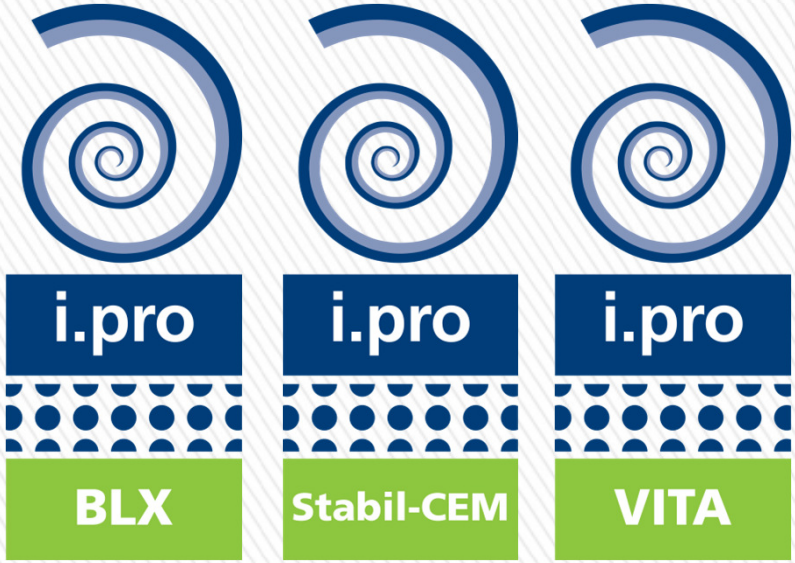
Environmentally Conscious Portland-Limestone Cement



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Learning Objectives

- Overview of Cement
- Types of Cement
- Overview of Carbon Dioxide
- Cement Production and CO_2
- History of Limestone Cement
- How Portland-Limestone Cement Works
- PLC Product Benefits
- ASTM Specifications
- PLC Environmental Benefits
- Conclusions

Portland Cement

Technical Definition:

A hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an inter-ground addition.

Portland Cement

Simple Definition:

The gray powder that reacts with water to a glue-like material that bonds aggregates together to form concrete.

History of Cement

- The usages of cement & concrete go back for thousands of years.
- Early version of cement made with lime, sand, and gravel was used in Mesopotamia in the third millennium B.C. and later in Egypt.
- Concrete floors were used in the royal palace of Tiryns, Greece – 1200 BC.
- The word concrete comes from the Latin word “concretus” (meaning compact or condensed).

The Megaron at Tiryns, Greece

History of Cement

- In 300 BC, the Romans began using pozzolana cement from Mt. Vesuvius.
- Romans used slaked lime as cementitious material.
- Animal fat, milk and blood used as the first admixtures to improve properties.
- Secret of Roman success was lost during the Middle Ages.

The Pantheon in Rome, Italy

History of Cement

Beginning of Portland Cement – named by inventor Joseph Aspdin for its resemblance to a building stone quarried on the Isle of Portland (1824)

Types of Portland Cement

Type I	Normal Cement
Type II	Moderate Sulfate Resistance
Type III	High Early Strength
Type IV	Low Heat of Hydration
Type V	High Sulfate Resistance

Other Types of Cement

- Air Entrained Cements (IA, IIA, IIIA)
- White & Colored Portland Cement
- Masonry Cements – Types N, S, M
- Expansive Cements – Type K

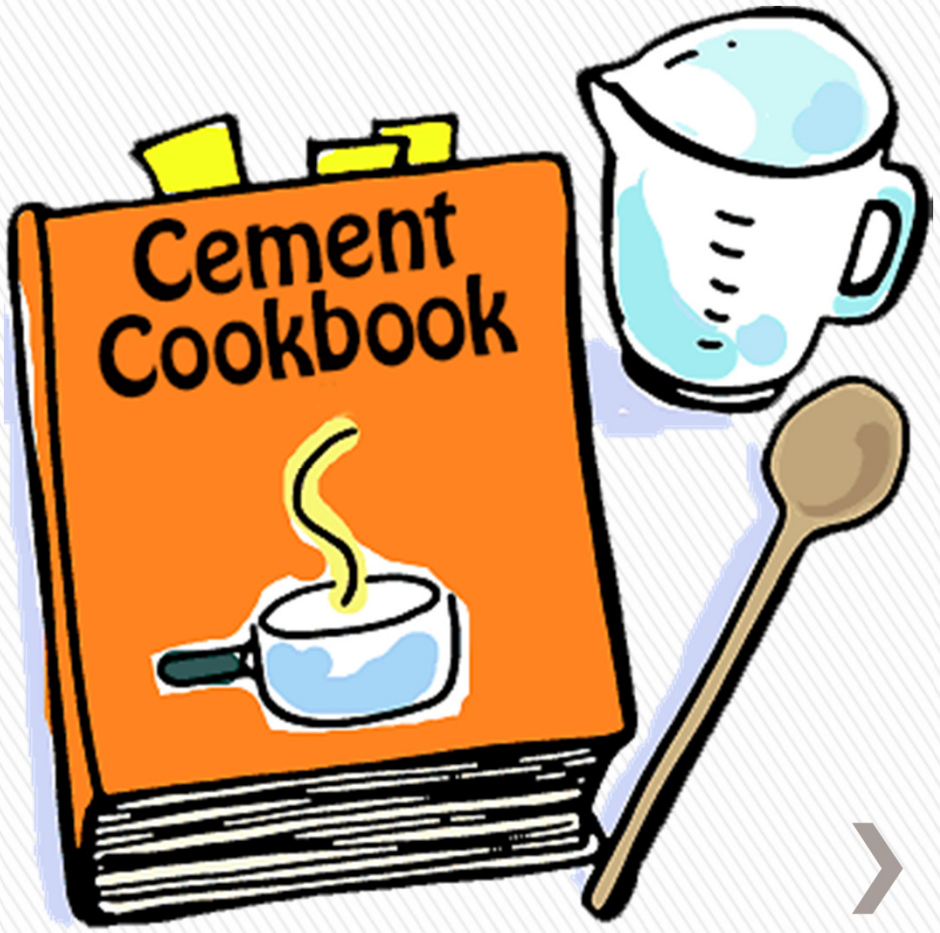
Types of Blended Cement

Type IS	Portland + slag cement
Type IP	Portland + pozzolan cement
Type IL	Portland-limestone cement
Type IT	Ternary blended cement

Composition of Cement

It's a Recipe (**LISA**)

- Limestone (Calcium)
- Iron
- Silica
- Alumina

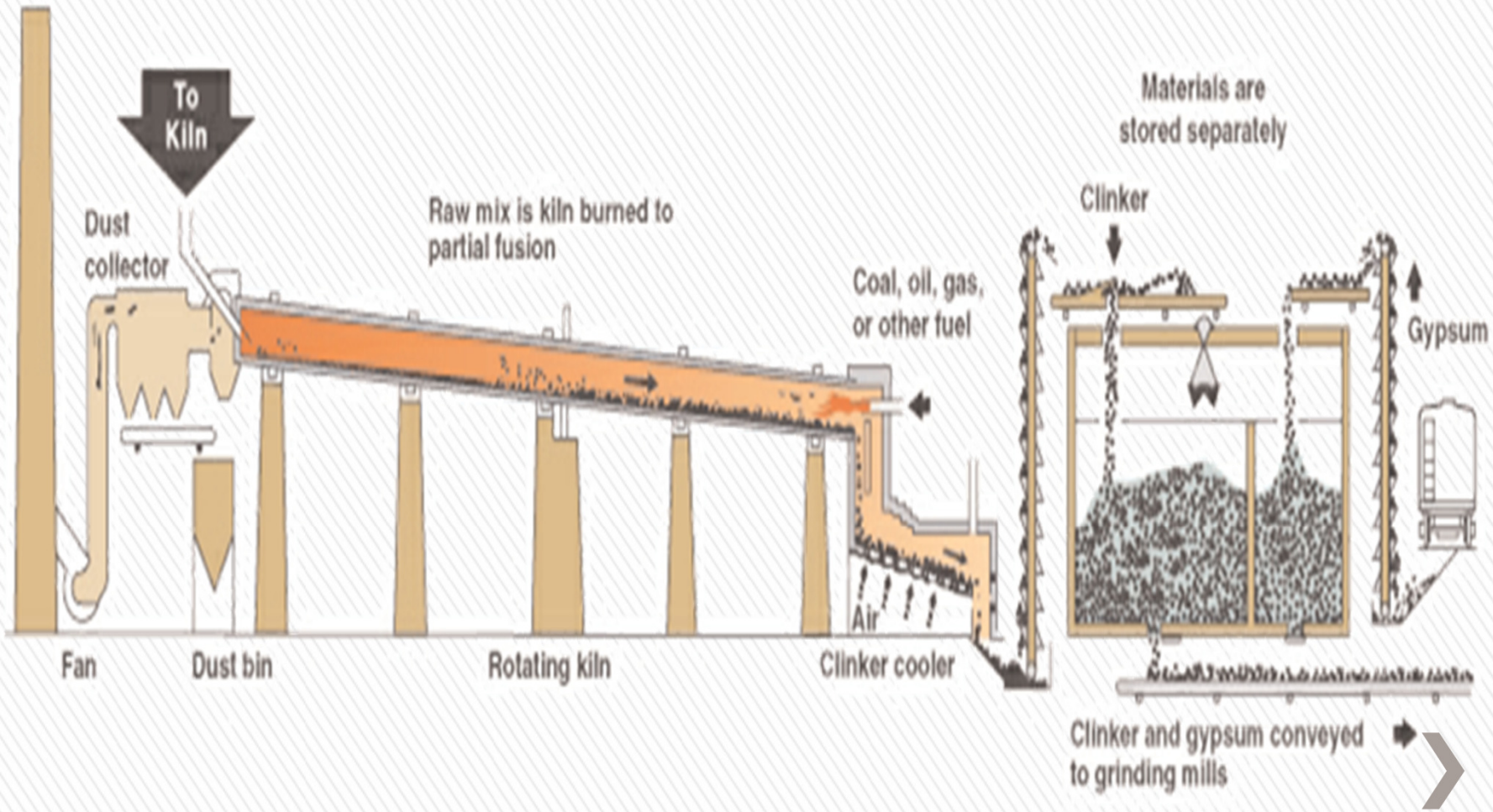


Manufacturing of Cement

Just like making a cake, we need the right amount of certain ingredients:

Type		Approx. %
> Lime	(CaO)	60
> Iron	(Fe_2O_3)	10
> Silica	(SiO_2)	20
> Alumina	(Al_2O_3)	10

Cement Clinker Production



Cement Clinker

Cement and Concrete

Cement is the key ingredient to **Concrete**.

Concrete is made of the following:

- Stone/Aggregate
- Sand
- Cement
- Water

Important!

- Paint and Dry Wall compound dries out to become hard.
- Cement reacts with water in order to make concrete hard.
- Cement requires water present for the concrete to gain strength.
- Proper curing of concrete is critical!
- Curing is a key factor in mitigating cracks in the concrete, which severely impacts durability.

Review of Carbon Dioxide

- Carbon dioxide come from our lungs and many other sources that exists naturally in the atmosphere.
- Along with other gases, CO_2 helps sustain life on our planet by retaining the sun's heat.
- Unnatural CO_2 is also being generated by many sources, mostly from burning fossil fuels.
- This and other sources of CO_2 are generally attributed to trapping heat and raising temperatures, thus contributing to what's called the "greenhouse effect."

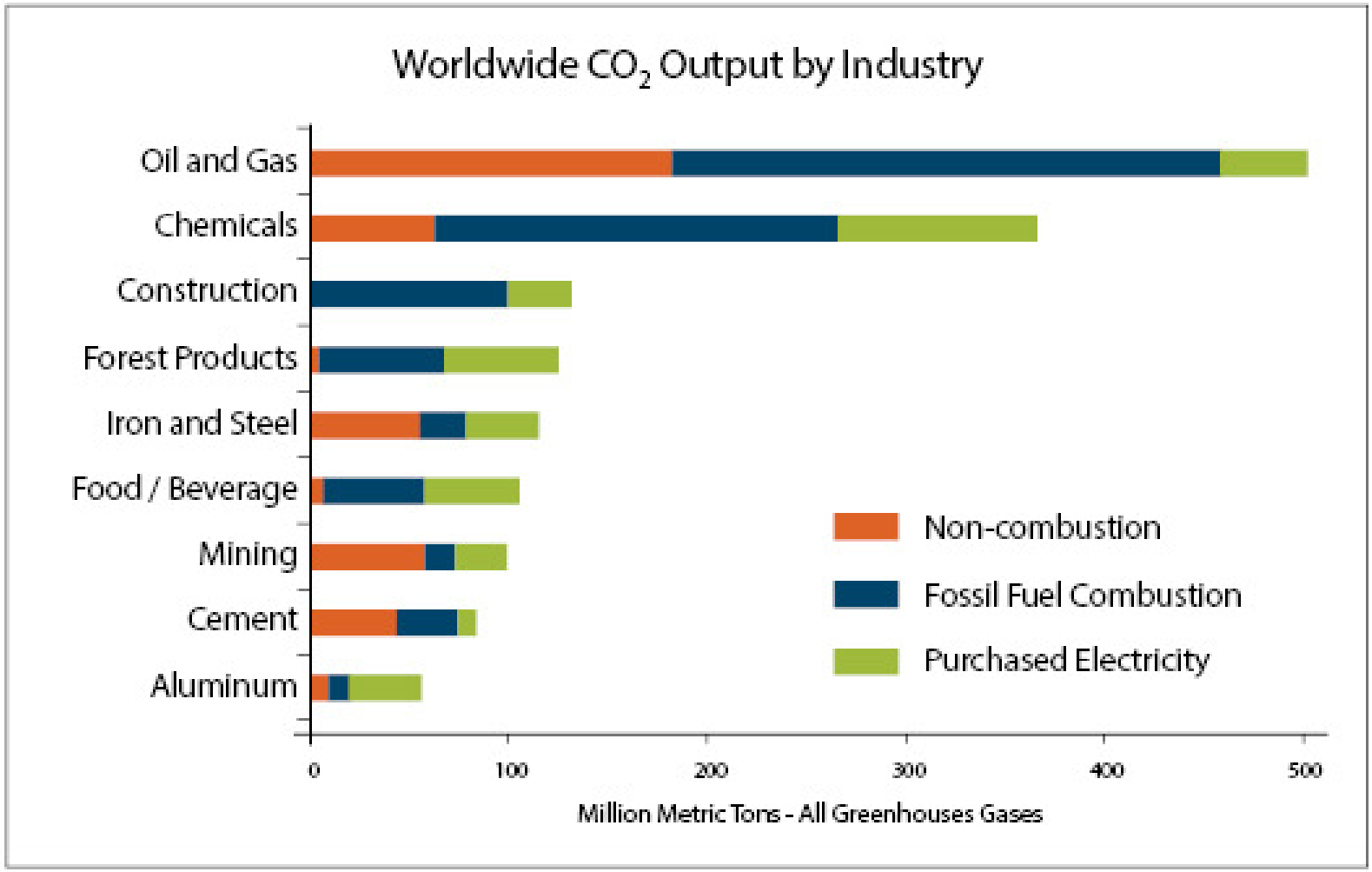
Many scientists believe this greenhouse effect causes global warming that will cause a rise in sea levels and increase the intensity of extreme weather.

Review of Carbon Dioxide

- The main human activity that emits unnatural CO_2 is the combustion of fossil fuels (coal, natural gas and oil) for energy and transportation.
- The main sources of CO_2 emissions in the U.S. according to the Environmental Protection Agency are:
  1. Generation of electricity – 40% of CO_2 emissions
  2. Transportation – 31% of CO_2 emissions
  3. Industry – 14% of CO_2 emissions

Source: National Precast Concrete Association

CO_2 Output by Industry



Source: National Precast Concrete Association

Cement Production and CO_2

Concrete is the most commonly used construction material on the planet.

In the U.S., the production of portland cement is ***only*** responsible for 1.5 - 2.0% of the United States' CO_2 emissions. Globally, cement production is responsible for 5 - 8% of world-wide CO_2 emissions.

- Forty percent of the CO_2 generated in making cement is the burning of fossil fuels to acquire and process raw materials to make clinker.
- Sixty percent of the CO_2 is from the calcination of the limestone or calcium carbonate ($CaCO_3$) itself, a necessary reaction in the production of portland cement.
  - Calcination process: $CaCO_3 \Rightarrow CaO + CO_2$

Source: Portland Cement Association

Cement Production and CO_2

Cement Industry's Strategies To Reduce Its Carbon Footprint.

CO_2 emissions reduced by 10% in last 20 years:

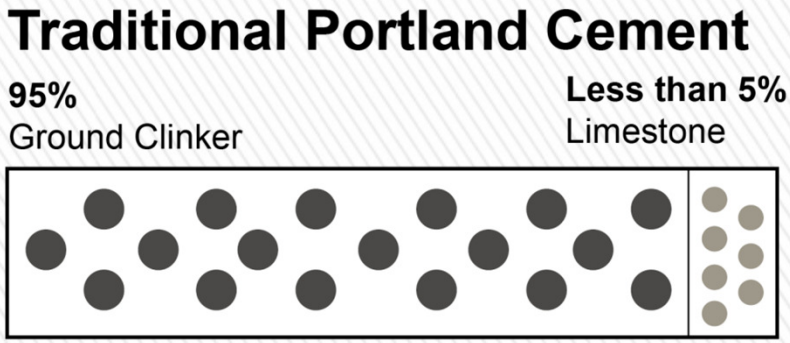
- Improvements in operating energy efficiencies
- Use of Alternative and Renewable Energy Sources
- Use of Supplementary Cementing Materials

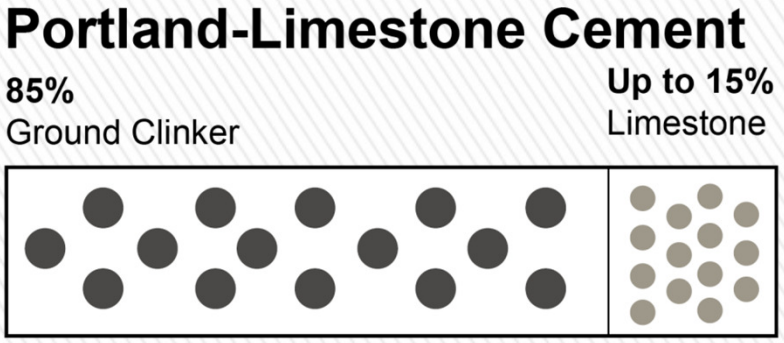
Source: Portland Cement Association

What is portland-limestone cement?

Portland-limestone cement is made by inter-grinding regular clinker with up to 15% limestone while regular portland cement contains up to 5% limestone

Portland-limestone cement is a finer ground product than regular portland cement





Limestone Cement Milestones

1965 – Heidelberg produces 20% limestone cement in Germany for specialty applications

1979 – French cement standards allow limestone additions

1983 – Canada's CSA -A5 allows 5% in Type 10 (now GU) cement

1992 – Up to 20% in limestone cement allowed in the UK

2000 – England's EN 197-1 allows 5% MAC (limestone) in all 27 common cements, as previously commonly practiced in various European cement standards

Source: Portland Cement Association

Limestone Cement Milestones

2000 – EN 197-1 creates CEM II/A-L (6-20%) and CEM II/B-L (21-35%)

2004 – ASTM C150 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

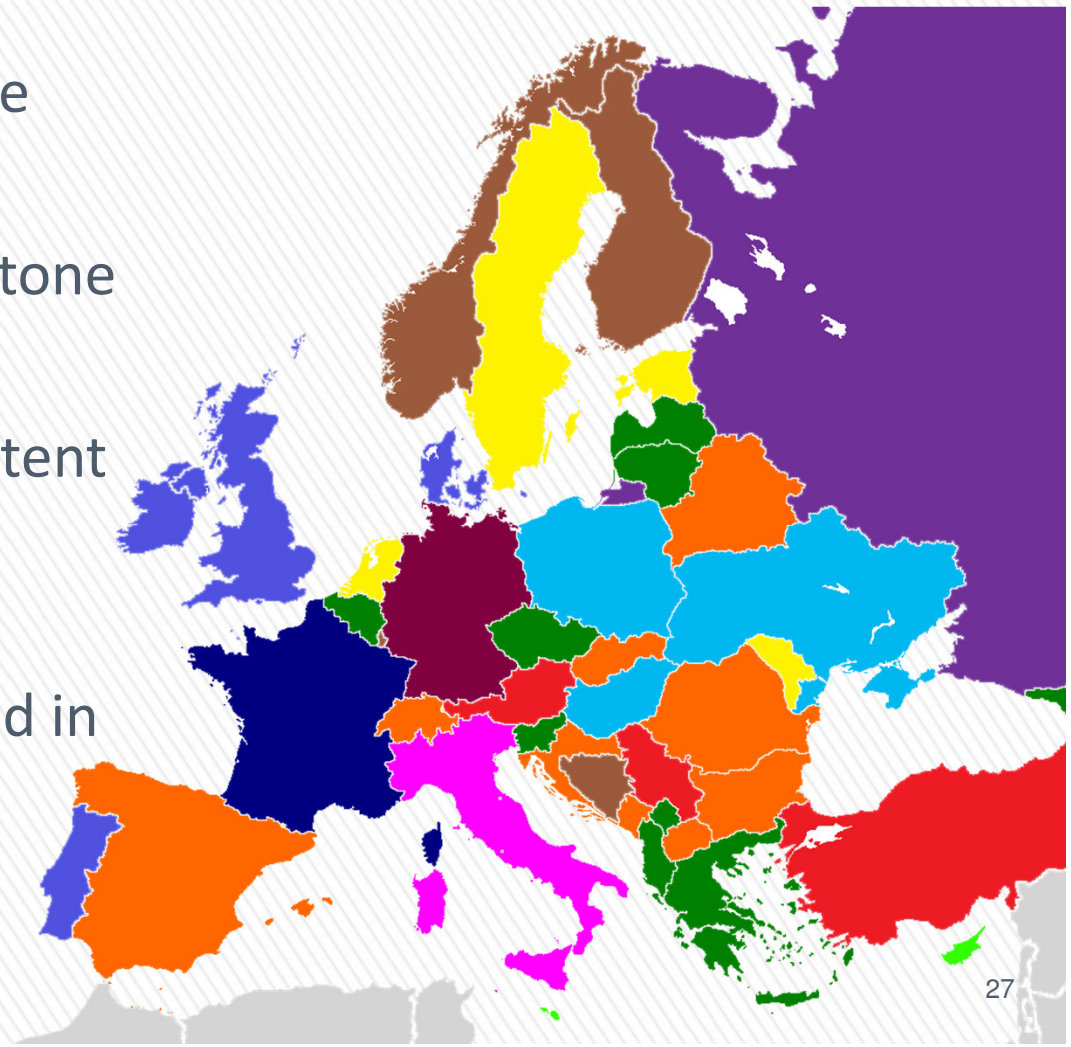
2008 – CSA A3001 includes PLC containing 5% -15% limestone

2012 – ASTM C595 / AASHTO M240 containing 5% -15% limestone

Source: Portland Cement Association

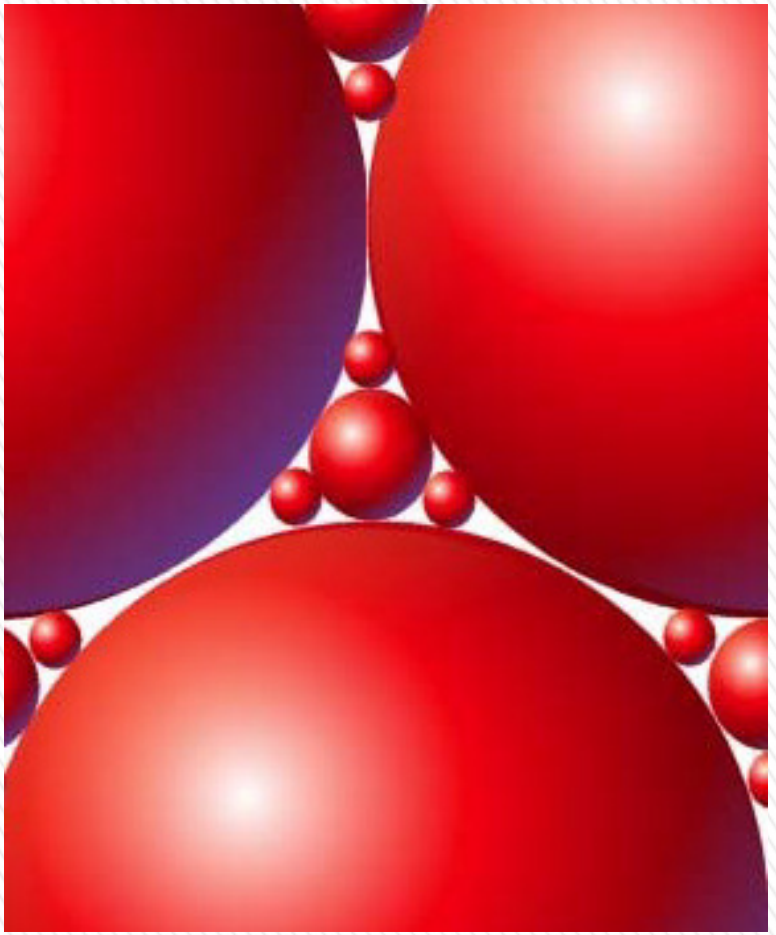
Proven Track Record In Europe

- Used successfully for over 28 years in a variety of applications and exposure conditions
- Known as portland-limestone cement
- Up to 35% limestone content allowed by European cement standards
- Most popular cement sold in Europe today has a limestone content of up to 20%



How Limestone Works

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



Source: Portland Cement Association

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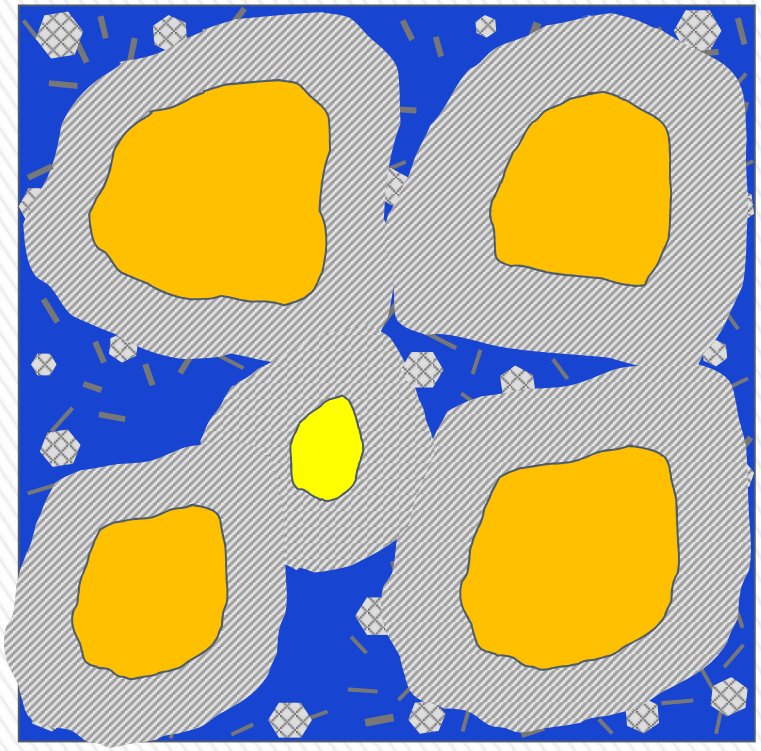

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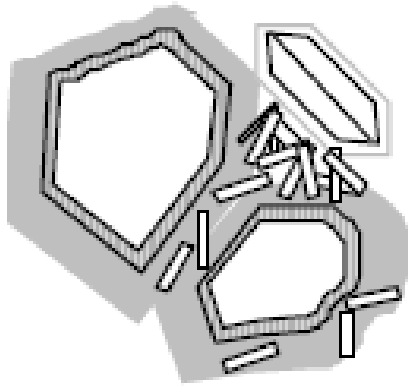


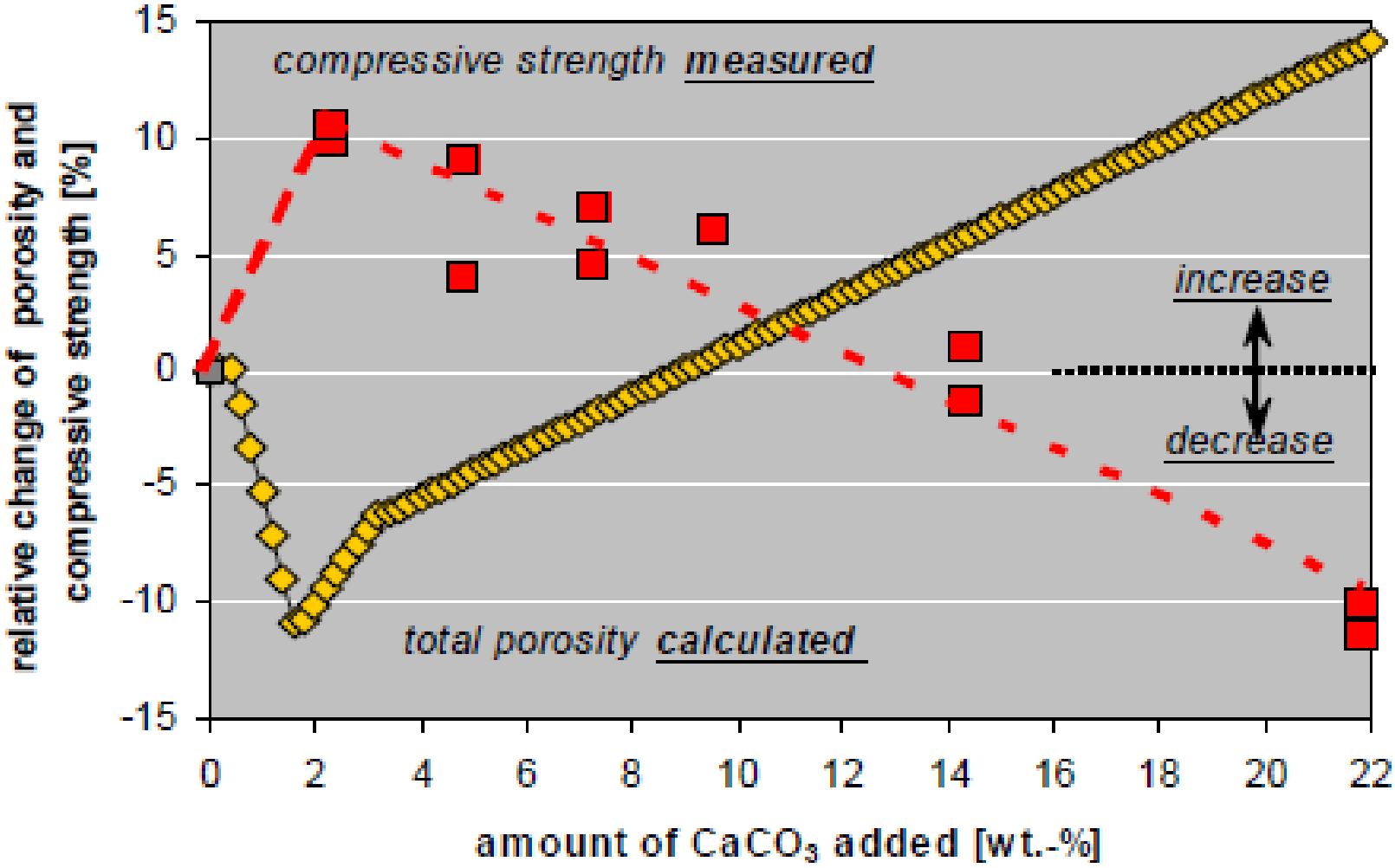
Ca^{2+} $CaOH^{+}$

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

CO_3^{2-}

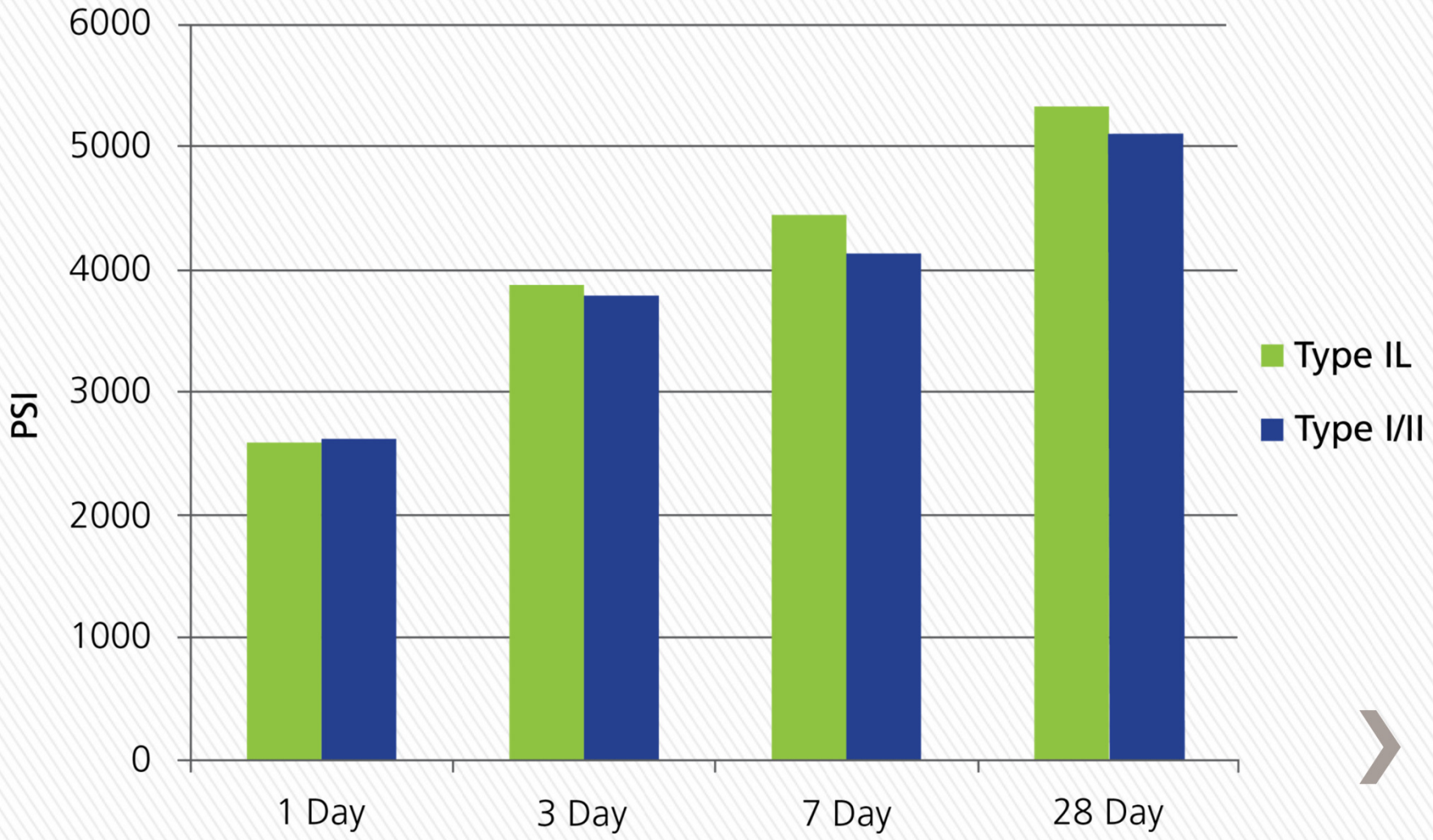
Source: Portland Cement Association

Why 15%?



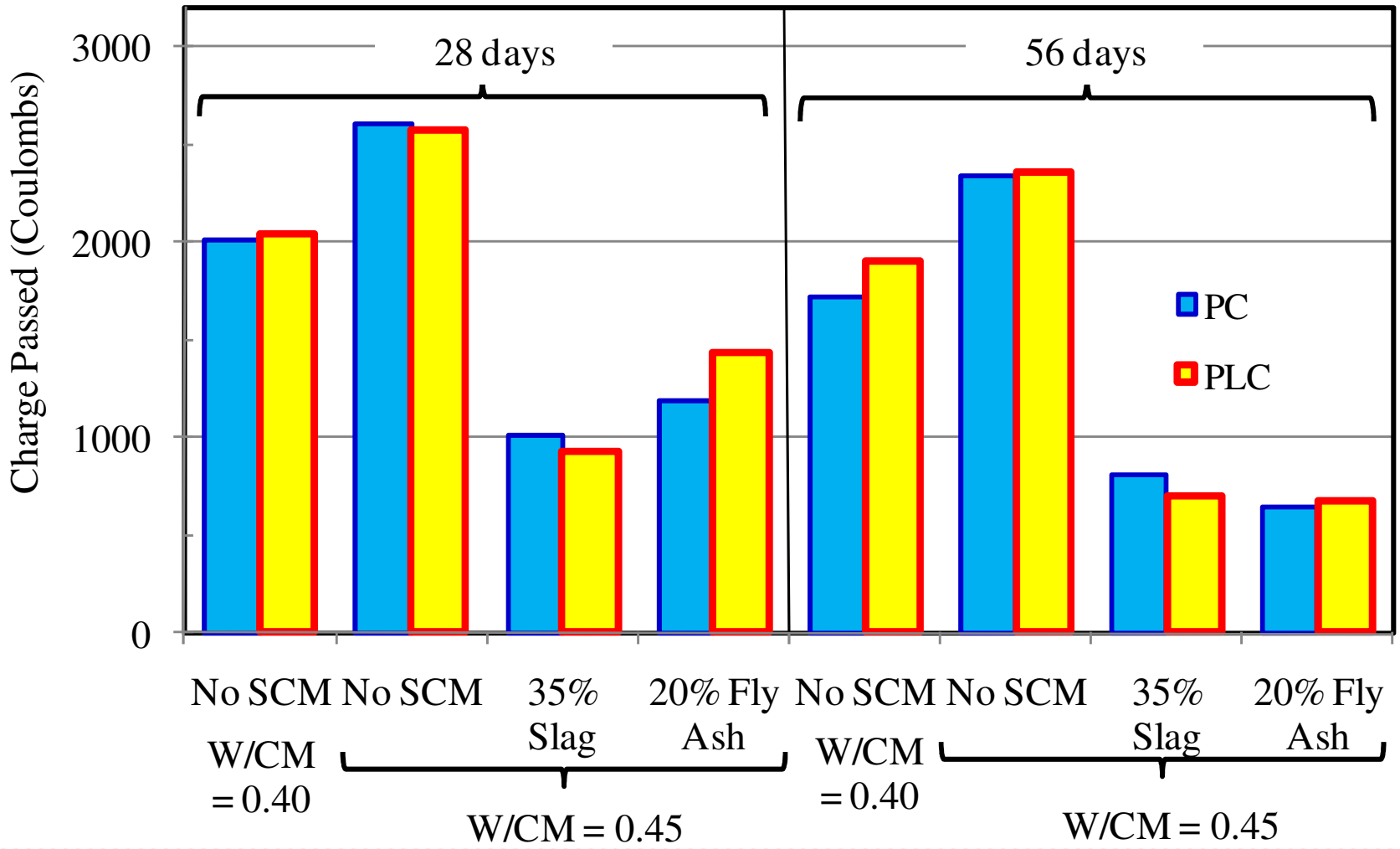
Source: Matschei, T.; Glasser, F. P.; Herfort, D.; and Lothenbach, B., "Relationships of Cement Paste Mineralogy to Porosity and Mechanical Properties,"

Type IL compared to Type I/II



Source: Essroc Cement Technical Services Lab Results

Permeability Performance



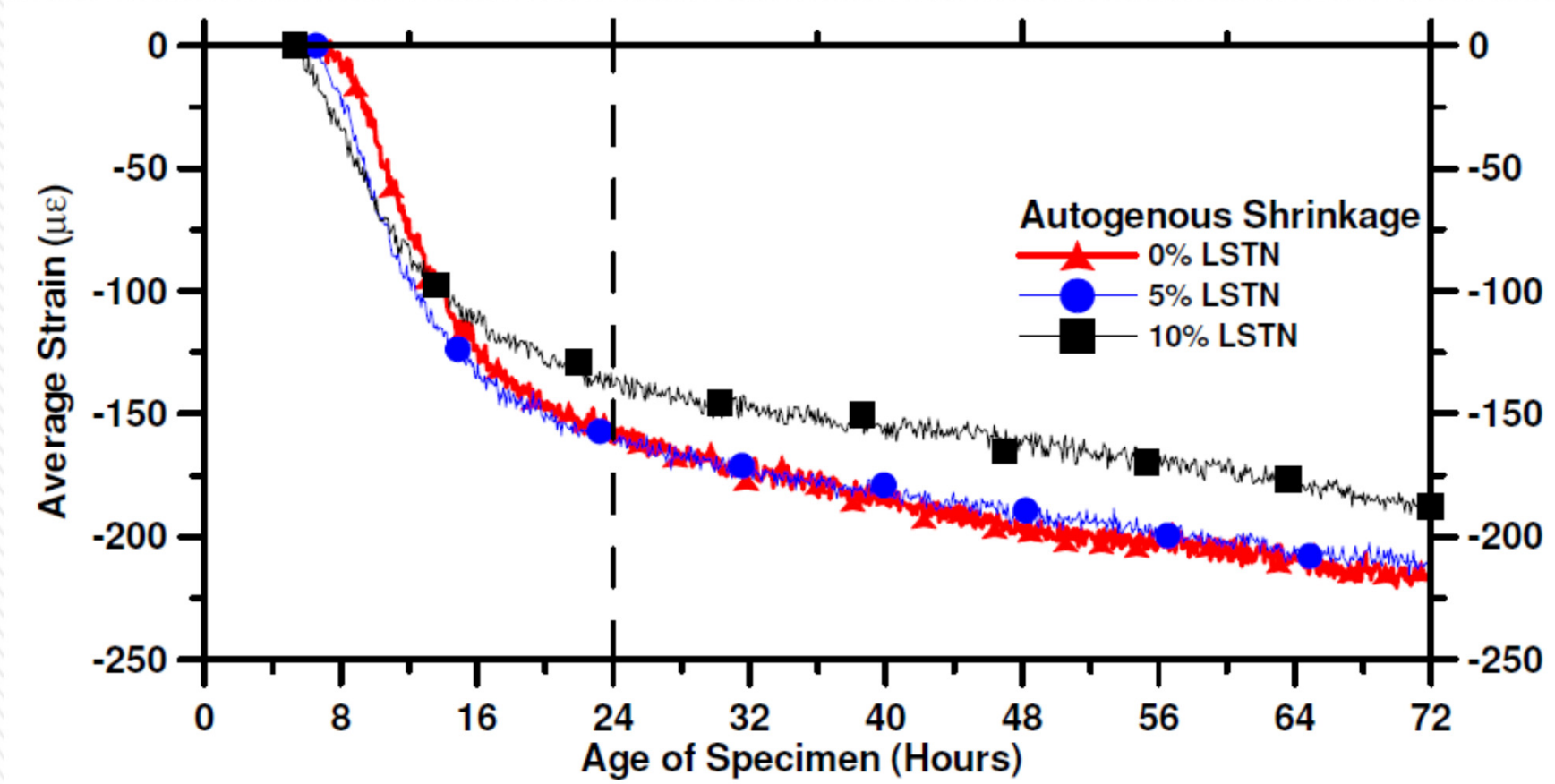
Source: Matschei, T.; Glasser, F. P.; Herfort, D.; and Lothenbach, B., "Relationships of Cement Paste Mineralogy to Porosity and Mechanical Properties,"

Creep and Shrinkage

	Limestone Content %				
	0%	15%	25%	35%	45%
Cube strength (MPa)	41.0	36.5	30.5	23.5	17.0
Creep (µm/m)	790	780	775	770	760
Drying shrinkage (µm/m)	680	630	605	590	575

Source: Matschei, T.; Glasser, F. P.; Herfort, D.; and Lothenbach, B., "Relationships of Cement Paste Mineralogy to Porosity and Mechanical Properties,"

Autogenous Shrinkage



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PLC Benefits in Block & Pavers

- Equivalent strengths to traditional Type I portland cement.
- Reduced efflorescence in concrete block and pavers.
- Contributes to the environmental footprint of structures - ‘green’ building solution.

PLC Benefits in Soil Stabilization

- Equivalent strengths to traditional Type I portland cement.
- Lower permeability of subgrade when used in Soil Stabilization applications

PLC Benefits in Ready Mix

- Equivalent strengths to traditional Type I portland cement.
- Improved finishing and pumpability of concrete.
- Contributes to the environmental footprint of structures - ‘green’ building solution.

ASTM Specifications

The Story of Three ASTM Specifications
ASTM C150 *vs* ASTM C595 *vs* ASTM C1157

There can be some confusion between the ASTM specifications.

- **ASTM C150/AASHTO M 85** allows up to 5% limestone to be added in portland cement production.
- **ASTM C595/AASHTO M 240** for blended cements currently allows blending/inter-grinding portland cement with fly ash and other pozzolans (IP), slag cement (IS), limestone (>70% CaCO3) (IL), and ternary blends (IT).
- **ASTM C1157** is a performance base standard for hydraulic cement which allows a wide range of cement based on the performance requirements.

The majority of states allow ASTM C1157 cements in their building and residential codes, but only a limited number of state Departments of Transportation (DOT) accept their use for transportation projects – requiring ASTM C150 and ASTM C595.

ASTM Specifications

ASTM C150 / C150M

Standard Specification for Portland Cement

- This specification covers eight types of portland cement:
  - Type I, Type IA, Type II, Type IIA, Type III, Type IIIA, Type IV, and Type V.
- The cement covered by this specification shall only contain the following ingredients: portland cement clinker; water or calcium sulfate, or both; limestone; processing additions; and air-entraining addition for air-entraining portland cement.

ASTM Specifications

ASTM C1157 / C1157M

Standard Performance Specification for Hydraulic Cement

- This performance specification covers hydraulic cements for both general and special applications.
- There are no restrictions on the composition of the cement or its constituents.
- There are two related hydraulic cement standards, ASTM C150 for portland cement and ASTM C595 for blended cements, contain BOTH prescriptive and performance requirements
  - This performance specification classifies cements based on specific requirements for general use, high early strength, resistance to attack by sulfates, and heat of hydration. Optional requirements are provided for the property of low reactivity with alkali-silica-reactive aggregates and for air-entraining cements.

ASTM Specifications

ASTM C595 / C595M

Standard Specification for Blended Hydraulic Cements

- This specification pertains to blended hydraulic cements for both general and special applications, using slag or pozzolan, or both, with portland cement or portland cement clinker or slag with lime.
- These cements are classified into two types: Type IS which is portland blast-furnace slag cement and Type IP which is portland-pozzolan cement. They can also be described according to air-entraining, moderate sulfate resistance, moderate heat of hydration, high sulfate resistance, or low heat of hydration properties.
- **Portland-limestone cements fall under ASTM C595.**

ASTM Specifications

ASTM C595 / C595M

Standard Specification for Blended Hydraulic Cements

- **Two types of portland-limestone cements fall under ASTM C595**

- Type IL: Portland-Limestone Cement
  - 5% to 15% limestone by mass
- Type IT: Ternary Blended Cements
  - Portland Cement with
    - Pozzolan and Limestone
    - Slag Cement and Limestone

PLC Environmental Savings

PLC Environmental Savings over Ordinary Portland Cement - *per million tons cement

Percent Limestone:	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

Source: Portland Cement Association

Replacing five million metric tons of portland cement with portland-limestone cement…

…is like taking 105,000 cars off U.S. roads annually.

In the U.S. 2013 cement consumption was 75 million metric tons 2018 cement consumption is estimated to be 120 million metric tons

Replacing five million metric tons of portland cement with portland-limestone cement…

…will reduce CO_2 emissions by 500,000 metric tons a year.

In the U.S. 2013 cement consumption was 75 million metric tons 2018 cement consumption is estimated to be 120 million metric tons

Replacing five million metric tons of portland cement with portland-limestone cement…

…is like planting 12.8 million trees a year.

In the U.S. 2013 cement consumption was 75 million metric tons 2018 cement consumption is estimated to be 120 million metric tons

Conclusion

- Cement is indispensable for our construction activity.
- Cement is the primary ingredient in concrete
  - Concrete is the second most consumed substance on Earth after water.
- The cement industry accounts for only around 5% of global CO_2
- The use of blended cement reduces CO_2 emissions.
- Portland-limestone cement (PLC) is manufactured by inter-grinding clinker with up to 15% limestone.
- PLC can cut CO_2 emissions by up to 15 percent compared to traditional portland cement.

Conclusion

Portland-limestone Cement:

- Improves particle packing. Finer limestone particles fill in between the larger cement grains.
- Higher surface area of fine limestone provides surfaces for silicates to form and grow.
- Provides equivalent properties and strengths to traditional Type I portland cement.
- Provides improved finishing and pumpability of concrete.
- Reduces efflorescence in concrete block and pavers.
- Contributes to the environmental footprint of structures - 'green' building solution.

Thank you for your time!

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