

How to Use CSA Cement for Rapid Production

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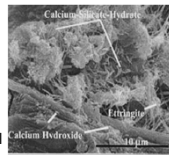
Portland Cement

- Most common binder for all forms of concrete
 - Inexpensive, readily available
 - Long working time
 - Good long-term strength
- Manageable disadvantages
 - Slow reacting (initial set 1-2 hours)
 - Slow strength gain (days to weeks)
 - Shrinkage prone from excess mix water
 - Vulnerable to efflorescence and ASR (alkali silica reaction)



Portland Cement Chemistry

- Primary Reaction Products
 - Calcium Silicate Hydrates (CSH) – *STRONG, glue*
 - Calcium Hydroxide Ca(OH)_2 (CH) – *WEAK, troublemaker*
 - Ettringite in various forms, some neutral, some detrimental
- Uses mix water slowly and incompletely
 - Hydration reactions only use a portion of the mix water
 - Most mix designs depend on higher w/c ratios for workability (0.30 to 0.40)
 - Slower reaction rates + higher free-water content = greater shrinkage



Portland Cement Chemistry

- Pozzolans (supplementary cementitious materials)
 - Minerals used as Portland cement replacement
 - **React with the weak CH to form more strong CSH**
 - Strength gain from pozzolans is generally delayed, long term



From Portland Cement Association

CSA Cement

- A different type of cement with different chemistry
- CSA stands for Calcium Sulfoaluminate

CSA Cement Chemistry

- Primary Reaction Products
 - Ettringite
 - Amorphous $\text{Al}(\text{OH})_3$
 - Monosulfate
- Uses mix water more quickly and completely
 - Gains strength more rapidly
 - Needs more mix water to sustain the rapid chemical reaction (.36 - .40 w/c)
 - Reduced porosity and lower shrinkage

CSA Cement Chemistry

- CTS Rapid Set is the only CSA cement available in North America that is a true stand-alone hydraulic cement
 - Not blended with Portland cement
 - Pozzolans are not used
 - Single cement yields very high early strengths
 - Different blended chemistry from other CSA products



CSA Cement: Rapid Set

Very rapid early strength gain **

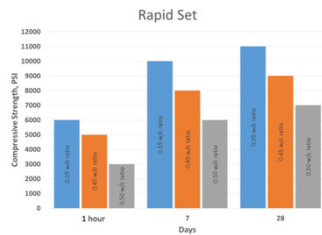
At a 50/50 (Cement/Sand ratio) and no retarder:

- 0.35 w/c ratio
 - 1 hour* = 6000 psi
 - 7 days = 10000 psi
 - 28 days = 11000 psi
- 0.45 w/c ratio
 - 1 hour* = 5000 psi
 - 7 days = 8000 psi
 - 28 days = 9000 psi
- 0.50 w/c ratio
 - 1 hour* = 3000 psi
 - 7 days = 6000 psi
 - 28 days = 7000 psi

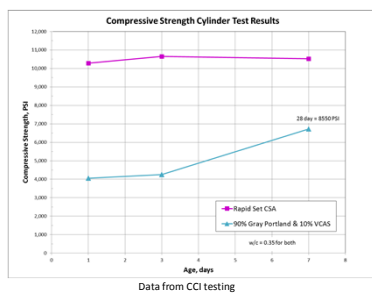
*after final set.

** Values will vary depending on environment and aggregates used.

Data from CTS Rapid Set



CSA Cement



CSA Cement Rules



- Use as a 100% Portland cement replacement
- Do not use with pozzolans
 - No weak calcium hydroxide CH is produced, so there is nothing for pozzolans to consume or react with
- Minimum W/C ratio: 0.35
 - Recommended range: 0.36 – 0.40
- Wet curing duration: 1-3 hours
- Get extra working time via chemical and thermal retardation

Extra working time with CSA cement



- Citric acid is a chemical retarder that delays initial set
 - Working dose range 0.1% - 0.4%
 - Maximum dose 1%
 - Each 0.1% dose adds 5 – 15 minutes of working time at around 70°F (21°C). This is very dependent upon mix design and is *only a rough guide*.
 - Higher doses add working time but slow early strength gain
 - Higher temperatures reduce delay
- Citric acid is readily available online or in health food stores

Extra working time with CSA cement



- Chemical retardation is improved by chilling the concrete
 - Chill the concrete with ice or cold water
 - Concrete at 50°F (10°C) reacts much slower
- A citric acid dose of 0.4% in CSA based concrete at 50°F (10°C) has a working time of about 1 hour.



Cooling with Ice



- Ice is part of mix water, so final w/c ratio is maintained
- Chilling concrete extends working time without lingering after-effects. Once the concrete warms up it sets and gains strength at faster rate.
- High doses of chemical retardation extend working time but also delay strength gain (hangover effect).



Cooling with Ice

- CCI Mix Calculators all have integrated Ice Cooling Calculation module
- Ice cooling calculator makes it easy to achieve target mix temperatures without fear of using too much ice (or too little).



CCI's Ice Cooling Calculator

**The Concrete Countertop Institute
Ice Cooling Calculator**

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Initial Temperature	
Dry Ingredients (Current Mix)	85 °F
Wet Ingredients (Water, Polymer)	75 °F
Mist/Face Coat	
Ice as water substitute	0.0 lbs
Final Temperature of Mixture	81 °F
Backer Coat	
Ice as water substitute	0.0 lbs
Final Temperature of Mixture	81 °F

Target Temperature should be between 50F and 60F
Final temperature may be within 2 to 4 degrees of calculated estimate.

No ice

**The Concrete Countertop Institute
Ice Cooling Calculator**

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Initial Temperature	
Dry Ingredients (Current Mix)	85 °F
Wet Ingredients (Water, Polymer)	75 °F
Mist/Face Coat	
Ice as water substitute	0.8 lbs
Final Temperature of Mixture	50 °F
Backer Coat	
Ice as water substitute	4.5 lbs
Final Temperature of Mixture	50 °F

Target Temperature should be between 50F and 60F
Final temperature may be within 2 to 4 degrees of calculated estimate.

With ice

CSA Cement Chemistry

Actually, calcium sulfoaluminate is called ye'elimite (C_4A_3S) and is the *basis* for what we know as CSA cement and CSA additive.

- "Pure" CSA = ye'elimite
- Ye'elimite is never used by itself

Calcium Sulfoaluminate Variations:

- Cement additive (CSA additive from Buzzi Unicem)
- Stand-alone cement (CSA cement from CTS Rapid Set)

CSA vs Portland Cement

	Portland cement (OPC)	Calcium sulfoaluminate cement (CSA)
Main phases *	C_3S , C_2S , C_3A , C_4AF	C_4A_3S = ye'elimite, C_2S , CA , C_3AS ...
Raw materials	limestone + clay	limestone, clay, anhydrite
Synthesis temperature	≈ 1450 °C	≈ 1250 °C
CO ₂ release from raw materials	C_3S : 1.80 g/ml C_3S	C_4A_3S : 0.56 g/ml C_4A_3S
Grindability of clinker	medium	very easy
Gypsum addition	≈ 4-8 M.-%	≈ 20-25 M.-%
w/c for complete hydration	≈ 0.4	≈ 0.6
Hydration products	C-S-H phases, $Ca(OH)_2$, ettringite	ettringite, monosulfate, amorphous $Al(OH)_3$

* Cement notation: C = CaO, S = SiO₂, A = Al₂O₃, F = Fe₂O₃, H = H₂O, s = SO₃

Frank Winnefeld / Laboratory for Concrete and Construction Chemistry
GEMO Workshop, October 28, 2019

CSA Cement Additive

Calcium Sulfoaluminate Cement **Additive**

- Must be blended with Portland cement
- **CSA additive** (Buzzi Unicem's "CSA Cement") used as a set accelerator and early strength booster for PC based concrete
- Typical doses range from 10-60% CSA additive replacement for PC
 - Lower CSA doses give more working time but minimize early strength gain
 - Higher CSA doses increase early strength but shorten set time

Buzzi Unicem CSA

- Portland Cement Additive
 - Faster set with elevated early strength gains

The following table provides useful information regarding the average strength of Buzzi Unicem USA CSA Cement mixes using different percentages with GreenCastle® Type 80 cement and no delay material (except for 100% CSA test $w/c=0.35$ with delay material added). Data obtained using ASTM C 109 with $w/c=0.34$.

Buzzi CSA	Set Time	3 Hrs. (psi)	24 Hrs. (psi)	28 Days (psi)
20%	65min.	N/A	3830	5960
30%	32 min.	990	1580	5740
40%	23 min.	1630	2220	5700
50%	18 min.	2790	4130	5630
60%	13 min.	3530	4360	6400
100%	11 min.	3720	5175	8700

Data from Buzzi Unicem



CSA Cement Additive Considerations/Drawbacks

Final properties, ultimate performance and durability highly dependent upon Portland cement chemistry and CSA dosing

- Using multiple reactive ingredients together increases complexity exponentially and makes undesired reactions and detrimental effects more likely
- Makes concrete mix design more complicated:
 - What w/c is appropriate?
 - Should pozzolans still be used?
 - If so, which ones are better?
 - And at what dose?
- End-user becomes responsible for formulation and QC
- Resulting concrete still more vulnerable to shrinkage, sulfate attack, etc.



CSA Cement Considerations/Drawbacks

Reasons you might not want to use CSA cement

- Availability
 - Cost
 - You need pure white
- (Note that you can use CSA-based grout to fill pinholes in PC-based concrete.)

CSA Cement Resource

CTS Rapid Set manufactures CSA cement

- www.ctscement.com
- Primary US distributors:
 - Whitecap
 - Home Depot



CSA Cement Resource

CTS Rapid Set Products (a few of many)

- CSA cement "Purple bag"
100% CSA cement
Available from Whitecap
Great for 100% from-scratch mix designs



- Cement All "Blue bag"
Blend of fine sand and CSA cement
Available from Home Depot and Whitecap
Perfect for GFRC

CCI's GFRC Mix Calculator for Cement All

- Tailored for CTS Rapid Set's Cement All

The Concrete Countertop Institute
Rapid Set Cement All
GFRC Calculator

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Job Name		Your Project Name	
Rapid Set Cement All	0.37	1	1.00
Fiber load, volume fraction in binder mix	0.00	1	0.00
Polymer latex content	51%	1	0.00
Water content	0.40%	1	0.00
Citric Acid Reducant	0.00%	1	0.00
pigment 1	0.00%	1	0.00
pigment 2	0.00%	1	0.00
pigment 3	0.00%	1	0.00
pigment 4	0.00%	1	0.00



How to Use CSA Cement with CCI Mix Calculators

Gravel Mix
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Project Name: _____

Volume of concrete: 1728.0 cu ft
1.00 cu ft

Concrete Formula inputs

w/c: 0.36

% Gray cement before pozzolan replacement: 100%

% Gray cement after pozzolan replacement: 100.0%

% Whole cement: 98%

Pozzolan replacement: none: CSA Cement used 0%

Pigment #1: 0.00% 0.0 grams

Pigment #2: 0.00% 0.0 grams

Pigment #3: 0.00% 0.0 grams

Pigment #4: 0.00% 0.0 grams

Superplasticizer: Rheokrete 0.40% 0.0 grams

Other admixture: Citric Acid retarder 0.40% 60.0 grams

No color change will

- Set w/c ratio to 0.36 – 0.40
- Set Gray Cement to 100% (CSA cement isn't really gray)
- Set Pozzolan to 0% (make a note CSA cement is used)
- Use Citric Acid at 0.1% dose to 0.4% dose

Questions & Resources

Mix Calculators

- Eliminate mixing mistakes and inconsistencies in Precast and GFRC mixes.
- Includes: Sample colors, Ice Calculator, metric version.
- Delivered instantly to your email inbox.
- Priced at \$79
- **Christmas 2014 SALE: Save 50%! Just \$39.50!** Ends TODAY December 30, 2014 at 11:59pm Eastern.

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