Transitioning from Type I to Type IL Portland Limestone Cement (PLC)

Claude Bergeron

Holcim - Technical Services


ENERGY SAVING
ALTERNATIVE
SMART
POWER
SUSTAINABILITY
RECYCLING
SAFETY
GREEN
INNOVATION
ENERGY
RENEWABLE
ECOLOGY
CLEAN
CITY
TECHNOLOGY
NATURE
ENVIRONMENT
DEVELOPMENT
PEOPLE
ECO

Cement & Concrete in the News

Guardian concrete week

Concrete: the most destructive material on Earth

After water, concrete is the most widely used substance on the planet. But its benefits mask enormous dangers to the planet, to human health - and to culture itself

CNN BUSINESS Markets Tech Media Success Perspectives Videos

The cement industry produces more CO_2 than most countries. It may not survive

By Charles Riley, CNN Business

Updated 12:49 PM ET, Mon July 22, 2019

VER VIDEO PODCAST NEWSLETTERS BIG THINK

We may have to abandon concrete to fight climate change, architectural experts say

The building material seems so ubiquitous — what can we use in its place?

MATT DAVIS 29 September, 2019

BUSINESS

Carbon-intensive cement industry feeling the heat

The cement sector accounts for 7% of all man-made CO_2 emissions, more than all 202 million trucks and more than the steel sector. Pressure is piling up on European cement companies to decrease their footprint.

Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) has been identified as a green-house-gas

Carbon Dioxide (CO_2)

1 ton of portland cement clinker is approximately equal to 1 ton of CO_2

2020: US estimated 90 million metric tons
2020: World estimated 4.1 billion metric tons

(*China estimated 2.2 billion, India estimated 340 million*)

1 Ton of Portland Cement Clinker

$\approx$

CO_2

Buy Clean Movement

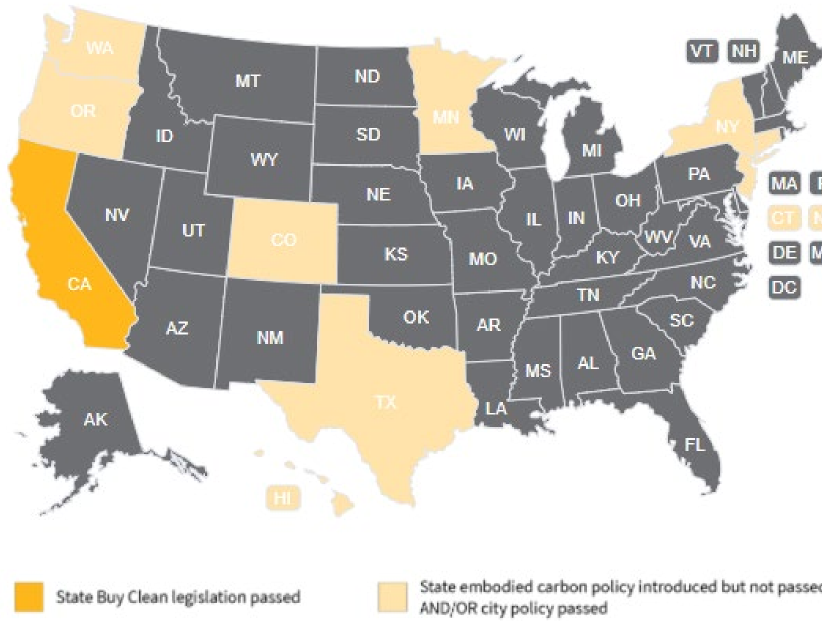
Buy Clean is a movement of non-profit organizations, private companies, and public officials working to end the consumption of high-carbon products and close the carbon loophole.

Governments and private companies around the world are changing the way products are made by **demanding low-carbon energy sources and climate-friendly processes in their supply chains.**

Buy Clean Policies

- **Federal:** A Buy Clean program was drafted in the Clean Futures Act, and clean manufacturing programs and incentives are included in Biden's Climate Action Plan and Infrastructure Plan.
- **State:** Iterations of Buy Clean were introduced in Oregon in 2017, Washington in 2018, Minnesota in 2019, and Colorado in 2020. Material-specific low-carbon incentives were also introduced in New York, Maryland and New Jersey
- **Local:** Cities are adopting regional or material-specific variations of Buy Clean, such as lower-carbon concrete procurement in Portland, Oregon and Kansas City, KS.

Buy Clean policies are spreading rapidly.



Clean Future Act

CLEAN Future Act, H.R.1512 – 117th Congress (2021 – 2022).

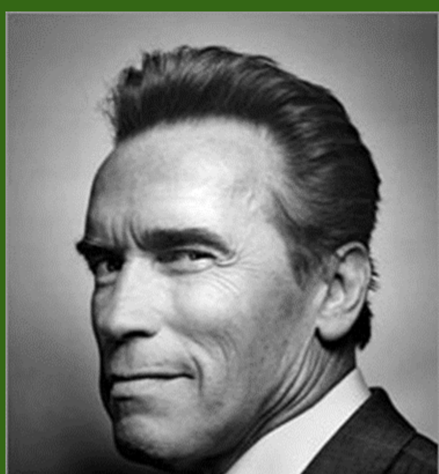
The CLEAN Future Act, also known as the *Leadership and Environmental Action for our Nation's Future*, is legislation which creates requirements and incentives to reduce emissions of greenhouse gases. The law establishes an interim goal to reduce greenhouse gas emissions to at least 50% below 2005 levels by 2030 as well as a national goal to achieve net-zero greenhouse gas emissions by 2050.

Every federal agency must develop a plan to achieve these goals.

Buy Clean Policies

Buy Clean acts are legislation that promotes use of typically low GWP products though common tactics of financial incentives/disincentives or exclusionary caps

- Started in California, then introduced in other states such as Minnesota and Colorado



*"**Cement factories** said there is no way to produce cement without polluting the way we do now. We found that there are many European companies producing cement that release only half the greenhouse gas, so there is the technology there… When we passed our $20 billion infrastructure bonds, we said, 'Let's not build any of those roads without that technology.'"*

-Arnold Schwarzenegger, CA Governor, 2007

Sustainability Becomes Policy

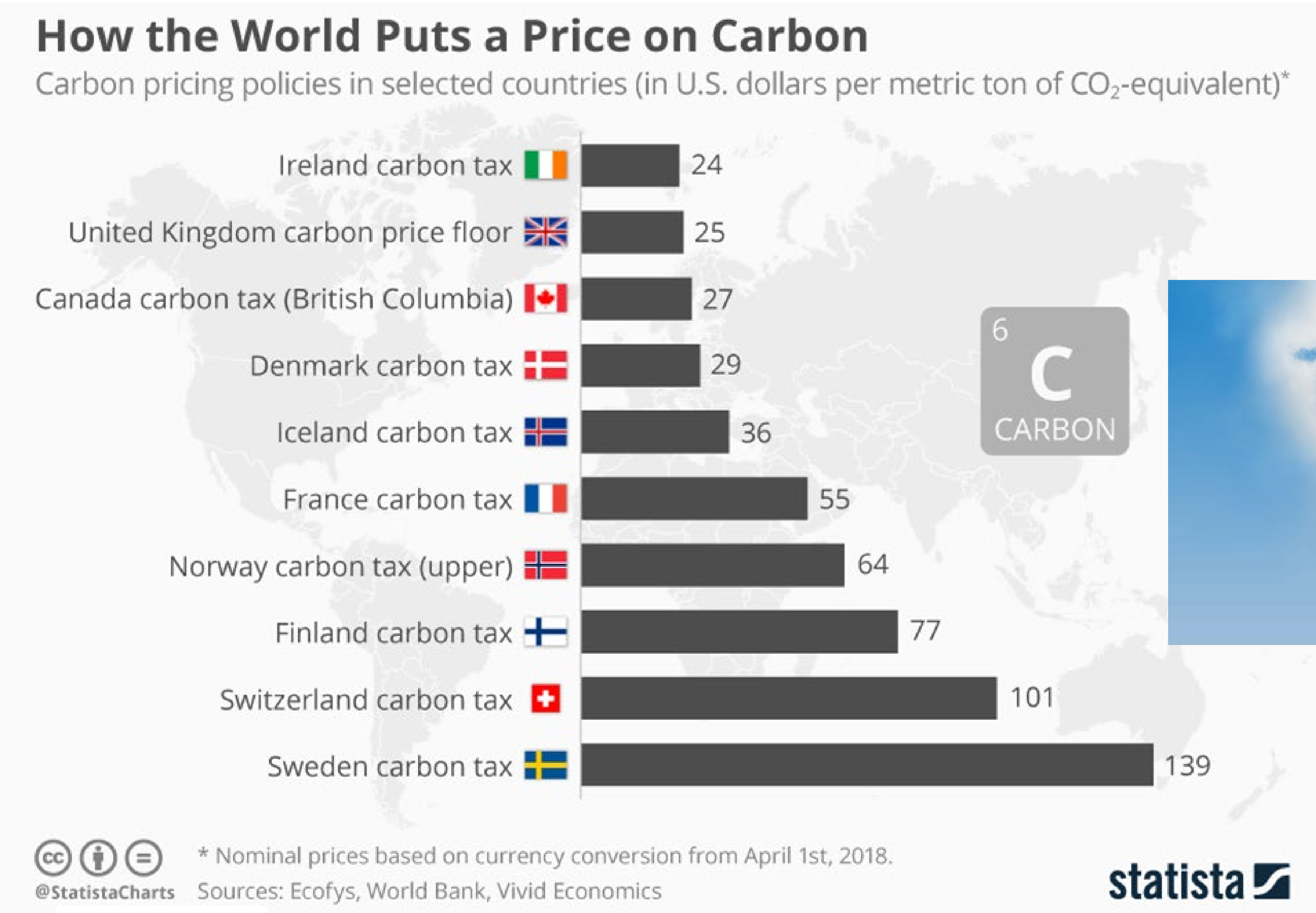
Private Sector

- “I want low-carbon products”
- Lower carbon footprint goals / requirements
- Market demanding consistent improvement and transparency
- Investors demanding the same

“I am optimistic that innovation can help reduce the downsides of concrete… researchers are developing new materials that would cut down on our need for concrete in the first place.”

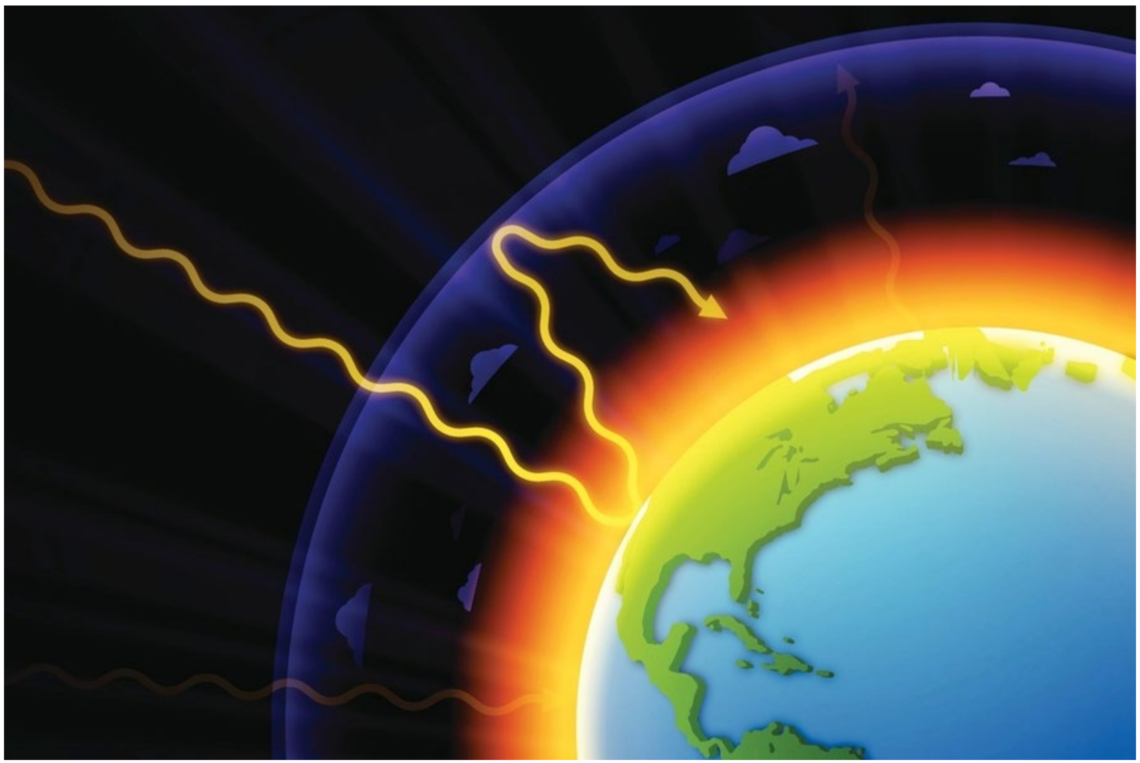
-Bill Gates, June 25, 2014

Sustainability Becomes Policy



Global Warming Potential (GWP)

GWP is a metric where the abilities of different gases to absorb heat is normalized to a CO_2 equivalent, represented in metric tons of CO_2/kg of the gas being evaluated



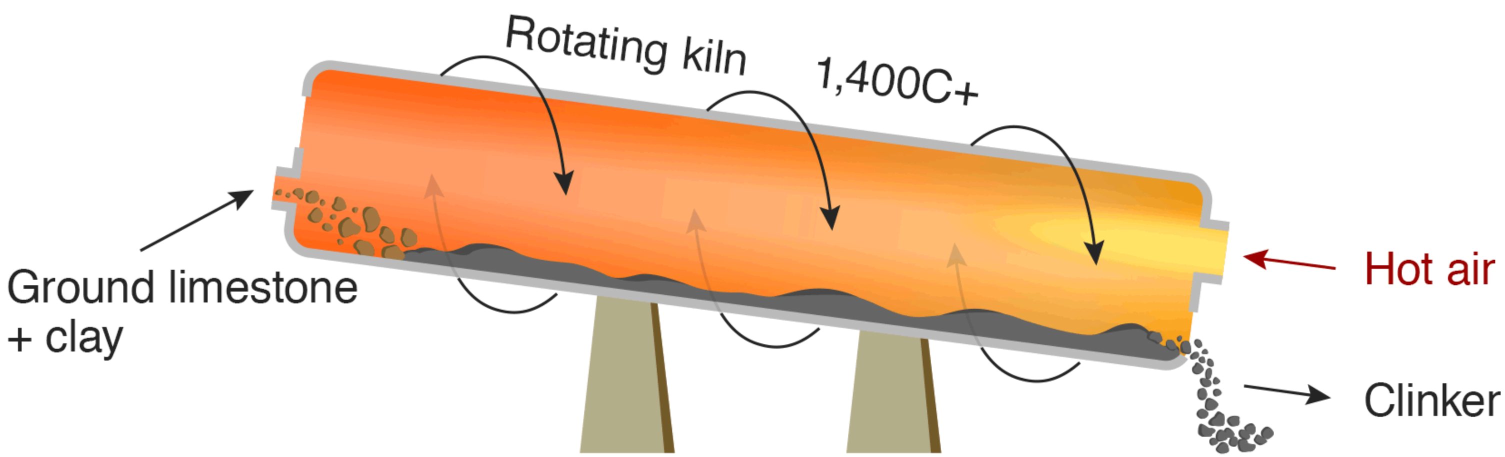
Industry Average:
Type I: 922 CO_2/kg

A relative measure of how much heat a green-house-gas traps in the atmosphere

Carbon Dioxide (CO_2) & Lowering the GWP

Limestone and raw materials are crushed and proportioned that the resulting mixture contains the desired composition cement

The material is fed into a kiln fueled by fossil fuels to approximately 3,000˚Fahrenheit (˚F)



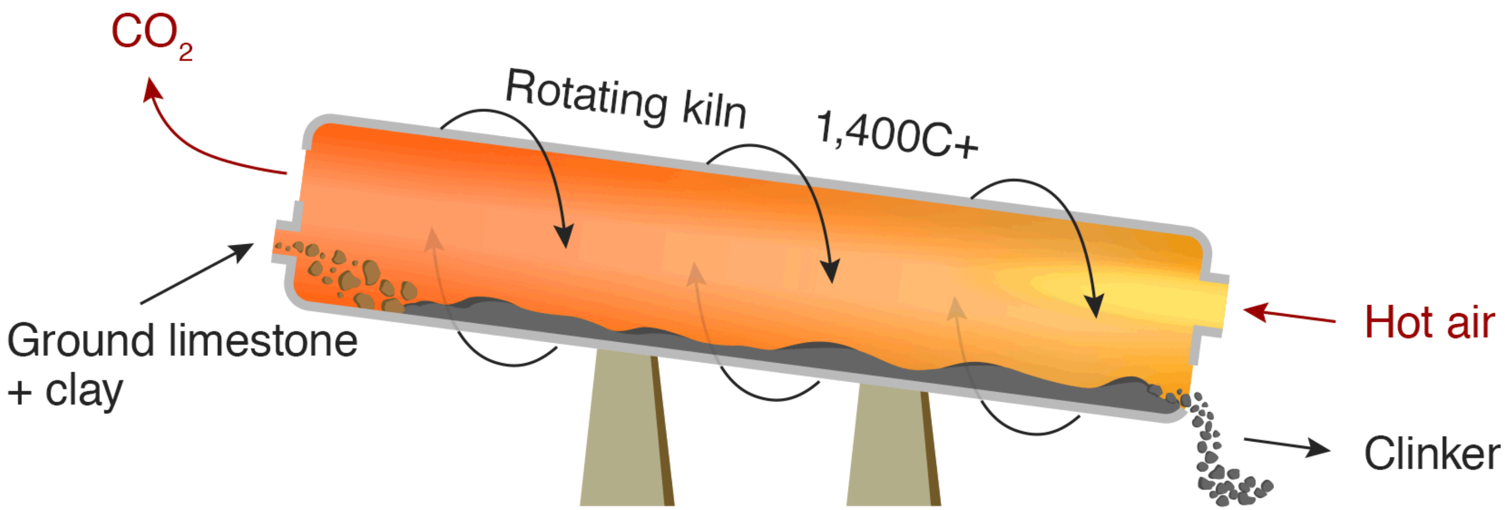
Source: Carbon Brief, Chatham House

BBC

Carbon Dioxide (CO_2) & Lowering the GWP

This process chemically changes the raw material into cement clinker which is then processed into cement

It is the burning of this material, termed 'calcination' that emits approximately 75% of the CO_2 a plant emits



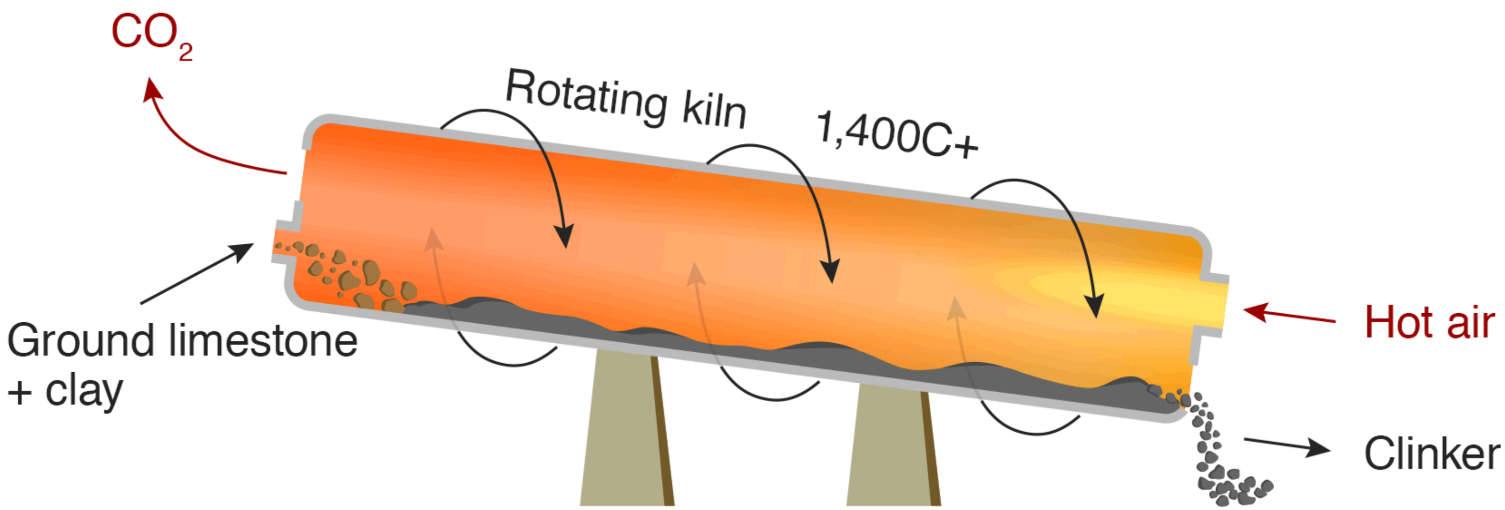
Source: Carbon Brief, Chatham House

BBC

Carbon Dioxide (CO_2) & Lowering the GWP

Any attempt made to reduce the amount of material fed into the kiln will reduce the CO_2 emissions at a plant

Transitioning from TI to TIL PLC will reduce the Global Warming Potential (GWP) of the plant



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1 Ton of Portland Cement Clinker

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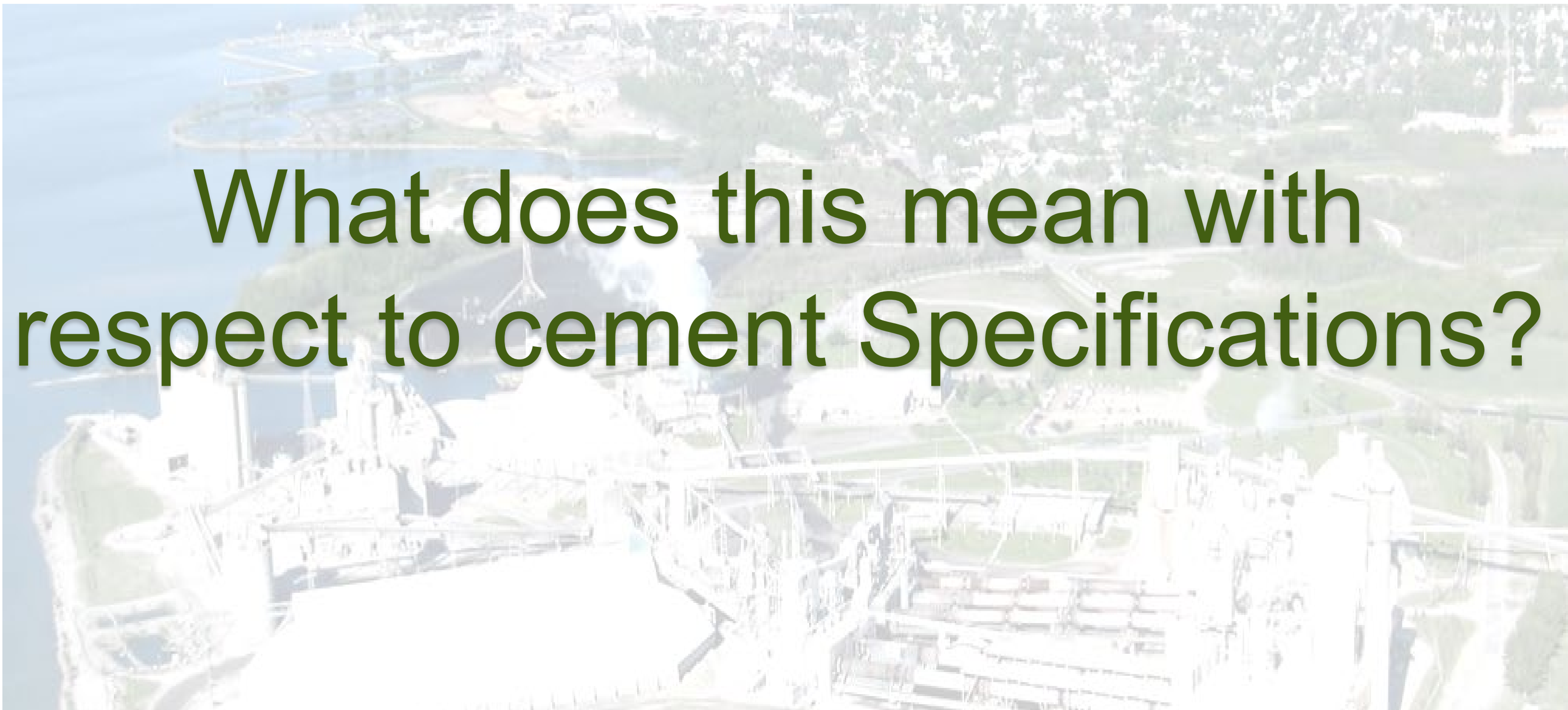
CO_2

Cement Specifications

Carbon dioxide (CO_2) has been identified as a green-house-gas



What does this mean with respect to cement Specifications?

Sp

Designation: C150/C15

INTERNATIONAL

Standard Specificat
Portland Cement[1]

This standard is issued under the fixed
of original adoption or, in the case of r
A superscript epsilon (ε) indicates an e

1. Scope*

1.1 This specification covers ten types o
as follows (see Note 2):

1.1.1 *Type I*—For use when the special p
for any other type are not required.

1.1.2 *Type IA*—Air-entraining cement fo
Type I, where air-entrainment is desired.

1.1.3 *Type II*—For general use, more esp
erate sulfate resistance is desired.

1.1.4 *Type IIA*—Air-entraining cement fo
Type II, where air-entrainment is desired.

1.1.5 *Type II(MH)*—For general use, mo
moderate heat of hydration and moderate su
desired.

1.1.6 *Type II(MH)A*—Air-entraining cen
uses as Type II(MH), where air-entrainmen

1.1.7 *Type III*—For use when high early

1.1.8 *Type IIIA*—Air-entraining cement f
Type III, where air-entrainment is desired.

1.1.9 *Type IV*—For use when a low he
desired.

1.1.10 *Type V*—For use when high su
desired.

NOTE 1—Some cements are designated wit
classification, such as Type I/II, indicating that t
requirements of the indicated types and is being offe
when either type is desired.

NOTE 2—Cement conforming to the requirement
carried in stock in some areas. In advance of specify
other than Type I, determine whether the proposed
can be made, available.

1.2 The values stated in either SI units o
are to be regarded separately as standard. T
each system may not be exact equivalent
system shall be used independently of the
values from the two systems may result in
with the standard. Values in SI units [or inch
be obtained by measurement in SI units [or

[1] This specification is under the jurisdiction of AST
Cement and is the direct responsibility of Subcommitte
Cements for General Concrete Construction.

Current edition approved March 15, 2016. Published
approved in 1940. Last previous edition approved in 201
DOI: 10.1520/C0150_C0150M-16.

*A Summa

C451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)
C452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate
C465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
C563 Test Method for Approximation of Optimum SO_3 in Hydraulic Cement Using Compressive Strength
C1038 Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water
C1702 Test Method for Measurement of Heat of Hydration of Hydraulic Cementitious Materials Using Isothermal Conduction Calorimetry
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions*—See Terminology C219.

4. Ordering Information

4.1 Orders for material under this specification shall include the following:

4.1.1 This specification number and date,

4.1.2 Type or types allowable. If no type is specified, Type I shall be supplied,

4.1.3 Any optional chemical requirements from Table 2, if desired, and

4.1.4 Any optional physical requirements from Table 4, if desired.

5. Ingredients

5.1 The cement covered by this specification shall contain no ingredients except as follows:

5.1.1 Portland cement clinker.

5.1.2 Water or calcium sulfate, or both. The amounts shall be such that the limits shown in Table 1 for sulfur trioxide and loss-on-ignition are not exceeded.

5.1.3 Limestone. The amount shall not be more than 5.0 % by mass such that the chemical and physical requirements of this standard are met (see Note 3). The limestone, defined in Terminology C51, shall be naturally occurring and consist of at least 70 % by mass of one or more of the mineral forms of calcium carbonate. If limestone is used, the manufacturer shall report the amount used, expressed as a percentage of cement mass, as determined using Annex A2, along with the oxide composition of the limestone.

NOTE 3—The standard permits up to 5 % by mass of the final cement product to be naturally occurring, finely ground limestone, but does not require that limestone be added to the cement. Cement without ground limestone can be specified in the contract or order.

5.1.4 Inorganic processing additions. The amount shall be not more than 5.0 % by mass of cement. Not more than one inorganic processing addition shall be used at a time. For amounts greater than 1.0 %, they shall have been shown to meet the requirements of Specification C465 for the inorganic processing addition in the amount used or greater. If an inorganic processing addition is used, the manufacturer shall

TABLE 1 Standard Composition Requirements

Cement Type[A]	Applicable Test Method	I and IA	II and IIA	II(MH) and II(MH)A	III and IIIA	IV	V
Aluminum oxide (Al_2O_3), max, %	C114	...	6.0	6.0	...	...	...
Ferric oxide (Fe_2O_3), max, %	C114	...	6.0[B]	6.0[B,C]	...	6.5	...
Magnesium oxide (MgO), max, %	C114	6.0	6.0	6.0	6.0	6.0	6.0
Sulfur trioxide (SO_3),[D] max, %	C114						
When (C_3A)[E] is 8 % or less		3.0	3.0	3.0	3.5	2.3	2.3
When (C_3A)[E] is more than 8 %		3.5	[F]	[F]	4.5	[F]	[F]
Loss on ignition, max, %	C114						
When limestone is not an ingredient		3.0	3.0	3.0	3.0	2.5	3.0
When limestone is an ingredient		3.5	3.5	3.5	3.5	3.5	3.5
Insoluble residue, max, %	C114	1.5	1.5	1.5	1.5	1.5	1.5
Tricalcium silicate (C_3S)[E], max, %	See Annex A1	...	...	...	...	35[C]	...
Dicalcium silicate (C_2S)[E], min, %	See Annex A1	...	...	...	...	40[C]	...
Tricalcium aluminate (C_3A)[E], max, %	See Annex A1	...	8	8	15	7[C]	5[B]
Sum of $C_3S + 4.75C_3A$[G], max, %	See Annex A1	...	...	100[C,H]	...	...	...
Tetracalcium aluminoferrite plus twice the tricalcium aluminate ($C_4AF + 2(C_3A)$), or solid solution ($C_4AF + C_2F$), as applicable, max, %	See Annex A1	...	...	...	...	...	25[B]

[A] See Note 2.
[B] Does not apply when the sulfate resistance limit in Table 4 is specified.
[C] Does not apply when the heat of hydration limit in Table 4 is specified.
[D] It is permissible to exceed the values in the table for SO_3 content, provided it has been demonstrated by Test Method C1038 that the cement with the increased SO_3 will not develop expansion exceeding 0.020 % at 14 days. When the manufacturer supplies cement under this provision, supporting data shall be supplied to the purchaser. See Note 6.
[E] See Annex A1 for calculation.
[F] Not applicable.
[G] See Note 5.

However, the cement industry needs to:

- **Decrease** its CO_2 output
- **Improve** its *Global Warming Potential* (GWP)

been added so that the resulting product complies with the air content of mortar requirements.

7.1.5 *Portland-Limestone Cement*—Portland-limestone cement shall be a hydraulic cement in which the limestone content is more than 5 % but less than or equal to 15 % by mass of the blended cement.

7.1.6 *Air-Entraining Portland-Limestone Cement*—Air-entraining portland-limestone cement shall be portland-limestone cement to which sufficient air-entraining addition has been added so that the resulting product complies with the air content of mortar requirements.

7.2 *Ternary Blended Cement*—Ternary blended cement shall be a hydraulic cement consisting of an intimate and uniform blend (see Note 8) produced either by intergrinding, by blending, or a combination of intergrinding, and blending portland cement clinker or portland cement with *(1)* two different pozzolans, *(2)* slag and a pozzolan, *(3)* a pozzolan and a limestone, or *(4)* a slag and a limestone. Ternary blended cement Type IT(S≥70) shall have a maximum limestone content of 15 % by mass and is permitted to contain hydrated lime. All other ternary blended cements shall have a maximum pozzolan content of 40 % by mass of the blended cement, a maximum limestone content of 15 % by mass of the blended cement, and the total content of pozzolan, limestone, and slag shall be less than 70 % by mass of the blended cement. Any slag, pozzolan, or limestone used as ingredient in portland cement used to manufacture a blended cement shall be included in the total amount of those materials reported in 4.2 or 15.1.

NOTE 8—The attainment of an intimate and uniform blend of two or more types of fine materials is difficult. Consequently, adequate equipment and controls must be provided by the manufacturer. The purchasers should assure themselves of the adequacy of the blending operation.

8. Chemical Composition

8.1 *Blended Cement*—Cement of the type specified shall conform to the applicable chemical requirements prescribed in Table 1.

NOTE 9—There are cases where performance of a cement is improved with SO_3 in excess of the Table 1 limits in this specification. Test Method C563 is one of several methods a manufacturer can use to evaluate the effect of sulfate content on cement characteristics. Whenever SO_3 content of a cement exceeds Table 1 limits, Test Method C1038 results provide evidence that excessive expansion does not occur at this higher sulfate content.

8.1.1 If the purchaser has requested the manufacturer to state in writing the composition of the blended cement purchased, the composition of the cement furnished shall conform to that shown in the statement within the following tolerances (see Note 10).

	Tolerance, ± %
Silicon dioxide (SiO_2)	3
Aluminum oxide (Al_2O_3)	2
Calcium oxide (CaO)	3

NOTE 10—This means that if the manufacturer's statement of the composition says "SiO_2: 32 %," the cement when analyzed, shall be found to contain between 29 and 35 % SiO_2.

8.2 *Limestone*—Limestone for use in the manufacture of portland-limestone cement, or a ternary blended cement in which limestone is an ingredient, shall have a calcium carbonate content of at least 70 % by mass. The calcium carbonate content of limestone shall be determined by multiplying the CaO content of the limestone, determined by Test Methods C114, by a factor of 1.785.

8.3 *Pozzolan*—Pozzolan for use in the manufacture of portland-pozzolan cement, or a ternary blended cement in which pozzolan is an ingredient, shall meet the loss-on-ignition requirement of Table 4.

9. Physical Properties

9.1 *Blended Cement*—Blended cement of the type specified shall conform to the applicable physical requirements prescribed in Table 2. When specified, blended cement with special properties shall conform to applicable physical requirements in Table 3, and requirements for compressive strength and air content in Table 3 supersede those in Table 2.

9.2 *Pozzolan or Slag*—Pozzolan or slag that is to be blended with cement shall be tested in the same state of subdivision as that in which it is to be blended. Pozzolan shall conform to the

TABLE 2 Physical Requirements for Blended Cements

Cement Type	Applicable Test Method	IL, IP, IS(<70), IT(S<70)	IS(≥70), IT(S≥70)
Fineness	C204, C430	[A]	[A]
Autoclave expansion, max, %[B]	C151	0.80	0.80
Autoclave contraction, max, %[B]	C151	0.20	0.20
Time of initial setting, Vicat test:[C]			
Set, minutes, not less than	C191	45	45
Set, hours, not more than		7	7
Air content of mortar, volume %, max	C185	12	12
Compressive strength, min, MPa [psi]:			
3 days	C109/C109M	13.0 [1890]	...
7 days		20.0 [2900]	5.0 [720]
28 days		25.0 [3620]	11.0 [1600]

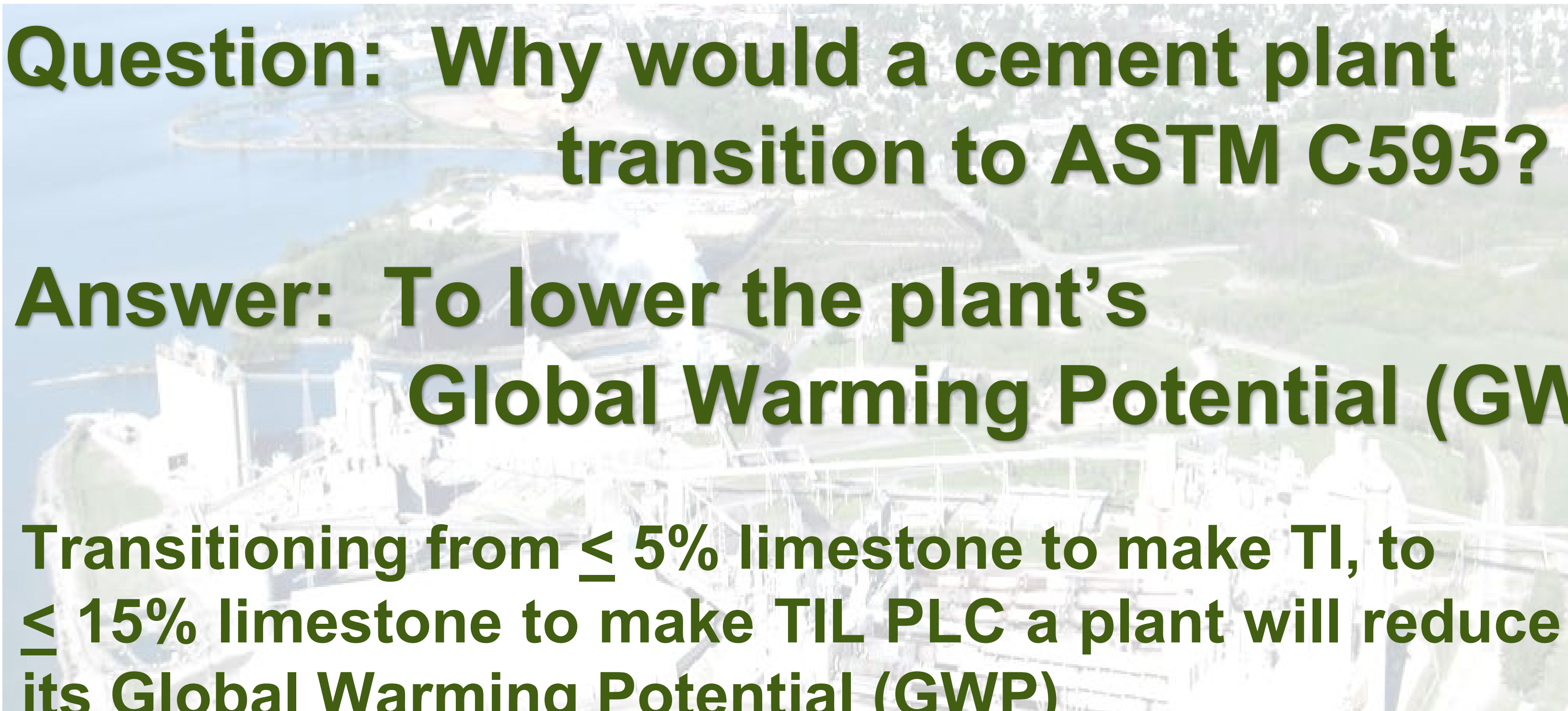
[A] Both amount retained when wet-sieved on 45-μm (No. 325) sieve and specific surface by air permeability apparatus, m^2/kg, shall be reported on all mill test reports requested under 15.4.

Specifications

- **ASTM C595 *Standard Specification for Blended Hydraulic Cements***
  - According to ASTM C595, the nomenclature is: **Type IL(X)** where X represents the amount of targeted limestone
    - For example: Type IL(10)
  - **Note: There are other ASTM C595 Cements**
    - For example: Type IS(30), or Type IP(5), Type IT(S30)(P5)
- **ASTM C1157 *Standard Performance Specification for Hydraulic Cement***
  - Type GU, General Use
  - There are no restrictions on the limestone addition or any other composition of the cement or its constituents

Lowering a Plant's GWP

Carbon dioxide (CO_2) has been identified as a green-house-gas



Question: Why would a cement plant transition to ASTM C595?

Answer: To lower the plant's Global Warming Potential (GWP)

Transitioning from ≤ 5% limestone to make TI, to ≤ 15% limestone to make TIL PLC a plant will reduce its Global Warming Potential (GWP)

History of ASTM C595 in Michigan & Ohio

- **MI & OH have been building with ASTM C595 cements since 2005**

UM - Big House
Football Stadium Renovations
Type IT(S25)(P5)

M-231 Bridges and Bypass
Holland & Grand Haven, MI
Type IT(S25)(P4)

History of ASTM C595 in Michigan & Ohio

- **MI & OH have been building with ASTM C595 cements since 2005**

Residential Driveways
Type IS(20)

Cement Specifications & Codes

TIL Portland Limestone Cements (PLC) are acknowledged and accepted for use wherever ASTM C150 TI is specified or cited in all National Codes, Specifications, Standards, and Guides

3.3.2.10 *Reinforcement through expansion joint*—Do not continue reinforcement or other embedded metal items bonded to concrete through expansion joints. If specified, dowels may continue through expansion joints if unbonded on one side of the joint.

SECTION 4—CONCRETE MIXTURES

4.1—General

4.1.1 *Scope*—This section covers the requirements for materials, proportioning, production, and delivery of concrete.

4.1.2 *Submittals*

4.1.2.1 *Mixture proportions*—Concrete mixture proportions and characteristics.

4.1.2.2 *Mixture strength data*—Field test records used to establish the required average strength in accordance with 4.2.3.3.

4.1.2.3 *Concrete materials*—The following information for concrete materials, along with evidence demonstrating compliance with 4.2.1:

4.1.2.3(a) For cementitious materials: types, manufacturing locations, shipping locations, and certificates showing compliance with ASTM C150/C150M, ASTM C595/C595M, ASTM C618, ASTM C845/C845M, ASTM C989/C989M, ASTM C1157/C1157M, or ASTM C1240.

4.1.2.3(b) For aggregates: types, pit or quarry locations, producers' names, aggregate supplier statement of compliance with ASTM C33/C33M, and ASTM C1293 expansion data not more than 18 months old.

4.1.2.3(c) For admixtures: types, brand names, producers' names, manufacturer's technical data sheets, and certificates showing compliance with ASTM C260/C260M, ASTM C494/C494M, ASTM C1017/C1017M, or ASTM D98.

4.1.2.3(d) For water and ice: source of supply, when nonpotable source is proposed for use, documentation on effects of water on strength and setting time in compliance with ASTM C1602/C1602M. If specified, documentation on optional requirements of ASTM C1602/C1602M.

the cementitious materials con...
in Table 4.1.2.9.

Table 4.1.2.9—Minimum ... content requirements ...

Nominal maximum size of aggregate, in.
1-1/2
1
3/4
3/8

CODE

CHAPTER 4—MATERIALS

4.1—Concrete

4.1.1 *Cementitious material*

4.1.1.1 Cement shall conform to ASTM C150/C150M, C595/C595M, or C1157/C1157M.

4.1.1.2 Fly ash and natural pozzolans shall conform to ASTM C618.

4.1.1.3 Slag cement shall conform to ASTM C989/C989M.

4.1.1.4 Silica fume shall conform to ASTM C1240.

4.1.2 *Aggregates*

4.1.2.1 Aggregates shall conform to ASTM C33/C33M or C330/C330M.

4.1.3 *Water*

4.1.3.1 Water used as mixing water in producing concrete shall conform to ASTM C1602/C1602M.

4.1.4 *Admixtures*

4.1.4.1 Air-entraining admixtures shall conform to ASTM C260/C260M.

4.1.4.2 Chemical admixtures shall conform to ASTM C494/C494M, except that admixtures for flowing concrete shall conform to ASTM C1017/C1017M.

4.1.4.3 Calcium chloride shall conform to ASTM D98.

4.1.5 *Recycled plastic concrete*

4.1.5.1 Recycled plastic concrete shall conform to ASTM C1798/C1798M.

4.2—Reinforcement

4.2.1 *Deformed reinforcement*

COMMENTARY

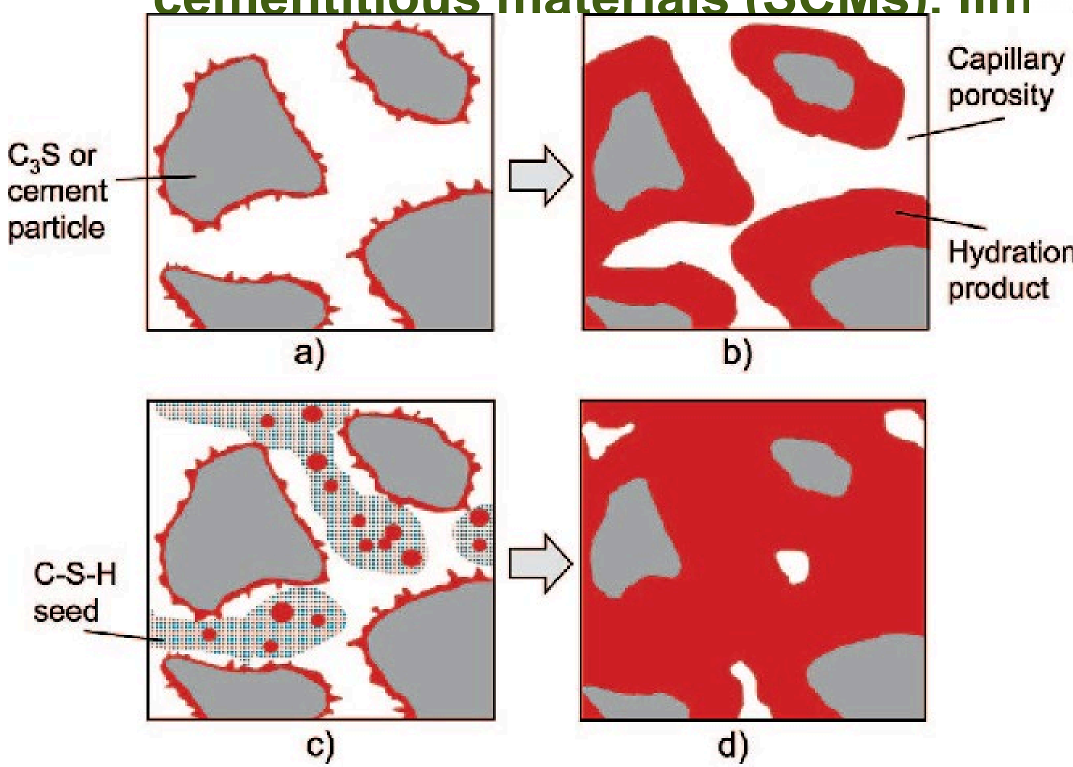
CHAPTER R4—MATERIALS

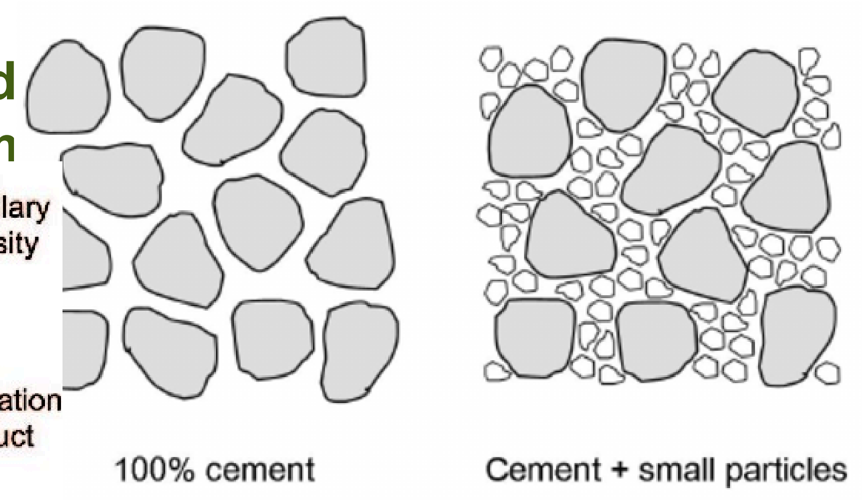
R4.2—Reinforcement

Why Would Codes & Specifications Allow PLC?

By following well-documented mix design and control practices, concrete made with PLC perform similarly to concrete without limestone

- **Although relatively inert compared cementitious materials (SCMs), lim**





dration products of traditional erated slightly; and

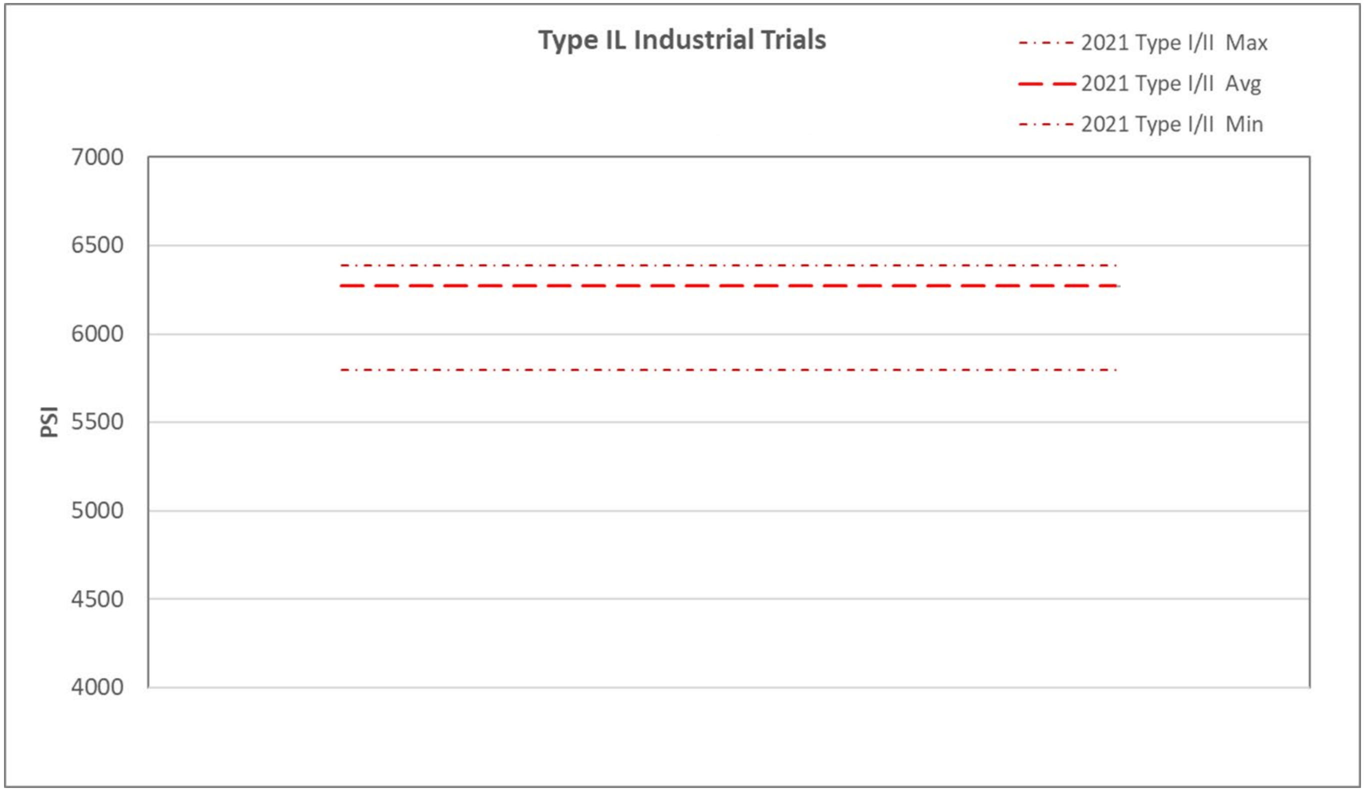
/ occur to a minor extent, to ıases, which can reduce porosity.

Portland Cement Association (PCA)
ıf *Limestone in Cements at Levels of up to 15%*
ꟼ. D. Tennis, M. D. A. Thomas, and W. J. Weiss

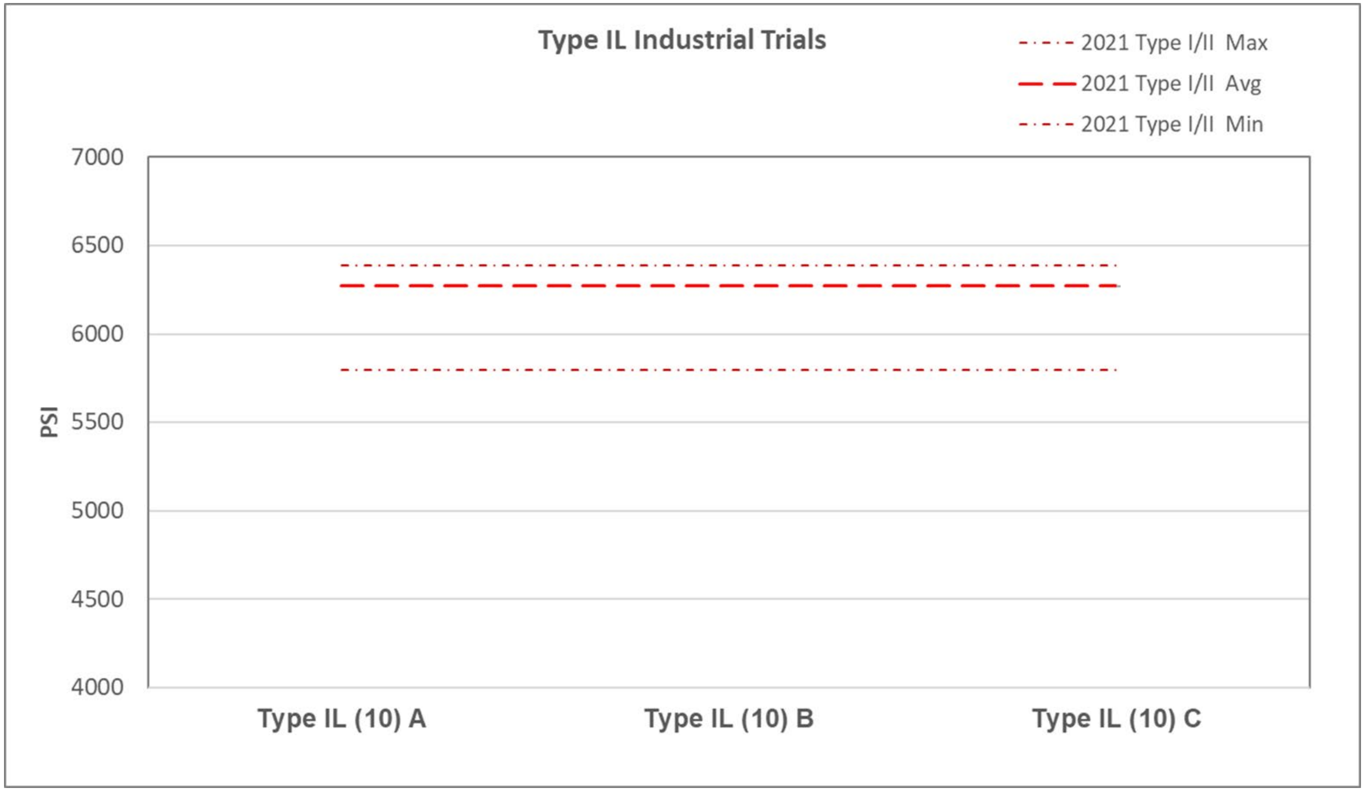
Comparisons: T-I to Type IL(10) PLC

Quarterly Competitive Test Program

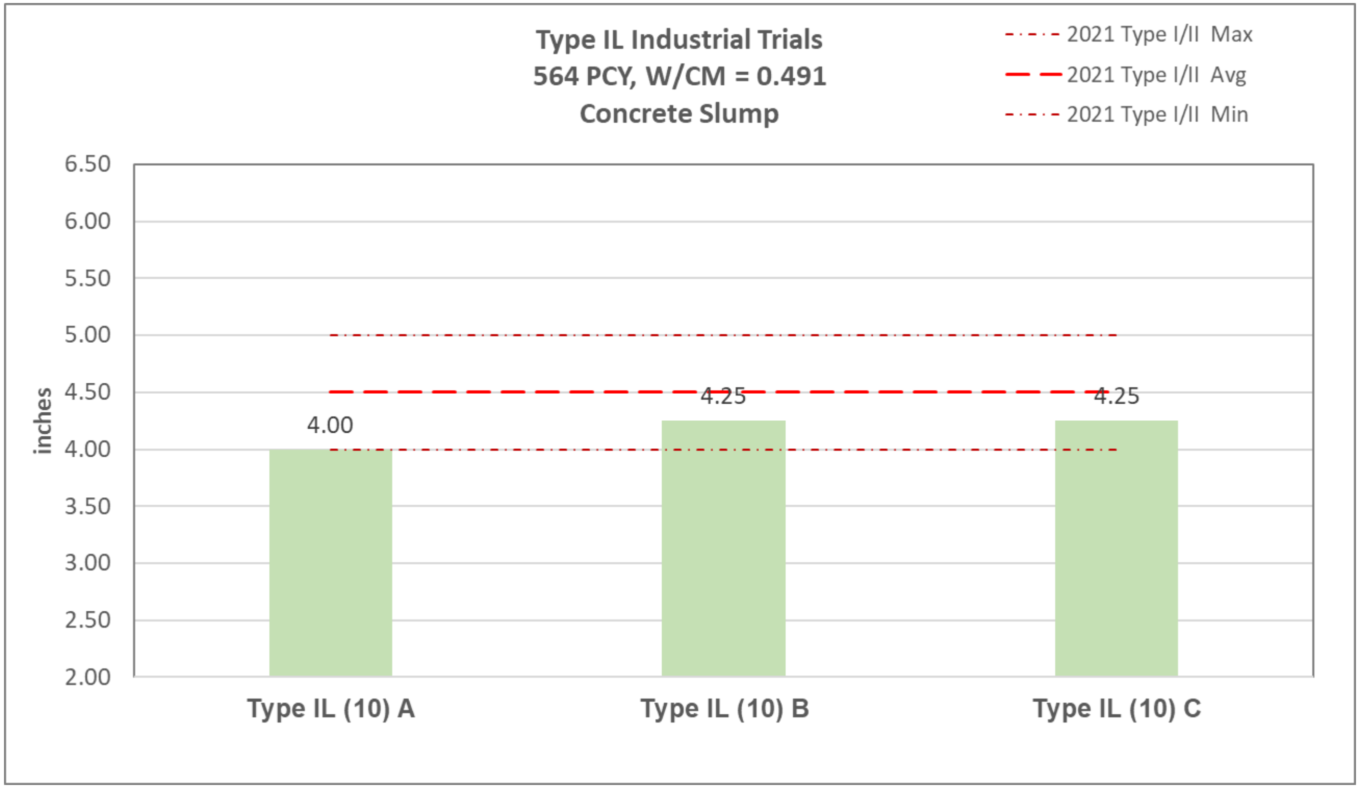
- Mix containing 564 lbs of cement, while incorporating:
  - Same aggregate source throughout the test program
  - Same laboratory personnel



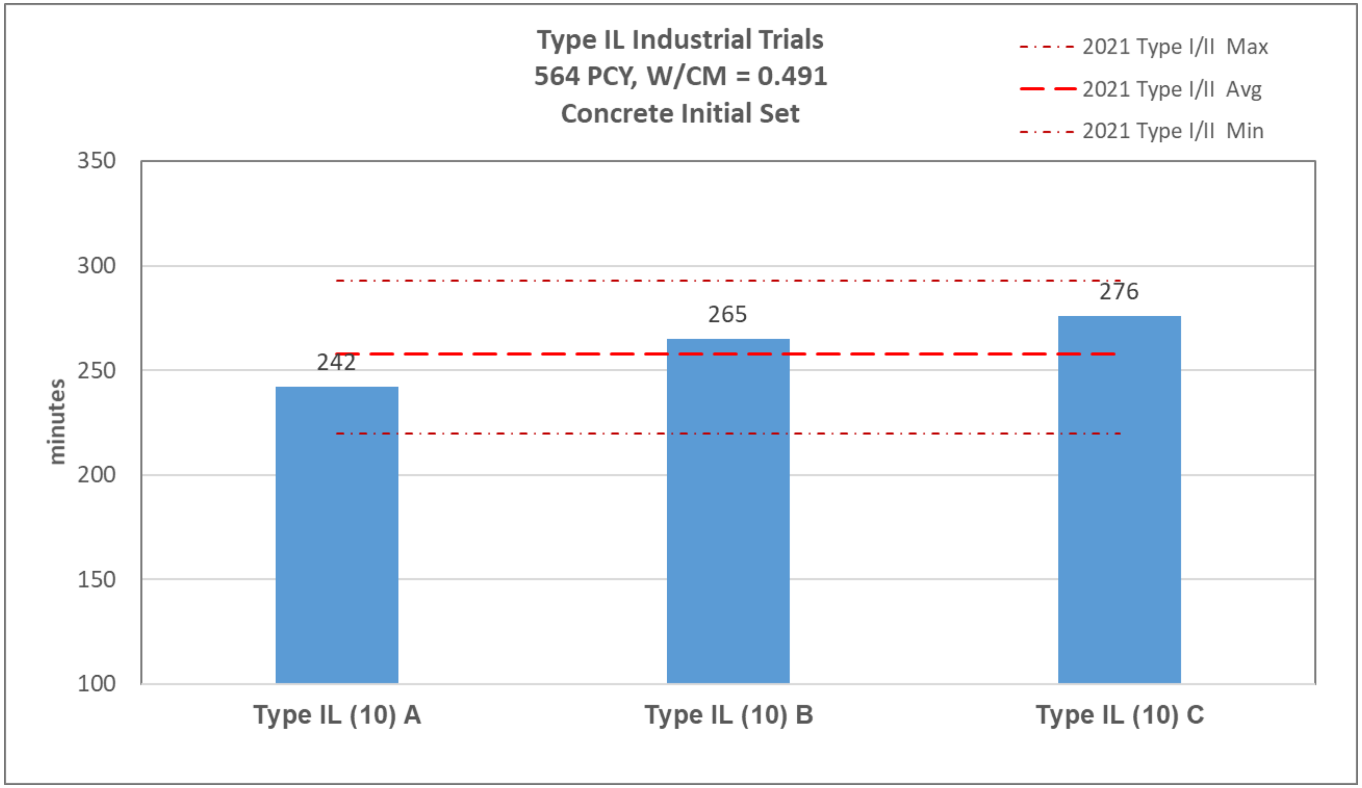
Type IL Industrial Trials
2021 Type I/II Max
2021 Type I/II Avg
2021 Type I/II Min
PSI
7000
6500
6000
5500
5000
4500
4000


Type IL Industrial Trials
2021 Type I/II Max
2021 Type I/II Avg
2021 Type I/II Min
7000
6500
6000
5500
5000
4500
4000
PSI
Type IL (10) A
Type IL (10) B
Type IL (10) C

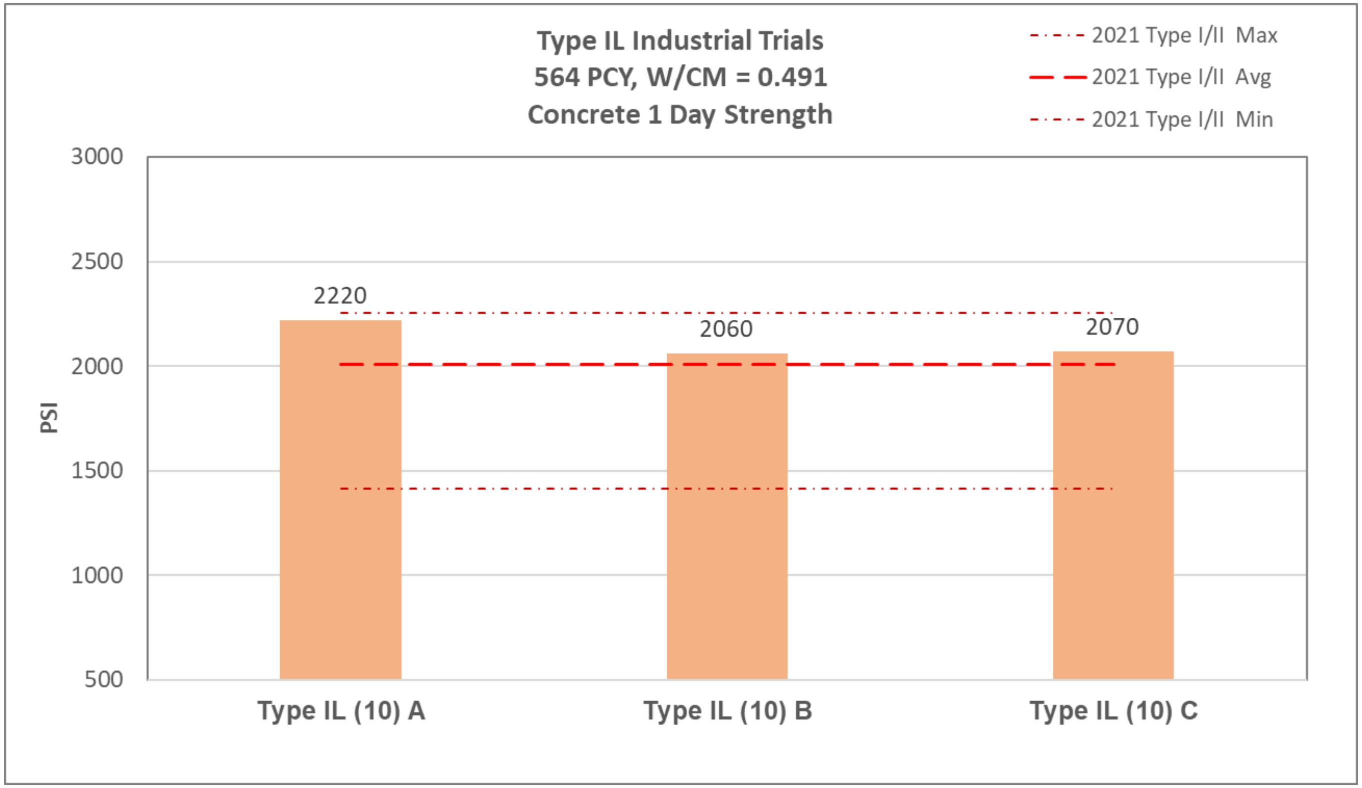
Type I v. Type IL(10) – *Slump*



Type I v. Type IL(10) – *Initial Set*



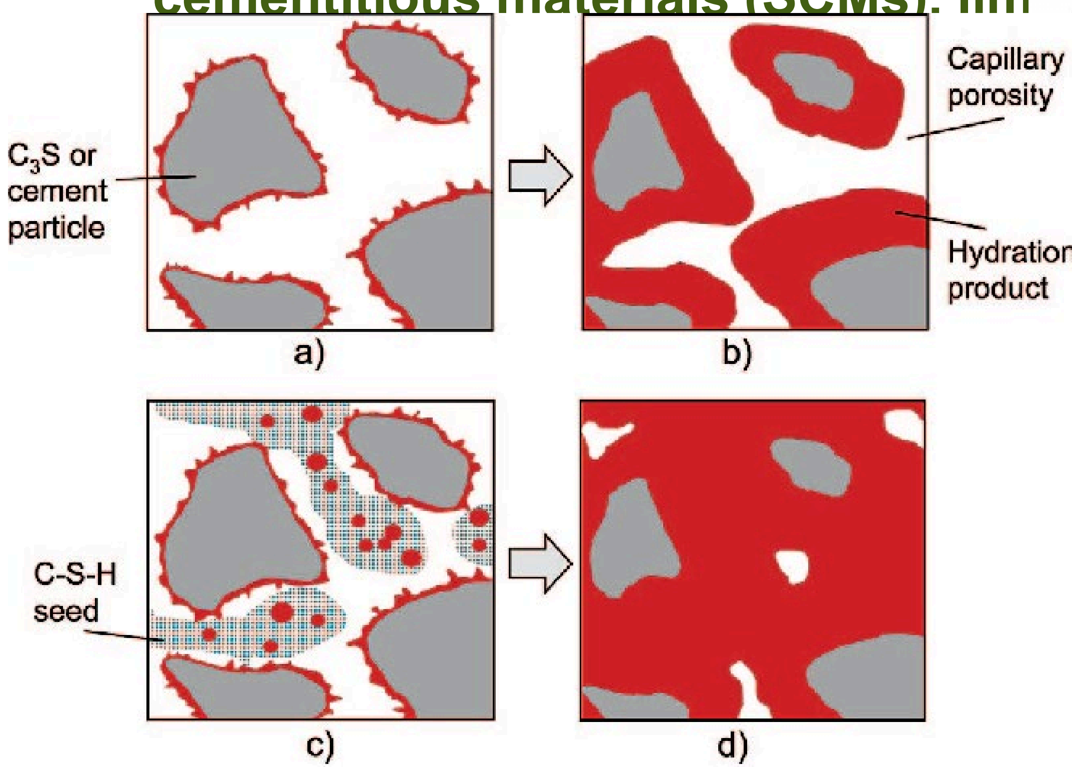
Type I v. Type IL(10) – *1 Day Strength*

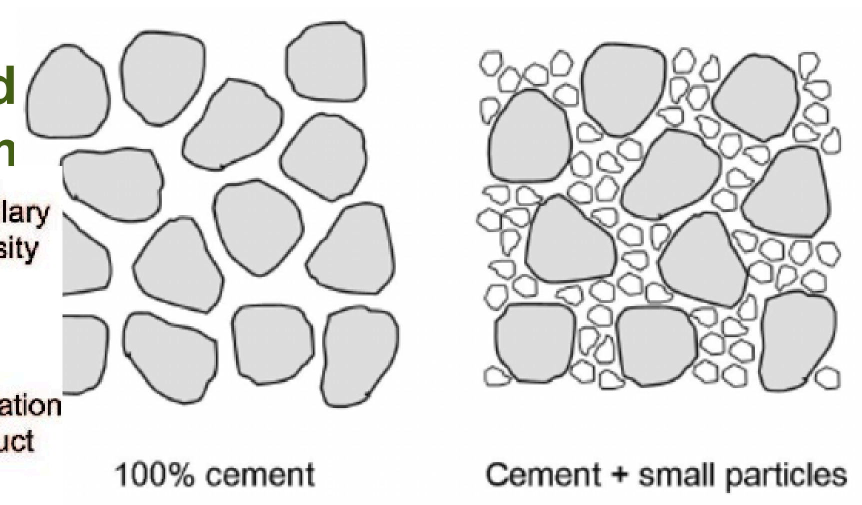


Why Would Codes & Specifications Allow PLC?

By following well-documented mix design and control practices, concrete made with PLC perform similarly to concrete without limestone

- **Although relatively inert compared**
cementitious materials (SCMs), lim



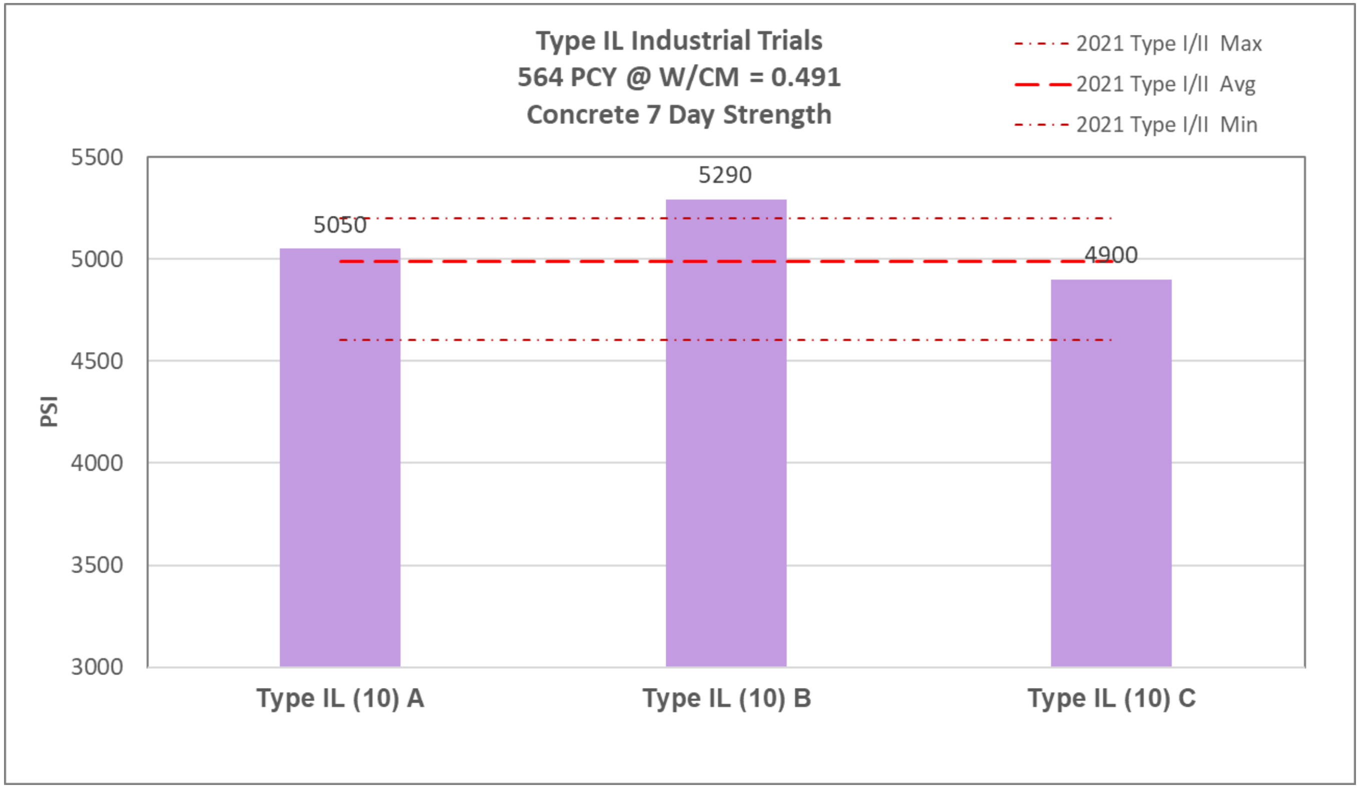


dration products of traditional
erated slightly; and

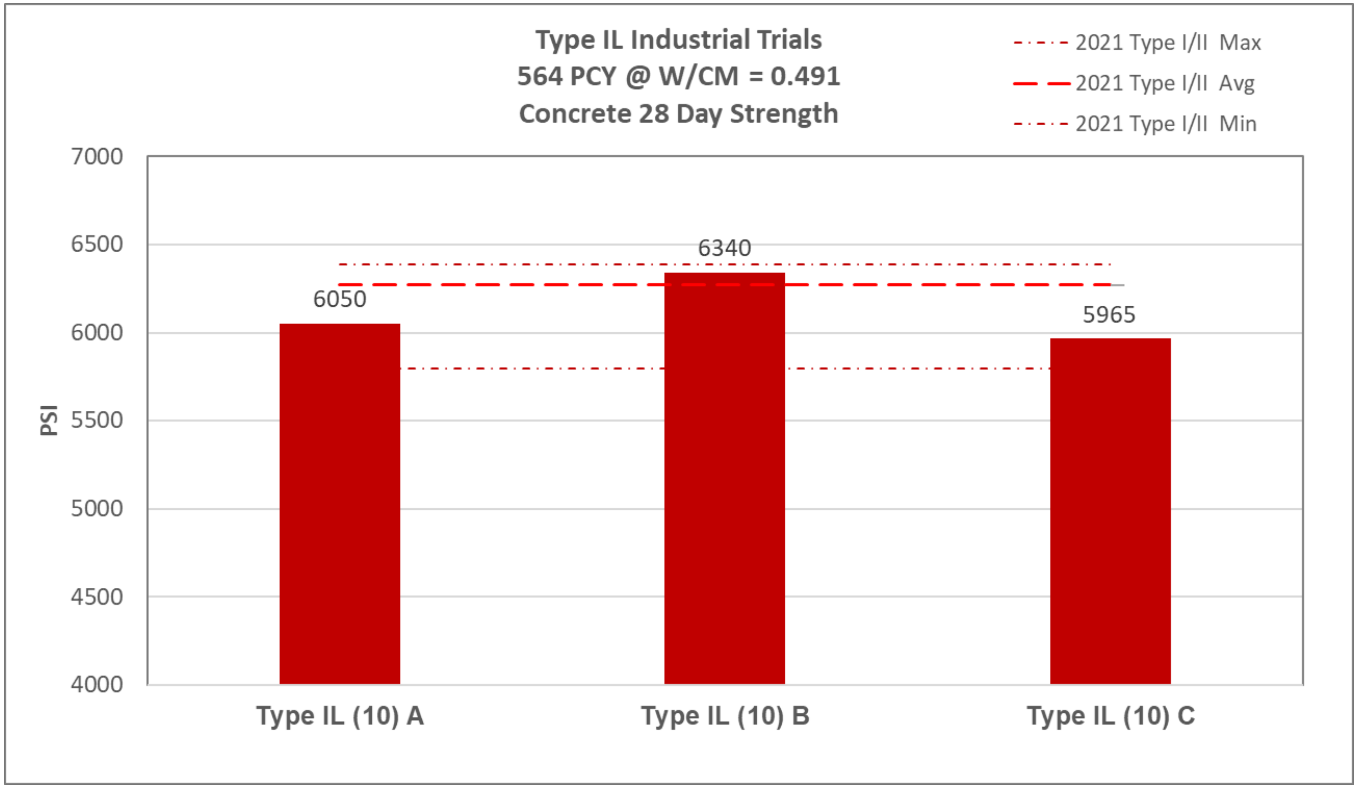
occur to a minor extent, to
ases, which can reduce porosity.

Portland Cement Association (PCA)
f Limestone in Cements at Levels of up to 15%
. D. Tennis, M. D. A. Thomas, and W. J. Weiss

Type I v. Type IL(10) – *7 Day Strength*



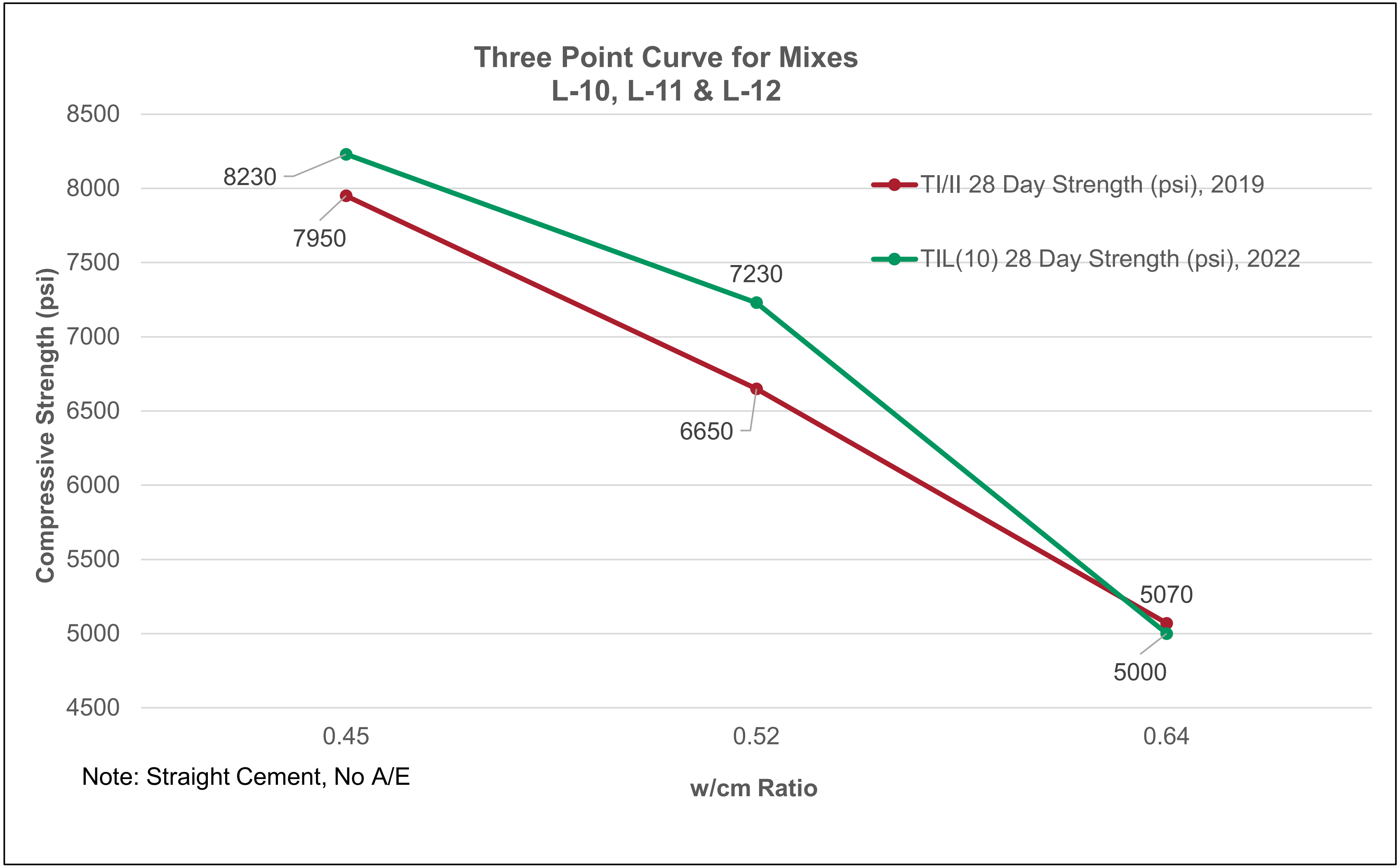
Type I v. Type IL(10) – *28 Day Strength*



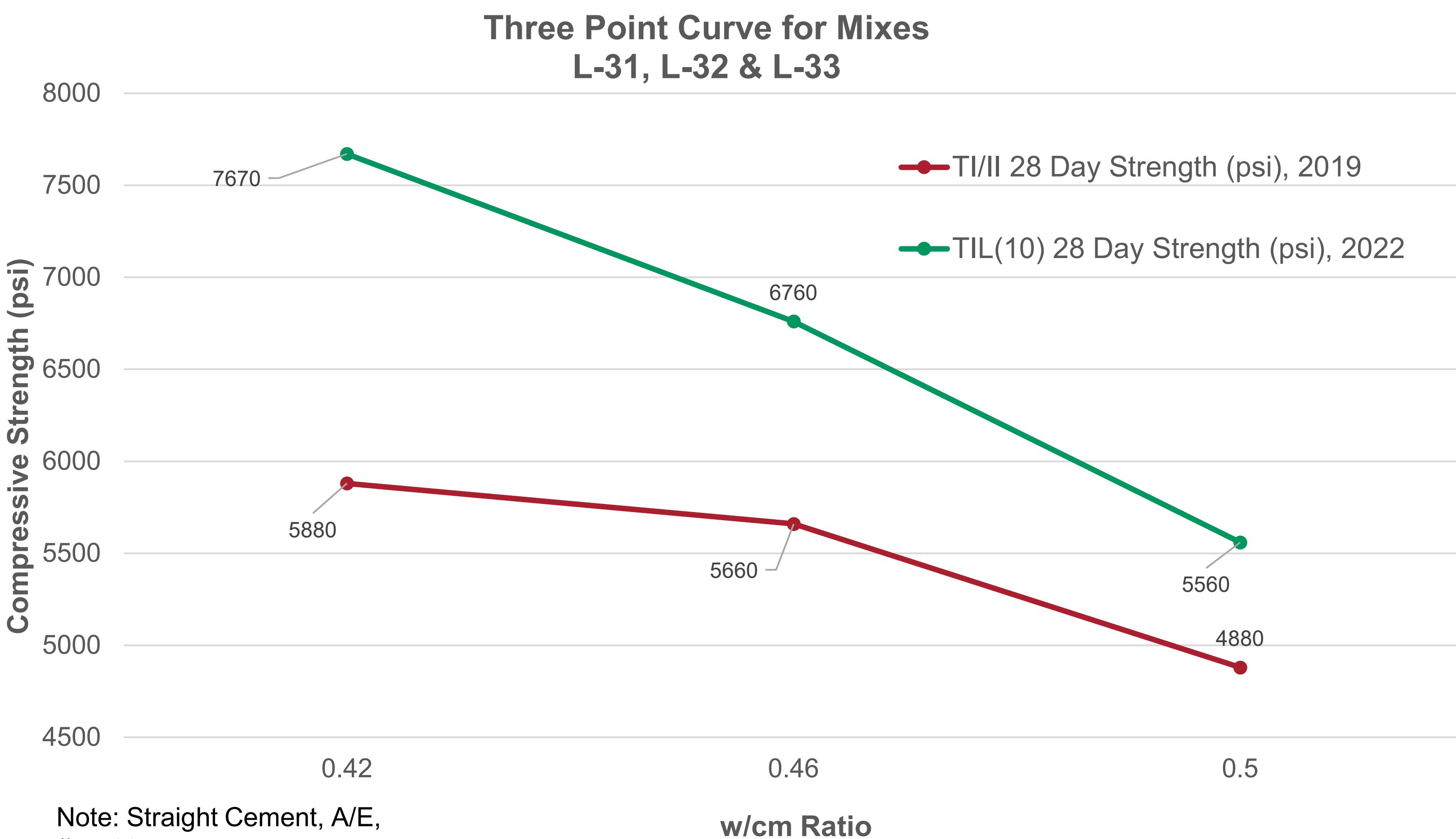
Comparisons: T-I to Type IL(10) PLC *Field Work*

Customer Field Work

Comparisons: T-I to Type IL(10) PLC *Field Work*



Comparisons: T-I to Type IL(10) PLC *Field Work*



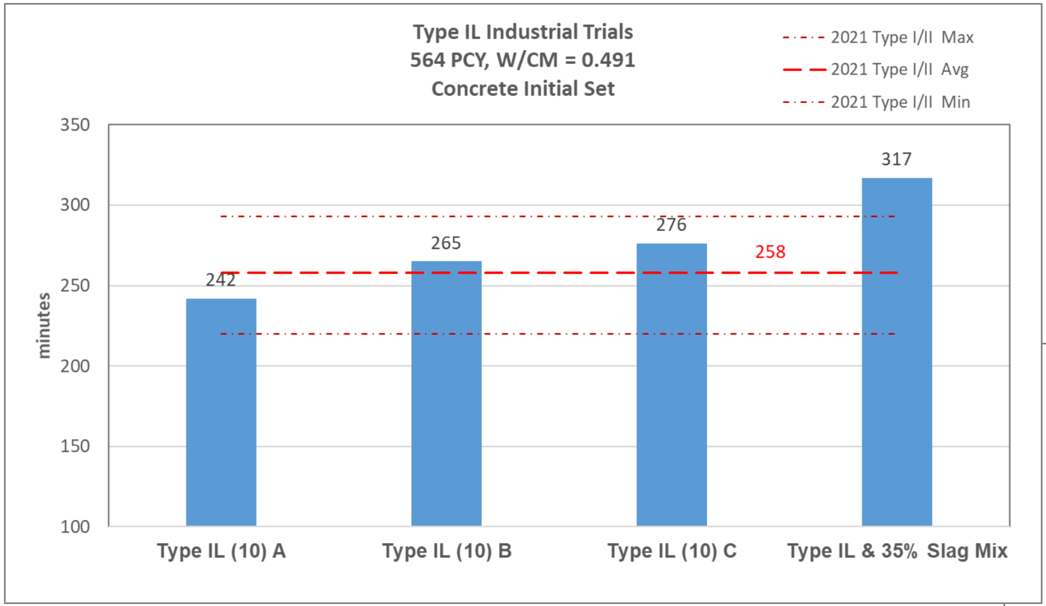
Note: Straight Cement, A/E,
57 Limestone

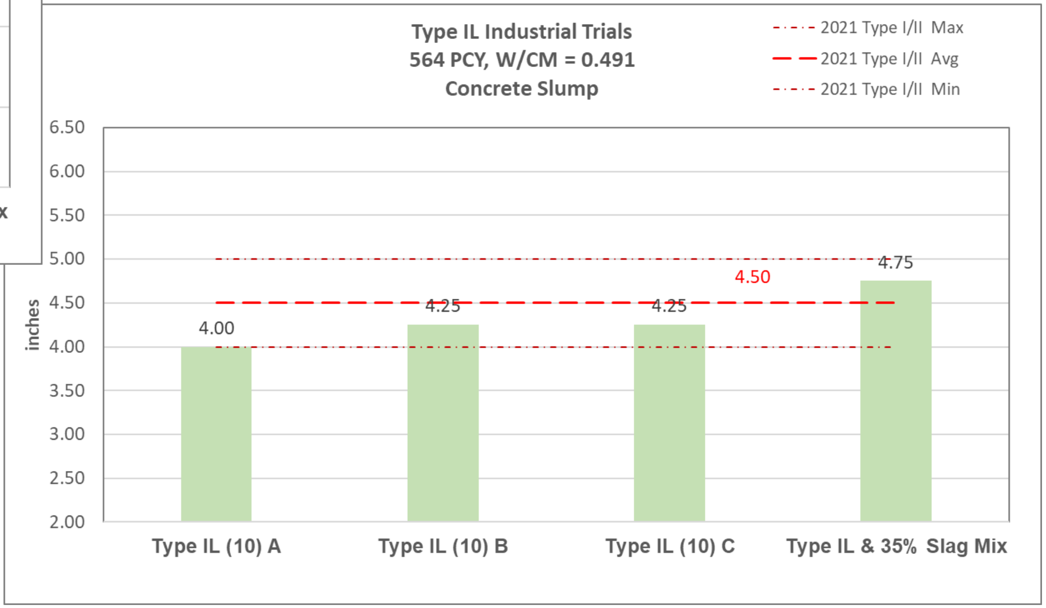
Comparisons: T-I to Type IL(10) PLC *Field Work*

Type I v. Type IL(10) – Data with Slag Cement

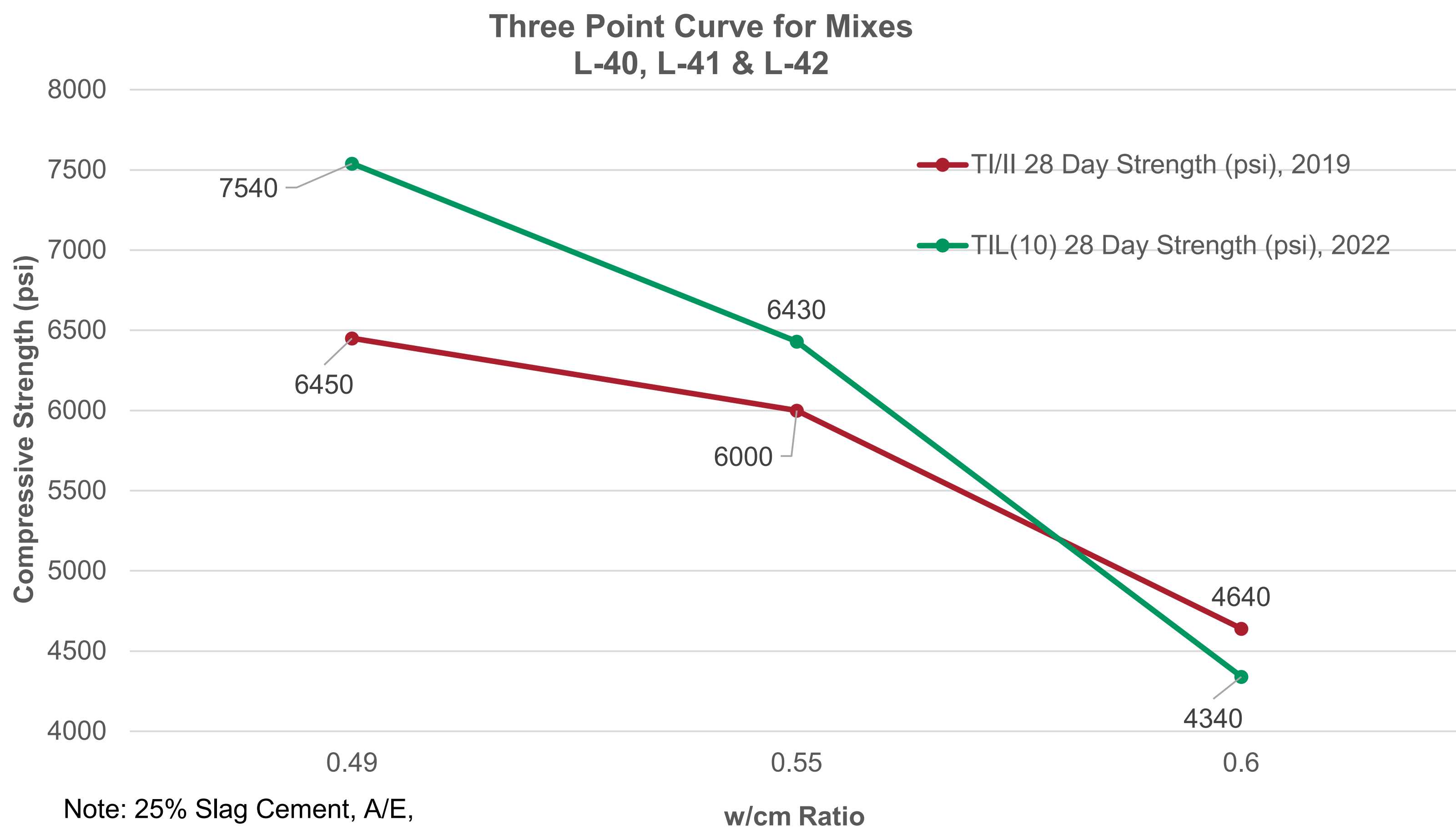
- The use of SCMs such, as fly ash or slag cement, and Type IL PLC will be similar to the use of Type I and SCMs

Type I v. Type IL(10) – *Slag Cement*





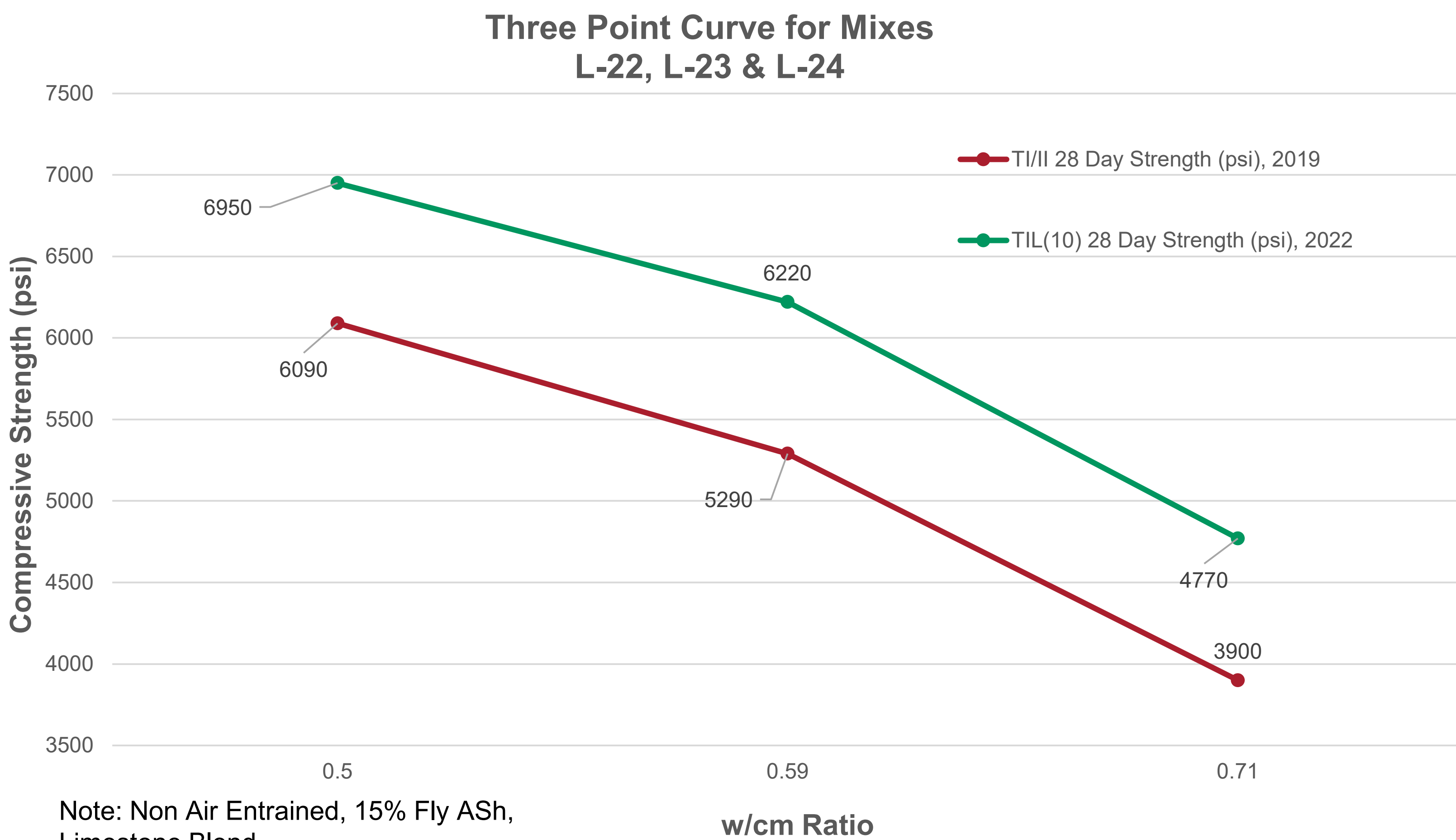
Comparisons: T-I to Type IL(10) PLC *Field Work*



Note: 25% Slag Cement, A/E,
Limestone Blend

LafargeHolcim

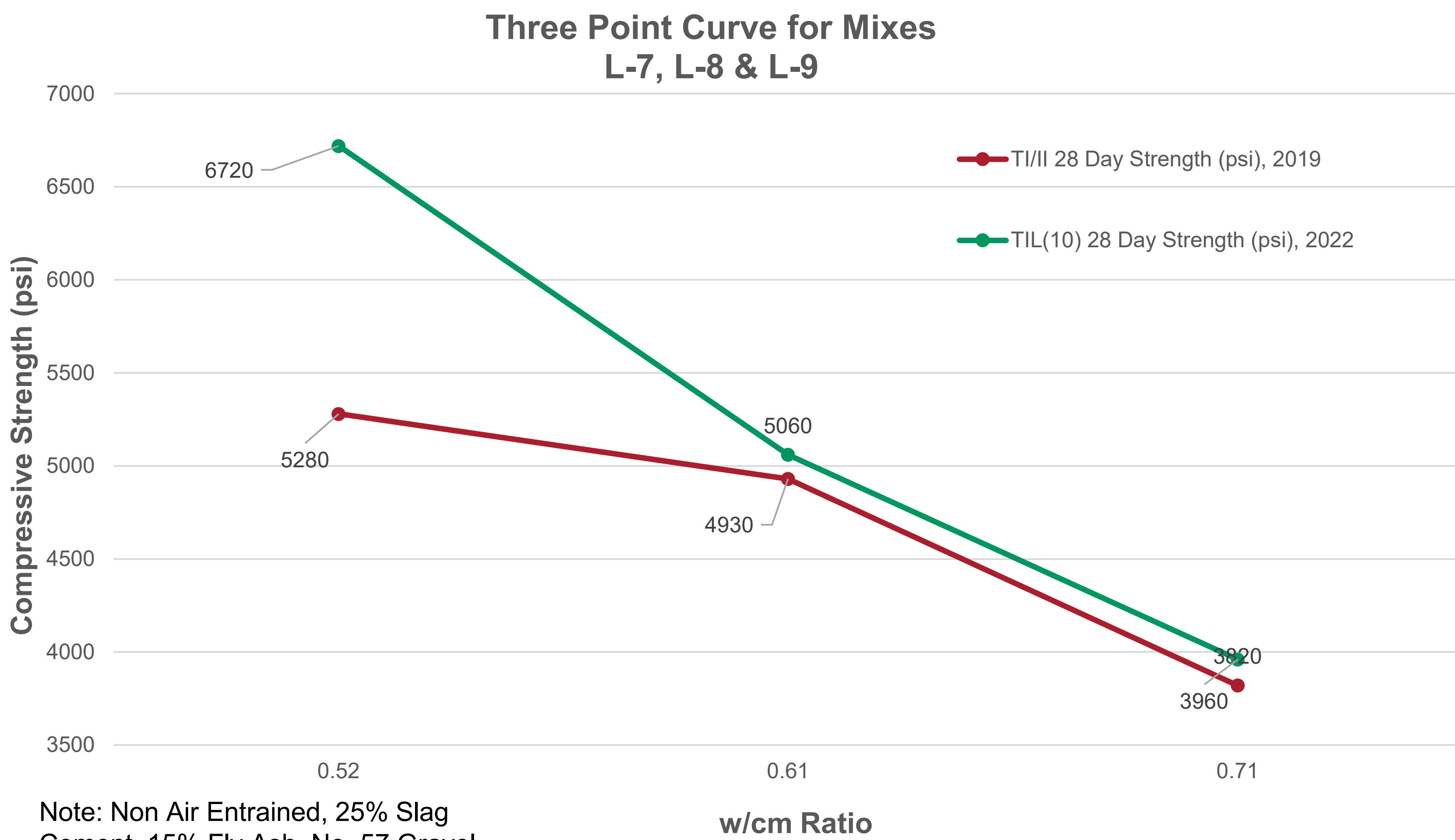
Comparisons: T-I to Type IL(10) PLC *Field Work*



Note: Non Air Entrained, 15% Fly ASh, Limestone Blend

LafargeHolcim

Comparisons: T-I to Type IL(10) PLC *Field Work*



Note: Non Air Entrained, 25% Slag Cement, 15% Fly Ash, No. 57 Gravel

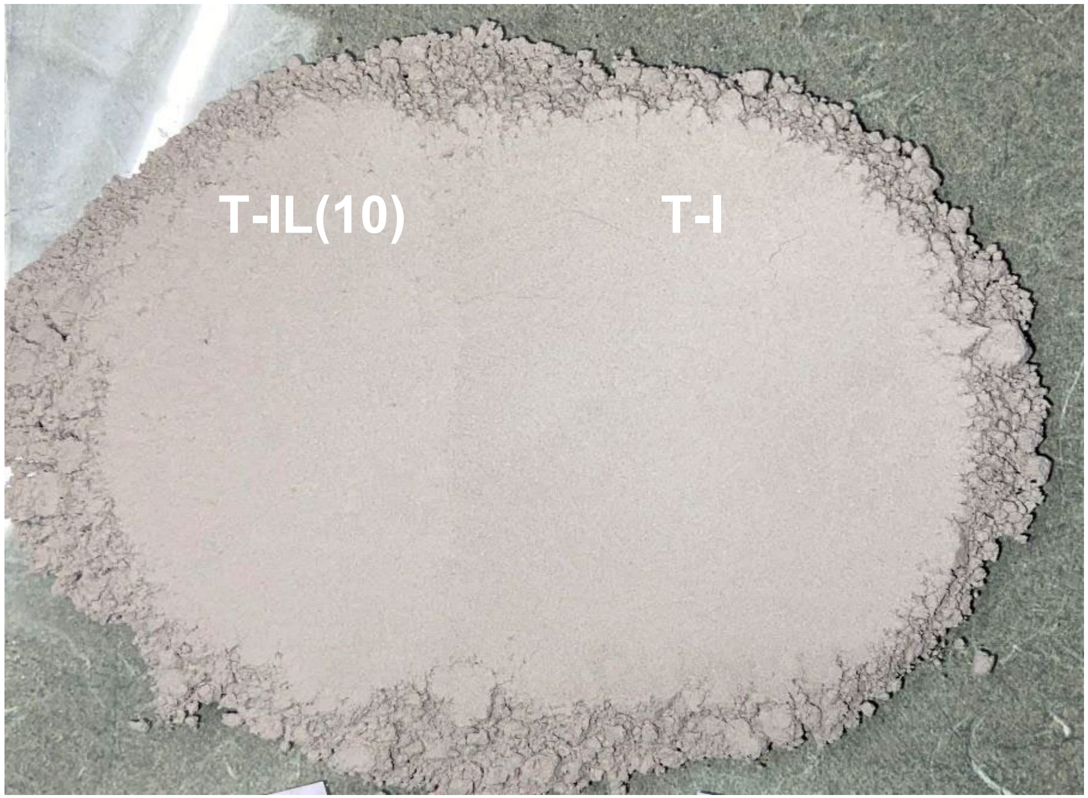
LafargeHolcim

Type I v. Type IL(10) – *Finishability*

- Finishers may notice about a 10% reduction in bleed, yet the TIL(10) concrete will appear to be creamer on the trowel

- Three mechanisms:
    1. Particle Packing Effects
    2. Nucleation Effects
    3. Chemical Reactions

Type I v. Type IL(10) – *Color*



Specifications and the

1. Warranty Period: 10 years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 CONCRETE, GENERAL

A. ACI Publications: Comply with ACI 301 unless modified by requirements in the Contract Documents.

2.2 CONCRETE MATERIALS

A. Source Limitations:

1. Obtain all concrete mixtures from a single ready-mixed concrete manufacturer for entire Project.
2. Obtain each type or class of cementitious material of the same brand from the same manufacturer's plant.
3. Obtain aggregate from single source.
4. Obtain each type of admixture from single source from single manufacturer.

B. Cementitious Materials:

1. Portland Cement: ASTM C150/C150M.
2. Fly Ash: ASTM C618, Class F, 20% maximum by weight.
3. Slag Cement: ASTM C989/C989M, Grade 100 or 120, 25% maximum by weight.

C. Normal-Weight Aggregates: ASTM C33/C33M, coarse aggregate or better, graded. Provide aggregates from a single source.

1. Alkali-Silica Reaction: Comply with one of the following:
   a. Expansion Result of Aggregate: Not more than 0.04 percent at one-year when tested in accordance with ASTM C1293.
   b. Expansion Results of Aggregate and Cementitious Materials in Combination: Not more than 0.10 percent at an age of 16 days when tested in accordance with ASTM C1567.
   c. Alkali Content in Concrete: Not more than 4 lb./cu. yd. for moderately reactive aggregate or 3 lb./cu. yd. for highly reactive aggregate, when tested in accordance with ASTM C1293 and categorized in accordance with ASTM C1778, based on alkali content being calculated in accordance with ACI 301.
2. Maximum Coarse-Aggregate Size: 1 inch nominal.
3. Fine Aggregate: Free of materials with deleterious reactivity to alkali in cement.

D. Lightweight Aggregate: ASTM C330/C330M, 1-inch nominal maximum aggregate size.

E. Air-Entraining Admixture: ASTM C260/C260M.

F. Chemical Admixtures: Certified by manufactu[...] not contribute water-soluble chl[...] not use calciu[...]

Specifications and the Design Community

- There is no considerable differences with respect to the hydration process of Type I and Type IL PLC
- The standard of the industry is that an ASTM C150, C595, and C1157 cementitious product shall be utilized identically or in a ‘**like-for-like**’ manner with respect to mix design calculations, and especially with w/cm calculations

- **Density and Relative Density (Specific Gravity) of TIL(10) Portland Limestone Cement**
- The particle density of portland cement ranges between 3.10 and 3.25, averaging 3.15 Mg/m3
- When calculating mix designs the relative density or Specific Gravity is a dimensionless number determined by dividing the cement density by the density of water at 39.2˚F (4˚C)
- As a standard of the industry, 3.15 is used for the relative density (Specific Gravity) of Portland
- However, the relative density (Specific Gravity) may change for your particular TIL PLC
    - *For example: Alpena TIL(10) is 3.10*

LAFARGE NSF

Certified to NSF/ANSI 61 & 372

Material Certification Report

Material: Portland Cement
Type: I Low Alkali

Test Period: 01-Nov-2021 to 30-Nov-2021
Date Issued: 13-Dec-2021

Certification

This cement meets the specifications of ASTM C150 and AASHTO M85 for Type I cement.

General Information

Supplier: Holcim (US) Inc. d/b/a LafargeHolcim US
Address: 8700 West Bryn Mawr Ave
Chicago, IL 60631
Contact:

Source Location: Alpena Plant
1435 Ford Ave
Alpena, MI 49707
Contact: Janelle Baier / (989) 358-3253

The following is based on average test data during the test period. The data is typical of product shipped from this source; individual shipments may vary.

Test Data on ASTM Standard Requirements

Chemical

Item	Limit [1]	Result
SiO_2 (%)	-	19.6
Al_2O_3 (%)	-	4.6
Fe_2O_3 (%)	-	3.0
CaO (%)	-	64.0
MgO (%)	6.0 max	2.8
SO_3 (%) [2]	3.0 max	2.9
Loss on Ignition (%) [5]	3.5 max	2.8
Insoluble Residue (%)	1.50 max	0.58
CO_2 (%)	-	1.8
$CaCO_3$ in Limestone (%)	70 min	89
Potential Phase Compositions [3]:		
C_3S (%)	-	61
C_2S (%)	-	10
C_3A (%)	-	7
C_4AF (%)	-	9
$C_3S + 4.75C_3A$ (%)	-	95

Physical

Item	Limit [1]	Result
Air Content (%)	12 max	7
Blaine Fineness (m^2/kg)	260 min	384
Autoclave Expansion (%) (C151)	0.80 max	0.04
Compressive Strength MPa (psi)		
1 day	-	13.0 (1890)
3 day	12.0 (1740) min	27.2 (3950)
7 day	19.0 (2760) min	34.8 (5050)
28 day (previous month's data)	-	37.9 (5500)
Initial Vicat (minutes)	45-375	125

Test Data on ASTM Optional Requirements

Chemical

Item	Limit [1]	Result
Equivalent Alkalies (%)	-	0.48

Physical

Item	Limit [1]	Result
Heat of Hydration kJ/kg (cal/g) (ASTM C1702) 3 Days [4]	-	284 (68)

Notes (*1-9)

1 - Dashes in the Limit / Result columns mean Not Applicable.
2 - It is permissible to exceed the specification limit provided that ASTM C1038 Mortar Bar Expansion does not exceed 0.020% at 14 days.
3 - Adjusted per Annex A1.6 of ASTM C150 and AASHTO M85.
4 - Test results represent the most recent value and is provided for information only.
5 - Limit = 3.0 when limestone is not an ingredient in the final cement product

Additional Data

Item	Limestone	Inorganic Processing Addition	Base Cement Phase Composition	Re
Amount (%)	4.5	1.0	C_3S (%)	
SiO_2 (%)	4.9	-	C_2S (%)	
Al_2O_3 (%)	0.9	-	C_3A (%)	
Fe_2O_3 (%)	0.7	-	C_4AF (%)	
CaO (%)	50.4	-		
SO_3 (%)	0.9	-		

Janelle K. Baier
Janelle
Quality

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Version: 180412

HOLCIM NSF

Certified to NSF/ANSI/CAN 61 & NSF/ANSI 372

Brand: OneCem®
Material: Blended Cement
Type: IL (10)

Material Certification Report

Test Period: 01-Mar-2022 to 31-Mar-2022
Date Issued: 13-Apr-2022

Certification

This cement meets the specifications of ASTM C595 and AASHTO M 240 for Type IL cement.

General Information

Supplier: Holcim (US) Inc.
Address: 8700 West Bryn Mawr Ave
Chicago, IL 60631
Contact:

Source Location: Alpena Plant
1435 Ford Ave
Alpena, MI 49707
Contact: Janelle Baier / (989) 358-3253

The following is based on average test data during the test period. The data is typical of product shipped from this source; individual shipments may vary.

Test Data on ASTM Standard Requirements

Chemical

Item	Limit [1]	Result
Sulfate as SO3 (%) [2]	3.0 max	2.7
Loss on Ignition (%)	10.0 max	4.8
$CaCO_3$ in Limestone (%)	70.0 min	87.5
Equivalent Alkalies (%)	-	0.43

Physical

Item	Limit [1]	Result
+45 um (No. 325) Sieve (%)	-	1.8
Blaine Fineness (m^2/kg)	-	422
Density (g/cm^3) (Specific Gravity)	-	3.08
Autoclave (%) (C151)	-0.20-0.80	0.05
Initial Vicat (minutes)	45-420	139
Air Content (%)	12 max	7
Compressive Strength MPa (psi)		
3 day	13.0 (1890) min	27.8 (4030)
7 day	20.0 (2900) min	34.6 (5020)
28 day (previous month's data)	25.0 (3630) min	41.5 (6020)
Mortar Bar Expansion (%) (C1038)	0.020 max	0.002

Test Data on ASTM Optional Requirements

Chemical

Item	Limit [1]	Result
Limestone (%) (ASTM)	12.5 max	8.7

Physical

Item	Limit [1]	Result

Notes (*1-9)

[2] It is permissible to exceed the specification limit provided that ASTM C1038 Mortar Bar Expansion does not exceed 0.020% at 14 days.
[3] This data may have been reported on previous mill certificates. It is typical of the cement being currently shipped.

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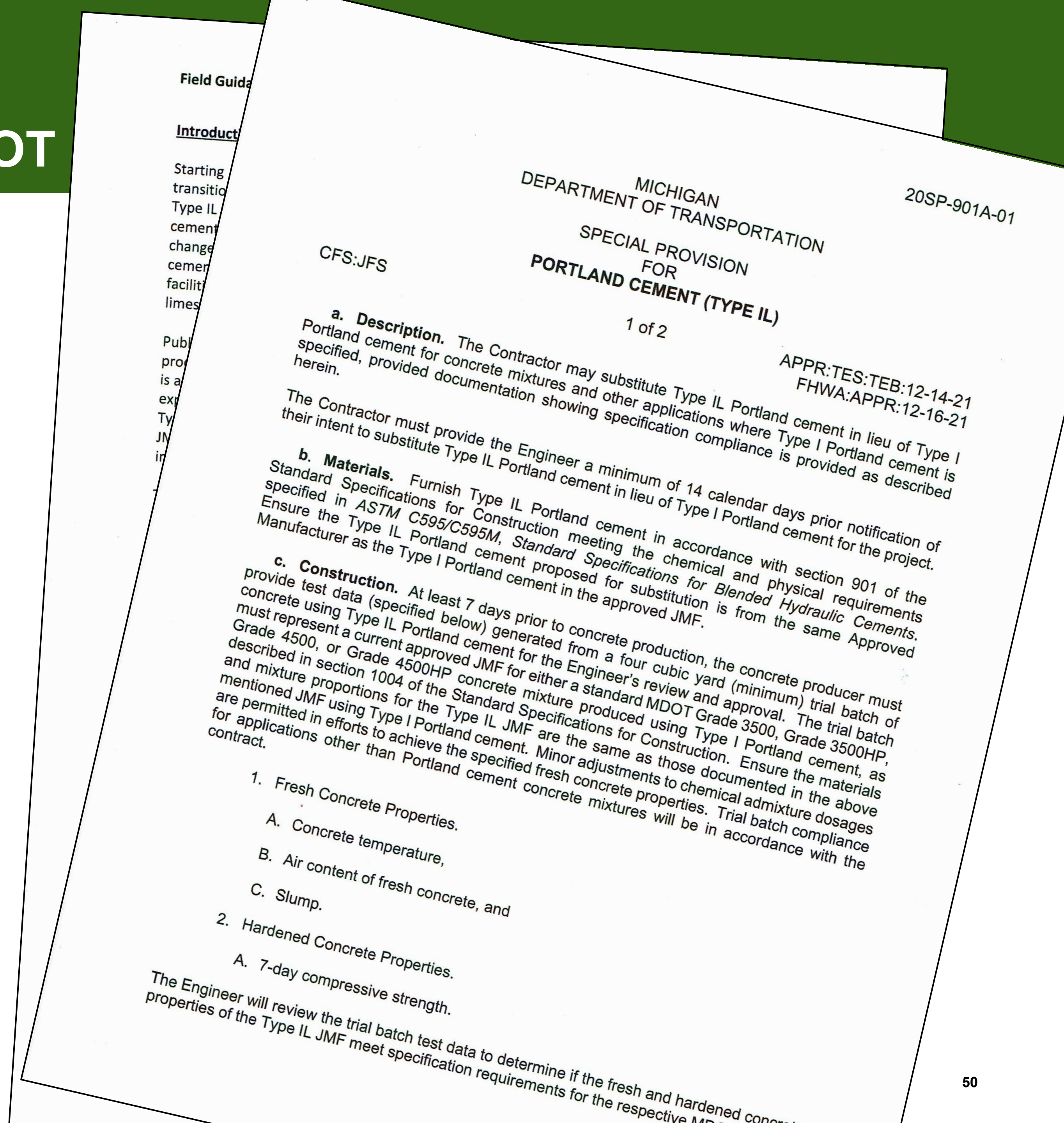
Version: 180412

Janelle K. Baier
Janelle Baier,
Quality Manager

Specifications: MDOT

- **MDOT recognizes ASTM C595 'as equal' to ASTM C150**

Michigan Department of Transportation



20SP-901A-01

MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
PORTLAND CEMENT (TYPE IL)

CFS:JFS

1 of 2

APPR:TES:TEB:12-14-21
FHWA:APPR:12-16-21

a. Description. The Contractor may substitute Type IL Portland cement in lieu of Type I Portland cement for concrete mixtures and other applications where Type I Portland cement is specified, provided documentation showing specification compliance is provided as described herein.

The Contractor must provide the Engineer a minimum of 14 calendar days prior notification of their intent to substitute Type IL Portland cement in lieu of Type I Portland cement for the project.

b. Materials. Furnish Type IL Portland cement in accordance with section 901 of the Standard Specifications for Construction meeting the chemical and physical requirements specified in *ASTM C595/C595M, Standard Specifications for Blended Hydraulic Cements*. Ensure the Type IL Portland cement proposed for substitution is from the same Approved Manufacturer as the Type I Portland cement in the approved JMF.

c. Construction. At least 7 days prior to concrete production, the concrete producer must provide test data (specified below) generated from a four cubic yard (minimum) trial batch of concrete using Type IL Portland cement for the Engineer's review and approval. The trial batch must represent a current approved JMF for either a standard MDOT Grade 3500, Grade 3500HP, Grade 4500, or Grade 4500HP concrete mixture produced using Type I Portland cement, as described in section 1004 of the Standard Specifications for Construction. Ensure the materials and mixture proportions for the Type IL JMF are the same as those documented in the above mentioned JMF using Type I Portland cement. Minor adjustments to chemical admixture dosages are permitted in efforts to achieve the specified fresh concrete properties. Trial batch compliance for applications other than Portland cement concrete mixtures will be in accordance with the contract.

1. Fresh Concrete Properties.
   A. Concrete temperature,
   B. Air content of fresh concrete, and
   C. Slump.
2. Hardened Concrete Properties.
   A. 7-day compressive strength.

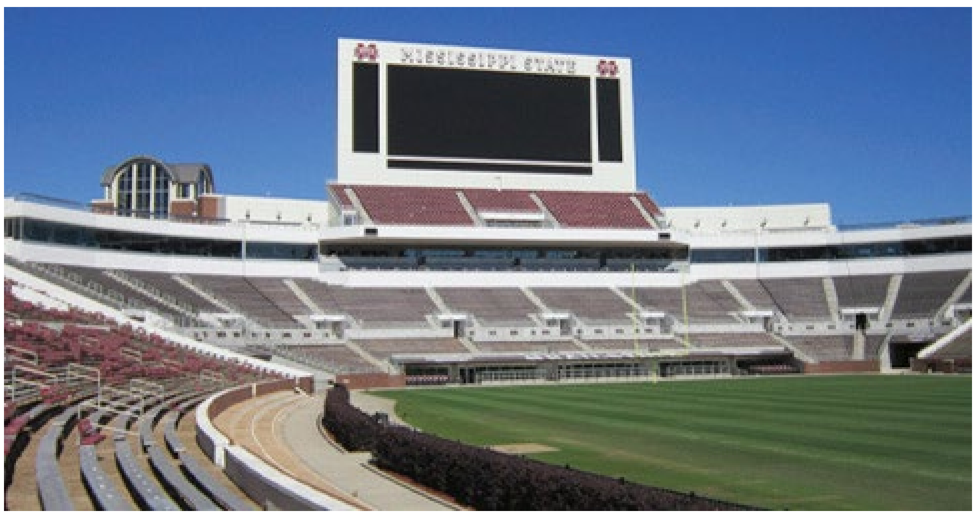
The Engineer will review the trial batch test data to determine if the fresh and hardened concrete properties of the Type IL JMF meet specification requirements for the respective M...

Specifications: MDOT

- **"Published national research supports findings that the fresh and hardened properties of concrete produced using Type IL Portland cement are like those of normal Type I." – *Field Guide***
- **"Further, there is added evidence that Type IL Portland cement may contribute toward improved durability for concrete exposed to harsh environmental conditions." – *Field Guide***
- **"The Contractor may substitute Type IL Portland cement in lieu of Type I Portland cement for concrete mixtures and other applications where Type I Portland cement is specified, provided documentation showing specification compliance as described herein." – *Special Provision***

Numerous Commercial Buildings -
Seattle, WA

I-40, Oklahoma City, OK



Renovations - *Davis Wade Stadium*
MSU, MS

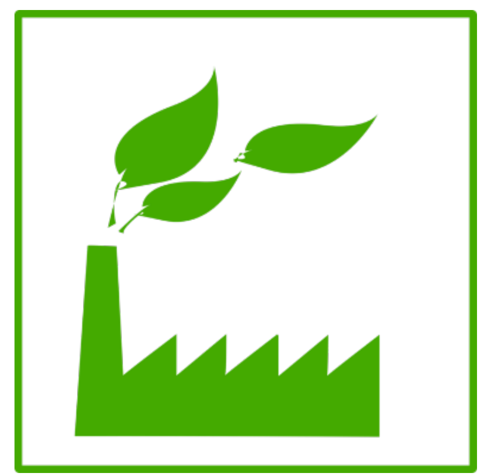
Batson Children's Hospital - Jackson, MS

Bridging North America (*Gordie Howe Bridge*)
Detroit, MI & Windsor, ON – Canada

Started in 2019 with: ASTM C595 Type IP(13)
2022 transitioned to: ASTM C595 Type IT(L9)(P13)

TIL Portland Limestone Cement (PLC) - Conclusions

- It is the responsibility of the cement and concrete industry to address the current climate situation
- Cement companies have taken steps to reduce the CO_2 output in the manufacturing process at their plants
- One of the greatest ways to reduce CO_2 emissions is by eliminating the production of ASTM C150 Type I, and replacing it with an ASTM C595 Type IL Portland Limestone Cement (PLC)



TIL Portland Limestone Cement (PLC) - Conclusions

- **Type IL (PLC) is an engineered product and, as a standard of the industry, is specified and considered 'as equal' to Type I**

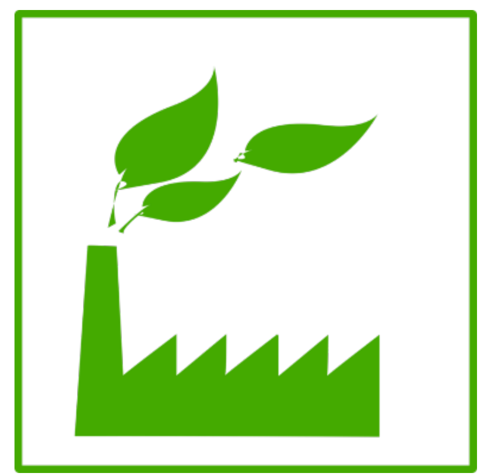
- **Type IL (PLC) is acknowledged and accepted for use wherever Type I is specified or cited in all Specifications, Codes, Standards and Guides**

- **To summarize: Responsible Governments, Owners, Specifiers, and Consumers demand Type IL (PLC)**

TIL Portland Limestone Cement (PLC) - Conclusions

Questions?

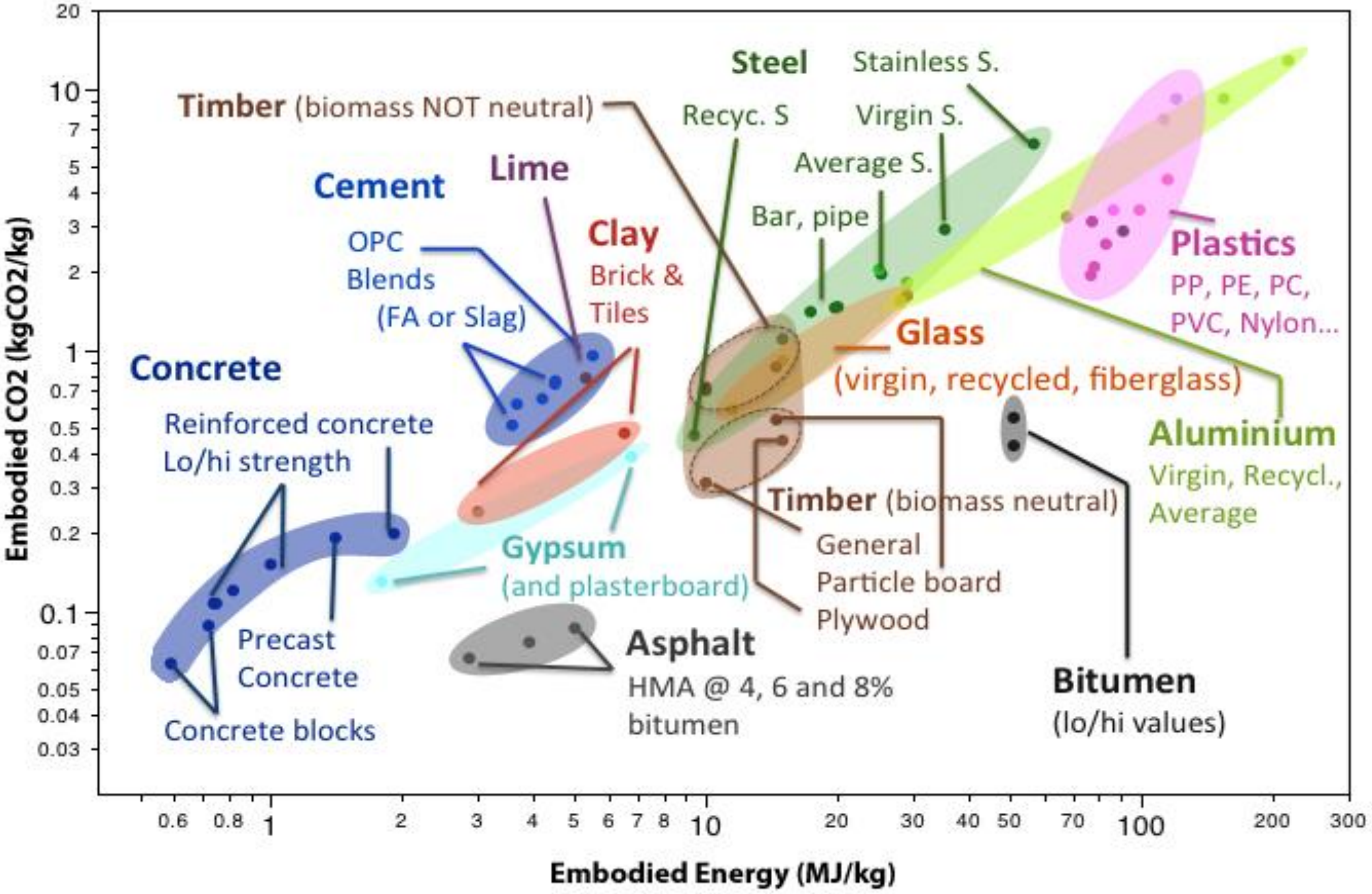
Claude Bergeron
Holcim Technical Services
Phone: (734) 231-3040
claude.bergeron@holcim.com



Working with Reduced Carbon Concrete Mixes

Daniel DeGraaf, P.E.
Michigan Concrete Association
6-9-22

Low Embodied Energy and Embodied CO2 contents of Concrete relative to other materials



Reduced Carbon Concrete Mixes

1. Type 1L Cement: What is it?, What changes should we see?, Documentation?
2. Well-graded Aggregates
3. Supplemental Cements – SCM's
4. Temperature control
5. Concrete Placement – including the addition of water
6. Curing Protection
7. Sealing prior to first winter

March 17,2022: GSA - New Requirement

2. The [prime contractor] shall provide **low embodied carbon concrete** that meets the global warming potential (GWP) limits of the table below, for concrete of the mix type and strength class.

	Maximum Global Warming Potential Limits for GSA Low Embodied Carbon Concrete (kilograms of carbon dioxide equivalent per cubic meter - CO_2e kg/m^3)		
Specified compressive strength (f'c in PSI)	**Standard Mix**	**High Early Strength**	**Lightweight**
up to 2499	**242**	**326**	**462**
2500-3499	**306**	**413**	**462**
3500-4499	**346**	**466**	**501**
4500-5499	**385**	**519**	**540**
5500-6499	**404**	**546**	**N/A**
6500 and up	**414**	**544**	**N/A**
These numbers reflect a 20% reduction from GWP (CO_2e) limits in proposed code language: "Lifecycle GHG Impacts in Building Codes" by the New Buildings Institute, January 2022.			

3. These requirements apply to all GSA projects that use at least ten (10) cubic yards of concrete.

4. If it is not feasible to meet GSA's EPD requirement or GWP limits, the [prime contractor] shall ask the GSA project manager to request a P100 waiver.

Conversions

The manufacturing of Type 1 cement produces approximately 0.9 pounds of CO2 for every pound of cement.

Mass / Volume

1	=	1.68555
Kilogram / Cubic meter		Pound / Cubic yard

CO2 Reduction

		Type 1	Type 1L	Net CO2	GSA GWP
	# Cement	# CO2	# CO2	Reduction	Kg/M3
Standard 6 sack Mix - to Type1L	564.0				
Type 1		507.6			301
Type 1L			456.8	10.0%	271
Well Graded aggregates	500.0				
Type 1	500	450		11.3%	267
Type 1L	500		405.0	20.2%	240
Use SCM's - 30%	395				
Type 1		355.5		30.0%	211
Type 1L			320.0	37.0%	190
Net Combined	350				
Type 1		315		37.9%	187
Type 1L			283.5	**44.1%**	**168**

How do I specify?

- Add the following to your list of approved cementitious materials:

  Type IL blended cement per ASTM C595/AASHTO M240

Type 1L is not considered a C-150 Cement even though it is produced with the identical clinker

Type 1L is produced to react just like Type 1

What about current Approved Mix Designs with ASTM C-150 Type 1 cement?

- MICHIGAN
- DEPARTMENT OF TRANSPORTATION
- SPECIAL PROVISION
- FOR
- **PORTLAND CEMENT (TYPE IL)**
- CFS:JFS 1 of 2 APPR:TES:TEB:12-14-21

FHWA:PR:12-16-21

- **a. Description.** The Contractor may substitute Type IL Portland cement in lieu of Type I Portland cement for concrete mixtures and other applications where Type I Portland cement is specified, provided documentation showing specification compliance is provided as described herein.

- The Contractor must provide the Engineer a minimum of 14 calendar days prior notification of their intent to substitute Type IL Portland cement in lieu of Type I Portland cement for the project.

c. Construction. At least 7 days prior to concrete production, the concrete producer must provide test data (specified below) generated from a four cubic yard (minimum) trial batch of concrete using Type IL Portland cement for the Engineer's review and approval. The trial batch must represent a current approved JMF for either a standard MDOT Grade 3500, Grade 3500HP, Grade 4500, or Grade 4500HP concrete mixture produced using Type I Portland cement, as described in section 1004 of the Standard Specifications for Construction. Ensure the materials and mixture proportions for the Type IL JMF are the same as those documented in the above mentioned JMF using Type I Portland cement. Minor adjustments to chemical admixture dosages are permitted in efforts to achieve the specified fresh concrete properties. Trial batch compliance for applications other than Portland cement concrete mixtures will be in accordance with the contract.

1. Fresh Concrete Properties.
   - A. Concrete temperature,
   - B. Air content of fresh concrete, and
   - C. Slump.
2. Hardened Concrete Properties.
   - A. 7-day compressive strength.

- The Engineer will review the trial batch test data to determine if the fresh and hardened concrete properties of the Type IL JMF meet specification requirements for the respective MDOT Grade of concrete represented by the trial batch. If the Engineer determines that the trial batch test data are in conformance with specification requirements, then the Type IL Portland cement will be permitted to be substituted in lieu of the Type I Portland cement for all approved concrete mixtures generated at the concrete production facility for the project. If the Engineer determines that the trial batch test data do not meet specification requirements for the respective MDOT Grade of concrete, the Contractor will not be permitted to substitute Type IL Portland cement in lieu of Type I Portland cement. Mix design and JMF documentation for concrete mixtures using Type IL Portland cement will then be required in accordance with subsection 1003.03.C of the Standard Specifications for Construction or the contract, where applicable.

- Once Type IL Portland cement is approved for use on the project, reinstatement of Type I Portland cement into the JMF is not permitted. Substitution of other material types or sources, including admixtures, as documented in the initial Type I JMF is not permitted.

- The Engineer will complete field sampling and testing for all production lots containing Type I Portland cement JMF prior to respective Type IL Portland cement substitution. Do not include concrete mixtures containing Type I and Type IL Portland cement types in the same production lot.

- **d. Acceptance.** The Contractor may substitute Type IL Portland cement in lieu of Type I Portland cement for the project with no additional laboratory trial batch requirements, as described in subsection 1003.03.C.2.a of the Standard Specifications for Construction, provided the Engineer has reviewed the concrete producer's test data generated from a four cubic yard (minimum) trial batch of concrete, described above, and has determined that the fresh and hardened concrete properties of the Type IL JMF meet specification requirements for the respective MDOT Grade of concrete represented by the trial batch.

- **e. Measurement and Payment.** The work included in this special provision will not be paid for separately and is included in other pay items in the contract.

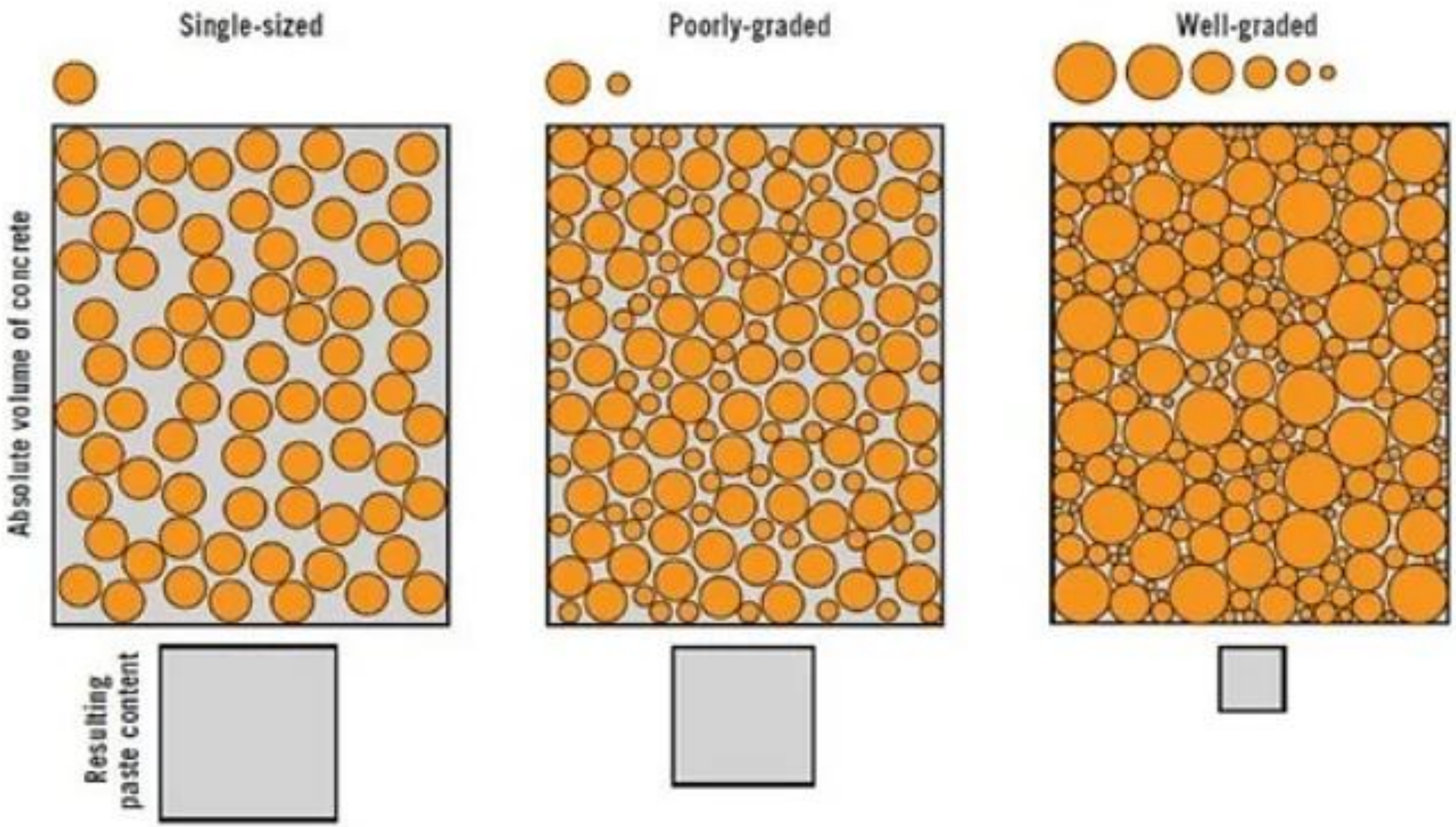
Long Term Performance of Type 1L

- ACI Concrete International January 2022
  - Durability of Portland Limestone Cement Concrete
  - Neil Berke – Tourney Consulting Group, LLC, Kalamazoo, MI
- 100-year service life concrete: Based on the concrete testing performed, PLC concrete with Class F fly ash can provide better performance related to chloride ingress than Type I/II OPC concrete with Class F fly ash.

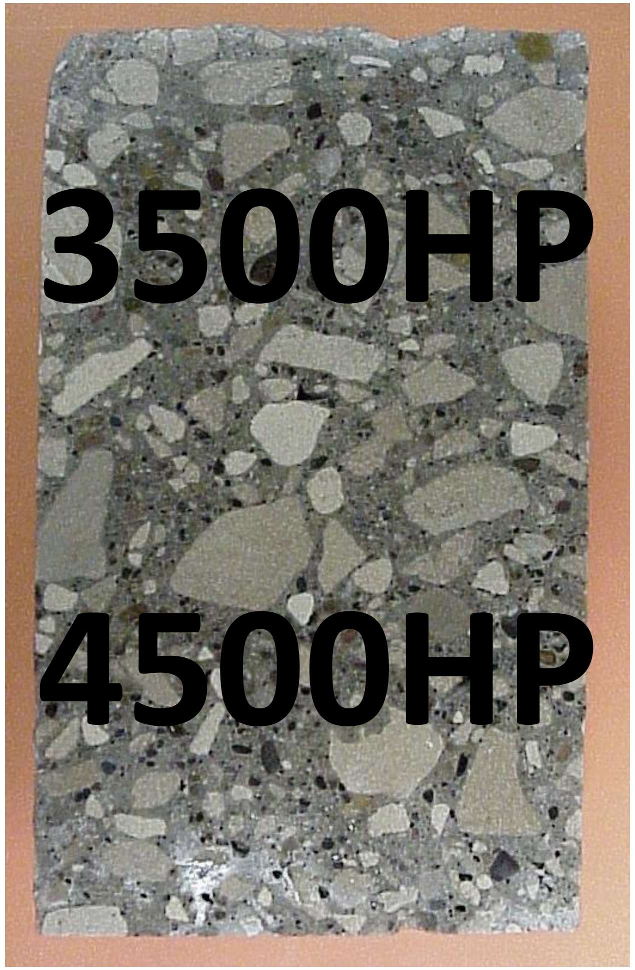
2. Well-graded Aggregates

- A uniform blend of all sizes of aggregates from big to small
- This makes it easier to move the material – the rocks roll over each other, they do not have to climb over themselves
- Small rocks fill small holes – we don't need as much cement paste – reduced CO2 output
- Aggregate is stronger than cement paste

2. Well Graded Aggregate



Optimized Aggregates



3. Utilize Supplemental Cement - SCM

- These are recycled materials that increase the concretes performance & reduce the CO2 output
- These materials react after the cement does and internally densifies and strengthens the concrete over a period of time

  (2 days to 90 days)
- The mix does not set up as fast – it is easier to work with
- The concrete is more durable when we place it correctly

Snow is coming – sometime?

4. Temperature Control

- With SCM's in the mix it will be a bit more workable
- Mix temperature is critical
  - Above 70-degree mix temperature the saw time will be similar
  - On hot summer days the mix temperature will likely stay below 90-dergees
- Pour early in the day when possible
  - This will allow more of the day-time temperature to help the setting reaction
  - Then set up for the next days pour in the afternoon
- Curing is a big deal –protect it from traffic - at least the first day

Caution on Saw times

- Summer –Ground is warm, concrete surface is warm & the Concrete sets from the surface down – ideal conditions for sawing joints
- Fall – Ground is warm while air and the concrete surface may be cool – concrete may set from the ground up creating a critical saw window. Heating the concrete mix will help
- Spring – Ground is cold, concrete materials are cold, set will likely be delayed.   Heating the concrete mix will help kick start the setting process

5. Proper Placement Practice

- Well graded mixes with SCM's do not need extra water – They just look stiff
- They do need vibration
- Water should be added at plant and not on the grade when possible
- Producers should not hold back water just so the contractor can add some on site

6. Keys to proper cure

- Apply curing compound immediately – this seals in the water needed for the cement to react and reach its full strength
  - You almost can't do it too soon
  - The surface is the most critical – we must protect it
  - Once the concrete dries the cement reaction stops!
- Must have complete coverage
  - If white: the surface should look like a clean sheet of paper
  - If blotchy – the surface will not reach proper strength
  - If plastic sheeting: completely cover until it reaches strength
- SCM's are secondary reacting cements
  - they must still have water available for several days
  - cannot let surface dry out

Curing

Start early – as soon as sheen disappears

Complete coverage – not blotchy

7. A word on sealers…

- **Paint it** – Surface coat: Epoxies, polyurethanes, methacrylate's, waxes, acrylics and chip seals.

- **Pore Blocker** – Reacts with CH forming a gel that blocks pores - Blocks moisture movement in and out of concrete: Lithium, linseed oil

- Chemically Reactive – **Water repellent** – Reacts with Silica or moisture to form a permanent attachment to the water-repellent molecule – allows moisture to leave the concrete: Silanes, Siloxanes

When to apply?

- Sealers are not curing membranes – they should be applied to hardened concrete, generally after 28 days.
- Keeping the water and salt out is critical
- SCM's provide great long-term density, as long as the reaction is allowed to be completed
- SCM's take time to fully react, this is long after reaching open to traffic strength
- Sealers are recommended for flat work installations prior to the first winter

Silane or Siloxane?

- **Silanes:**
  - Extremely small molecular size – deeper penetration
  - Chemically bond with silica to form a permanent attachment to water-repellent molecule
  - Don't change the skid or slip resistance
  - Performs better on poured in place concrete
- **Siloxanes:**
  - Slightly larger molecular structure
  - They do not chemically bond to the silica – they react with moisture to form hydrophobic resin
  - Ideal for treating concrete block or non-cementitious materials like brick, stucco and stone

Questions

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