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EMC Cement

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BY EMAIL ONLY
(hyperlinks below in blue)

November 1, 2023

Helpful Insight Further to SB 596 Community Meeting 10/11/23 ("Meeting")

Dear Addressees:

We write further to the above-referenced Meeting (**here**), our having noted especially the comments made by attendees Stephen Rosenblum and Scott Shell. This letter's aim to provide useful insight further to our September letter kindly placed by Ms. Fuji onto the CARB docket for SB 596's Second Workshop (**here** | PDF **here**). As you may recall, that letter relies on the Calgreen innovations of 08.01.23 (**here**) and Caltrans' latest Standard Specifications ("Caltrans-2023"). Since that letter, we note New York State has published low carbon concrete limits (**here**) that are more ambitious than Calgreen's latest innovations. Further, and perhaps most pertinent of all, since our letter the U.S. DOE has published its long-awaited report *Pathways to Commercial Liftoff: Low-Carbon Cement* (PDF **here**), which confirms the United States' national ambition in such regards. Placed to the top of the DOE's ambition, what do we see as priority #1?

> **"Rapid scale-up of clinker substitution, alternative fuels, and efficiency measures from 2023 through the early 2030s,** accelerated by low-carbon procurement standards and high-profile demonstrations of low-clinker cement and concrete blends." [p.4, emph. ret.]

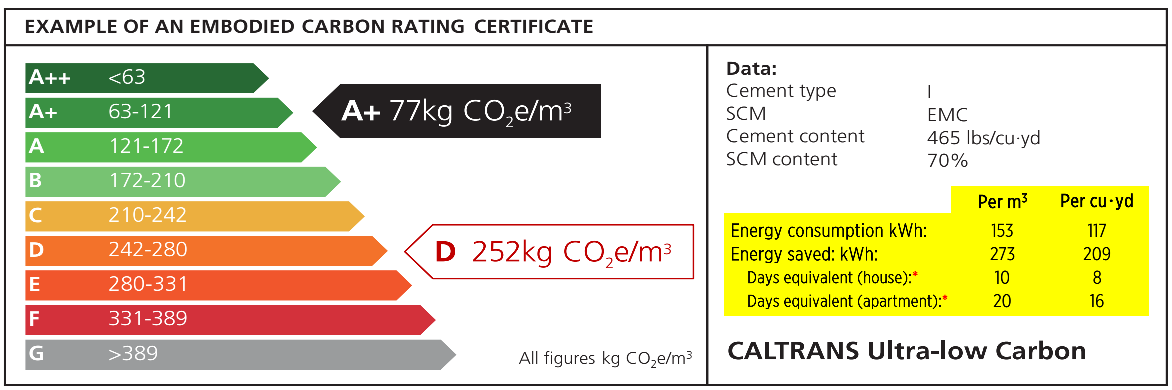
The above features speak to the dynamics evolving in the United States. Equally, since our letter the Tokyo Stock Exchange has started to trade carbon credits allied to Japan's new J-Credit Scheme (**here**). As the World's 5th largest CO_2 emitter, Japan aims to cut emissions by 46% from 2013 levels by 2030 and is the latest among Asian nations to enable a carbon pricing mechanism and ETS. Under the scheme, Japan's government certifies the amount of CO_2 mitigation a project generates. The resulting "credit" can be used for various purposes (*see,* PDF **here**), hence forming a *link* between project finance and national ambition. But what of the cash mechanism? Whereas supply-side participation by SME project holders is encouraged, the market's buy-side comprises large concerns that concurrently are having CO_2 limits imposed, together with a legal requirement to either not exceed such limits or buy-in "credits". Hence, a J-Credit can be retired *directly* against that regulatory burden. This is in contrast to the Californian and EU ETS, that prevent project-holders from both generating fungible credits or receiving ETS credits for such project-holders (*i.e.*, even upon their proving a project's mitigation) to then sell to the buy-side of those ETS markets unless—in California's case—mitigation projects are allowed into (for example) its Low Carbon Fuel Standard ("LCFS"). In contrast, in the EU there is currently no such inroad possible.

All-electric low-energy zero-carbon EMC Technology will transform Californian volcanics into clinker substitutes. This letter seeks to bear witness as to how EMC Technology could be deployed in California right now by leveraging a duly-modified LCFS against the DOE's Title 17 that since 2020 has included "Technologies or processes for reducing GHGs from industrial applications including … cement"(*see,* 42 U.S. Code §16513(b)(12), **here**). Such a project would surely dovetail with the DOE's #1 priority ambition.

<u>Put Another Way, EMCs Serve as a Slag Substitute</u>.

> "I particularly appreciate the comment earlier that you're looking for replicable solutions and I think for that the cost effectiveness is really key. CCS is going to be expensive … so we're interested in using all the other strategies possible to get the cost down. Some of these are not at the cement level which SP 596 is focused on, but at the concrete level. For example … at the design specification level often prescriptive specifications include unnecessary requirements that drive-up cement, you know water-cement ratios minimum cement use…"
>
> **Scott Shell** | Associate Director, Industry | Climate Works Foundation (The Meeting at **58:24**)

Per the Meeting, slag and fly ash are also considered as alternate cement materials ("ACMs"). However, the *vast* majority of California's slag is imported. Volumes are severely impinged. Per Caltrans' Concrete Task Force's report *SCM Supply Look-Ahead* (**here**), Caltrans admits it has limited demand for <u>raw</u> volcanics ("NPs"). Yet, ironies aside, California literally sits on abundant stockpiles of NPs that could be put to use as EMC Volcanics — when there is little doubt that making EMC Volcanics available is the only surefire route for ACMs to deliver SB596's aims in any reasonable timeframe. To illustrate the point, the Annex to our September letter sets out a number of visualizations based on the *Low Carbon Routemap* schema developed for the concrete sector by the U.K.'s Institution of Civil Engineers (**here**), serving to rate the embodied energy and CO_2 for a stated cement blend *v.* a purely clinker-cement mix:



* Based on California's average daily domestic electricity-consumption

Sample concrete-rating label per I.C.E. schema, synthesized using Caltrans-2023 Specifications (**see Annex to our September letter, here**).

To address Scott Shell's point about otherwise prescriptive standards and that the solution is not at "cement level", we agree with him and go further. In our September letter we have already stated that we fully support Caltrans' drive to reduce the embodied carbon in concrete and we welcome that the majority of Caltrans-2023 does not prescribe minimum cement dosages. Similarly, Calgreen's GWP scores appear to be fully decoupled from dosage minimums. As stated in our September letter, this means market participants will get to choose and apply the factors important to them when specifying projects.

However, Catrans-2023 *is* prescriptive in parts. For example, we have noted also the very significant impact of the 11F *v.* 19F boundaries per the equation set out at §90-1.02I(2)(a) Caltrans-2023. Simply put, whereas slag applies 11F as the ratio's component numerator, NP applies 19F. At the designated minimum total cementitious dosage of 590lbs/cu·yd for freeze-thaw concrete, this means using only NP ACMs limits the clinker cement replacement to ~36%, whereas slag is limited to ~63% replacement. If NPs are processed using EMC Technology, there is no discernible justification for such a distinction. Hence, we have written to Caltrans seeking a dialogue to figure how that prescriptive rule may be modified. To such ends, we are no stranger to causing such rule-modifications — <u>as our prior experience in Texas shows</u>.

Our prior experience in Texas: An Example of Stunning Project Execution

Caltrans' *Supply Look-Ahead* report notes (p.37): "TX is allowing blended and modified fly ash in specifications, with no direct mention of a reference standard". **First**, the reason TXDOT incorporated "modified fly ash" ("MFA") into its rules was **only** because of our work in Texas in 2004! **Second**, in terms of its performance, our "MFA" was considered equivalent to slag.

In April 2003, we filed our USPTO patent application for EMC Technology's activation of fly ash. In a period of 17-months, we went from filing a USPTO patent to producing saleable goods at full commercial scale, all from what had been a "greenfield" site. We literally planned and built every aspect of that EMC Plant and its buildings. During those astonishing 17-months, the following steps were executed:

- Identification of raw-materials source (coal-powered generating plant in Jewett, Texas).
- Purchase of land for the EMC Plant while simultaneously securing raw-material supply.
- The project's financing was arranged, negotiated and closed.
- Design, engineering, equipment-supply contracts, together with all permitting.
- Design, construction and commissioning of our dedicated EMC Plant.

During that same period, we engaged with TXDOT to modify its rules. Such a process can last for years, but because our then raw material—Class F fly ash—was already in TXDOT's rules, it meant that by the time the EMC Plant was ready to deliver, TXDOT had made the required rule changes. TXDOT introduced a new class of approved materials called Modified Class F Fly Ash. Importantly, TXDOT allowed MFAs the same level of clinker substitution as slag. Please see the Annex. It confirms: (i) the draft rule changes in 2004; (ii) TXDOT's final rule; (iii) our plant was TXDOT's only approved MFA supplier.

Our MFAs were used in all types of projects, including Houston Bayport and *Katy Freeway*. In 2007, we began perfecting the process for exploiting NPs as our new feedstock. By 2011, we had perfected our technology to solve the *water demand* paradox associated with NPs. This gave rise to historic levels of clinker substitution. Our new USPTO patent was filed and then granted. Believing there would be new Caltrans' rules for low-carbon concrete, we spent well-over $1mn prospecting and securing rights for NP deposits, testing them, and building a mini-plant for delivering large demo-pours, for example with Superior Concrete (*video*, **here**). Testing (**here**) was overseen by the same Dr. Boris Stein who features in Caltrans' *SCM Supply Look-Ahead* report. We established contacts with leading users in California. These included Central Concrete in San José, Vulcan, A&A Concrete, Granite Rock, Holiday Rock — and many others. We initiated an outreach with Caltrans upon the express invite of Governor Schwarzenegger that allowed us to work with Caltrans to suggest pro-competitive changes to its ruleset that would have led to the rise in all ACMs. However, whereas the changes we had hoped for never materialized, that was then.

The Myth of Alternates — and CCUS' Irrelevance to CARB's LCFS

> "Senate Bill 905 is really going to take a close look at carbon capture and sequestration and assessing things like the permanence of sequestration and the safety of pipelines and other factors that are important to assessing its viability so I expect a lot more opportunities to provide feedback and comment on CCUS that is kind of going to be the venue where that carbon capture and sequestration is primarily unfolding at CARB so it through the SB 905 process and that is just getting started."
>
> **Mark Sippola** | Chief Cap 'n' Trade and Climate Change Programs | CARB (The Meeting at **65:14**)

> "If CCUS is applied on an industrial scale, the power demand of cement manufacturing will increase significantly. As described, carbon capture technologies will require high power consumption to e.g. supply consumables like oxygen, pump solvents, operate power driven separation devices like membrane or cryogenic units and purify and compress the CO_2 in order to meet the required conditions of downstream processes. Therefore, CCUS will increase power consumption by 50 to 300% at plant level."

> "To reduce the technological complexity of the integration of new technologies on the conventional kiln system, separate indirect calcining is proposed to focus on capturing CO_2 from the calcination process only. The capture efficiency is high but still limited to 60-70% of the total CO_2 emissions from the clinker process ... Pipelines will be the only long-term solution to transport relevant amounts of CO_2 from industrial point sources to the storage sites. Depending on the local circumstances, in the short-term CO_2 transportation by ship or railway can play an important role. Today's projects face transport and storage costs, which can amount to more than 100 €/t CO_2."

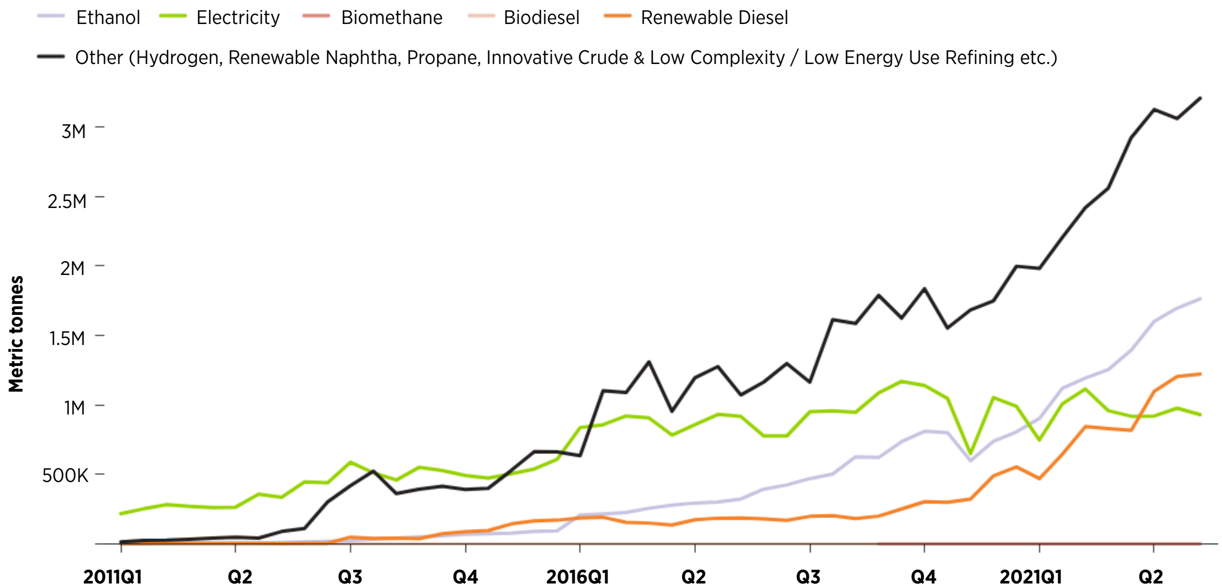
> "An up to "90%" CO_2 emission reduction compared to Portland cement is postulated. However, this does not take into account emissions due to the production of the activators (e.g. sodium silicate). In comparisons between Portland cement concrete and geopolymer concretes with an equal performance, geopolymer concretes are mostly more expensive and exhibit mostly a significantly higher resource depletion potential, a higher cumulative energy demand. The global warming potential can even exceed that of Portland cement concrete"

ECRA | State of the Art Cement Manufacture: Current Technologies & Future Development (2022) | **here**

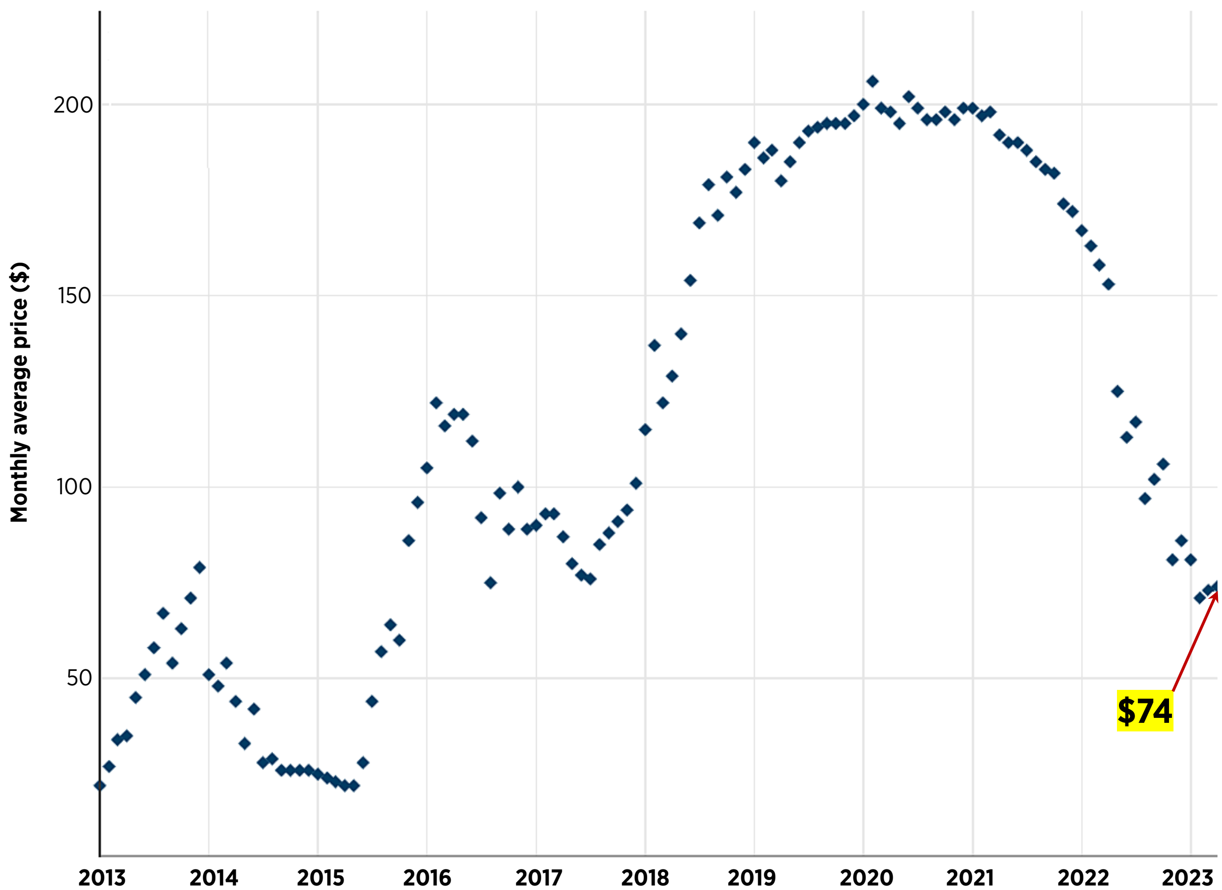
ECRA's words speak for themselves. ECRA's recent findings state the collective wisdom of the clinker cement industry's own research thinktank in Europe (**here**) having in mind that, ignoring China, the World's top-three largest producers are European (**here**). The first two excerpts deal with CCS, serving to support CARB's overall caution as regards CCS deployment in the clinker cement industry. The third excerpt deals with the claims made by those touting alternate binders activated by novel alkali systems (for example, C-Crete, **here**). As stated in our September letter, we support the overall drive towards EPDs in California because innovators seeking project approval will also be required to deliver EPDs by law. Hence, we hope that there will be little prospect for greenwashing or for wild or dubious technological claims. Equally, ECRA is quite clear of CCS' high costs — even though CCS is served favorably by the high exhaust temperatures generated during clinker production.

CCUS denotes the *usage* of captured carbon (rather than its permanent sequestration) and has been touted by the clinker industry as a possible "Hail Mary" in an attempt to mitigate the high costs of plain CCS. In principle at least, this might be aided in California by the LCFS given its expansion to allow for fuels generated by carbon capture. California's generosity in such regards is so ample that fuels generated from wildly expensive *direct air capture* CCS ("DACCUS") are allowed to claim under the LCFS even if the DAC installation is located outside California or the United States (*see,* PDF **here** at p.8). However, according to CARB, no DACCUS applications have been made (**here**). A close regard of LCFS' dynamics reveals at least a partial reason as to why: as the LCFS has become more successful (*i.e.*, as measured by its issuances), its prices have tumbled (*see,* diagram on next page). At best, price dynamics serve to partially explain the reason why no DACCUS applications have been made. Perhaps most fundamental of all, is that the conversion of the captured carbon into a useful fuel is fraught with both technical complexities and a very high energy need. Aside from the irony that such systems require the captured CO_2 to be first converted into solid *calcium carbonate—i.e.*, the same constituent in limestone that has its CO_2 driven-off in the first place to make clinker—then transported, thermally decomposed, and pressurized to become *ultra-pure* CO_2 gas feedstock, the real challenge is the so-called *carbon efficiency loss problem*, which is "more detrimental to products with more electrons transferred" (**here**). Simply? CCUS for fuels is decades' away.

LCFS Credits (metric tonne) by Fuel Type Q1 2011 to Q4 2022

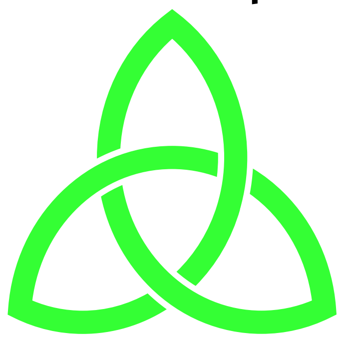


LCFS Credit Prices for 10yr period 2013 to 2023



Two diagrams serving to confirm: (**I**) The LCFS is producing discernable results. By Q4 2022 the issuances stood at >6mn metric tonnes CO_2 abatement; (**II**) DACCUS has no operation in the LCFS; and (**III**) The effect on LCFS prices as volumes have increased | here

<u>This is Not Just About ACMs: It's About Strategic *Impact* in the Wider Scheme of Things</u>



A 'Trinity Test' for Climate Action: EMC Technology offers an exceptionally rare 'trinity' usually reserved only for renewables...

This past summer, such are the effects of climate change conjoined with the severe limits of California's generation capacity, that its Energy Commission voted to extend the life of three gas power plants along California's southern coast through 2026 (**here**). However, only now is low-energy electrification being recognized by the *cognoscenti* as the ultimate Climate Action goal (**here**). Yet, at least the EIA has consistently pressed the scale of the challenge. For example, for United States' energy-related CO_2 emissions to fall to 25–38% of their 2005 levels, *efficiencies*, *technological advancements* and an *electrification drive* are, according to the EIA, absolute requirements under any U.S. growth scenario (**here**). In contrast, synthesized fuels formed from carbon capture carry very low efficiency, typically converting less than 20% of the gaseous CO_2 into fuel, with the remainder simply lost. Further, the overall energy costs of that utilization route have yet to be reliably measured at scale. Therefore, we doubt the LCFS will ever be utilized as intended there, let alone to any meaningful scale. Whence, a significant chunk of the LCFS' *raison d'être* will <u>likely remain fallow</u> — at the very least for a significant period maybe measured in decades.

Thankfully, the Meeting served to confirm CARB's long-term pledge towards *cracking the code* for delivering low carbon solutions into the cementitious materials market. We welcome this and especially the comment made by Scott Shell that his organization *Climate Works Foundation* is looking to "do anything we can to support that". Nonetheless, the Meeting highlighted the troubling perception that a substantial solution is still many years away and hence a misunderstanding that an ACM revolution is not possible today. **It is**. So the question must be, <u>how can we get there</u>?

There are three routes by which to generate credits in the LCFS: fuel pathways (for CCUS, see 7 CA Code of Regs 95490 **here**), projects, and capacity-based crediting. We believe that the ruleset can be modified efficiently to allow-in electrical zero-carbon low-energy pathways. For example, if "Electricity Used as a Transportation Fuel" is allowed in (PDF **here**, p.31), there is no reason to not include this type of pathway as we suggest here, given that the clinker cement industry is both energy intensive—with 90% of its fuel stock comprising fossil fuels—and <u>hard to abate</u>. The only question then remaining would be whether the credit volume generated is to be tied to CO_2 abatement or the energy-quotient saved.

<u>Conclusion: Now is the Time for *Energy Efficient* Californian Natural ACMs</u>!

Over 20-years' ago, arguably the most thorough—and prescient—report ever compiled on causing cement's decarbonization was published. *Towards a Sustainable Cement Industry* was a major study that rightly concluded abating cement's CO_2 hinges largely on swapping-out a concrete's clinker. In that same context, the 2002 WBCSD report also explicitly recognized EMCs. Since then, <u>we've innovated so much</u>.

Today, EMC Volcanics deliver stunning results time and again (**here**), giving rise to the real prospect for a *net negative effect* across a concrete's full LCA (**here**). Moreover, across twenty years we have proven the technological and commercial viability of enhanced ACMs processed using EMC Technology. As the attached Annex demonstrates, our first U.S. experience was assisted by TXDOT's very real need for high volume high-performance ACMs, in respect of which *only* we could supply so-called MFAs. Across several years' R&D, we then focused on NPs. We perfected our methods to deliver high-performance Californian volcanics, with no inherent loss of workability (*i.e.*, field-use productivity was unaffected) giving rise to a new paradigm *process* patent (*i.e.*, not merely *compositional*). Since then, our continuing R&D has enabled us to further increase the substitution level for NPs. Today, EMC Volcanics can replace clinker by 70% with no loss of performance and without having to increase the overall total cement dose in the concrete. This gives rise to the real prospect of a truly historic shift towards ACMs — to deliver superb quality concretes of exceptionally low EPD scores, which is the real point of SB596 in the first place.

The simple facts are these: California is slated to be the largest state-recipient of U.S Federal IIJA cash (**here**), has no nascent fly ash, is tied to importing the vast majority of its ACMs, while it sits on abundant stockpiles of raw material that EMC Technology can transform like nothing else. Transforming raw Californian NPs into high performance slag substitutes, in a zero-carbon, low-energy, all-electric setting (**here**) makes perfect sense when, after all, Caltrans has admitted that it has very little need for *raw* NPs anyhow. All told, we believe now is the time. Hence, we are seeking to execute on that strategy.

While the new J-Credit Scheme bears witness to Japanese innovation and Japan's willingness to develop tools to marry Climate Action with national ambition, our goal is to bring our pozzolanic revolution to California. Specifically, we ask you to modify the LCFS rules to allow EMC Technology the LCFS benefits granted to DACCUS (*see,* 17 CA Code reg 95488.7, **here**), which lies fallow serving no one. Such a rule-innovation will augment U.S. DOE funding to exploit our *per se* eligibility under Title 17 (**here**) having in mind also the May 2023 changes made to the LPO's rules per 88 FR 34428 (PDF **here**).

We do not ask for anything that it has not done already for others — but we do ask for CARB to modify its rules for all Title 17-eliglible non-clinker cements demonstrating verifiable carbon mitigation using low-energy all-electric processes, so that we can deliver the high-performance natural ACMs that are needed in California — and at a small fraction of the energy costs of clinker cement.

Finally, for further insight please visit: **www.lowcarboncement.com**.

Sincerely

Atle Lygren | C.E.O. EMC Cement BV
ENC: *Annex: TXDOT documentation from our archives.*

Read more here:
WIKIPEDIA

SPECIAL PROVISION

421---035

Hydraulic Cement Concrete

For this project, Item 421, "Hydraulic Cement Concrete," of the Standard Specifications is hereby amended with respect to the clauses cited below, and no other clauses or requirements of this Item are waived or changed hereby.

Article 421.2.D. Water, Table 1. Chemical Limits for Mix Water is voided and replaced by the following:

Table 1
Chemical Limits for Mix Water

Contaminant	Test Method	Maximum Concentration (ppm)
Chloride (Cl)	ASTM C 114	
Prestressed concrete		500
Bridge decks and superstructure		500
All other concrete		1,000
Sulfate (SO_4)	ASTM C 114	2,000
Alkalies ($Na_2O + 0.658K_2O$)	ASTM C 114	600
Total Solids	ASTM C 1603	50,000

Article 421.2.B. Supplementary Cementing Materials (SCM) is supplemented with the following:

6. **Modified Class F Fly Ash (MFFA).** Furnish MFFA conforming to DMS-4610, "Fly Ash."

Article 421.2.D. Water, Table 2. Acceptance Criteria for Questionable Water Supplies is voided and replaced by the following:

Table 2
Acceptance Criteria for Questionable Water Supplies

Property	Test Method	Limits
Compressive strength, min. % control at 7 days	ASTM C 31, ASTM C 39[1,2]	90
Time of set, deviation from control, h:min.	ASTM C 403[1]	From 1:00 early to 1:30 later

1. Base comparisons on fixed proportions and the same volume of test water compared to the control mix using 100% potable water or distilled water.
2. Base comparisons on sets consisting of at least two standard specimens made from a composite sample.

Article 421.2.E.1 Coarse Aggregate. The fourth paragraph is voided and replaced by the following:

Unless otherwise shown on the plans, provide coarse aggregate with a 5-cycle magnesium sulfate soundness when tested in accordance with Tex-411-A of not more than 25% when air entrainment is waived and 18% when air entrainment is not waived. Crushed recycled hydraulic cement concrete is not subject to the 5-cycle soundness test.

Article 421.2.E.2 Fine Aggregate. The fifth paragraph is voided and replaced by the following:

Acid insoluble (%) = {(A1)(P1)+(A2)(P2)}/100
where:

A1 = acid insoluble (%) of aggregate 1
A2 = acid insoluble (%) of aggregate 2
P1 = percent by weight of aggregate 1 of the fine aggregate blend
P2 = percent by weight of aggregate 2 of the fine aggregate blend

Article 421.2.E.2. Fine Aggregate. The final paragraph is voided and replaced by the following:

For all classes of concrete, provide fine aggregate with a fineness modulus between 2.3 and 3.1 as determined by Tex-402-A.

Article 421.2.E. Aggregate is supplemented by the following:

4. **Intermediate Aggregate.** When necessary to complete the concrete mix design, provide intermediate aggregate consisting of clean, hard, durable particles of natural or lightweight aggregate or a combination thereof. Provide intermediate aggregate free from frozen material and from injurious amounts of salt, alkali, vegetable matter, or other objectionable material, and containing no more than 0.5% clay lumps by weight in accordance with Tex-413-A.

   If more than 30% of the intermediate aggregate is retained on the No. 4 sieve, the retained portion must meet the following requirements:

   - must not exceed a wear of 40% when tested in accordance with Tex-410-A.
   - must have a 5-cycle magnesium sulfate soundness when tested in accordance with Tex-411-A of not more than 25% when air entrainment is waived and 18% when air entrainment is not waived.

   If more than 30% of the intermediate aggregate passes the 3/8” sieve, the portion passing the 3/8” sieve must not show a color darker than standard when subjected to the color test for organic impurities in accordance with Tex-408-A and must have an acid insoluble residue, unless otherwise shown on the plans, for concrete subject to direct traffic equal to or greater than the value calculated with the following equation:

$$AI_{ia} \geq \frac{60 - (AI_{fa})(P_{fa})}{(P_{ia})}$$

   where:

   AI_{fa} = acid insoluble (%) of fine aggregate or fine aggregate blend
   P_{fa} = percent by weight of the fine aggregate or fine aggregate blend as a percentage of the total weight of the aggregate passing the 3/8” sieve in the concrete mix design
   P_{ia} = percent by weight of the intermediate aggregate as a percentage of the total weight of the aggregate passing the 3/8” sieve in the concrete mix design

Article 421.2.F. Mortar and Grout is supplemented by the following:

Section 421.4.A.6, "Mix Design Options," does not apply for mortar and grout.

Article 421.3.A. Concrete Plants and Mixing Equipment is supplemented by the following:

When allowed by the plans or the Engineer, for concrete classes not identified as structural concrete in Table 5 or for Class C concrete not used for bridge-class structures, the Engineer may inspect and approve all plants and trucks in lieu of the NRMCA or non-Department engineer sealed certifications. The criteria and frequency of Engineer approval of plants and trucks is the same used for NRMCA certification.

Article 421.3.A.2. Volumetric Mixers is supplemented by the following:

Unless allowed by the plans or the Engineer, volumetric mixers may not supply classes of concrete identified as structural concrete in Table 5.

Article 421.4.A Classification and Mix Design. The first paragraph is voided and replaced by the following:

Unless a design method is indicated on the plans, furnish mix designs using ACI 211, "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete," Tex-470-A, or other approved procedures for the classes of concrete required in accordance with Table 5. Perform mix design and cement replacement using the design by weight method unless otherwise approved. Do not exceed the maximum water-to-cementitious-material ratio.

Article 421.4.A. Classification and Mix Design, Table 5 Concrete Classes is voided and replaced by the following:

Table 5
Concrete Classes

Class of Concrete	Design Strength, Min. 28-day f'_c (psi)	Maximum W/C Ratio[1]	Coarse Aggregate Grades[2,3]	General Usage[4]
A	3,000	0.60	1–4, 8	Inlets, manholes, curb, gutter, curb & gutter, conc. retards, sidewalks, driveways, backup walls, anchors
B	2,000	0.60	2–7	Riprap, small roadside signs, and anchors
C[5]	3,600	0.45	1–6	Drilled shafts, bridge substructure, bridge railing, culverts except top slab of direct traffic culverts, headwalls, wing walls, approach slabs, concrete traffic barrier (cast-in-place)
C(HPC)[5]	3,600	0.45	1-6	As shown on the plans
D	1,500	0.60	2–7	Riprap
E	3,000	0.50	2–5	Seal concrete
F[5]	Note 6	0.45	2–5	Railroad structures; occasionally for bridge piers, columns, or bents
F(HPC)[5]	Note 6	0.45	2–5	As shown on the plans
H[5]	Note 6	0.45	3–6	Prestressed concrete beams, boxes, piling, and concrete traffic barrier (precast)
H(HPC)[5]	Note 6	0.45	3–6	As shown on the plans
S[5]	4,000	0.45	2–5	Bridge slabs, top slabs of direct traffic culverts

Class of Concrete	Design Strength, Min. 28-day f'_c (psi)	Maximum W/C Ratio[1]	Coarse Aggregate Grades[2,3]	General Usage[4]
S(HPC)[5]	4,000	0.45	2–5	As shown on the plans
P	See Item 360	0.45	2–3	Concrete pavement
DC[5]	5,500	0.40	6	Dense conc. overlay
CO[5]	4,600	0.40	6	Conc. overlay
LMC[5]	4,000	0.40	6–8	Latex-modified concrete overlay
SS[5]	3,600[7]	0.45	4–6	Slurry displacement shafts, underwater drilled shafts
K[5]	Note 6	0.45	Note 6	Note 6
HES	Note 6	0.45	Note 6	Note 6

1. Maximum water-cement or water-cementitious ratio by weight.
2. Unless otherwise permitted, do not use Grade 1 coarse aggregate except in massive foundations with 4-in. minimum clear spacing between reinforcing steel bars. Do not use Grade 1 aggregate in drilled shafts.
3. Unless otherwise approved, use Grade 8 aggregate in extruded curbs.
4. For information only.
5. Structural concrete classes.
6. As shown on the plans or specified.
7. Use a minimum cementitious material content of 650 lb/cy of concrete. Do not apply Table 6 over design requirements to Class SS concrete.

Article 421.4.A. Classification and Mix Design, Table 6 Over Design to Meet Compressive Strength Requirements. Footnote 3 is supplemented by the following:

For Class K and concrete classes not identified as structural concrete in Table 5 or for Class C concrete not used for bridge-class structures, the Engineer may designate on the plans an alternative over-design requirement up to and including 1,000 psi for specified strengths less than 3,000 psi and up to and including 1,200 psi for specified strengths from 3,000 to 5,000 psi.

Article 421.4.A.1. Cementitious Materials is supplemented by the following:

The upper limit of 35% replacement of cement with Class F fly ash specified by mix design Options 1 and 3 may be increased to a maximum of 45% for mass placements, high performance concrete, and precast members when approved.

Article 421.4.A.3. Chemical Admixtures is supplemented by the following:

When a corrosion-inhibiting admixture is required, use a 30% calcium nitrite solution. The corrosion-inhibiting admixture must be set neutral unless otherwise approved. Dose the admixture at the rate of gallons of admixture per cubic yard of concrete shown on the plans.

Article 421.4.A.4 Air Entrainment is voided and replaced by the following:

Air entrain all concrete except for Class B and concrete used in drilled shafts unless otherwise shown on the plans. Unless otherwise shown on the plans, target an entrained air content of 4.0% for concrete pavement and 5.5% for all other concrete requiring air entrainment. To meet the air-entraining requirements, use an approved air-entraining admixture. Unless otherwise shown on the plans, acceptance of concrete loads will be based on a tolerance of ± 1.5% from the target air content. If the air content is more than 1.5 but less than 3.0% above the target air, the concrete may be accepted based on strength tests. For specified concrete strengths above 5,000 psi, a reduction of 1% is permitted.

Article 421.4.A Table 7 Air Entrainment is voided.

Article 421.4.A.6. Mix Design Options. The first and second paragraphs are voided and replaced by the following:

For structural concrete identified in Table 5 and any other class of concrete designed using more than 520 lb. of cementitious material per cu. yd., use one of the mix design Options 1–8 shown below, unless otherwise shown on the plans.

For concrete classes not identified as structural concrete in Table 5 and designed using less than 520 lb. of cementitious material per cu. yd., use one of the mix design Options 1–8 shown below, except that Class C fly ash may be used instead of Class F fly ash for Options 1, 3, and 4 unless sulfate-resistant concrete is shown on the plans.

Do not use mix design Options 6 or 7 when High Performance Concrete (HPC) is required. Option 8 may be used when HPC is required provided: a minimum of 20% of the cement is replaced with a Class C fly ash; Tex-440-A, "Initial Time of Set of Fresh Concrete" is performed during mix design verification; the additional requirements for permeability are met; and the concrete is not required to be sulfate-resistant.

Article 421.4.A.6.b. Option 2 is voided and replaced by the following:

b. Option 2. Replace 35 to 50% of the cement with GGBFS or MFFA.

Article 421.4.A.6.c. Option 3 is voided and replaced by the following:

c. Option 3. Replace 35 to 50% of the cement with a combination of Class F fly ash, GGBFS, MFFA, UFFA, metakaolin, or silica fume; however, no more than 35% may be fly ash, and no more than 10% may be silica fume.

Article 421.4.A.6.f. Option 6 is voided and replaced by the following:

f. Option 6. Use lithium nitrate admixture at a minimum dosage determined by testing conducted in accordance with Tex-471-A, "Lithium Dosage Determination Using Accelerated Mortar Bar Testing." Before use of the mix, provide an annual certified test report signed and sealed by a licensed professional engineer, from a laboratory on the Department's List of Approved Lithium Testing Laboratories, certified by the Construction Division as being capable of testing according to Tex-471-A, "Lithium Dosage Determination Using Accelerated Mortar Bar Testing."

Article 421.4.A.6.g. Option 7 is voided and replaced by the following:

g. Option 7. When using hydraulic cement only, ensure that the total alkali contribution from the cement in the concrete does not exceed 3.5 lb. per cubic yard of concrete when calculated as follows:

$$\text{lb. alkali per cu. yd.} = \frac{(\text{lb. cement per cu. yd.}) \times (\%\ Na_2O \text{ equivalent in cement})}{100}$$

In the above calculation, use the maximum cement alkali content reported on the cement mill certificate.

Do not use Option 7 when any of the aggregates in the concrete are listed on the Department's List of Aggregate Sources Excluded from Option 7 ASR Mitigation.

Article 421.4.A.6.h. Option 8 is voided and replaced by the following:

h. Option 8. For any deviations from Options 1–5, perform annual testing on coarse, intermediate, and fine aggregate separately in accordance with ASTM C 1567. Before use of the mix, provide a certified test report signed and sealed by a licensed professional engineer, from a laboratory on the Department's List of Approved ASTM C 1260 Laboratories, demonstrating that the ASTM C 1567 test result for each aggregate does not exceed 0.08% expansion at 14 days.

Do not use Option 8 when any of the aggregates in the concrete are listed on the Department's List of Aggregate Sources Excluded from Option 8 ASR Mitigation. When HPC is required, provide a certified test report signed and sealed by a licensed professional engineer demonstrating that AASHTO T 277 test results indicate the permeability of the concrete is less than 1,500 coulombs tested immediately after either of the following curing schedules:

- Moist cure specimens 56 days at 73ºF.
- Moist cure specimens 7 days at 73ºF followed by 21 days at 100ºF.

Article 421.4.B. Trial Batches is supplemented by the following:

Once a trial batch substantiates the mix design, the proportions and mixing methods used in the trial batch become the mix design of record.

Article 421.4.B. Trial Batches. The fourth sentence of the second paragraph is voided and replaced by the following:

Test at least one set of design strength specimens, consisting of two specimens per set, at 7-day, 28-day, and at least one additional age.

Article 421.4.D. Measurement of Materials, Table 9 is voided and replaced by the following:

Table 9
Measurement Tolerances – Non-Volumetric Mixers

Material	Tolerance (%)
Cement, wt.	-1 to +3
SCM wt.	-1 to +3
Cement + SCM (cumulative weighing), wt.	-1 to +3
Water, wt. or volume	±3
Fine aggregate, wt.	±2
Coarse aggregate, wt.	±2
Fine + coarse aggregate (cumulative weighing), wt.	±1
Chemical admixtures, wt. or volume	±3

Article 421.4.E. Mixing and Delivering Concrete. The first paragraph is supplemented with the following:

Do not top-load new concrete onto returned concrete.

Article 421.4.E.3. Truck-Mixed Concrete. The first paragraph is voided and replaced by the following:

Mix the concrete in a truck mixer from 70 to 100 revolutions at the mixing speed designated by the manufacturer to produce a uniform concrete mix. Deliver the concrete to the project in a thoroughly mixed and uniform mass and discharge the concrete with a satisfactory degree of uniformity. Additional mixing at the job site at the mixing speed designated by the manufacturer is allowed as long as the requirements of Section 421.4.A.5, "Slump" and Section 421.4.E, "Mixing and Delivering Concrete" are met.

DMS - 4610

FLY ASH

EFFECTIVE DATE: MARCH 2009

4610.1. Description. This Specification establishes the requirements, test methods, and the Fly Ash Quality Monitoring Program (FAQMP) for Class C, Class F, Ultra-Fine (UFFA), and Modified F (MFFA) fly ash used in concrete products. Fly ash is the finely divided residue or ash that remains after burning finely pulverized coal at high temperatures.

4610.2. Units of Measurements. The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

4610.3. Material Producer List. The Materials and Pavements Section of the Construction Division (CST/M&P) maintains the material producer list (MPL) of all materials conforming to the requirements of this Specification. Materials appearing on the MPL, entitled "Fly Ash," require no further testing, unless deemed necessary by the Project Engineer or CST/M&P.

4610.4. Bidders' and Suppliers' Requirements. The fly ash must be pre-qualified and accepted into the FAQMP in accordance with the requirements of this Specification before supplying to a contract.

4610.5. Pre-Qualification Procedure.

A. Pre-Qualification Request. Prospective producers interested in submitting their product for evaluation must submit a written request to participate in the FAQMP to the Texas Department of Transportation, Construction Division, Materials and Pavements Section (CP51), Cement Laboratory, 125 East 11th Street, Austin, Texas 78701-2483

Include the following information with the request:

- Name, address, and contact information of the supplier
- Name and location of the power plant
- Coal origin and classification being used by the power plant
- Class of fly ash being collected
- Capacity of the storage facilities
- Six months of weekly physical and chemical test data meeting ASTM C 618 or AASHTO M 295 and Article 4610.6 of this Specification
- Details of the supplier's Quality Control Program, including measures taken to ensure that fly ash meeting the requirements of this Specification is kept separate from fly ash that does not, including, but not limited to, fly ash produced during power plant shutdown, start-up, or other transient operational periods

Fly ash sources will be pre-qualified for the specific class of fly ash as stated in the written request. Any change in the class of the fly ash produced will require re-qualification of the source under the new class.

B. Sampling and Testing. Sampling will be in accordance with Tex-733-I. Testing will be in accordance with the requirements of ASTM C 618 and the additional requirements specified in Article 4610.6. Sampling is at the mutual convenience of the Department and the supplier.

The Department or a designated Department representative will take pre-qualification samples at a frequency of at least one sample per week for 5 weeks. For each fly ash on the FAQMP, producers will submit monthly composite samples at the beginning of each month. Monthly QM samples should be received by the 15^{th} of each month. The Department reserves the right to conduct random sampling of materials for testing and to perform random audits of test reports.

Department representatives may sample material from the plant, terminal, transportation containers, and concrete plants to verify compliance with Article 4610.6.

C. Criteria for Acceptance. The laboratory or laboratories performing the physical and chemical tests for the supplier must participate in the Cement and Concrete Reference Laboratory Pozzolan Proficiency Program.

The supplier must have a permanent location and:

- Be located in the State of Texas
- Maintain an established terminal within Texas through which all fly ash must pass or
- Agree to reimburse the Department for all sampling expenses based on mileage and per diem costs for Department personnel traveling outside the State or for direct costs of sampling and shipping when sampling is accomplished through third-party agreements

D. Evaluation. CST/M&P will notify prospective bidders and suppliers after completion of material evaluation.

1. **Qualification.** If approved for use by the Department, the material will be accepted to the FAQMP and added to the MPL.

2. **Failure.** Producers not qualified under this Specification may not furnish materials for Department projects and must show evidence of correction of all deficiencies before reconsideration for qualification.

   Costs of sampling and testing are normally borne by the Department; however, the costs to sample and test materials failing to conform to the requirements of this Specification are borne by the Contractor or supplier. This cost will be assessed at the rate established by the Director of CST/M&P and in effect at the time of testing.

   Amounts due the Department will be deducted from monthly or final estimates on contracts or from partial or final payments on direct purchases by the State.

E. Reporting Requirements. Submit the following:

- Monthly mill certificate that shows the fly ash complies with the Specification requirements
- Monthly test report with the following information:
  - coal origin
  - test date
  - results of all specified physical and chemical requirements, except available alkalis, but including 'Supplementary Specification Requirements' and
- Monthly split sample from the same material used to generate the monthly test report

Note—The split sample size must be approximately 1 pt., or 2.5 lbs., of fly ash. Mail the sample with a Material Safety Data Sheet (MSDS) to the Texas Department of Transportation, Construction Division, Materials and Pavements Section, Cement Laboratory (CP51), 9500 Lake Creek Parkway, Austin, Texas 78717.

Notify the Department when a change in production occurs. This includes, but is not limited to, changes in a coal source or major alteration of plant operations.

F. Periodic Evaluation. The Department reserves the right to conduct random sampling of pre-qualified materials for testing and to perform random audits of test reports and material management records. Department representatives may sample material from the plant, terminal, transportation containers, and concrete plants to verify compliance with Article 4610.6 of this Specification.

G. Disqualification. The Department may remove the source or supplier from the FAQMP for any of the following reasons:

- Any change in production procedures impacting fly ash quality or composition
- Failure of any sample to meet Specification requirements
- Failure to meet reporting and testing requirements as detailed in Article 4610.6 of this Specification
- Inactivity or not supplying fly ash to Department projects for a period of 1 year

H. Re-Qualification. To re-qualify to the FAQMP, submit a written request for re-qualification to the address listed in Sub Article 4610.5.A. Detail the corrections or changes made that warrant reinstatement. If approved, all costs of pre-qualification sampling must be borne by the supplier.

4610.6. Material Requirements.

A. Class C and Class F. Base classification of the fly ash on chemical composition. Both classes of fly ash must meet all the physical and chemical requirements of both ASTM C 618 and Table 1.

Table 1

Supplementary Specification Requirements

Item	Limit
Calcium oxide (CaO) variation in percentage points of CaO from the average of the last 10 samples (or less, provided 10 have not been tested) must not exceed ±	4.0
Moisture content, maximum, %	2.0
Loss on ignition, maximum, %	3.0
Increase of drying shrinkage of mortar bars at 28 days, maximum, %	0.03

B. Ultra Fine. Ultra-fine fly ash must conform to the requirements listed above for Class F fly ash with the exceptions and additions listed in Table 2.

Table 2

Additional Ultra-Fine Specification Requirements

Item	Limit
Pozzolanic activity index	
▪ 7-day, minimum, % of control	85
▪ 28-day, minimum, % of control	95
Particle size distribution, as measured by laser particle size analyzer	
▪ particles less than 3.25 microns, minimum, %	50.0
▪ particles less than 8.50 microns, minimum, %	90.0
Fineness, amount retained when wet-sieved on 45-µm sieve, maximum, %	6.0
Moisture content, maximum, %	1.0
Loss on ignition, maximum, %	2.0

C. Modified F. Modified F fly ash must consist of Class F fly ash blended by grinding with no more than 10% cementitious material with or without approved accelerating and water-reducing admixtures and conform to the requirements listed above for Class F Fly Ash, with the exceptions and additions listed in Table 3.

Table 3

Additional Modified F Specification Requirements

Item	Limit
Pozzolanic activity index	
▪ 3-day, minimum, % of control	70
▪ 28-day, minimum, % of control	95
Alkali Content, maximum, %	1.5

4610.7. Archived Versions. Archived versions are available.

Fly Ash

NOTE: Refresh the page to view the most current list.

The following sources are prequalified in accordance with DMS-4610, "Fly Ash" or DMS-4615, "Fly Ash for Soil Treatment."

The Department reserves the right to conduct random sampling of prequalified materials for testing and to perform random audits of test reports. Department representatives may sample material from the manufacturing plant, terminal, shipping container, and concrete plant. CST/M&P reserves the right to test samples to verify compliance with DMS-4610, "Fly Ash" or DMS-4615, "Fly Ash for Soil Treatment."

All sources approved as Class F and Class C are also approved as Class FS and CS, respectively.

Producers and Products

- Class F (Type A) Sources

Class F (Type A) Fly Ash Sources				
Producer Code	**Plant**	**Unit**	**Location**	**Supplied by**
99296	Apache	1	Cochise, AZ	Boral Materials Tech.
99778	Big Brown	1	Fairfield, TX	Boral Materials Tech.
99876	Celanese Station	1 & 2	Pampa, TX	Lafarge North America
99161	Cholla	1	Joseph City, AZ	Phoenix Cement
~~99676~~	~~Coronado~~	~~1~~	~~St. Johns, AZ~~	~~Mineral Resources~~
99086	Dolet Hills	1	Mansfield, LA	Headwaters Resources
99699	Escalante	1	Prewit, NM	Phoenix Cement
99299	Four Corners	1	Fruitland, NM	Phoenix Cement
99754	Limestone	1 & 2	Jewett, TX	Headwaters Resources
99097	Martin Lake	1 & 2; 3	Tatum, TX	Headwaters Resources
99776	Monticello	3	Mt. Pleasant, TX	Boral Materials Tech.
98028	Petersburg	3 & 4	Petersburg, IN	Mineral Resources
99673	Pirkey	1	Hallsville, TX	Headwaters Resources
99779	Sandow	1	Rockdale, TX	Boral Materials Tech.
99056	San Juan	3 & 4	Farmington, NM	Phoenix Cement

- Class C (Type B) Sources

Class C (Type B) Fly Ash Sources				
Producer Code	**Plant**	**Unit**	**Location**	**Supplied by**
99750	Coleto Creek	1	Fannin, Tx	Boral Materials Tech.
99782	Deely	1, 2	San Antonio, TX	Boral Materials Tech.
99765	Fayette	1 & 2; 3	La Grange, TX	Mineral Resources
99507	Flint Creek	1	Gentry, AR	Mineral Resources
99137	Gibbons Creek	1	Carlos, TX	Mineral Resources Tech.
99460	Grand River Dam Authority (GRDA)	1	Chouteau, OK	Mineral Resources Tech.
99775	Harrington	1; 2; 3	Amarillo, TX	Lafarge North America
99774	Hugo	1	Hugo, OK	Headwaters Resources
99376	Independence	1; 2	Newark, AR	Headwaters Resources
99034	Labadie	1	Labadie, MO	Mineral Resources Tech.
99773	Nelson	6	Westlake, LA	Headwaters Resources
98171	Muskogee	1	Fort Gibson, OK	Lafarge North America
99139	Northeastern	1	Oolagah, OK	Lafarge North America
99781	Oklaunion	1	Oklaunion, TX	Lafarge North America
98113	Port Neal	4	Salix, Iowa	Headwaters Resources
99113	Rodemacher	1	Boyce, LA	Headwaters Resources
98001	Rush Island	1	Fetus, MO	Mineral Resources Tech.
98036	Sooner	1	Red Rock, OK	Lafarge North America
99005	Spruce	1	San Antonio, TX	Boral Materials Tech.
99752	Tolk Station	1	Earth, TX	Lafarge North America
99780	W.A. Parish	5; 6; 7; 8	Thompsons, TX	Headwaters Resources
99777	Welsh	1; 2; 3	Cason, TX	Lafarge North America
99377	White Bluff	1; 2	Redfield, AR	Headwaters Resources

- Ultra-Fine Fly Ash (UFFA) Sources

UFFA Sources				
99779	Sandow	1	Rockdale, TX	Boral Materials Tech.

- Modified Class F Fly Ash (MFFA) Sources

MFFA Sources				
98095	Cem-Pozz (Limestone)		Jewett, TX	Texas EMC Products

- Class FS Sources

Class FS Fly Ash Sources				

- Class CS Sources

Class CS Fly Ash Sources				
98045	Twin Oaks	1; 2	Bremond, TX	Headwaters Resources

NOTES:

- An ampersand (&) designates the two units are collected in the same silo and sold as one.
- A semicolon (;) designates the units are collected individually and sold individually.