MAXIMIZE PERFORMANCE

WITH ADVANCED CEMENT TECHNOLOGY

Infrastructure and Transportation Product Line Overview

www.CTScement.com

Rapid Set KOMPONENT

by CTS Cement Manufacturing Corp.

MAXIMIZE PERFORMANCE & EXTEND ASSET LIFE

Concrete, the world's most widely used building material, has a proven track record of long-term performance in the development of infrastructure, commerce and many modern conveniences in today's built environment.

The current state of America's infrastructure, a well-publicized "Poor" rating for roads and bridges across the country, illustrates the precarious condition of these integral economic assets. This requires a paradigm shift in designing new structures, and in repairing and rehabilitating existing ones. Industry initiatives are focused on preventing deterioration and failure, maximizing durability and service life, and improving safety. By improving performance standards, these objectives can be achieved.

Integrating higher quality materials, design and construction methods also minimizes maintenance, repair and replacement costs, and inconveniences to commuters and businesses. This ensures wise stewardship of today's investments for tomorrow's generations, creating a safer, more sustainable built environment.

[1] ASCE 2013 Report Card for America's Infrastructure; http://www.infrastructurereportcard.org

CHANGING THE PARADIGM

The most common challenges associated with concrete deterioration and failure are related to cracking, chemical attack, and long-term durability. Traditional industry solutions designed to overcome the shortcomings of ordinary portland cement concrete can have undesirable side effects on other key performance aspects, like compressive strength and long-term dimensional stability.

The answer lies beyond ordinary portland cement and prescriptive admixtures – in advanced Rapid Set® Cement technology powered by belitic calcium sulfoaluminate (bCSA) cement. The CSA cement technology in Rapid Set® Cement, originally developed in the 1950s, is engineered to achieve significantly higher levels of performance in these three key performance areas: crack resistance, chemical resistance, and long-term durability. Today, millions of cubic yards of concrete using CSA cement technology are placed worldwide each year.

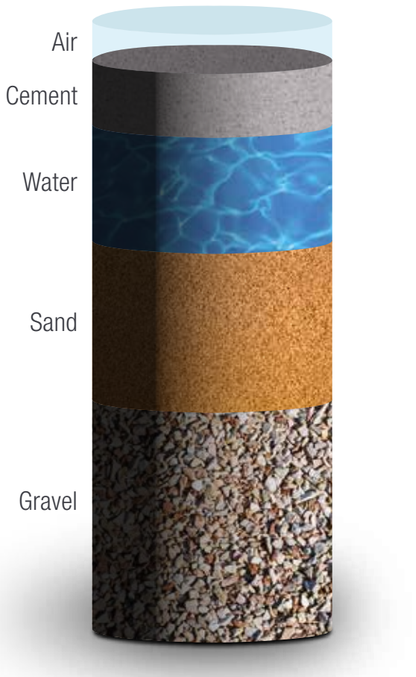
CRACKING CONCRETE

Drying shrinkage is one of the major causes of cracking in ordinary portland cement (OPC) concrete and concrete repair materials, leading to deterioration and failure. A certain amount of water (roughly 0.45 w/c ratio by weight) is required in all hydraulic cement concretes to coat the cement particles and ensure adequate fluidity for placement. When the cement particles hydrate and form cementitious compounds, some of this mix water is consumed in the associated chemical reaction. Any leftover water is termed “water of convenience” and migrates to the surface as ”bleed water". This excess water increases the w/c ratio at the surface, and creates capillary channels and voids that result in drying shrinkage, and creates points of entry for contaminants.

Rapid Set® Cement technology addresses this issue. By using a more efficient hydration mechanism when water is combined with CSA cement, over 98% of the mix water is consumed in the hydration reaction, compared to roughly 50% consumption in OPC concrete. Greater consumption of water with CSA cement minimizes “water of convenience” and the resulting drying shrinkage cracking. This produces stronger, more durable concrete and concrete repair materials. These characteristics are intrinsic to Rapid Set® Cement’s chemical composition and are achieved without supplementary cementitious materials or admixtures.

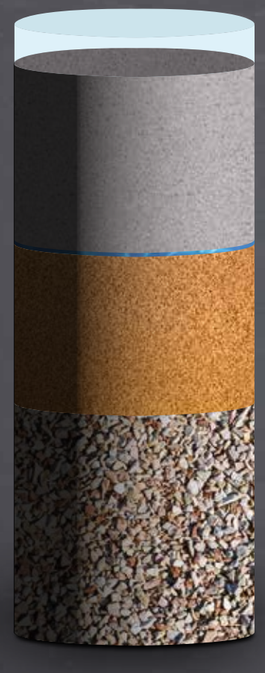
PORTLAND CEMENT CONCRETE

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



IMPROVE PERFORMANCE

1 Eliminates Water of Convenience
from migrating to the surface. This prevents voids and capillary channels common within OPC placements that lead to shrinkage cracking, contamination and deterioration.

2 Eliminates Curling and Warping
of concrete placements due to rapid moisture loss at slab surfaces. Preventing these common occurrences reduces corner breaks and impact spalls that occur when exposed to in-service traffic, and associated repair and maintenance costs.

3 Maintains Design Strength
throughout the concrete/concrete repair placement by eliminating a detrimental change in w/c ratio at the surface. This results in higher impact, abrasion and spall resistance.

98%

Full hydration of cement particles and efficient consumption of 98% or more of the mix water achieves key industry objectives.

PROOF POSITIVE

ASTM C1581, known as the "Ring Test", is the industry standard for determining crack resistance by quantifying the age of initial cracking of restrained concrete or mortar material. Results are based on evaluation of shrinkage, tensile strength, modulus, and tensile creep. Comparative results based on independent lab tests of Rapid Set® Concrete and a competitive portland cement/admixture mix design provide insights about the exceptional performance characteristics of CSA cement-based materials.

METHOD	TRADITIONAL OPC + ADDITIVES	RAPID SET® CONCRETE	RAPID SET® ADVANTAGES
ASTM C157 • Length Change • 3x3 Shrinkage Bars • 28 Day Water Cure • 28 Day Air Cure	Average -0.045%	Average -0.020%	Less than 1/2 the Shrinkage of OPC Concrete
ASTM C1581 • Restrained Shrinkage, Net Time to Cracking • 3 Ring Specimens • 50% RH, 73°F	Average Cracked at 8.90 Days	Average None at 90 Days	Exceptional Crack Resistance
ASTM C1581 • Restrained Shrinkage, Stress Rate • 3 Ring Specimens • 50% RH, 73°F	Average 22.53 psi/day	Average 1.66 psi/day	14x Lower Stress Rate
ASTM C1581 • Restrained Shrinkage, Cracking Potential • 3 Ring Specimens • 50% RH, 73°F	Moderate to High	Low	Exceptional Crack Resistance

ASTM C1581 Ring Test

This test is designed to determine the age of initial cracking of restrained concrete repair materials. Forces contributing to cracking are evaluated. Material is cast around a steel ring with strain gauge sensors on the interior that measure developed stresses at defined intervals. Susceptibility to cracking is relative to tensile stresses exceeding tensile strength of the material.

SULFATE RESISTANCE

Rapid Set® Cement provides the highest resistance to sulfate attack. Unlike OPC (including Type II moderate sulfate resistance and Type V high sulfate resistance), Rapid Set® Cement contains no tri-calcium aluminate (C_3A) compounds. Because "[it] is the C_3A that attacks sulfates, concrete vulnerability can be reduced by using cements low in C_3A."[2] Rapid Set® Cement minimizes the potential for sulfate attack by eliminating C_3A altogether.

Rapid Set® Cement also provides low porosity, low permeability, and lower alkali content. This makes it an exceptional solution for reducing alkali-silica reaction (ASR)[3] and preventing catastrophic concrete failures. Its low porosity and prevention of drying shrinkage cracking resists chloride ion penetration and resulting deterioration of the concrete and corrosion of steel reinforcement.

FREEZE/THAW RESISTANCE

Rapid Set® Cement's low permeability is resistant to freezing and thawing exposures. Its rapid hydration and strength gain allow it to be used in cold weather installations that are not possible with OPC mix designs. This extends the construction, repair and maintenance season in colder regions and provides a ready solution for emergency repairs when colder conditions prevail.

DIMENSIONAL STABILITY

The early, marginal expansive nature of Rapid Set® Cement makes it ideal for use in concrete repair and renovation, and restrained placement applications. Rapid Set® materials are highly compatible with portland cement-based materials, and create a strong bond that eliminates "shrink back" at patch or repair perimeters, and prevents de-bonding.

[2] American Concrete Institute, "ACI 365.1R-00 – Service-Life Prediction" (Farmington Hills, MI: ACI Committee 365, 2000)

[3] CTL Report 059154. "ASTM C 1600-07 Testing, Rapid Hardening Cement," (Skokie, IL: CTLGroup ID 2236701, 2010)

[4] National Transportation Product Evaluation Program. "NTPEP Product Evaluation Report #2014-01-010 and #2014-01-011," (Washington, D.C.: NTPEP Reports, 2015)

NOT ALL RAPID STRENGTH CEMENTS ARE ALIKE

Rapid Set® Cement excels in key performance criteria including: advanced material properties, installation efficiencies, application versatility, and sustainability. Rapid Set® is not ordinary portland cement mixed with admixtures, nor is it an accelerator. And, it is not a calcium aluminate cement prone to strength regression. It is an innovative, proven belitic calcium sulfoaluminate (bCSA) advanced cement technology used worldwide on projects where time, money and long-term durability are essential.

		RAPID SET® (CSA CEMENT) ASTM C1600	Competitive Rapid Setting Cements				Other
			ACCELERATED TYPE-III FOUR HOUR PORTLAND CEMENT ASTM C150	CSA PORTLAND BLEND ASTM C157, C595, C1600	HAC / CAC (CALCIUM ALUMINATE) ASTM C1600	REACTIVE FLY ASH CEMENT ASTM C1600	ASPHALT
SUSTAINABILITY	Durable 80+ Year Lifetime	✓					
	Zero Shrinkage	✓					
	Low CO_2 Technology	✓				✓	
ADVANTAGES	In Use with Proven Performance Since 1994	✓					✓
	Structural Stength in One Hour	✓		✓	✓	✓	
	Volumetric & Ready-Mix Production	✓		✓			
APPLICATIONS	Pavements	✓	✓	✓	✓	✓	✓
	Bridge Deck Overlays	✓	✓				✓
	Repair Applications	✓		✓	✓	✓	
	Structural Repair Applications	✓	✓	✓			
MATERIAL PROPERTIES	Unaffectd by Strength Regression	✓	✓	✓		✓	✓
	Low Porosity	✓					
	100% Sulfate Resistant	✓					✓

FAST IS DURABLE

RAPID SET® CHANGES THE GAME

Structural Stength in One Hour

Rapid Set® Cement products gain structural strength in one hour, allowing quick return to service and minimal commuter disruption and congestion. You save significant time and money, with reduced installation times and labor requirements – while maximizing goodwill in the surrounding communities and businesses.

Short-Term Repair Can Be a Long-Term Solution

Rehabilitated concrete is often associated with a limited life span. With Rapid Set® Cement technology, that is no longer the case. Extensive independent fatigue testing proves that Rapid Set® Cement concrete achieves a service life of up to 100 years. This extended life span maximizes asset life while minimizing lifecycle costs and ensuring maximum return on the asset investment.

The Near Zero Shrinkage Solution

Traditional concrete and concrete repair materials shrink extensively leading to cracking, curling, spalling, and ultimately, deterioration and failure. With Rapid Set® Cement technology, drying shrinkage is reduced to near zero. Durability is increased and the potential for cracking minimized or eliminated without the use of additives. This cannot be achieved with ordinary portland cement and shrinkage reducing admixtures.

Low Carbon Footprint, Maximum Sustainability

Rapid Set® Cement has several sustainability advantages: 32% reduced carbon emissions, 65% lower consumption of natural resources and energy, and 2 times the service life of traditional cement. By maximizing long-term durability and extending service life, you achieve a higher level of sustainability and minimize resource utilization, asset maintenance, repair and replacement.

A common misconception in concrete and concrete repair materials is that trade-offs are unavoidable and concessions must be made between speed and performance. This is due to the adverse effects of common prescriptive additives used in portland cement-based materials.

With Rapid Set® Cement technology, the paradigm shifts. Concessions do not need to be made. You can achieve speed and exceed performance.

Decades of proven in-service performance, extensive independent testing, and collaborative industry and academic testing programs have demonstrated the exceptional performance of CSA cement-based Rapid Set® technology.[5]

After 2 Years
Type II Portland (8% C_3A)

After 6 Years
$C_4A_3\overline{S}$ Cement (0% C3A)

[5] *CTL Report 103009. "CTS-Sulfate 08-98," (Skokie, IL: CTLGroup, 1998)*

AN INNOVATIVE SOLUTION

Demands on existing infrastructure continue to increase. The construction of new assets is vital to continued economic growth and regional development worldwide. And for stakeholders, time is money. Maximizing service life while minimizing thoroughfare disruption and associated user costs for construction, maintenance, and repair is essential. Rapid Set® Cement technology provides an innovative solution to achieve exceptional, sustainable results. Building a safer, more sustainable and economical built environment is possible today.

1. ★★★★★ Maximize Productivity with 1-Hour Structural Strength
2. ★★★★★ Ideal for Low Temperature Installations
3. ★★★★★ Low Shrinkage, Thin Overlays Are Possible
4. ★★★★★ Optimize Panel and Precision Grouting Operations
5. ★★★★★ Minimize Disruptions and Downtime

AVAILABILITY & SUPPORT

Rapid Set® Cement and pre-blended Rapid Set® products are available in bulk transport for large infrastructure and construction projects. Bagged products are available for small and medium sized applications and repair projects. Materials are distributed in the United States and worldwide.

Production options include Volumetric (or “Mobile”) mixers that produce concrete “on-demand”, ensuring a fresh mix every time while eliminating overages, shortages and lost loads. Regional Ready-Mix and portable on-site batch plants are also available.

CTS Cement’s Engineering, Technical Service and Support teams are available to provide training to engineering and construction teams, participate in pre-construction meetings, and assist with mix designs and pre-qualification requirements

CASE STUDIES

OHIO TURNPIKE

In the early 1980s, the Ohio Turnpike Authority initiated a High Performance Bridge Deck Replacement Program that included an evaluation of bridge deck replacements using conventional portland cement concrete and Type K Shrinkage-Compensating Concrete. The Type K Shrinkage-Compensating Concrete was used on a variety of bridge decks located on US Route 33, I-675 and I-80.

In 2008, results of the High Performance Bridge Deck Replacement Program were published noting a dramatic improvement in performance of the Type K Shrinkage-Compensating Concrete placements. In decks placed between 1984 through 1989, inspection reports indicated 95 to 97.8% of the bridge decks to be “crack free” with less than 3% reported with only minor cracking related to drying shrinkage. No Moderate or Severe cracking was noted on any of the Type K bridge decks.

The Ohio Turnpike Authority Chief Engineer offered commendation for the performance results. “Type K Shrinkage-Compensating Concrete addresses many concerns for the safety to ride characteristics. We don’t even think about cracks, crack maintenance or spalls on our shrinkage-compensating concrete decks. We’re expecting 35-year life on the decks’ wearing surface.”

This is a testament to the industry’s leading technology for durable, long-life pavement solutions for both new construction, renovation and repair.

ROCKFORD AIRPORT

Eliminating joints in runways and taxiways has long been an objective of the Federal Aviation Administration (FAA). Joints are usually the location of spalling, causing a “bumpy” landing experience for passengers. They also create safety hazards for airport personnel, costly maintenance and repair projects, and expensive engine repairs when loose concrete fragments (e.g. foreign object debris – FOD) are sucked into jet engine intakes.

After lengthy research initiatives conducted by the FAA to identify the most durable pavement solution that would reduce the number of joints required on airport runways and taxiways and significantly reduce the costs associated with maintenance and repair, Type K Shrinkage-Compensating Concrete was chosen for use on one of the most unusual concrete slabs ever constructed. In 1993, this innovative, post-tensioned, steel fiber reinforced pavement solution was placed at the Rockford International Airport’s Runway Extension project in Rockford, Illinois. It was placed next to a conventional portland cement concrete “control” section to provide comparative performance results.

Using steel fiber reinforced Type K Shrinkage-Compensating Concrete, the contractor was able to place two contiguous “Innovative Pavement Slabs” (IP1 and IP2, respectively) of taxiway paralleling a new runway extension. IP1 and IP2 were placed in 75-foot wide pavement sections with post-tensioning able to be delayed up to 7 days. The additional flexural strength provided by using steel fibers allowed a reduction in pavement thickness to 10 inches. Transverse joints were cut in IP1 at varying span lengths from 85 feet to 200 feet to test how far apart natural cracking of the material would be with increased joint spacing. IP2 used steel fiber reinforced Type K Shrinkage-Compensating Concrete for a 1,200 foot long placement with longitudinal post-tensioning and no saw-cut shrinkage control joints. A slip-sheet was used to reduce subgrade drag. IP2 utilized the longitudinal pre-stressing characteristics of Type K with post-tensioned tendons placed 12 inches apart to prevent shrinkage cracking. The increased flexural strength provided by post-tensioning allowed further reduction in slab thickness to only 7 inches.

The FAA’s “Constructability Report” recorded that the “use of Type K did not create handling, storing or delivery problems.” The pavement was inspected quarterly for five years. And after 10 years of heavy use, the slab was performing exceptionally well with minimal cracking and virtually no spalling. The FAA’s Pavement Condition Index (PCI) reported the conventional OPC control slab in Good condition (PCI of 67), the non post-tensioned Type K cement slab (IP1) in Very Good condition (PCI of 82), and the post-tensioned Type K cement slab (IP2) in Excellent condition (PCI of 98).

With proven performance for over 60 years, Type K Shrinkage-Compensating Concrete is the industry’s most durable long-life pavement solution engineered to reduce life-cycle costs, maximize sustainability, prevent costly FOD damage and repairs – all while keeping runways and taxiways open and passengers satisfied with on-time performance!

“The pavement has held up extremely well. The cracking has been very, very minimal. There were some initial concerns with the fibers breaking loose, but that has not occurred. It has not caused any Foreign Object Damage (FOD) concern.”

– Franz Olson, Deputy Director of Operations & Facilities at Chicago-Rockford International Airport

HIGHWAY 280

Northbound lanes of the elevated freeway between downtown San Francisco and Highway 101 reopened on a busy Labor Day weekend, more than seven hours ahead of schedule. The highway had been closed as workers replaced two hinges, a complicated process requiring two 60-foot wide, 25-foot-long sections, 1/2 mile apart to be completely dismantled and rebuilt.

Joon Kang, the Project Manager for Caltrans, said the replacement work went without a hitch. The job required workers to demolish the entire 60-foot width of the bridge, leaving 25-foot long gaps. That required cutting through two 5-foot thick concrete sections. Due to the limited room to work beneath the elevated freeway, construction crews couldn't work on both hinges simultaneously. They had to remove and replace one hinge, then the other.

The intention was to complete the work over the holiday weekend when traffic was light, but that meant crews were under a tight deadline. Crews worked 24 hours a day over the four day timeline, with mobile concrete mixers standing by with Rapid Set® Concrete ready to mix and pour on-demand.

Kang said, "The Labor Day weekend project was a more intensive undertaking than other hinge replacement projects, because the two hinges were being replaced in one fell swoop. A conventional concrete pour requires a 28-day cure to achieve full strength and open to vehicular traffic, but we didn't have that time. We used Rapid Set® to improve efficiencies and meet the project deadline, and it is performing beautifully."

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