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Specification Requirements and Environmental Performance of Portland-Limestone Cements

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Minneapolis

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Portland-Limestone Cement

- What is a PLC?
- What are the spec requirements?
- What are the benefits?
- How does it work?
- Why?

ASTM and AASHTO

2012 Editions
AASHTO M240 & ASTM C595

- Same physical requirements as pre-existing C595/M240 cement types
- Chemical requirements – sulfate content, LOI
- Sulfate resistance – no MS or HS designation, initially
- Limestone requirements– $CaCO_3$, MBI, TOC

Chemical Requirements for Blended Cements

	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%.

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Requirements for Limestone

	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%

Limestone Testing

A2. METHYLENE BLUE INDEX TEST FOR LIMESTONE

A2.1 Scope

A2.1.1 This annex describes the laboratory procedures for the quantitative determination of methylene blue dye adsorption index of limestone for use as an ingredient in blended cement.

A2.1.2 The text of this annex references notes and footnotes which provide (excluding those in tables and figures) shall not be considered as requirements of

A2.1.3 *Units*—The values stated in SI units are to be regarded as standard. this annex.

A2.1.4 *This annex does not purport to address all of the safety concer responsibility of the user of this standard to establish appropriate safety and he regulatory limitations prior to use.*

A2.2 Summary of test

A2.2.1 The sample is reduced to a fine powder prior to testing. Increme successively to a suspension of the prepared test portion in water. The adsorptio after each addition of solution by carrying out a stain test on filter paper to dete of free dye is confirmed, the methylene blue index value (*MBI*) is calculated and of the sample tested.

A2.3 Significance and Use

A2.3.1 This annex provides a means to determine the amount of methylene limestone. Methylene blue dye is preferentially adsorbed by clay minerals that m adsorbed is related to the clay type and content. Certain clays may increase t cements if present in sufficient quantity in the limestone when used an ingredien the methylene blue index of limestone permitted as an ingredient in blended ceme

A2.4 Apparatus

A2.4.1 The equipment and materials, including the temperature and humidity water, shall meet the requirements of C511, unless otherwise specified.

A2.4.2 The following equipment shall be included to perform this test:

(a) burette, with capacity of either 100 mL or 50 mL and graduation of either micro-pipette;

A3. TOTAL ORGANIC CARBON CONTENT OF LIMESTONE

A3.1 Scope

A3.1.1 This annex specifies the laboratory procedures for the quantitative determination of the total organic carbon content of limestone for use as an ingredient in blended cement.

A3.1.2 The text of this annex references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the annex.

A3.1.3 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this annex.

A3.1.4 *This annex does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

A3.2 Summary of test

A3.2.1 Total organic carbon is determined either on a sample from which the inorganic carbon has been removed through hydrochloric acid extraction or by difference of inorganic carbon from total carbon.

A3.3 Significance and Use

A3.3.1 This annex provides a means to determine the total organic carbon content of a sample of finely ground limestone. The organic carbon content of a limestone used as an ingredient in cement may increase the air-entraining agent dosage required to achieve a specific air content in concrete. The specification places a limit on the total organic carbon content of limestone permitted as an ingredient in blended cement.

A3.4 Apparatus

A3.3.1 The equipment shall meet the requirements of Specification C 511, unless otherwise specified.

A3.3.2 The following equipment shall be included to perform this test:

(a) analytical balance, precision = 0.1 mg;
(b) beaker, 800 mL;
(c) vacuum flask, 1000 mL;
(d) glass frit, 40 mm diameter, and porosity = G4;
(e) magnetic stirrer;
(f) magnetic stir bar;
(g) oven, able to maintain a temperature of 45°C ± 5 °C;

Summary of Provisions

- PLC: Type IL and Type IT with 5% to 15% limestone
- Same physical requirements
- Similar chemical requirements
- No provisions for sulfate resistance
- Min $CaCO_3$ content, MBI and TOC

Environmental Benefits

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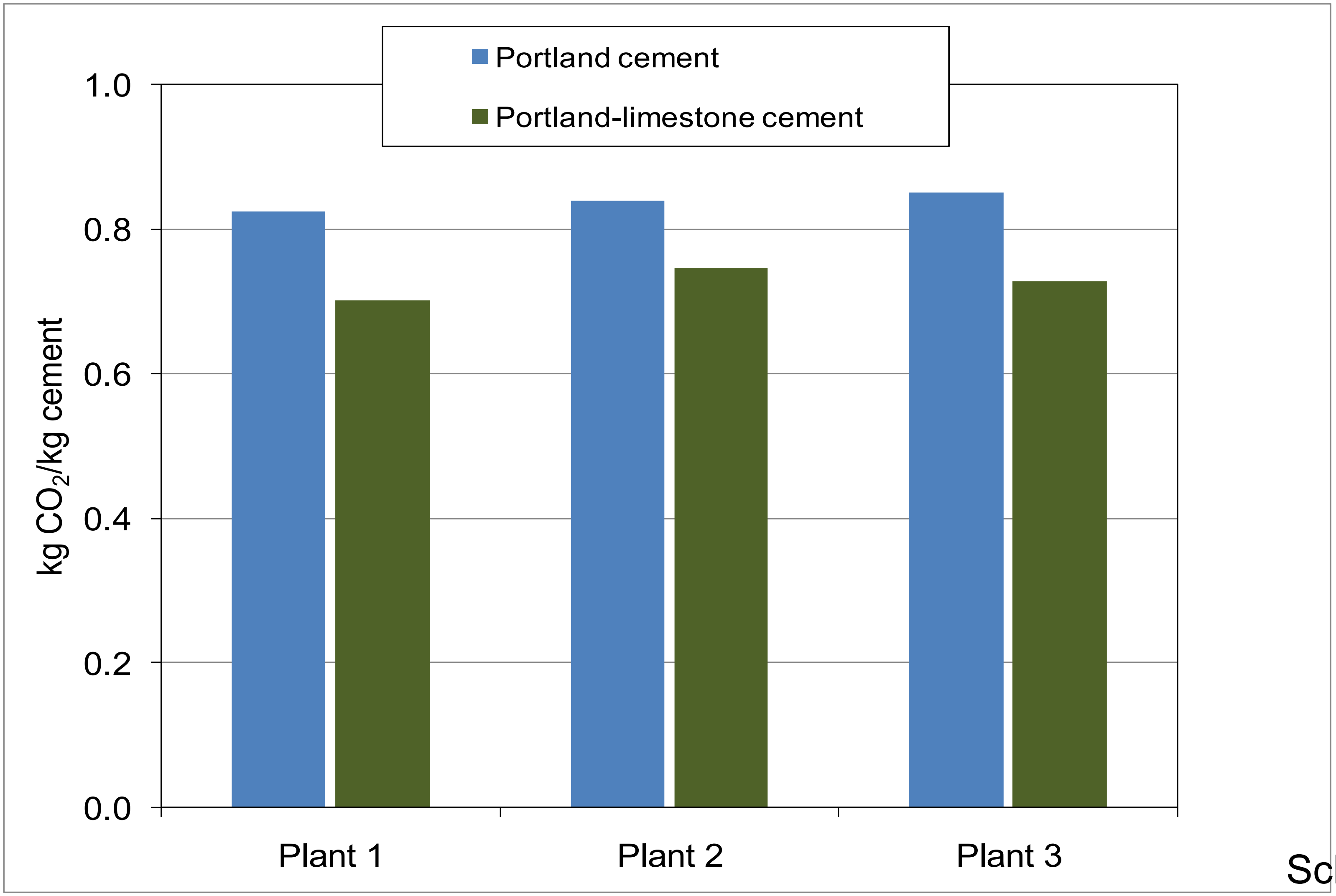
Environmental Benefits



Schmidt 1992

Environmental Benefits

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

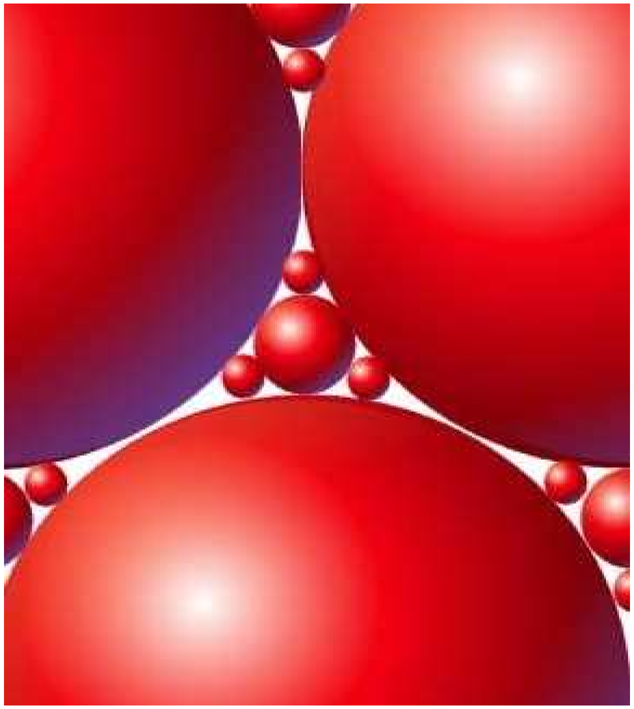
Environmental Benefits

- Cement accounts for approximately
  - 95 % of concrete CO_2 emissions
  - 85 % of concrete energy consumed
- PLC is an option to implement proven technology to obtain desired performance and improve sustainability of concrete

Marceau et al. 2007

How Limestone Works

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



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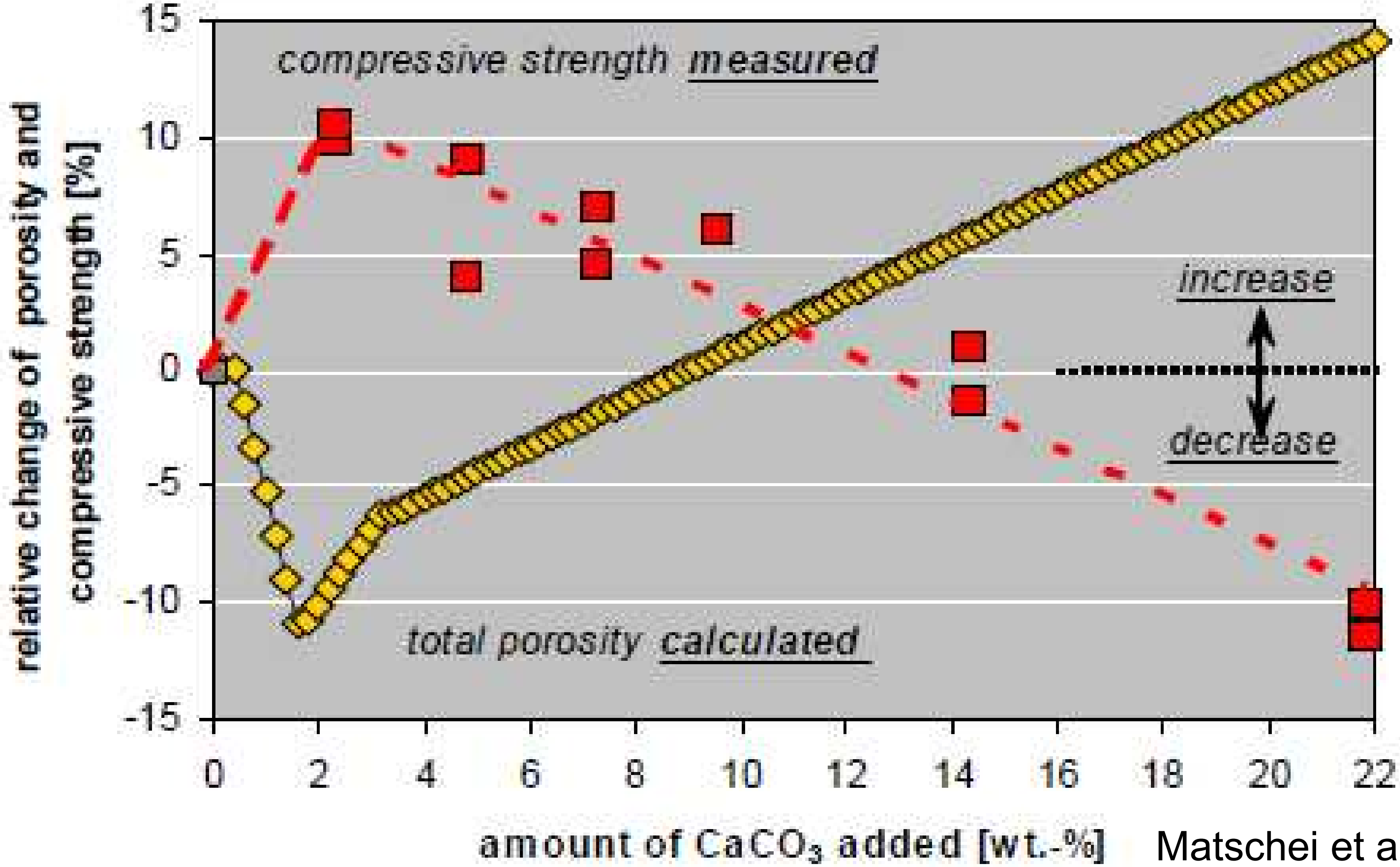
Why 15%?



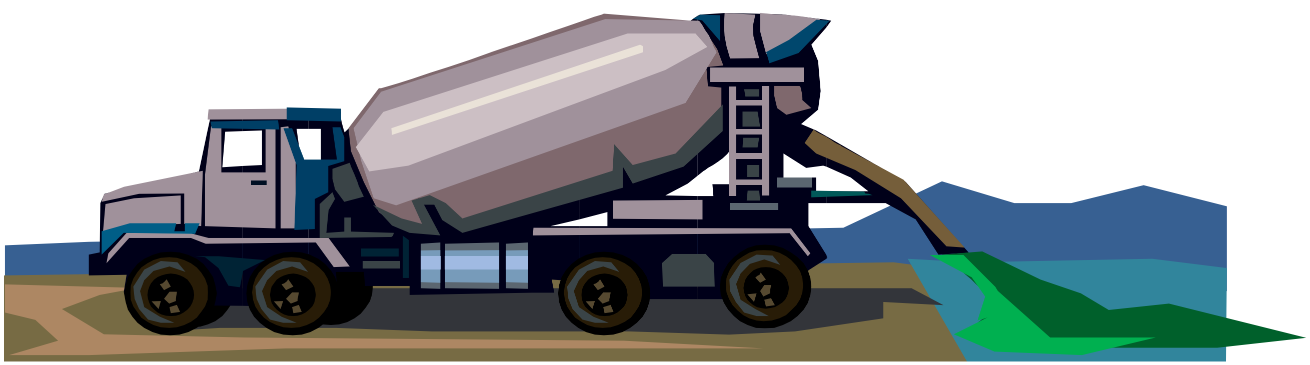
Matschei et al. 2007

Brief History of PLC

- 1965 German standards include PLC (20%) specialty applications
- 1979 French standards include PLC
- 1990 PLC with 15±5% limestone routinely used in Germany
- 1992 UK standards reference PLC (20%)
- 2000 EN 197-1 creates CEM II/A-L (6-20%) and CEM II/B-L (21-35%)
- 2008 CSA A3001 defines PLC containing 5%-15% limestone
- 2012 ASTM C595 and AASHTO M240 include PLC

Summary

- PLC is a new (to US) cement type
- 5% to 15% limestone
- Performance similar
- Environmental benefits



Additional Information

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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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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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