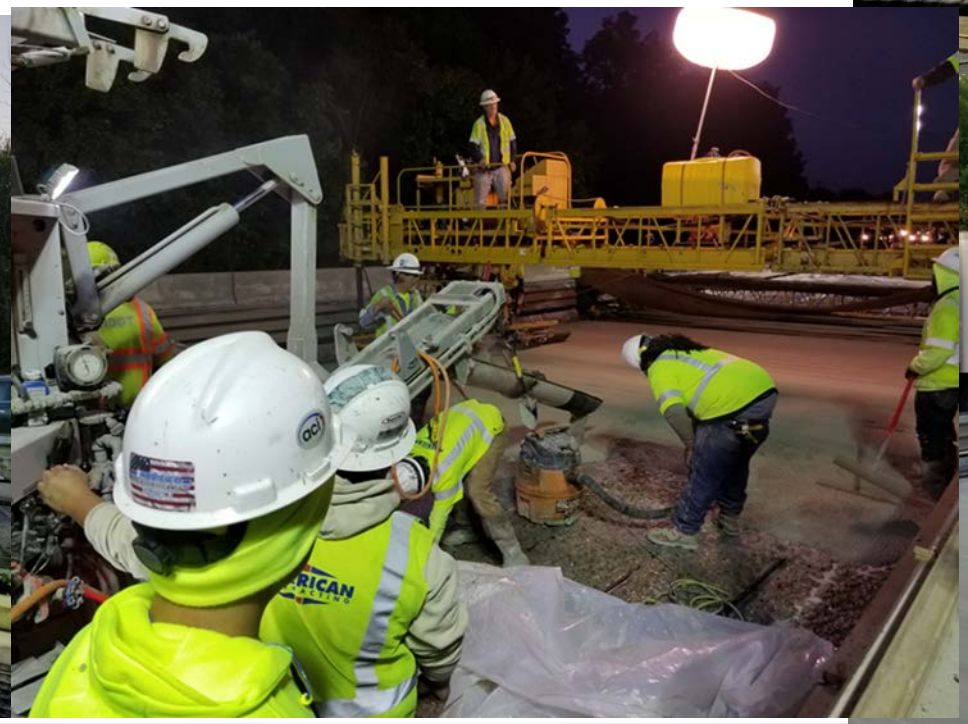
**IN DOT**
**2018 Construction**
**I-65 Columbus IN**



# RSLMC Bridge Decks

**IN DOT**
**2018 Construction**
**I-465 Carmel IN**



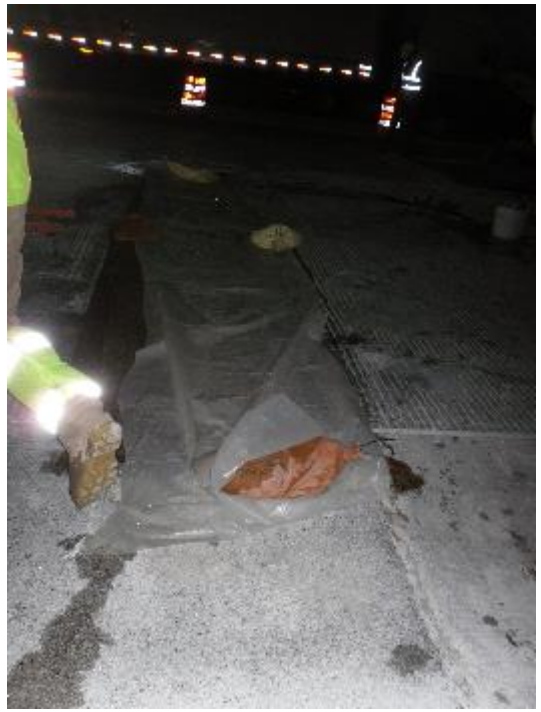


# Bridge Decks Closer Pours

**TN DOT**
**2018 Construction**
**Poplar Street Bridge over I-240**
**Closure Pour**



# IL Toll Road Precast Panel Closures and Bedding Grout



# Tyndall AFB
# Laboratory Crater Repair

**Damage to reopening**
**4 Hours 10 Craters 1 Crew**


f. **Rapid Set is recommended as the user's choice for crater repairs due to its ease of use, controllable set time, performance, and fast cure time.**

g. **Future exercises should be conducted to determine if the recommended repairs could be completed in the 4-hr time frame using manpower and equipment similar to that available during expedient and sustainment operations.**

h. **The required cap thickness as a function of backfill strength and expected aircraft loading should be explored through additional field testing and/or the use of finite element models. Until this testing is complete, Table 34 provides a matrix of layer thicknesses for standard pavement sections for typical design aircraft, traffic levels, conservative material properties, and relevant environmental conditions for expedient and sustainment repair.**

# Government

- Rapid Set Repair Mix is used by US Military all over the World at Bases  for Concrete Repairs
- Shipped in one ton sacks

# LaGuardia Airfield | Taxiway Full Depth Panel Replacement

- 300 cu. yd. @ 20” thick
- Weekend replacement
- Ready mix delivery with batch plant on-site
- Opening strengths achieved and on-time performance delivered

# SEA-TAC Airfield Rehabilitation

Runway 16C Concrete Panel Replacement Program
(1994-2005)


- **1,200 aircraft movements daily**
- **600 aircraft landing on rapid set CSA concrete panels (slabs) daily**
- **35,000 $yd^3$ of Rapid Set® CSA concrete placed (708 panels)**
- **Runway and Taxiways**

# 1994 –Seattle Airport Runway

## Largest Use of B-CSA on Airfield Pavement in the World


**Fast Runway Rehabilitation**

**Fast Taxiway and Apron Rehabilitation**

**1995-current**

**39,239 Cu yds of BCSA Concrete**

**Now used by more than 40 Airports Worldwide**

# SEA-TAC Airfield Rehabilitation Research

2012

## FATIGUE LIFE RESEARCH

***"Flexural Fatigue Behavior of Plain Concrete Fabricated with CSA Cement"***

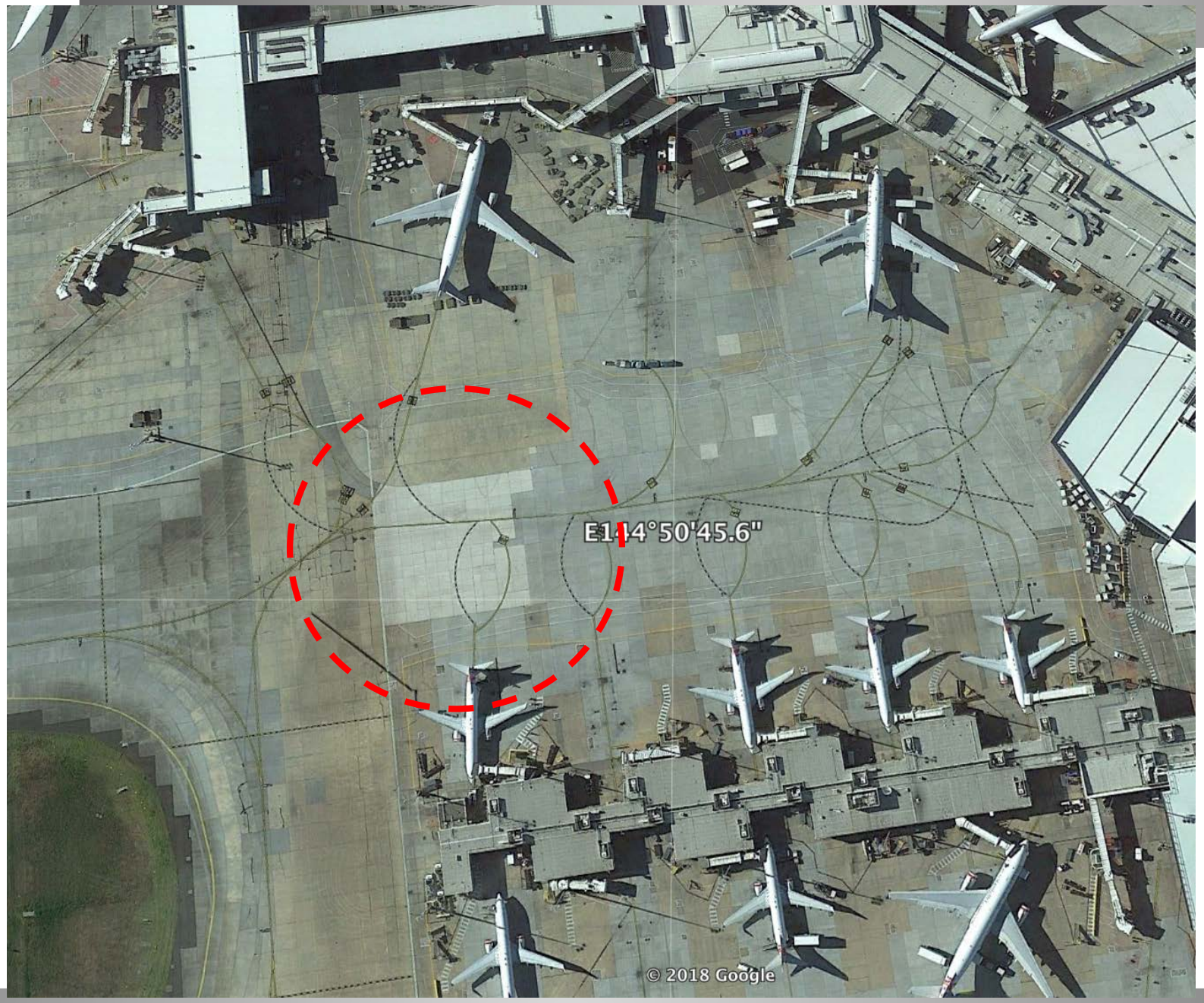
**OPC Mix** | Replacement Rate: 35.5%
**CSA Mix** (ASTM 1600) | Replacement Rate: 3.8%

**Estimation of Fatigue Life = 87 years**

*Report and Testing by Construction Technology Laboratories, Inc. (CTL)*

- *Static Flexural Strength (ASTM C78)*
- *Repetitive Loading at Various Stress Ratios (0.48 – 0.89) (ASTM D1195/D1195M)*

Melbourne
Tullamarine



# Hartsfield-Jackson Atlanta International

## Full Depth Panel Replacement

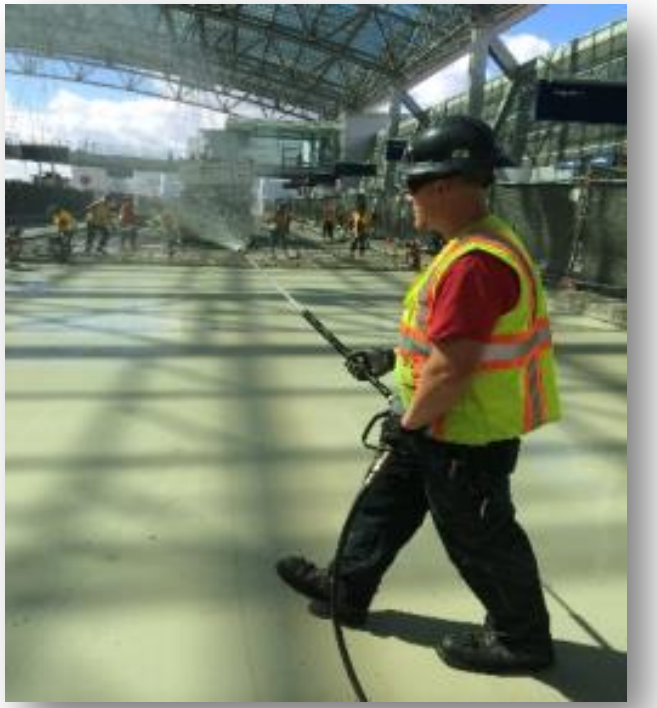


***The World's Busiest Airport with 5,000 Flights/Day***

# Hartsfield-Jackson Atlanta International

## Full Depth Panel Replacement


# PDX Elevated Departure Road



- Over 140 yds. placed over 2 Day Shifts
- 1 Day compressive breaks averaged 4,350 psi

# Panel Replacement

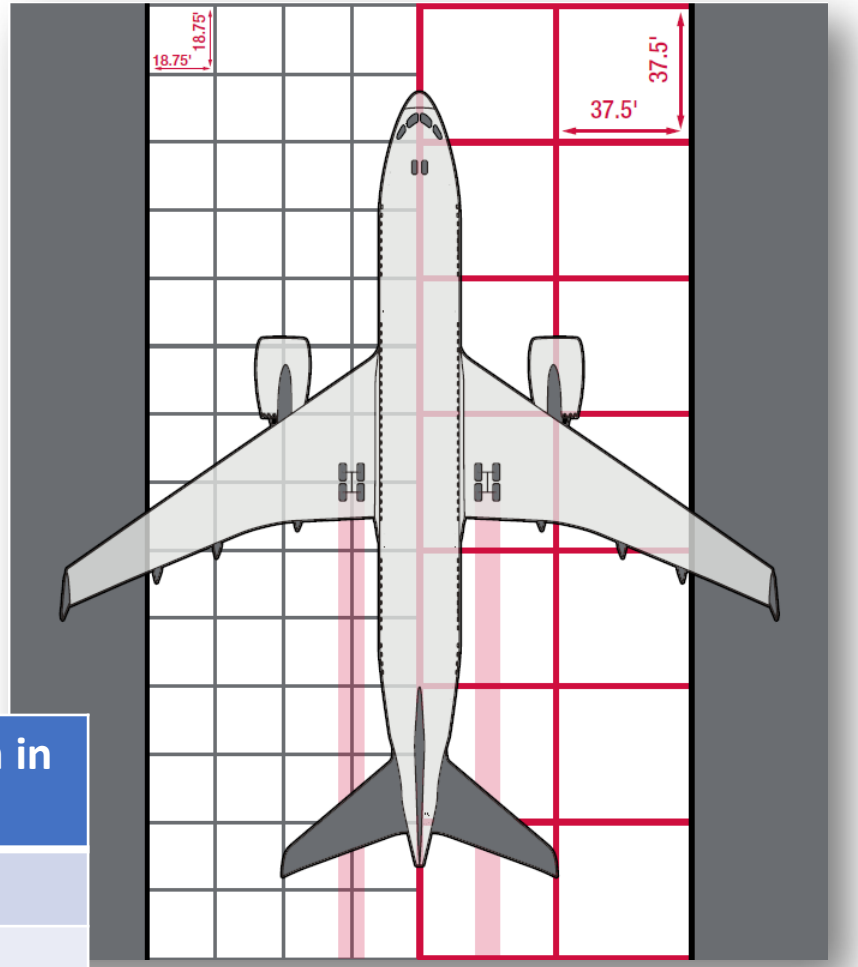
## Airports Around the World

- **Los Angeles International (LAX)**
- **Boston Logan (BOS)**
- **Savannah/Hilton Head (SAV)**
- **Portland International (PDX)**
- **Auckland International (AKL)**
- **And more…**

| Airport | Date | Application |
|---|---|---|
| SEA – Seattle-Tacoma Int'l Airport | 1994-1998 | Runway Panel R&R |
| MDW – Midway Int'l Airport | 1998 | Runway Panel R&R – Bulls-Eye Intersection |
| SNA – John Wayne Int'l Airport | 1998 | Parking Garage |
| BOS – Boston/Logon Int'l Airport | 2004 | Runway Repairs |
| ICT - Wichita Dwight D Eisenhower Airport | 2004 | Runway and Apron Repairs |
| KCI – Kansas City Int'l Airport | 2004 | Runway and Apron Repairs |
| ATL – Atlanta/Hartsfield Int'l Airport | 2004 | Runway and Taxiway Repairs |
| EWR - Newark Liberty Int'l Airport | 2005 | Runway and Taxiway Repairs |
| JFK - John F. Kennedy Int'l Airport | 2006 | Runway and Taxiway Repairs |
| LGA - LaGuardia Int'l Airport | 2006 | Runway and Taxiway Repairs |
| **TSA – Taipei Songshan Int'l Airport** | 2007 | Panel R&R, Patch work, & ELT Lights |
| CAE - Columbia Metropolitan Airport | 2007 | Runway and Apron Repairs |
| MEM - Memphis Int'l Airport | 2008 | Runway and Apron Repairs |
| SDF - Louisville Int'l Airport | 2008 | Panel R&R |
| STL - Lambert–St. Louis Int'l Airport | 2008 | Parking Garage Repairs, Panel R&R |
| LAX – Los Angeles Int'l Airport | 2008 | Runway Repair & ELT Lights |
| PHL - Philadelphia Int'l Airport | 2009-2010 | Runway and Taxiway Repairs |
| **SYD – Sydney Int'l Airport, Australia** | 2009 | Runway and Taxiway Repairs |
| PHX - Phoenix Sky Harbor Int'l Airport | 2010 | Runway and Taxiway Repairs |
| **DXB - Dubai Int'l Airport** | 2011 | Runway Patch repairs |
| **MEL - Melbourne Int'l Airport** | 2011 | Runway and Taxiway Repairs |
| **SPN - Saipan Int'l Airport** | 2012 | Taxiway Panel R&R & ELT Lights |
| PDX – Portland Int'l Airport | 2014 | EDR overlay |

# On-Going Research

- **FAA Standards Limit Airport Slab Sizes to 20-25 feet**
- **Larger Slab Sizes. . .**
  - Reduce Maintenance By Reducing the Number of Linear Feet of Joints
  - Prevent the Outside Wheel of Wide-Bodied Aircraft from Rolling Along a Joint
  - Minimize FOB Concerns



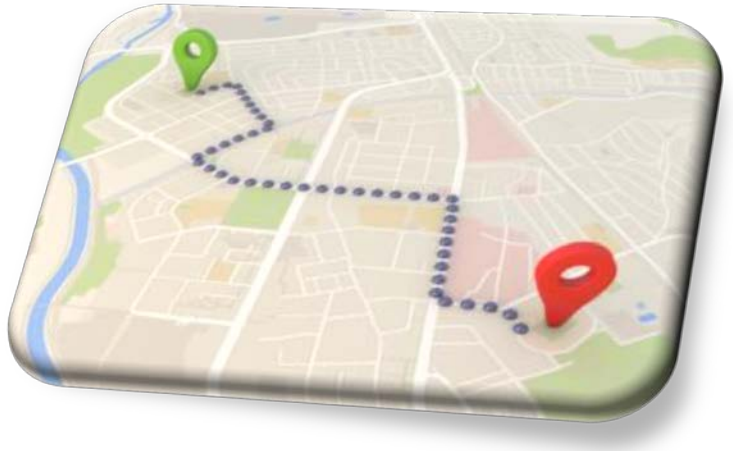

| Slab Size | Number of Slab | Linear Feet of Joints | % Reduction in Joints |
|---|---|---|---|
| 18.75’ | 3,840 | 134,850 | --- |
| 25’ | 2,160 | 98,850 | 27% |
| 37.5’ | 960 | 62,850 | 53% |

## Mix Designs

- **Mix Designs Can Be Customized To Suit the Project Timeline**
- **Offers Flexibility in Phasing**
  - Provide Structural Strength in 1 up to 12 Hours
  - Accommodate Accelerated Schedules
  - Contractor Friendly – Provides More Working Time

## Must provide enough time to allow for transport & placement

- **Options**
  - Retarding Admixtures
  - Amount and temperature of water added
  - Temperature of materials at time of mixing
  - Method of Delivery



# Production

## Ready-Mix Delivery

- Produced at a local batching plant
- Delivered to job site by tuck mounted in-transit mixers
- Measured by weight of ingredients
- More precise than on-site batching plants
- Final quality & working time influenced by time in transit
- Additional fees apply

## Volumetric On-Site Batch Plant


- A.k.a. “Metered Concrete”
- Concrete components mixed on-demand; produce the precise amount needed
- No excess, no waste
- Measures by volume instead of by weight
- Most precise method of production (highest quality control)
- Prevent short load challenges
- Pay for actual usage

# Spécifications: ASTM C1600

Designation: C1600/C1600M – 11

**Standard Specification for**
**Rapid Hardening Hydraulic Cement**[1]

(must be reported on manufacturer's certification)

| | Cement Type | | | |
|---|---|---|---|---|
| | URH | VRH | MRH | GRH |
| Compressive Strength (See Section 9 for procedures), min, MPa [psi] | | | | |
| 1½ h | 21 [3000] | 12 [1700] | . . . | . . . |
| 3 h | 28 [4100] | 15 [2200] | 10 [1500] | 7 [1000] |
| 6 h | . . . | . . . | 14 [2000] | 10 [1500] |
| 1 day | 35 [5100] | 24 [3500] | 17 [2500] | 14 [2000] |
| 7 days | 41 [6000] | 28 [4100] | 28 [4100] | 24 [3500] |
| 28 days | 57 [8300] | 35 [5100] | 31 [4500] | 28 [4100] |
| Drying Shrinkage, max % | | | | |
| 7 days | 0.06 | 0.06 | 0.08 | 0.10 |
| 28 days, air storage | 0.07 | 0.07 | 0.09 | 0.12 |
| Min Time of Final Set C191 apparatus | | | | |
| Minutes[A] | 10 | 10 | 10 | 10 |
| Autoclave, max expansion % | 0.8 | 0.8 | 0.8 | 0.8 |

[A] The initial setting time typically ranges from 10 to 45 min for rapid hardening cements of various types and composition.

Best Approach: Specify Early strength AND Low Shrinkage

# Thank You!


***We are committed to growing our businesses together with you!***

***ASTM C878***

***Standard Specification for the Restrained Expansion of Shrinkage-Compensating Concrete***

**Vs.**

***Keeping restrained expansion in perspective….***