Concrete Thinking for a sustainable world

PCA Portland Cement Association

AASHTO M240 & ASTM C595 Portland-Limestone Cement *An Option to Improve Sustainability*

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Presented at Spring 2012 NCC/TTCC Meeting

Objectives

- What is portland-limestone cement
- Performance
  - Environmental
  - Concrete
- Changes to the Specifications

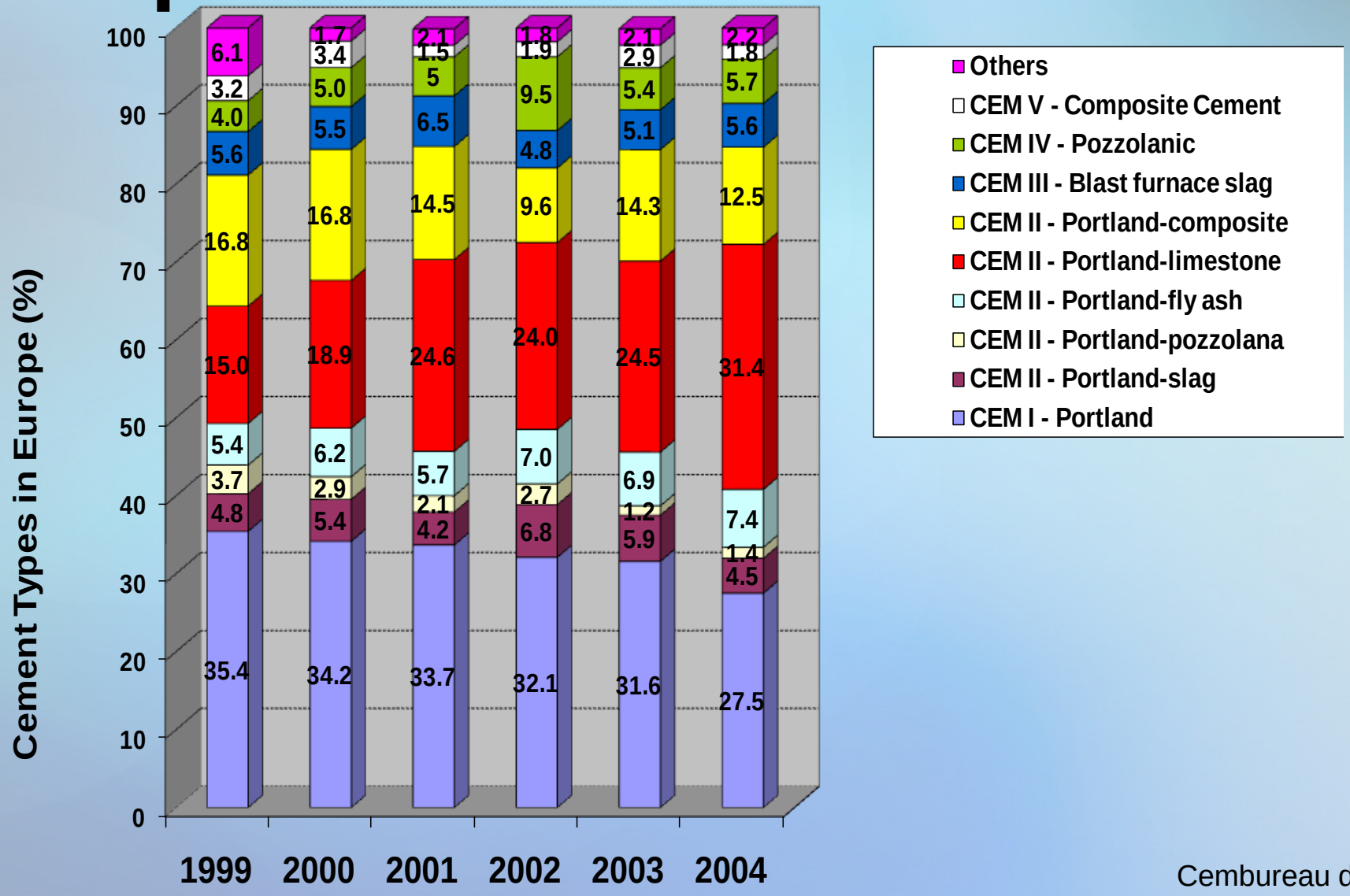
Portland-Limestone Cement

- What is a PLC?
  - Type IL cement
    - 5% to 15% limestone in ASTM C595/AASHTO M240
    - Ternary cements
- Why the proposal?
  - Option to implement proven technology to obtain desired performance and improve sustainability of concrete

Historical Use of Limestone in Cements

- 1965 Heidelberger produces 20% limestone cement in Germany for specialty applications (Schmidt 1992)
- 1979 French Cement Standards allows limestone additions.
- 1983 CSA A5 allows 5% in Type 10 (now GU) cement
- 1990, 15+/-5% limestone blended cements being used in Germany
- 1992, in UK, BS 7583 allows up to 20% in Limestone Cement
- 2000 EN 197-1 allows 5% MAC (Typ. Limestone) in all 27 common cements, as was commonly practiced in various European cement standards prior to that.
- 2000 EN 197-1 creates CEM II/A-L (6-20%) and CEM II/B-L (21-35%)
- 2004 ASTM C 150 allows 5% in Types I-V
- 2006 CSA A3001 allows 5% in other Types than GU
- 2007 AASHTO M85 allows 5% in Types I-V
- 2008 CSA A3001 includes PLC containing 5%-15% limestone

European Cements

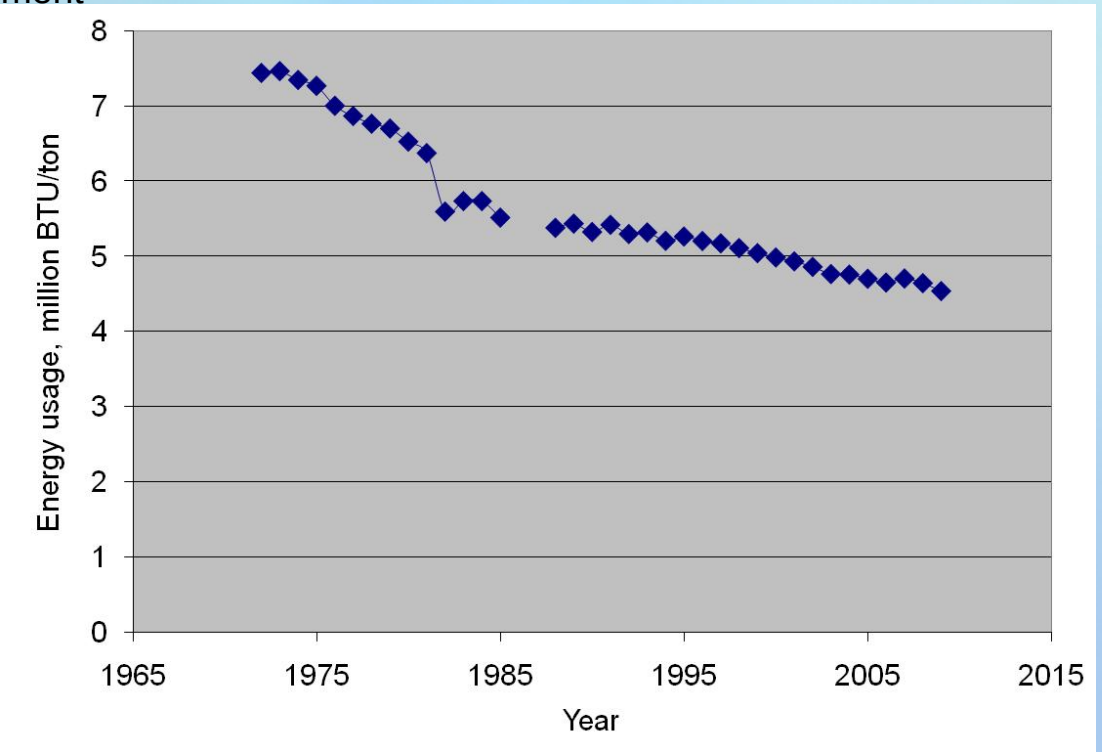


Cembureau data

Why: Environmental Benefits

	10%	15%
Energy Reduction*		
Fuel (million BTU)	443,000	664,000
Electricity (kWh)	6,970,000	10,440,000

* Per million tons cement

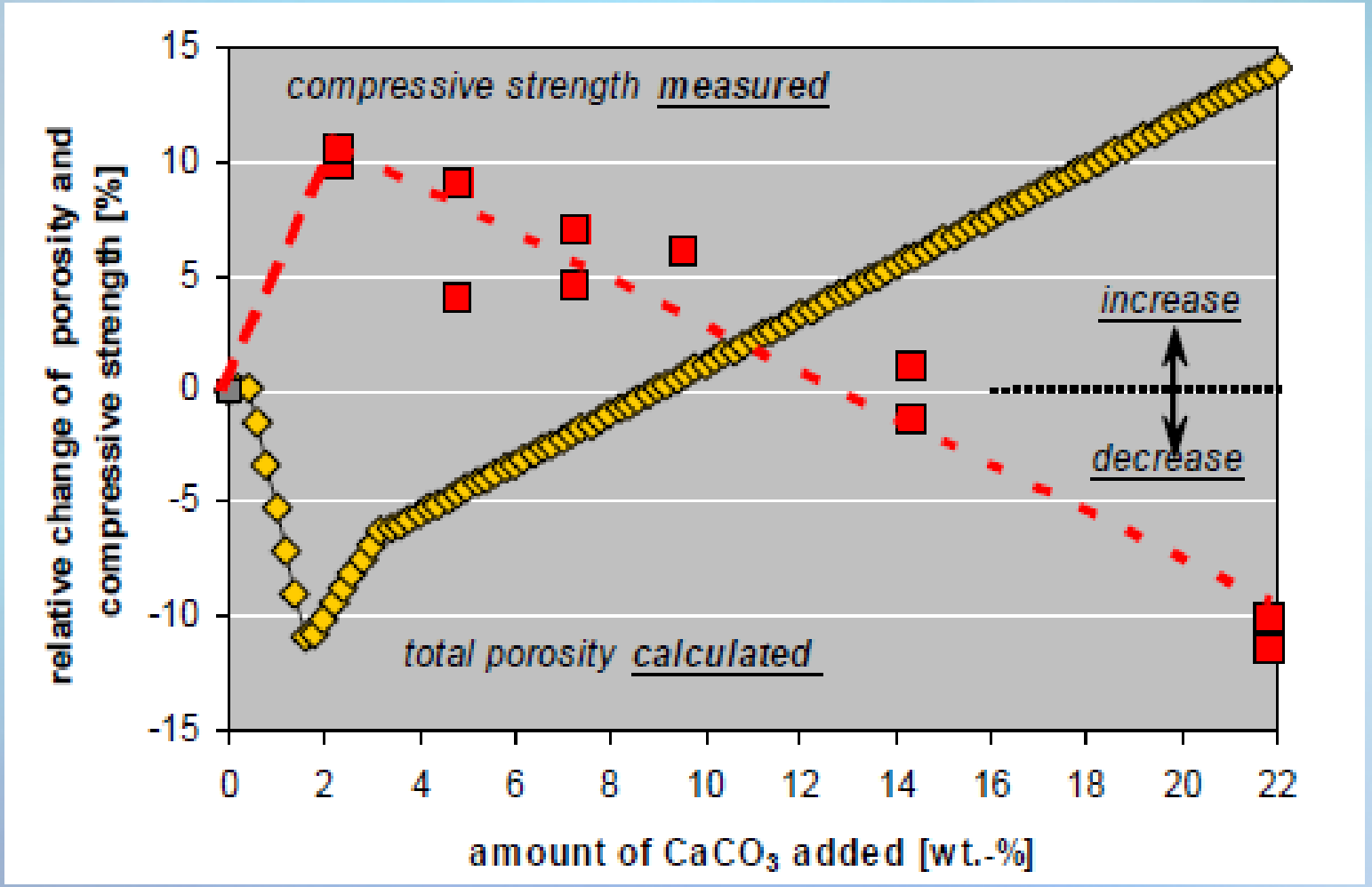


Why: Environmental Benefits

	10%	15%
Emissions Reduction*		
SO_2 (lb)	581,000	870,000
NO_X (lb)	580,000	870,000
CO (lb)	104,000	155,000
CO_2 (ton)	189,000	283,000
Total hydrocarbon, THC (lb)	14,300	21,400

* Per million tons cement

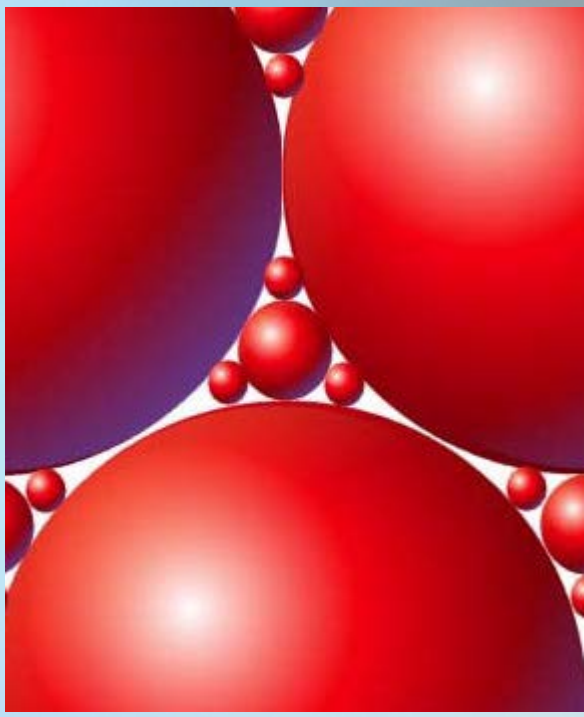
How Limestone Works: Why 15%?



Matschei et al. 2008

How Limestone Works

- Particle packing
  - Improved particle size distribution
- Nucleation
  - Surfaces for precipitation
- Chemical reactions
  - Only a small amount, but…



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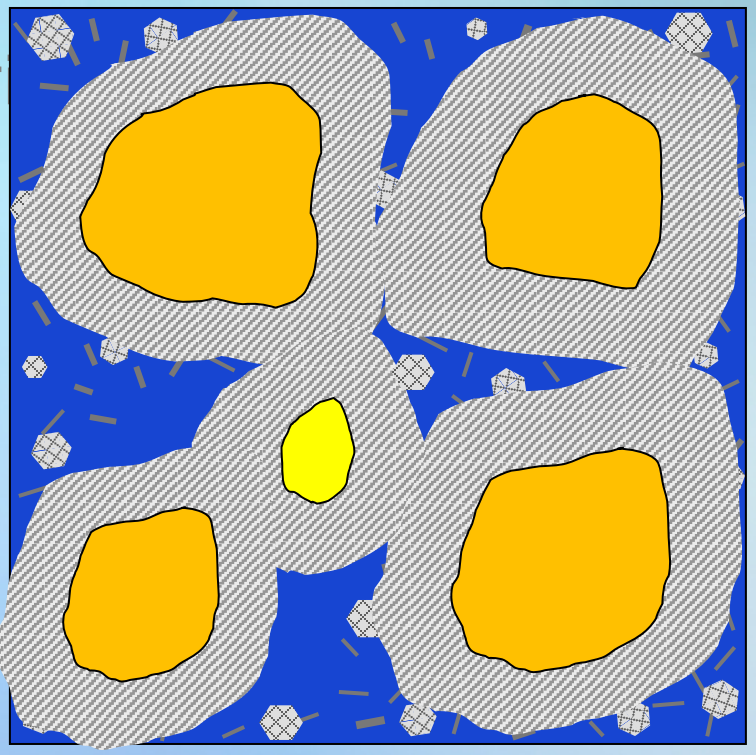

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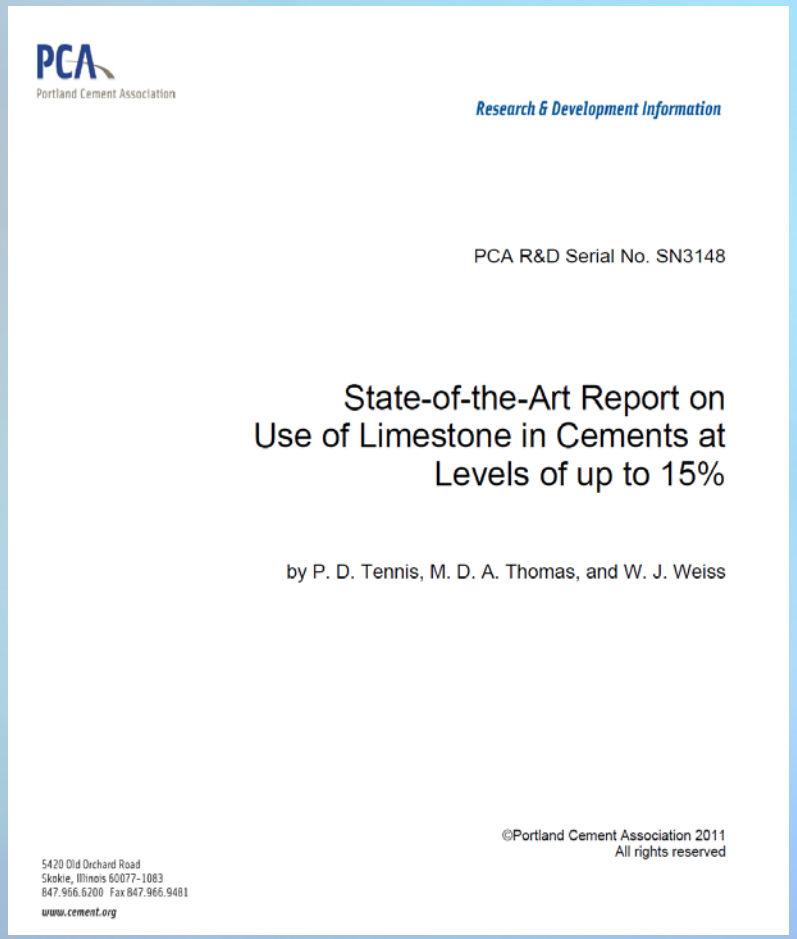
Ca^{2+} $CaOH^{+}$

$HSiO_3^{-}$ SO_4^{2-}

CO_3^{2-}

Concrete Performance



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Research & Development Information

PCA R&D Serial No. SN3148

State-of-the-Art Report on Use of Limestone in Cements at Levels of up to 15%

by P. D. Tennis, M. D. A. Thomas, and W. J. Weiss

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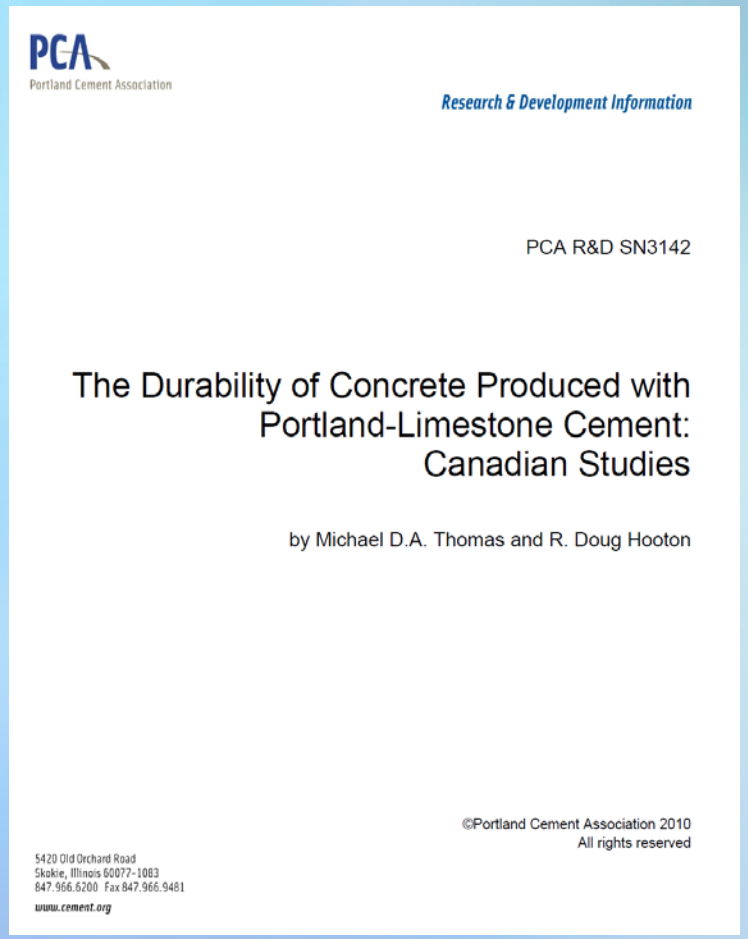
www.cement.org



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Research & Development Information

PCA R&D SN3142

The Durability of Concrete Produced with Portland-Limestone Cement: Canadian Studies

by Michael D.A. Thomas and R. Doug Hooton

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AASHTO M240 & ASTM C595 Requirements

- **Type IL**—Portland-limestone blended cement
  - Example: Type IL(10) = 10% limestone
- **Type IT**—Ternary blended cement with limestone
  - Example 1: Type IT(L10)(P10) = 10% limestone and 10% pozzolan
  - Example 2: Type IT(S15)(L10) = 15% slag and 10% limestone
- Limestone content 5% to 15%

AASHTO M240 & ASTM C595 Requirements

- Same physical requirement as existing C595/M240 cement types
- Chemical requirements – sulfate content, LOI
- Sulfate resistance – no MS or HS in initial ballot
- Limestone quality – $CaCO_3$, MBI, TOC

2009 Cement Specs Update

	IS (<70), IT(P<S<70), IP, IT(P≥S) **IL IT(L<S<70), IT(P>L), IT(L≥S), IT(L≥P)**	IS (< 70) (MS), IT(P<S<70)(MS) IP(MS), IT(P≥S)(MS)	IS (< 70) (HS), IT(P<S<70)(HS) IP (HS), IT(P≥S)(HS)	IS(≥70), IT(S≥70)	IP(LH), **IL(LH),** IT(P≥S)(LH) **IT(L<S<70)(LH) IT(P>L)(LH) IT(L≥S)(LH) IT(L≥P)(LH)**
Fineness	c	c	c	c	c
Autoclave exp, max, %	0.80	0.80	0.80	0.80	0.80
Autoclave contr, max %	0.20	0.20	0.20	0.20	0.20
Vicat test: minutes, not less than	45	45	45	45	45
hours, not more than	7	7	7	7	7
Air content of mortar, volume %	12	12	12	12	12

2009 Cement Specs Update

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Compressive strength, min., MPa (psi):					
3 days	13.0	11.0	11.0	...	...
	(1890)	(1600)	(1600)	...	...
7 days	20.0	18.0	18.0	5.0	11.0
	(2900)	(2610)	(2610)	(720)	(1600)
28 days	25.0	25.0	25.0	11.0	21.0
	(3620)	(3620)	(3620)	(1600)	(3050)
Heat of Hydration, max., kJ/kg (cal/g):					
7 days	290	290	290	...	250
	(70)	(70)	(70)	...	(60)
28 days	330	330	330	...	290
	(80)	(80)	(80)	...	(70)

2009 Cement Specs Update

	IS (<70), IT(P<S<70), IP, IT(P≥S) IL IT(L<S<70), IT(P>L), IT(L≥S), IT(L≥P)	IS (< 70) (MS), IT(P<S<70)(MS) IP(MS), IT(P≥S)(MS)	IS (< 70) (HS), IT(P<S<70)(HS) IP (HS), IT(P≥S)(HS)	IS(≥70), IT(S≥70)	IP(LH), IL(LH), IT(P≥S)(LH) IT(L<S<70)(LH), IT(P>L)(LH) IT(L≥S)(LH) IT(L≥P)(LH)
Water req. max %	...	...	...	...	64
Drying shrinkage, max, %	...	...	...	...	0.15
Mortar expansion, max, %:					
14 days	0.020	0.020	0.020	0.020	0.020
8 weeks	0.060	0.060	0.060	0.060	0.060
Sulfate resistance, expansion, max, %:					
at 180 d		0.10	0.05		
at 1 year			0.10		

Chemical Requirements for Blended Cements

Cement Type	IS(< 70), IT(P<S<70), IT(L<S<70)	IS(≥70), IT(S≥70)	IP, IT(P≥S), IT(P>L)	IL IT(L≥S), IT(L≥P)
MgO, max, %	. . .	. . .	6.0	. . .
SO_3, max, %	3.0	4.0	4.0	**3.0**
S^{2-}, max, %	2.0	2.0	...	. . .
Insol. res. max, %[C]	1.0	1.0	...	. . .
LOI, max, %	3.0[D]	4.0[D]	5.0[D]	**10.0**

[C] Insol res max does not apply to ternary blended cements.

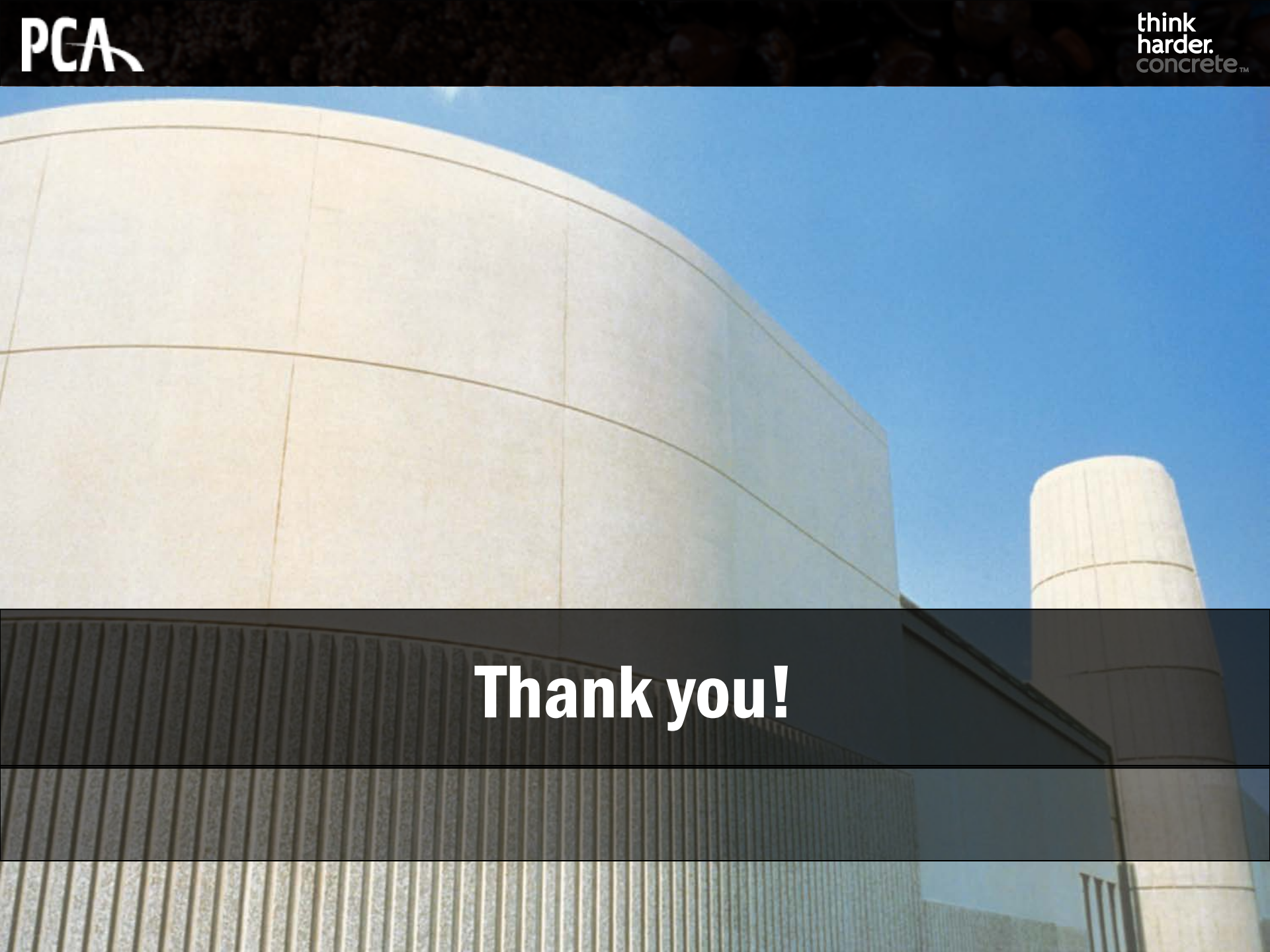
[D] For ternary blended cements with limestone LOI max = 10%.

Requirements for *Limestone* for Use in Blended Cements

	Test Method	Limit
$CaCO_3$ content	C114/T105	Min. 70%
Methylene blue index	See Annex A2	Max. 1.2 g/100g
Total organic carbon	See Annex A3	Max. 0.5%

Summary

- Portland-limestone cements
  - Type IL and Type IT cements
  - Blended cements with 5% to 15% limestone
  - Good history of performance
  - An option for greener concrete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think
harder.
concrete™
Thank you!