Building a Safer, More Sustainable World ...
One Project at a Time

Rapid Bridge Deck Repair and the Use of Volumetric Concrete Mixer Trucks

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CTS Cement Manufacturing Corp.

Leader in advanced belitic CSA cement technology with an extensive history of providing innovative and high-performance cement products to the construction industry.

CTS Cement is the leading manufacturer of:

Rapid Set®

A stand-a-lone, high performance, fast setting, high early strength Calcium Sulfoaluminate (CSA) cement

KOMPONENT®

A CSA-cement based expansive cementitious additive blended with local portland cement to create Type K shrinkage compensating concrete and grout materials

WHO WE ARE

Leading manufacturer of belitic CSA (bCSA) cement technology

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

TODAY'S DISCUSSION

1. What is Rapid Setting Cement?
2. RSC Testing
3. RSC Delivery via Volumetric Trucks
4. RS Mix Design vs. RS DOT Mix Design
5. RS Production & Placement

4 Main Categories of RSC

1. Accelerated portland cement
2. Calcium aluminate cement
3. Blended calcium sulphoaluminate cement
4. Non-blended belitic calcium sulphoaluminate cement
   bCSA (Rapid Set®)

4 Main Categories of RSC

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   bCSA (Rapid Set®)

A **stand-a-lone**, high performance, fast setting, high-early strength **belitic-Calcium Sulfoaluminate** (bCSA) cement

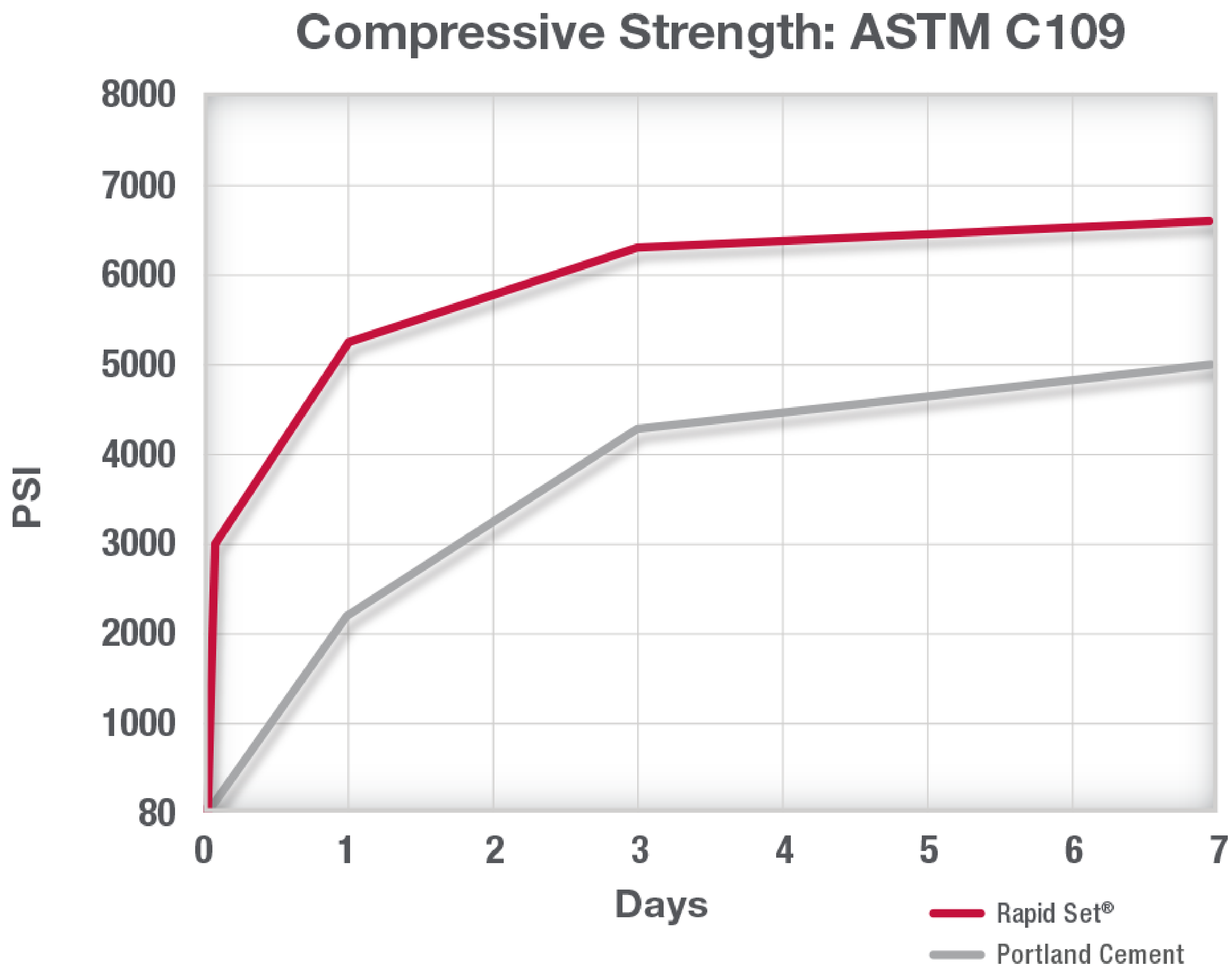
Key Characteristics of Portland Cement Concrete

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

Key Characteristics of BCSA Concrete

Strength Gain	5070 PSI in **1.5 hours** (w/o accelerators)	- Fast Return of Infrastructure to Service - Minimize Impact to traveling public and stakeholders - Minimize safety concerns - Ultimate compressive strength as high as 8700 PSI (Higher strength than portland cement at equal w/c)
Shrinkage	100-300 Microstrains @ 28d (w/o shrinkage-reducing admixtures)	- Prevent Cracking - Slab Size (up to 35 ft) - Distance Between Joints - Reduce Cost of Joint Maintenance - Service Life (80-100 years)
Porosity	10-20% of Volume	- Resistance to ASR, Ingress of Chlorides, Sulfates, etc. - High sulfate resistance due to absence of C_3A - Service Life (80-100 years)
Carbon Footprint	0.67 t CO_2/ t BCSA cement	- 32% Reduction in CO_2 Impact - 65% Reduction in use of Natural Resources & Energy - More Sustainable in Manufacture & Service Life

FAST STRENGTH GAIN



Specified via 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 for RSC concrete: Specify Early strength AND Low Shrinkage

Specified via ASTM C1600

Designation: C 1600/C 1600M – 08

Standard Specification for
Rapid Hardening Hydraulic Cement[1]

TABLE 2 Optional Requirements

Sulfate expansion[A] (C 1012)				
6 months, max %	0.05	0.05	0.05	0.05
1 year, max %	0.10	0.10	0.10	0.10
ASR Expansion[B] (C 441)				
14 days, max %	0.020	0.020	0.020	0.020
56 days, max %	0.060	0.060	0.060	0.060
Heat of Hydration (C 186)				
7 days, max, kJ/kg (kcal/kg)	250 [60]	250 [60]	250 [60]	250 [60]
28 days, max, kJ/kg (kcal/kg)	290 [70]	290 [70]	290 [70]	290 [70]
Expansion in Water (C 1038)				
14 days, max %	0.10	0.10	0.10	0.10

PRIMARY DIFFERENCES

Portland Cement Composition

	Early Strength Gain	Long-Term Strength Gain	Attacked by Sulfates		
ASTM C150 TYPE	C3S	C2S	C3A	C4AF	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

Belitic CSA Cement Composition - Rapid Set

	Early Strength Gain	Long-Term Strength Gain	Attacked by Sulfates		
ASTM C1600	C4A3S	C2S	C3A	C4AF	CS
Rapid Set	30	45	0	2	15

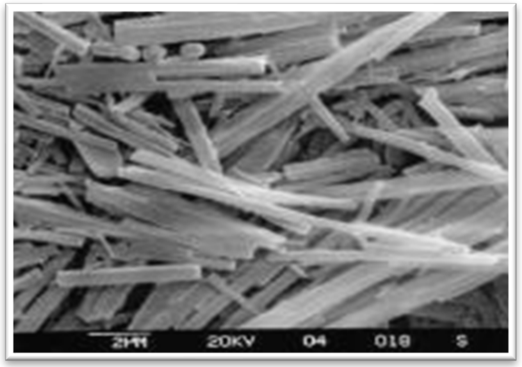
Quantities represent % composition

- **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**

ENHANCING PERFORMANCE

Advanced Hydration Mechanism

- Mix water is chemically retained ("bound") within the ettringite structure
- More efficient use of mix water (minimal water of convenience)
- Contributes to rapid hydration process and strength gain
- Rapid formation allows fast repair & quick in-service turnaround
- Increases density
- Lowers porosity & permeability
- Enhances resistance to chloride penetration



Maximum Formation of Ettringite Crystals Achieves High 1 to 1.5 Hr. Strength (Up to 7,000 psi)

Calcium Sulfoaluminate Cement

$C_4A_3\bar{S} + 8CaSO_4 + 6CaO + 96H_2O \rightarrow 3(C_3A \bullet 3CaSO_4 \bullet 32H_2O)$

CSA Cement + Calcium Sulfate (Anhydrite) + Lime + Water → Ettringite Crystals

Portland Cement

$2Ca_3SiO_5 + 7H_2O \rightarrow 3CaO \bullet 2SiO_2 \bullet 4H_2O + 3Ca(OH)_2$

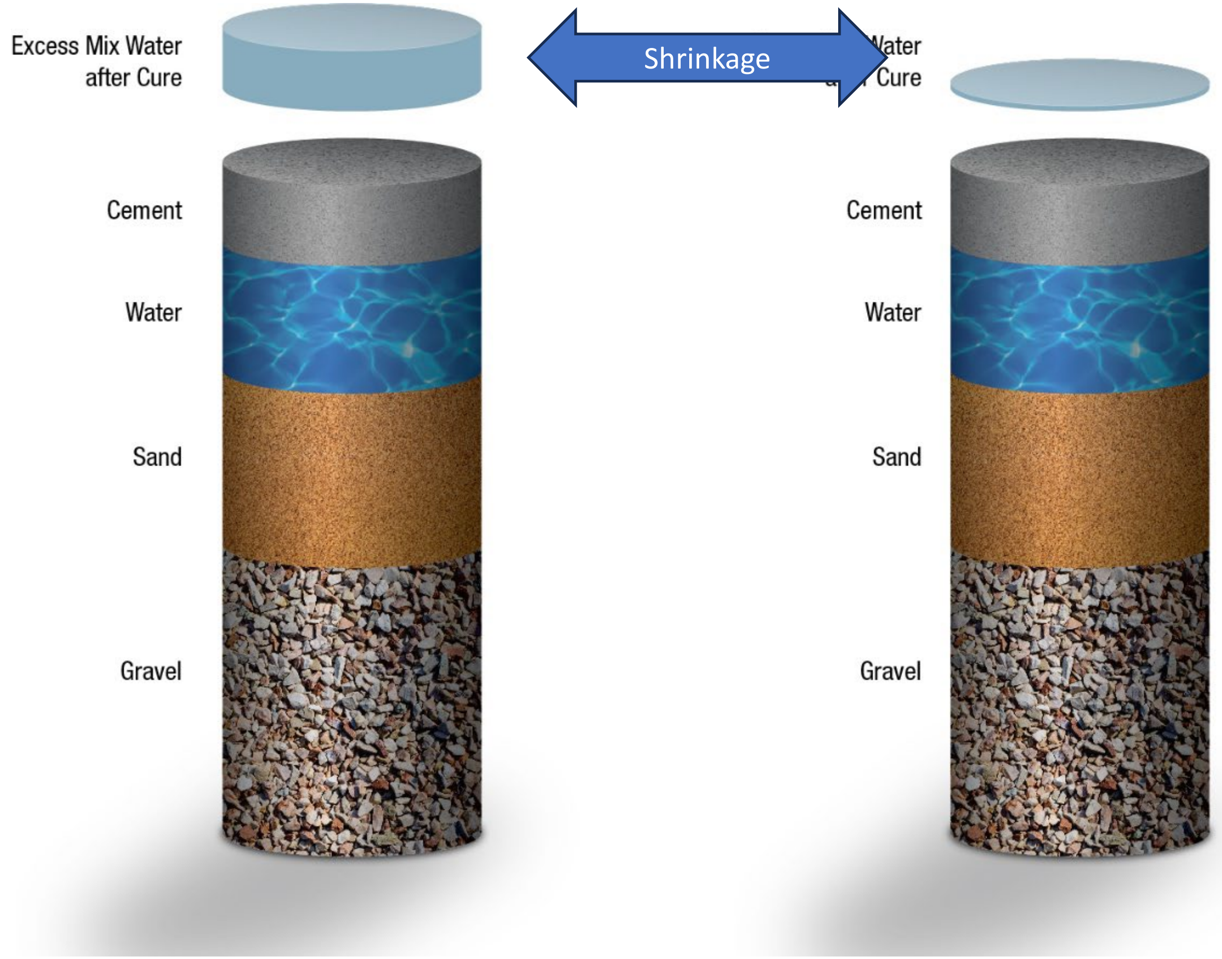
$2Ca_2SiO_4 + 5H_2O \rightarrow 3CaO \bullet 2SiO_2 \bullet 4H_2O + Ca(OH)_2$

Portland Cement + Water → Ettringite Crystals + Calcium Hydroxide Platelets

DIFFERENTIATING PERFORMANCE

Portland Cement Concrete

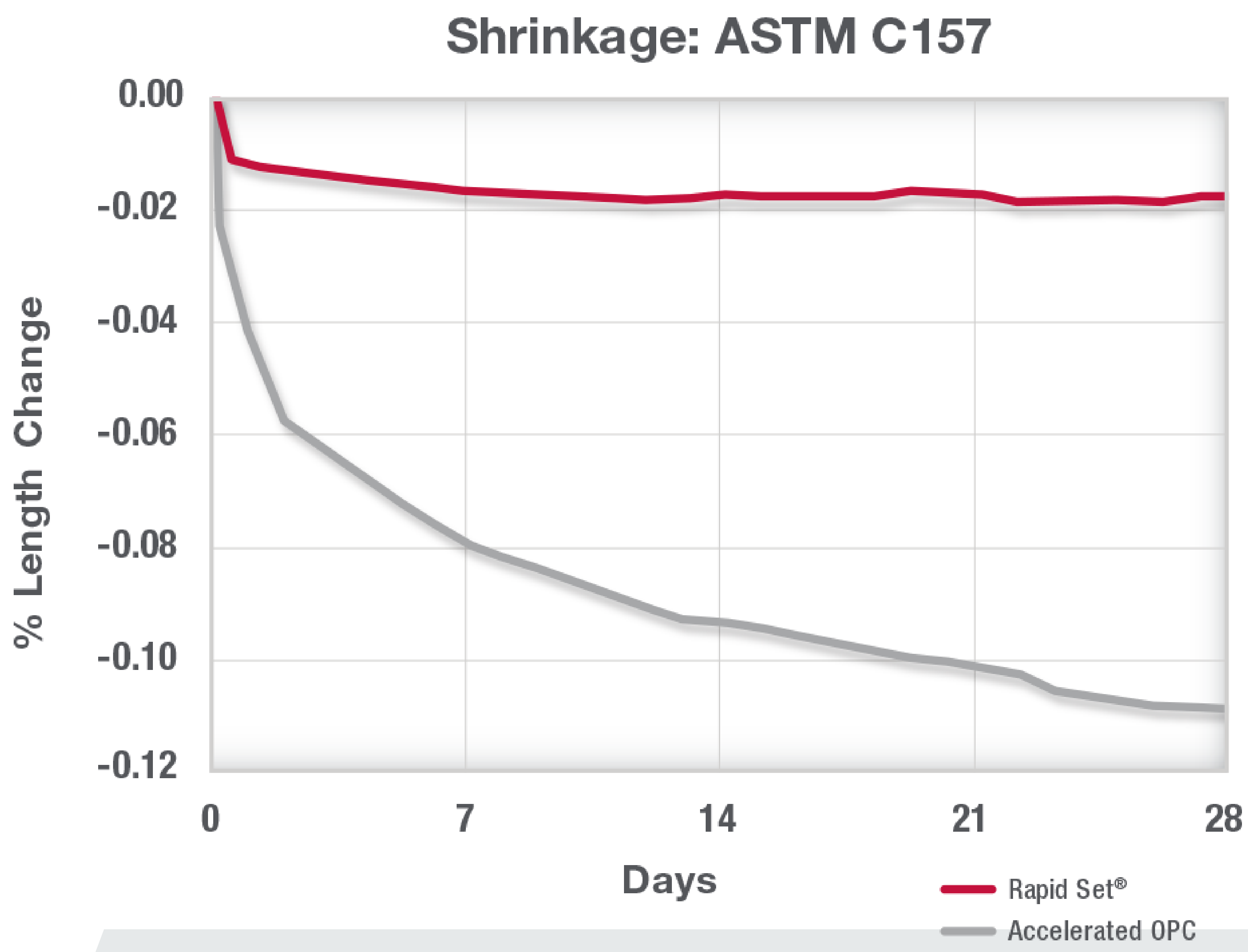
Only hydrates approximately 55% of the mix water leaving approximately 45% for evaporation



CSA-Based Cement Concrete

Hydrates approximately 98% of the mix water leaving approximately 0-2% for evaporation

LOW SHRINKAGE



RING TEST | C1857 RESULTS

NELSON TESTING LABORATORIES
EXPERIENCED | INNOVATIVE | AUTHENTIC

Concrete Study
NTL Project #1150-13

- ✓ **Low Shrinkage**
- ✓ **High Performance**

METHOD	TRADITIONAL OPC + ADDITIVES	RS BELITIC CSA CEMENT	PERFORMANCE
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, 73ºF	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, 73ºF	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, 73ºF	Moderate to High	Low	Exceptional Crack Resistance

Results:

	Belitic CSA Cement Mix #2013-009	Accelerated Portland Mix #2013-010
Net Time to Cracking		
*Specimen 1	none @ 90.00 days	cracked @ 7.94 days
**Specimen 2	none @ 90.00 days	cracked @ 9.54 days
**Specimen 3	none @ 90.00 days	cracked @ 9.21 days
AVERAGE	**none @ 90.00 days**	**cracked @ 8.90 days**
Stress Rate		
*Specimen 1	1.35 psi/day	33.16 psi/day
**Specimen 2	0.27 psi/day	13.15 psi/day
**Specimen 3	3.36 psi/day	36.28 psi/day
AVERAGE	**1.66 psi/day**	**22.53 psi/day**
Potential For Cracking		
*Specimen 1	Low	Moderate-High
**Specimen 2	Low	Moderate-High
**Specimen 3	Low	Moderate-High
AVERAGE	**Low**	**Moderate-High**

**Specimens cast from Mix 1*
***Specimen cast from Mix 2*

DIMENSIONAL STABILITY

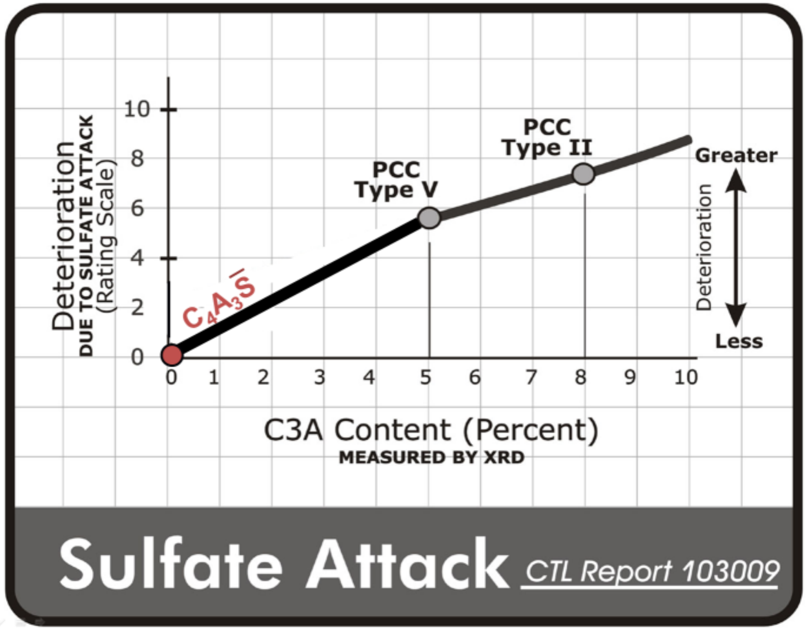
- *Concrete in new construction requires dimensional stability to ensure long-term performance is achieved.*
- *For repairs, dimensional stability requires a strong bond between existing material and new material.*
- *Bond failure is usually caused by shrinkage. Commonly soon after the new concrete material is cast.*
- *Repair materials must be essentially "shrinkage-free" to maintain a strong bond.*

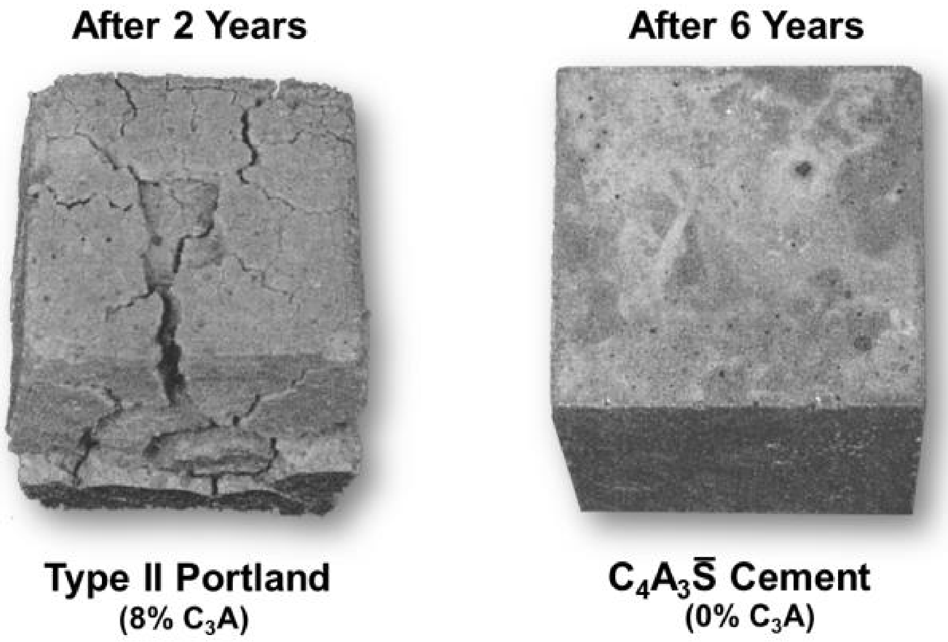
RS Belitic CSA Cement provides dimensional stability by providing

- ✓ Ultra low shrinkage
- ✓ Tenacious bond making it ideal for concrete repair, renovation and restrained placement applications
- ✓ Compatible with portland cement-based materials
- ✓ Creates a strong bond that eliminates shrink-back at patch or repair perimeters
- ✓ Prevents de-bonding

RS Belitic CSA Cement offers absolute sulfate resistance

- ✓ Contains negligible C3A content





CHLORIDE ION PENETRATION

- *This destroys the protective film on metal reinforcement.*
- *When oxygen and moisture reach the unprotected reinforcement, corrosion begins.*

RS Belitic CSA Cement helps prevent corrosion due to chloride ion penetration by reducing common penetration points (shrinkage cracks, voids & capillary channels)

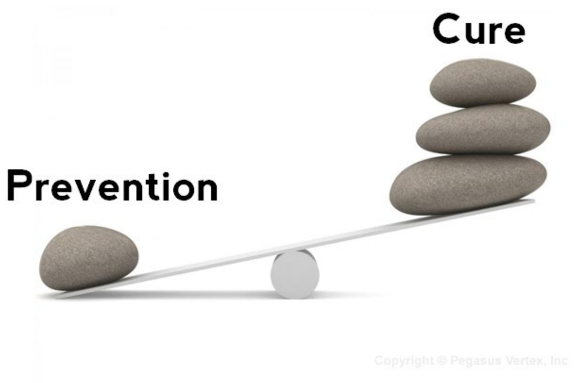
- ✓ Minimizing or eliminating drying shrinkage cracking
- ✓ Reducing the porosity and permeability* of the concrete
- ✓ *Mix design compatibility and versatility to achieve permeability requirements

ALKALI-SILICA REACTION (ASR)

- *Swelling reaction that occurs over time*
- *Reaction between highly alkaline cement paste and reactive non-crystalline aggregates in the presence of moisture*

RS Belitic CSA Cement helps mitigate ASR effects

✓ Ultra-low alkaline cement



FREEZE/THAW RESISTANCE

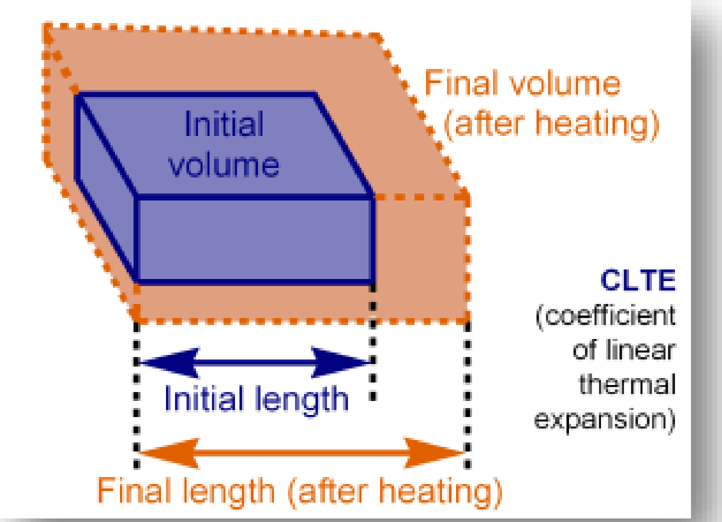
- *When water freezes it expands, producing pressure in the pores of the concrete.*
- *If pressure exceeds the tensile strength of the concrete, the cavity will expand and rupture.*
- *Cumulative freeze-thaw cycles and disruption of paste and aggregate eventually cause cracking, scaling, and crumbling of the concrete.*

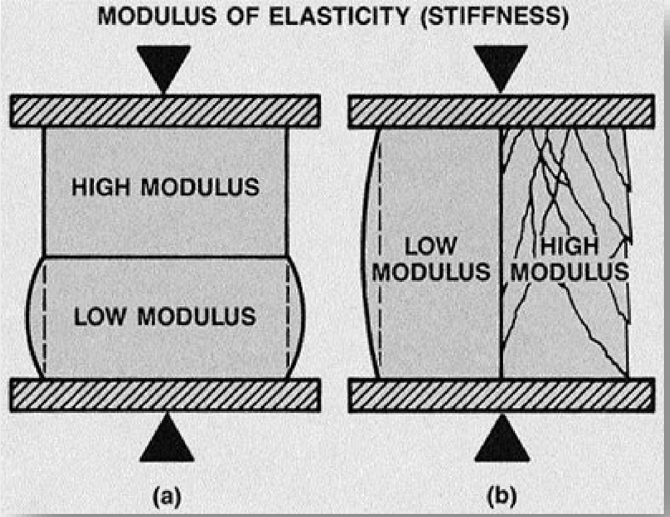
RS Belitic CSA Cement helps prevent freeze/thaw deterioration by advanced, rapid hydration mechanism and rapid strength gain

- ✓ Rapid strength gain is ideal for lower temperature installations
- ✓ Ideal for emergency repairs in lower temperature conditions
- ✓ Efficient and essentially complete consumption of mix water
  - Helps prevent detrimental freeze/thaw effects (voids & capillaries within the concrete are prevented)
  - Addition of entrained air provides exceptional freeze/thaw performance (more consistent “small bubbles”)

COEFFICIENT OF THERMAL EXPANSION & MODULUS OF ELASTICITY

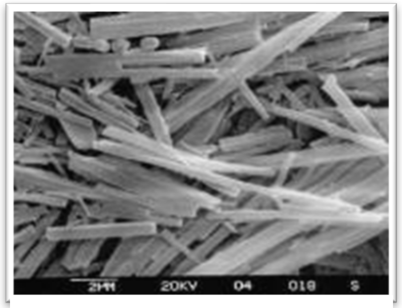
- ✓ Due to the high aggregate and sand content in concrete mix designs the coefficient of thermal expansion performance, as well as modulus of elasticity are substantially the same.
- ✓ The influence of the performance of the cement paste itself will be immaterial.



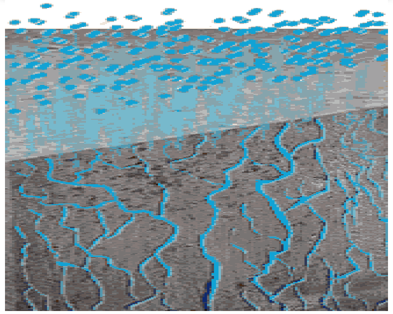


DIFFERENTIATING PERFORMANCE

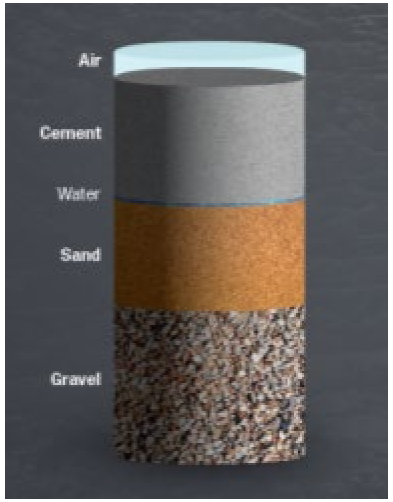
1



2



3



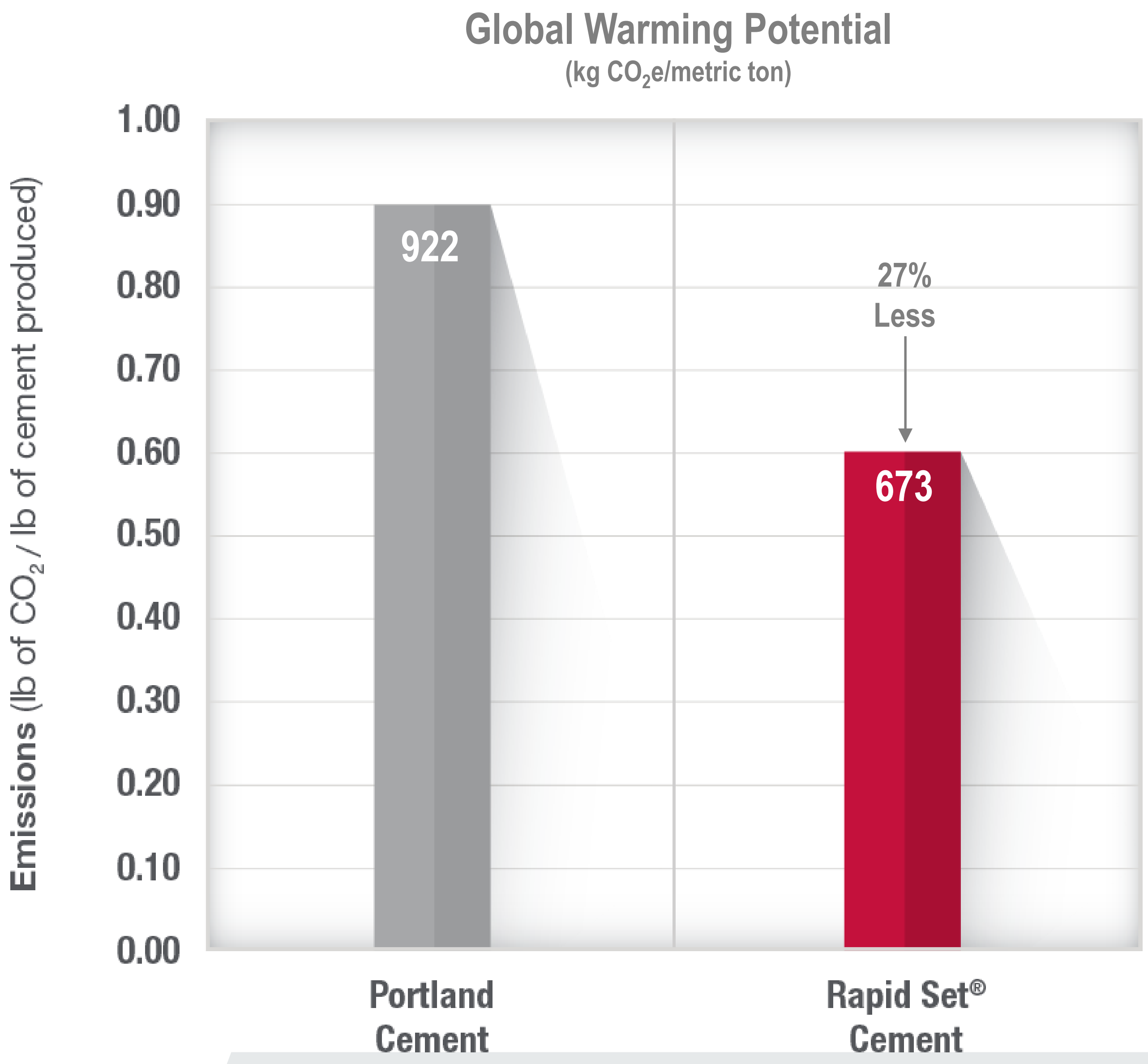
- **Maximum Utilization of H_2O Used in Hydration**
  - Eliminate Capillary Channels and Voids
  - Low Shrinkage
- **Maximum Formation of Ettringite Crystals Achieves High 1 to 1.5 Hr. Strength (Up to 8,700 PSI)**
- **Can Have Expansive Qualities (Type K)**
- **High Sulfate Resistance (No C_3A)**

✓ **Low Porosity = Low Chloride Diffusion**

✓ **Low Permeability**

✓ **Maximum Durability**

LOW CARBON FOOTPRINT

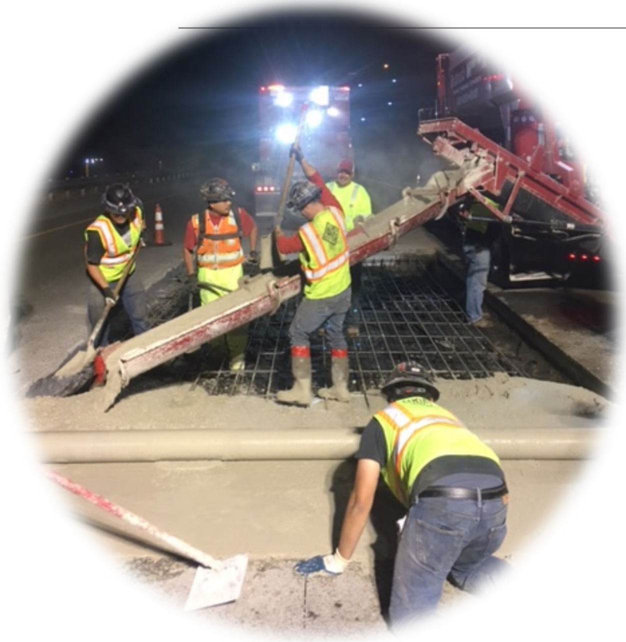


- ✓ Reduce GWP of concrete mix designs using CSA cements
- ✓ Lower CO_2-eq per metric ton
- ✓ Reduced emissions from raw materials
- ✓ Fewer natural resources consumed
- ✓ Reduced energy consumption
- ✓ Meets GSA's definition of top 20% of low embodied carbon (LEC) cement
- ✓ EPDs available

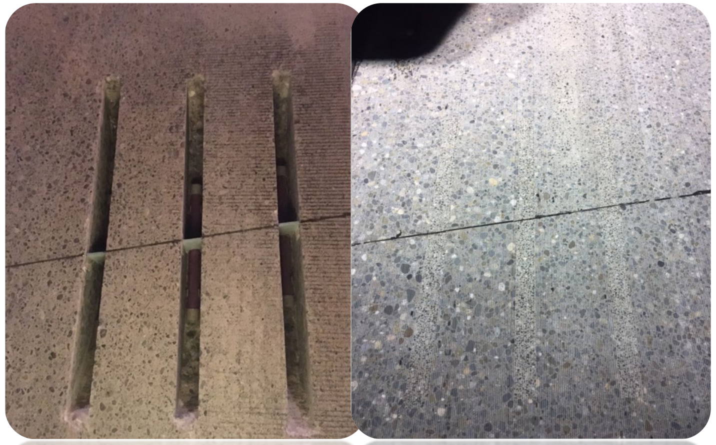
Fast-Setting Hydraulic Cement Materials *ASTM C1600*

- 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

COMMON PAVEMENT APPLICATIONS



- Approach / Departure Slabs
- Control Density Fill
- Dowel Bar Retrofits
- Spall Repairs
- Bridge Joint Seals
- Closure Pours
- Pavement Notch Extensions
- Bridge Deck Hinge
- Partial & Full Depth Repairs
- Cast-in-Place (CIP) Pavement
- Continuous Reinforced Pavement
- Panel Replacements
- Bridge Deck Overlays



IDEAL 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

SEISMIC REPAIR

- Collapse of Interstate 10 Overpass
- Approach Slab Repairs
- Re-opened 74 days ahead
- $14.5m bonus for the contractor

Tyndall AFB
Laboratory Crater Repair

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/MILITARY

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

ROADS & BRIDGES

Highway 280
San Francisco

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

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

Highway 280
San Francisco

INTERSTATE
CALIFORNIA
280

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

1 Hinge July 4th

2 Hinges Labor Day Weekend

METHOD OF DELIVERY

Most Common

- Standard trade practices for transporting, placing and consolidating apply
- Must provide enough time to allow for transport & placement

METHOD OF DELIVERY

Volumetric On-Site Batch Plant

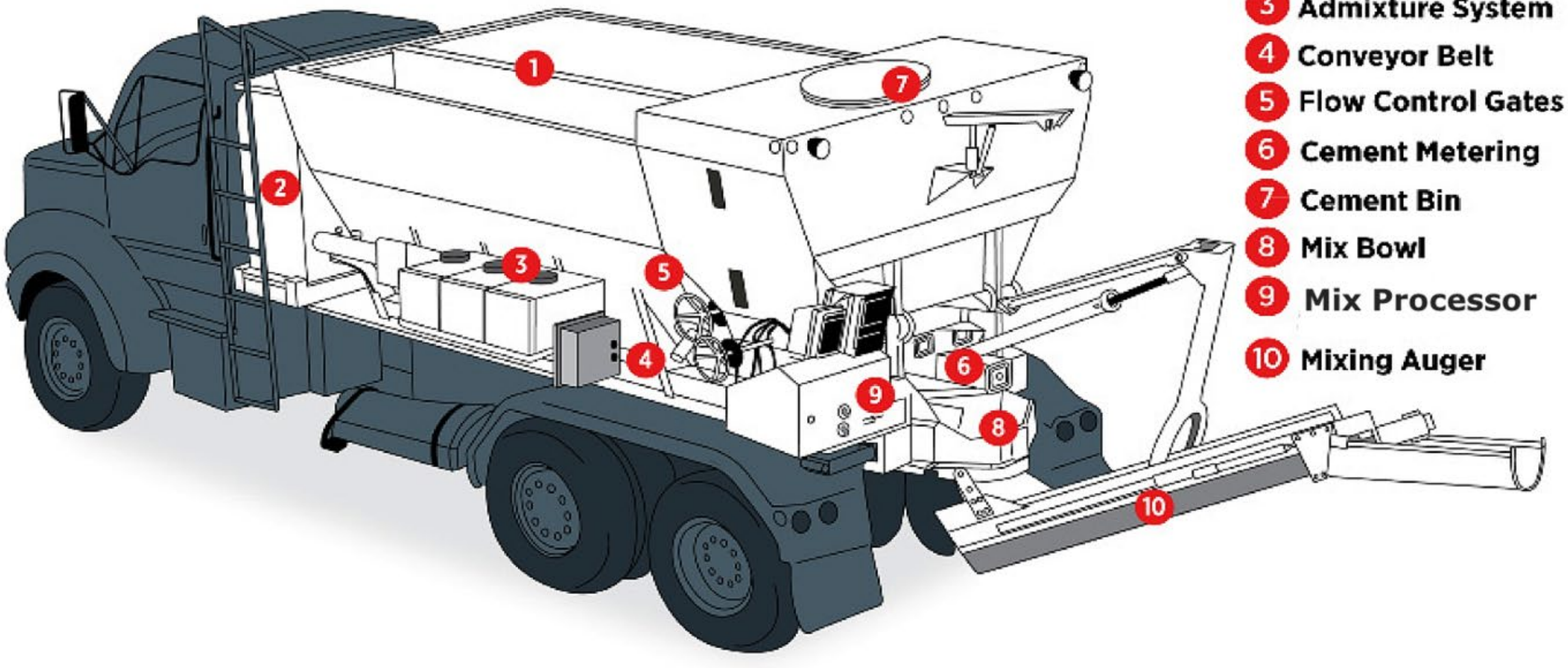
- **Most common method for RS Concrete**
- Mixed on-demand; produce the precise amount needed (“fresh concrete every time”)
- On site control of set time and slump
- Reduces waste
- Measures by volume instead of by weight
- Uniform proportioning
- Prevent short load challenges - Pay for actual usage
- Unaffected by traffic delays
- Ideal for remote locations

METHOD OF DELIVERY

Ready Mix Delivery

- Produced at a local batching plant
- Delivered to job site by tuck mounted in-transit mixers
- Measured by weight of ingredients
- Final quality & working time influenced by time in transit
- **Retarders must be used**
- Additional fees can apply

VOLUMETRIC MOBILE MIXERS



1. Aggregate Bins
2. Water Supply
3. Admixture System
4. Conveyor Belt
5. Flow Control Gates
6. Cement Metering
7. Cement Bin
8. Mix Bowl
9. Mix Processor
10. Mixing Auger

VOLUMETRIC MOBILE MIXERS

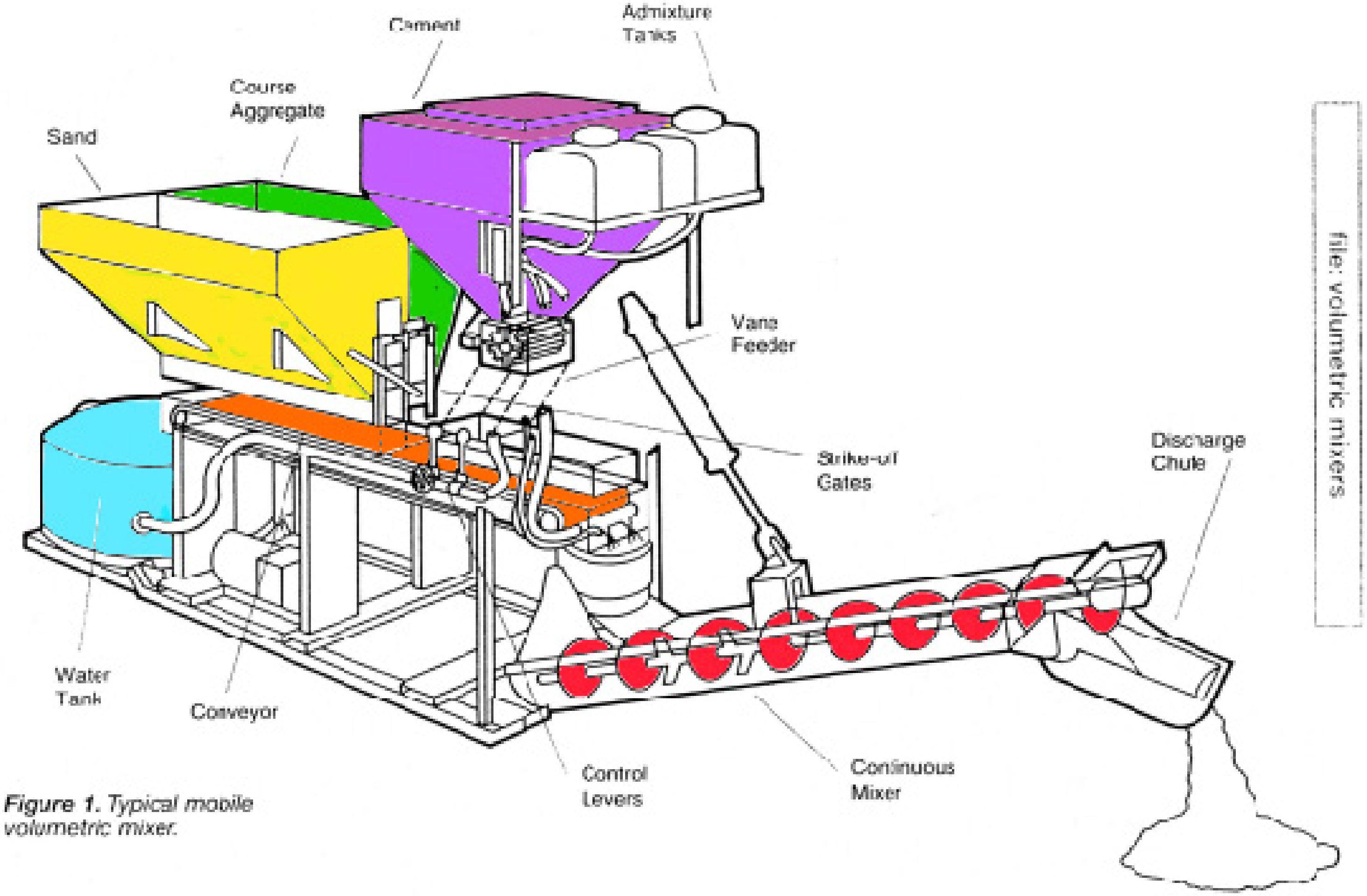


Figure 1. Typical mobile volumetric mixer.

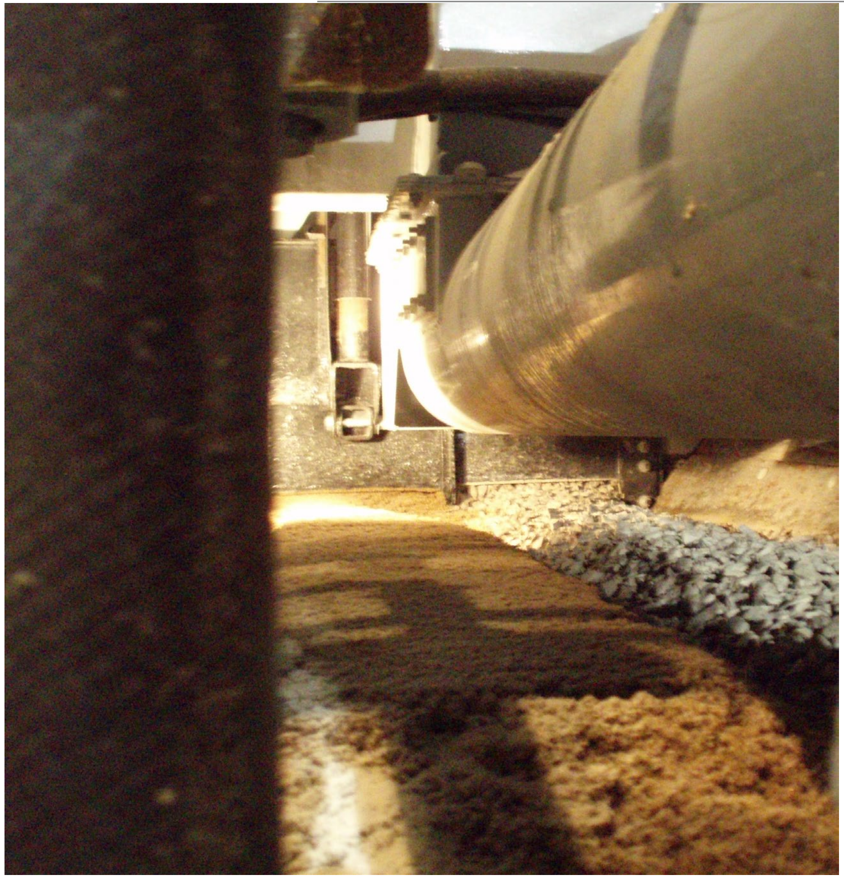
CONCRETE CONSTRUCTION / AUGUST 1992

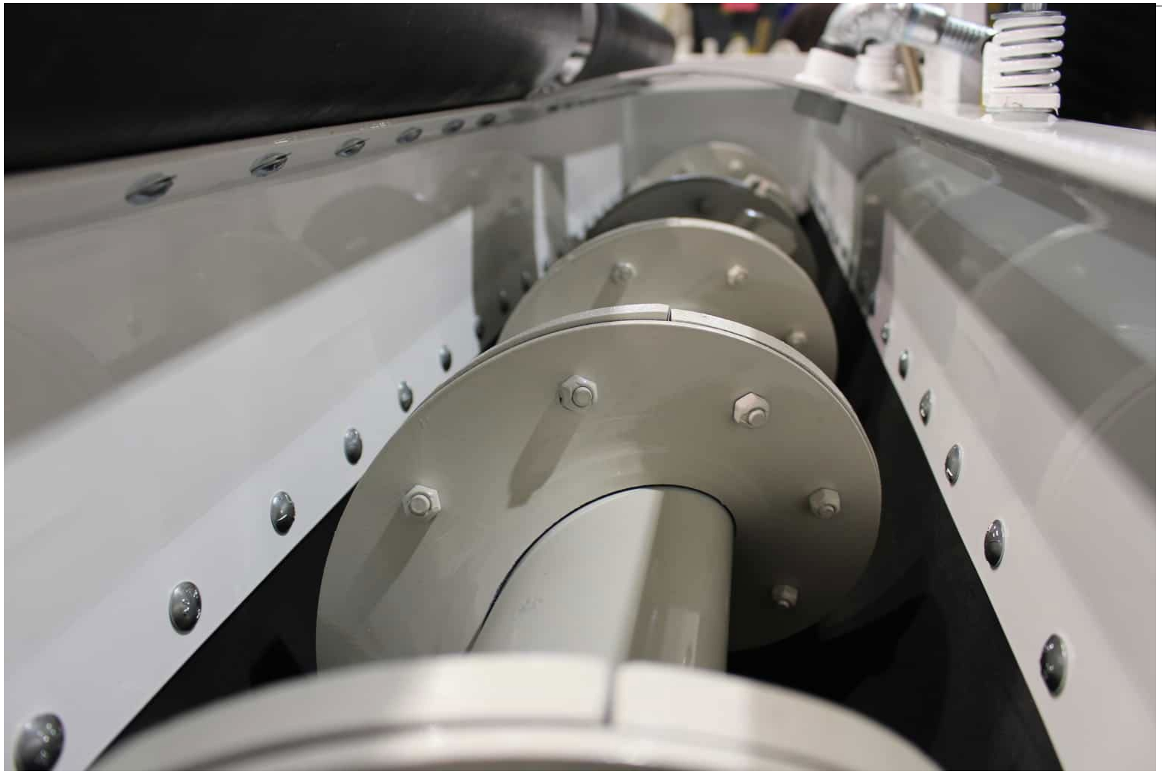
595


ZIM-MIXER
WATER
ZI
ZIMMERMAN
INDUSTRIES
EPHRATA, PA.

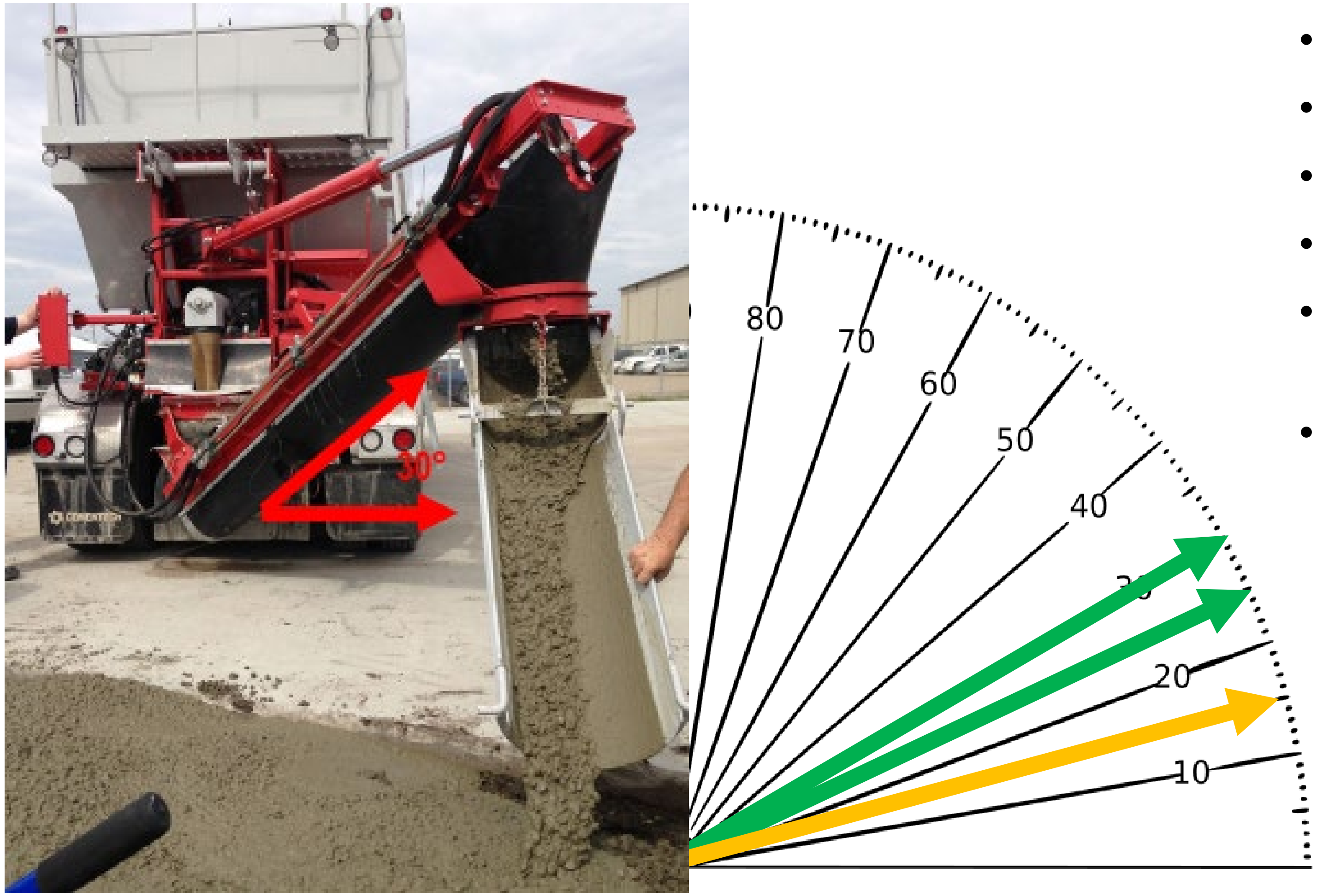

CEMENTECH
CEMENT
STONE
C SERIES
WATER


FLY ASH
CEMENT
CONCRETE DISPENSER



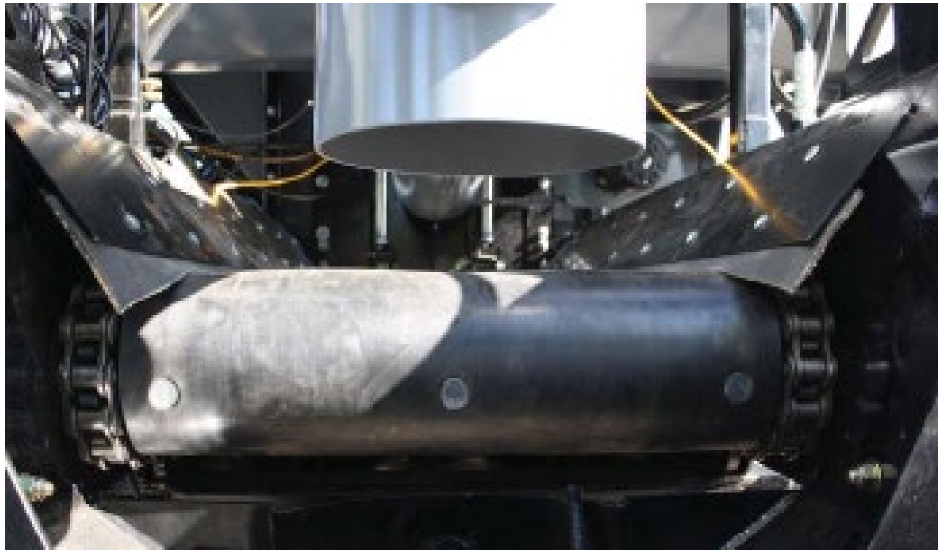


AUGER ANGLE

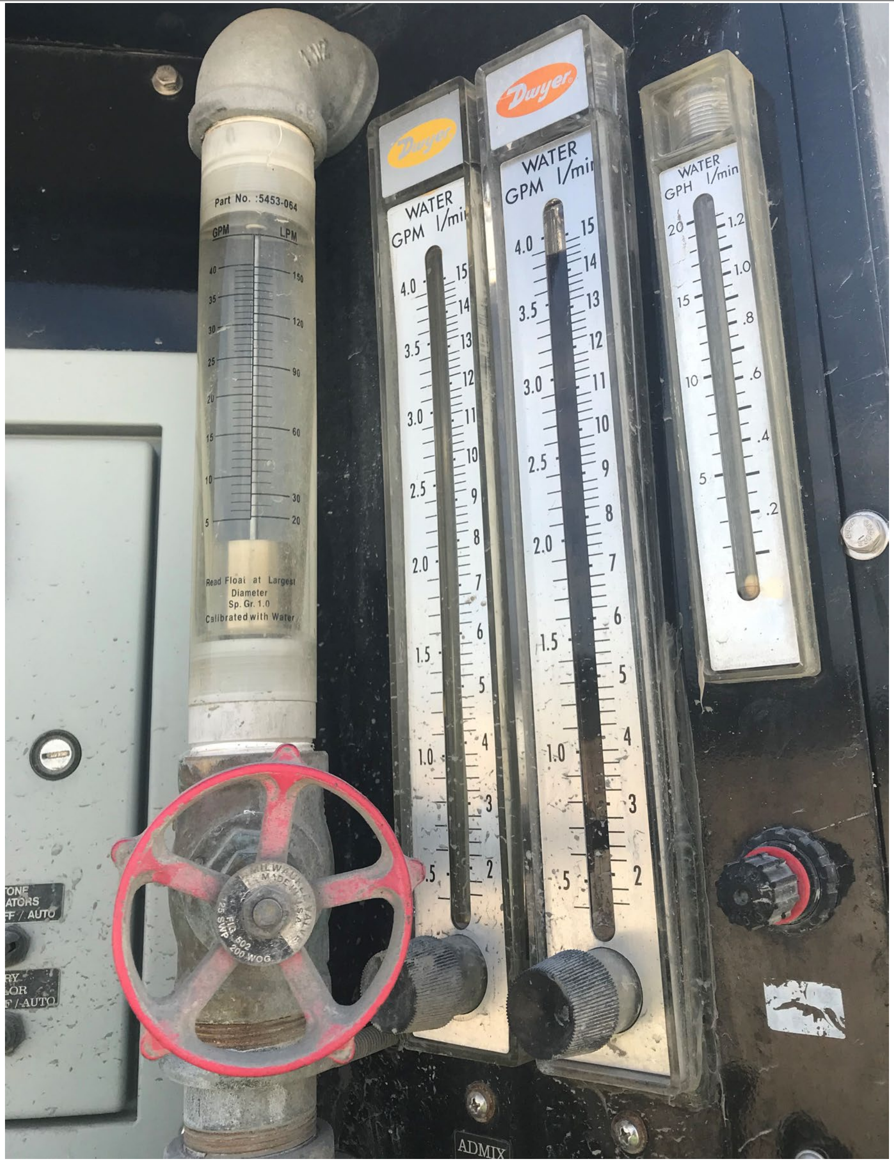


- 25° - 30° for optimal mixing
- As low as 15°
- Higher angle = longer mixing time
- Lower angle = less mixing time
- Remember, mixing occurs on average between 10-15 seconds
- Maintaining optimal mix angle is key


ZIM-MIXER™
Zimmerman Industries, Inc.
SAND
STONE




BAY LYNX
WARNING
STAY CLEAR
CRUSH AND
PINCH HAZARDS


Part No. :5453-064
GPM
LPM
Read Float at Largest
Diameter
Sp. Gr. 1.0
Calibrated with Water
Dwyer
WATER
GPM l/min
Dwyer
WATER
GPM l/min
WATER
GPH l/min
ADMIX

KEY TO SUCCESS

Calibration

ASTM C685-17 *"Standard specification for concrete made by volumetric batching and continuous mixing"*

- Verify calibration of mix design
- 1/4 cu yd yield box
- Slump
- Air

Pros for RSC

- ✓ Fresh concrete ALWAYS
- ✓ On-the-fly adjustments
- ✓ Less waste
- ✓ Easier for remote locations
- ✓ Emergency repairs
- ✓ Different mixes, same truck
- ✓ Several repair locations

Cons for RSC

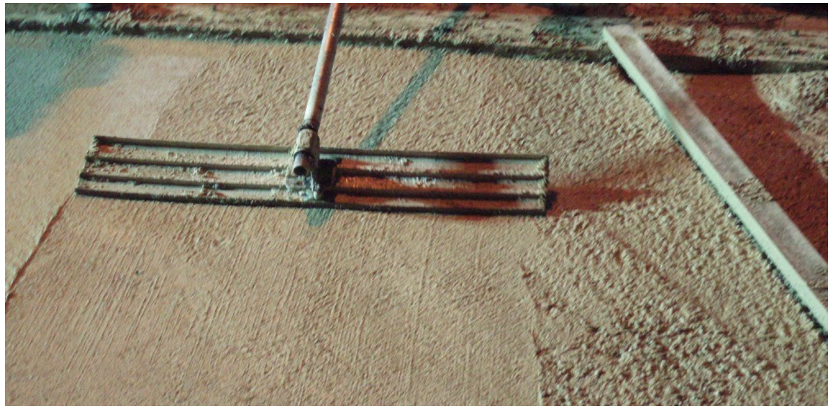
- ✓ Truck calibration can make or break performance
- ✓ Heavily reliant upon operator
- ✓ Auger can lock up if material is left inside

#1 Key to Success for Placing and Finishing RSC

Workers MUST be organized with a placement game plan.

Placing, finishing, and curing will occur in an accelerated time frame.

PLACING & FINISHING



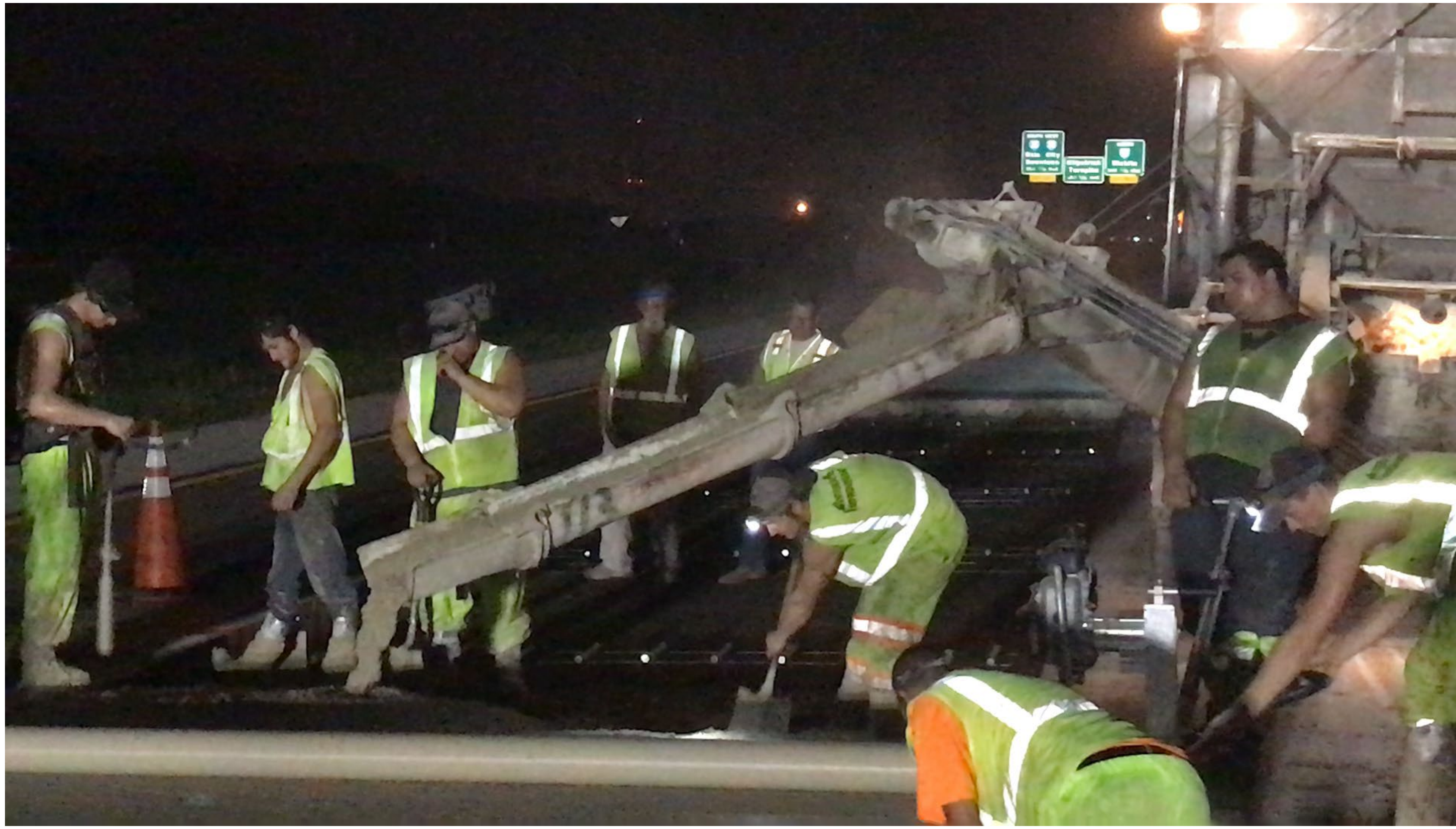
Placing of RSC is Similar to Portland Cement Concrete

PLACING & FINISHING

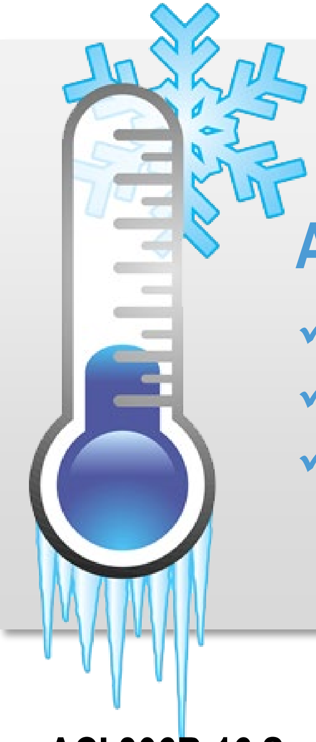
Effective removal of concrete to be replaced
Then clean and patch well

Proper surface prep

PLACING & FINISHING



STANDARD HOT & COLD WEATHER PRACTICES



As Temperatures Decrease

- ✓ Evaporation can vary
- ✓ Set time increases
- ✓ Water demand usually decreases

As Temperatures Increase

- ✓ Evaporation increases
- ✓ Set time decreases
- ✓ Water demand increases

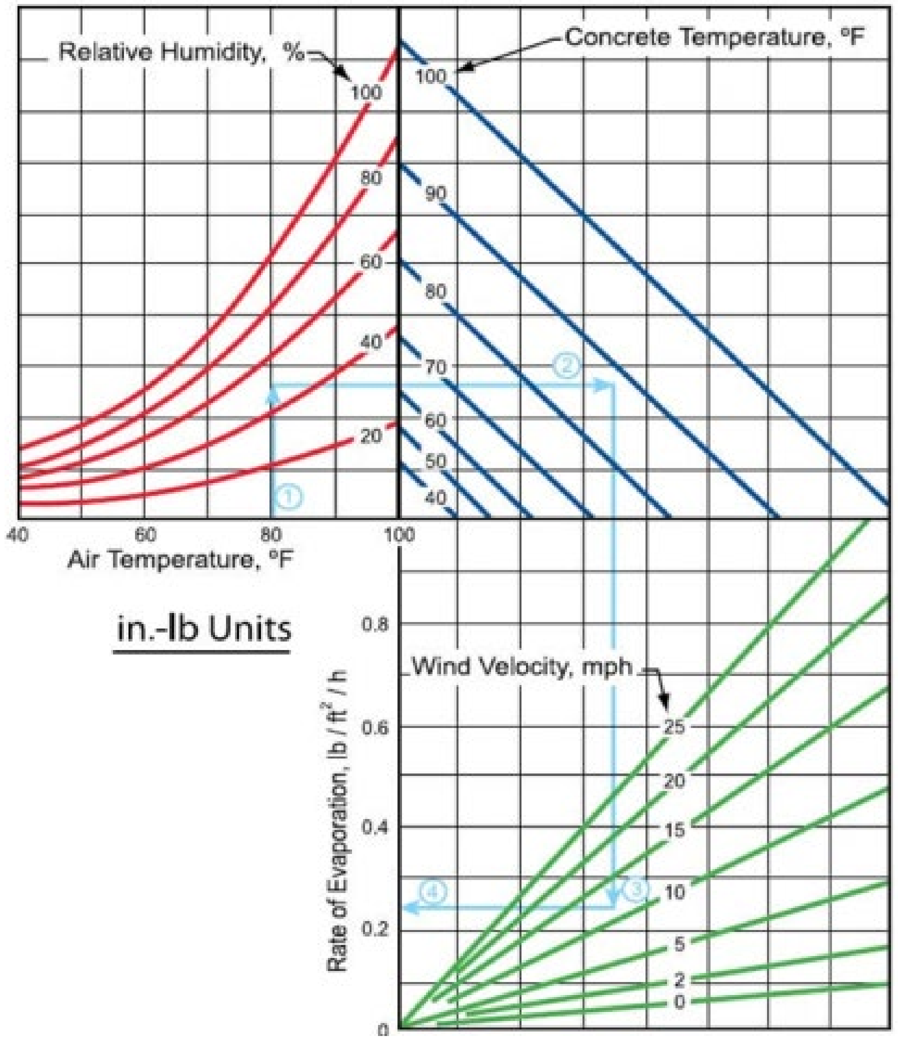
ACI 306R-16 Specification
for Cold Weather Concreting

"The conditions of cold weather concreting exist when the air temperature has fallen to, or is expected to fall below, 40°F (4°C) during the protection period. The protection period is defined as the time required to prevent concrete from being affected by exposure to cold weather."

ACI 305R-20 Specification
for Hot Weather Concreting

"One or a combination of the following conditions that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise causing detrimental results: high ambient temperature; high concrete temperature; low relative humidity; and high wind speed."

EVAPORATION NOMOGRAPH



With RSC

- Protection from evaporation when evaporation rate exceeds 0.2 lb./ft^2/hr.
- Excessive surface drying and plastic shrinkage cracks can occur if not protected properly.

HOT WEATHER MITIGATION

- Liquid nitrogen
- Ice/chilled water
- Fogging
- Wet burlap / poly burlap
- Wind breaks
- Curing blankets
- Shade cement silo
- Moisten and turn aggregate piles
- Fill up with $H_2$0 just before leaving for jobsite
- Use a retarder

COLD WEATHER MITIGATION

- Hot water
- Heat/dethaw subgrade
- Wind breaks
- Curing blankets *(insulated and/or heated)*
- Heat aggregate piles
- Portable heaters
- Heat curing box for cylinders

One of the Easiest Way to Improve the Longevity of Concrete…
…Often the Most Neglected Aspect of a Concrete Job

- Maintaining adequate moisture in the concrete

+

- Maintaining a proper concrete temperature range

=

- ✓ Durability
- ✓ Strength
- ✓ Water tightness (permeability)
- ✓ Abrasion resistance
- ✓ Volume stability
- ✓ Resistance to freezing and thawing

MOST COMMON CURING METHODS

- Wet cure
  (burlap, poly burlap, curing blankets)
- Curing compound
  - PAMS (ASTM C309, Type 2, Class B)
- Others are not as effective

- Apply ASAP after final finish has been applied
- Not marring top surface
- Not washing away top paste

Thank You!

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CTS CEMENT | Rapid Set | KOMPONENT Shrinkage Compensating Concrete Additive