Concrete Mix Components: Trends & Challenges

Bob Neal
Lehigh Cement Co
Virginia Concrete Conference
March 3, 2016

Concrete Mix Components: Trends & Challenges

Portland Cement Manufacturing

The Challenges

- Environmental Pressures
  - CO_2 Emissions
  - Preservation of Raw Materials

The Challenges

- Portland Cement
  - 92 – 95% Clinker
- Clinker Production = CO_2
  - ~ 50 – 60% Calcination of Limestone
  - Balance from Fuels
- CO_2 ~0.9 MT/MT Clinker Produced

The Challenges

- U.S. Clinker Production 70 million MT (2013)
- CO_2 = 63 million MT
- Still only about 1.5% of total U.S. CO_2

Source: NRMCA

The Trend:

- Clinker Content Reduction
- Interground Limestone Additions in Portland Cement

The Trend: Clinker Content Reduction

- U.S. Limestone Additions in Portland Cement
- ASTM C 150
  - 2007: Up to 5% permitted
    - Typical 3%
  - 2016: ASTM Change on LOI and Insoluble Residue
    - Will allow closer to the 5% addition
  - CO_2 Savings
    - ~ 2 –3 million MT in U.S.

The Trend: Clinker Content Reduction

- Limestone Additions in Portland Cement
- Skepticism!
- Good Track Record

The Trend: Further Reductions

- <u>2012: ASTM C 595 Type IL Cement</u>
  - Portland – Limestone Cement
- <u>Limestone Addition: 5% to 15%</u>

The Trend – CO_2 Reductions.

- <u>ASTM C 595 Type IL Cement –</u>
- Example assuming 75 million MT cement production

Limestone Content	10%	15%
CO_2 Reduction per million MT Clinker	94,000 MT	141,000 MT

Source PCA SN3148

The Trend – CO_2 Reductions.

- <u>ASTM C 595 Type IL Cement –</u>
- Example assuming 75 million MT cement production

Limestone Content	10%	15%
CO_2 Reduction Total U.S.	7 million MT	11 million MT

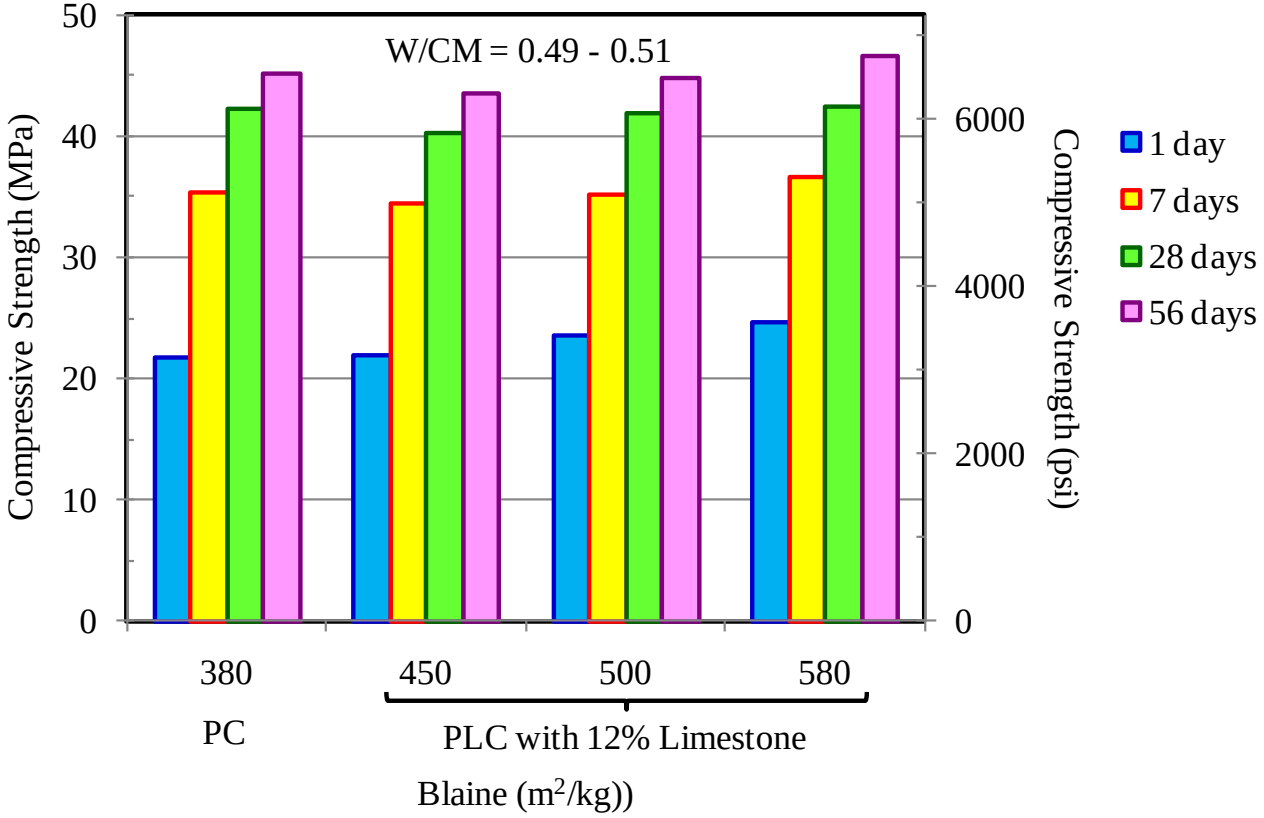
Source PCA SN3148

The Trend – Type IL Performance

- Skepticism !!!
- Comparable to Type I or Type II Cement
- Without/With SCMs

The Trend – Type IL Performance

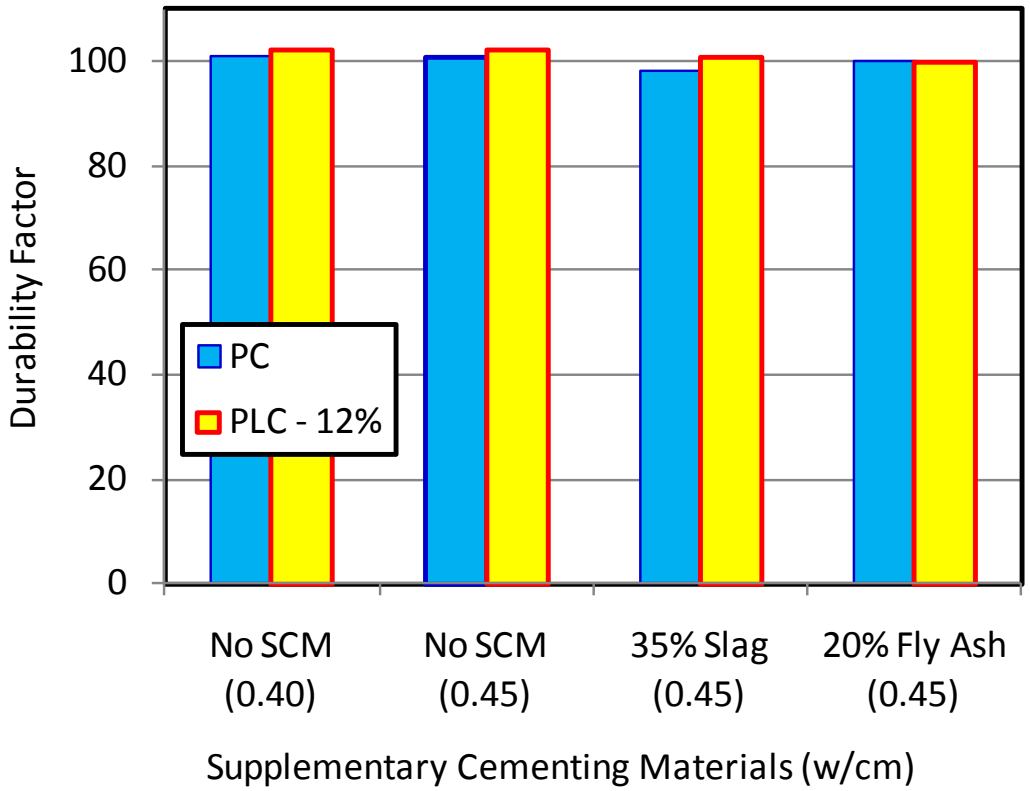
- Strength



Source PCA SN3148

The Trend – Type IL Performance

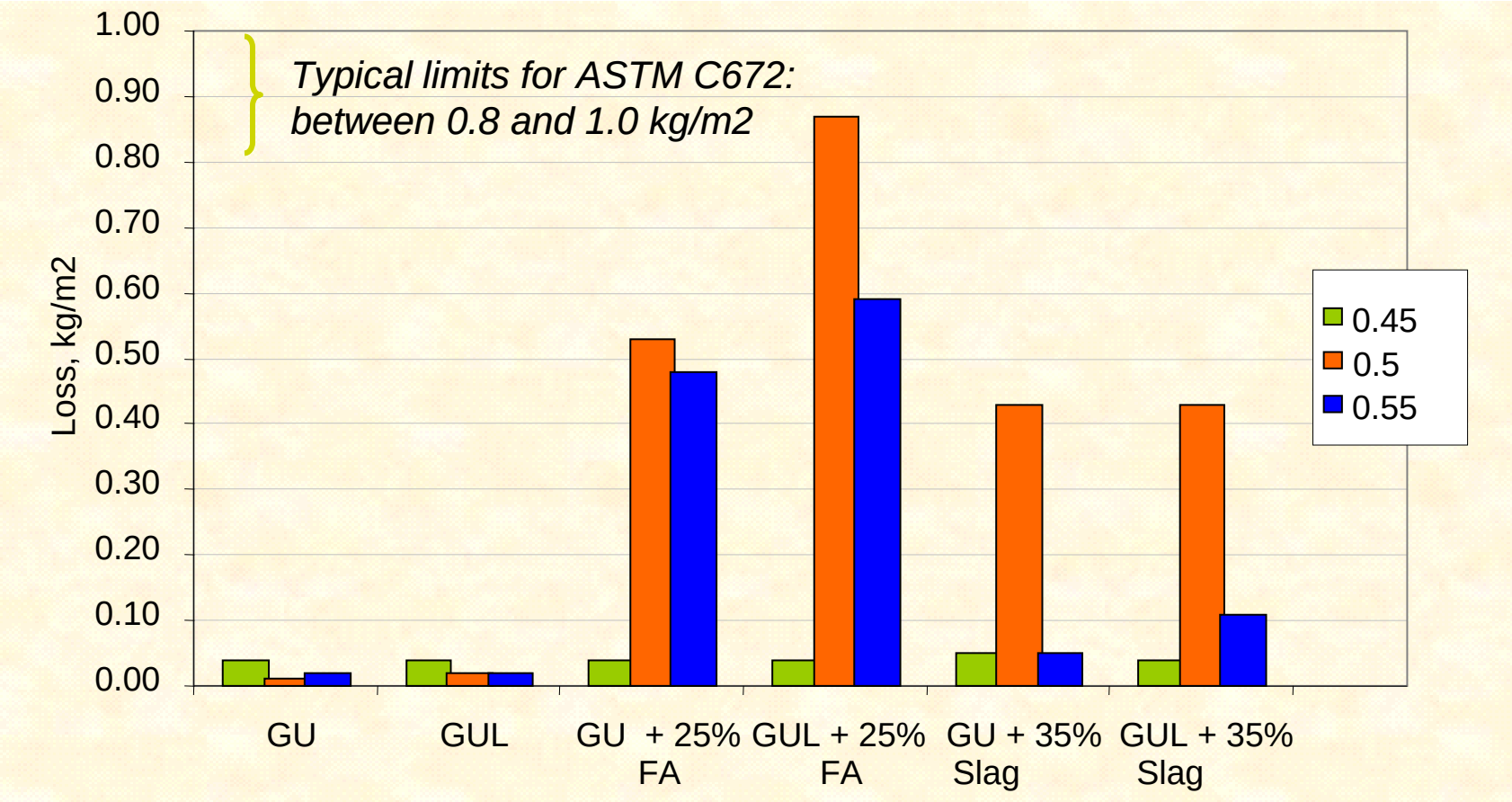
- Freeze/Thaw Resistance: ASTM C 666



Source PCA SN 3148

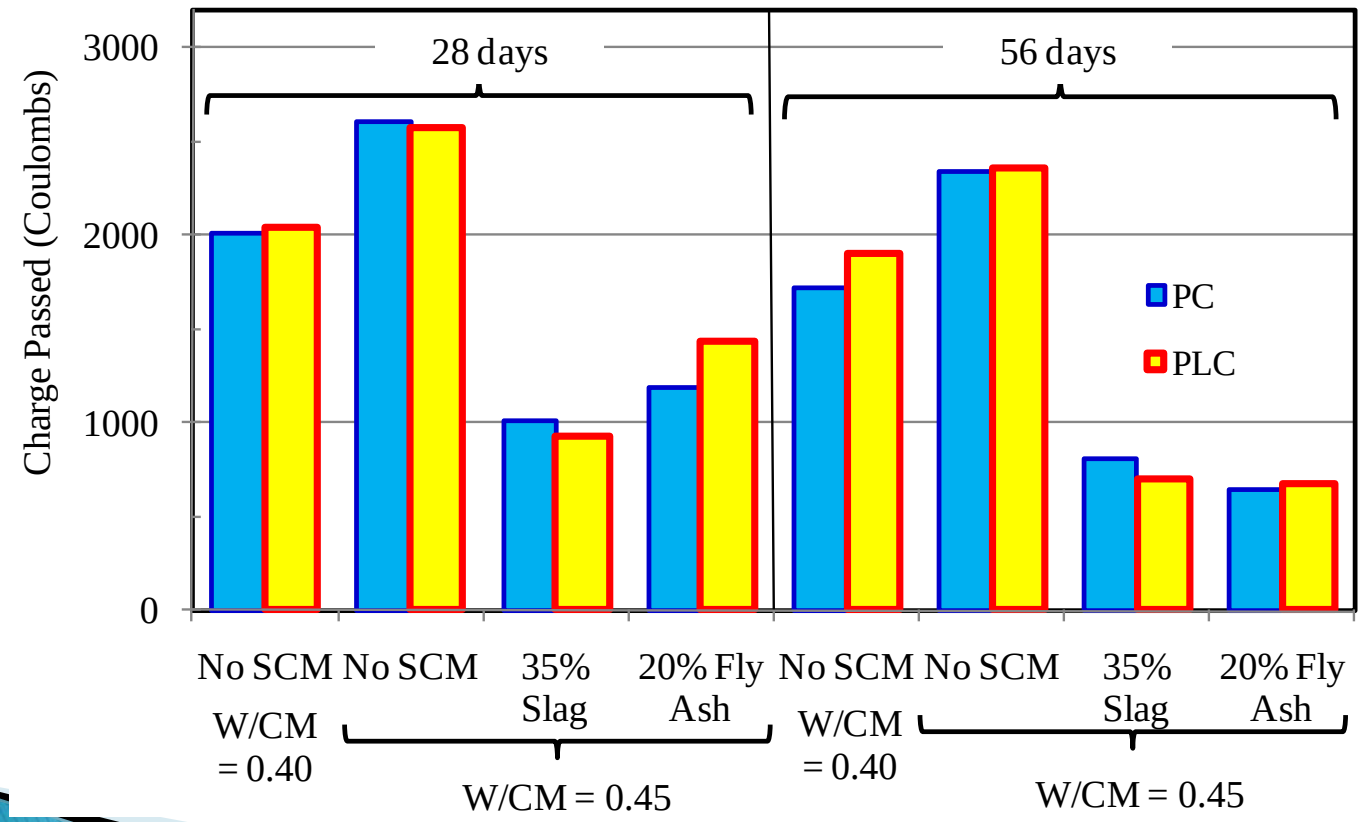
The Trend – Type IL Performance

- Scaling Resistance: ASTM C 672



The Trend – Type IL Performance

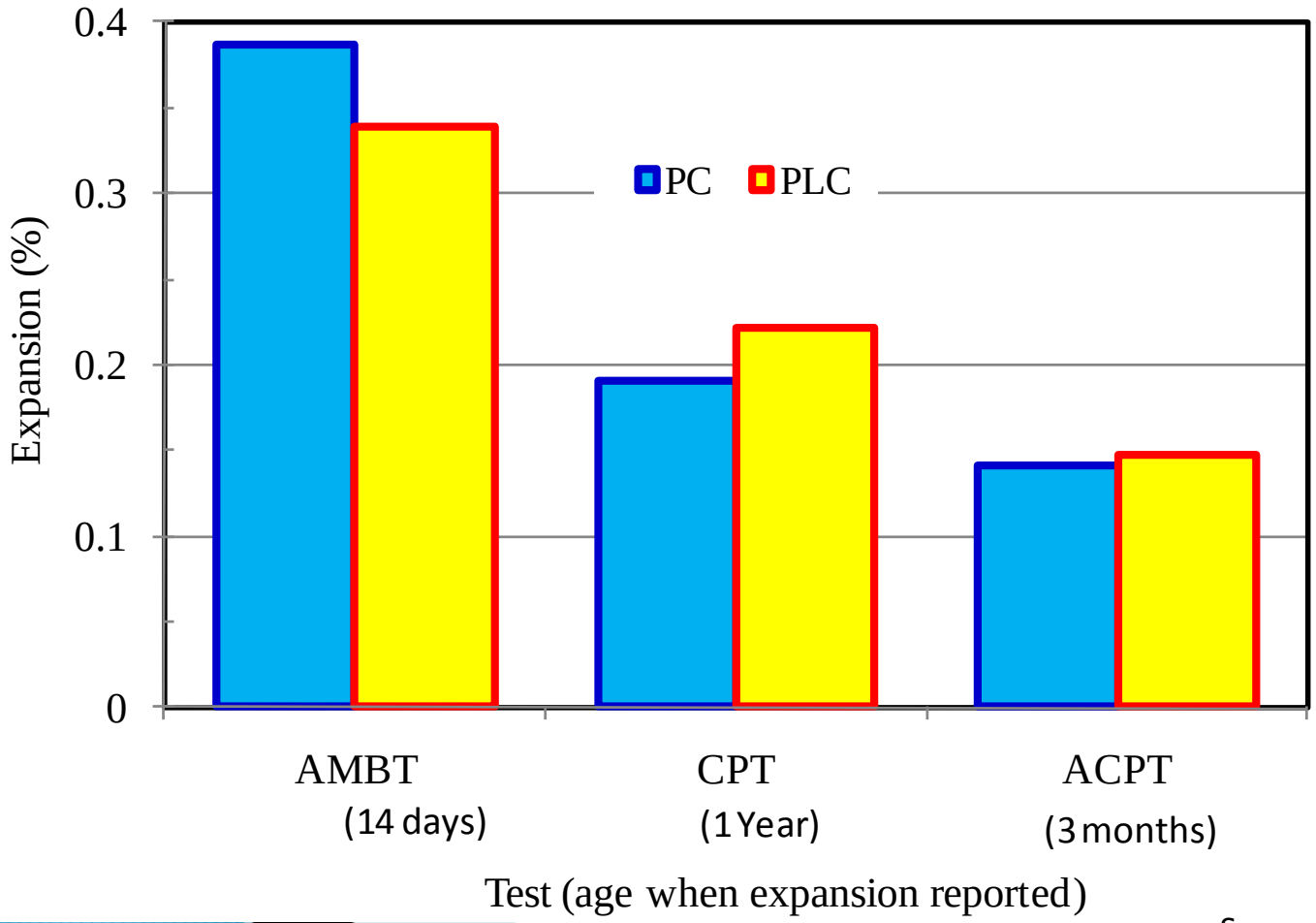
- Permeability: ASTM C1202



Source PCA SN3148

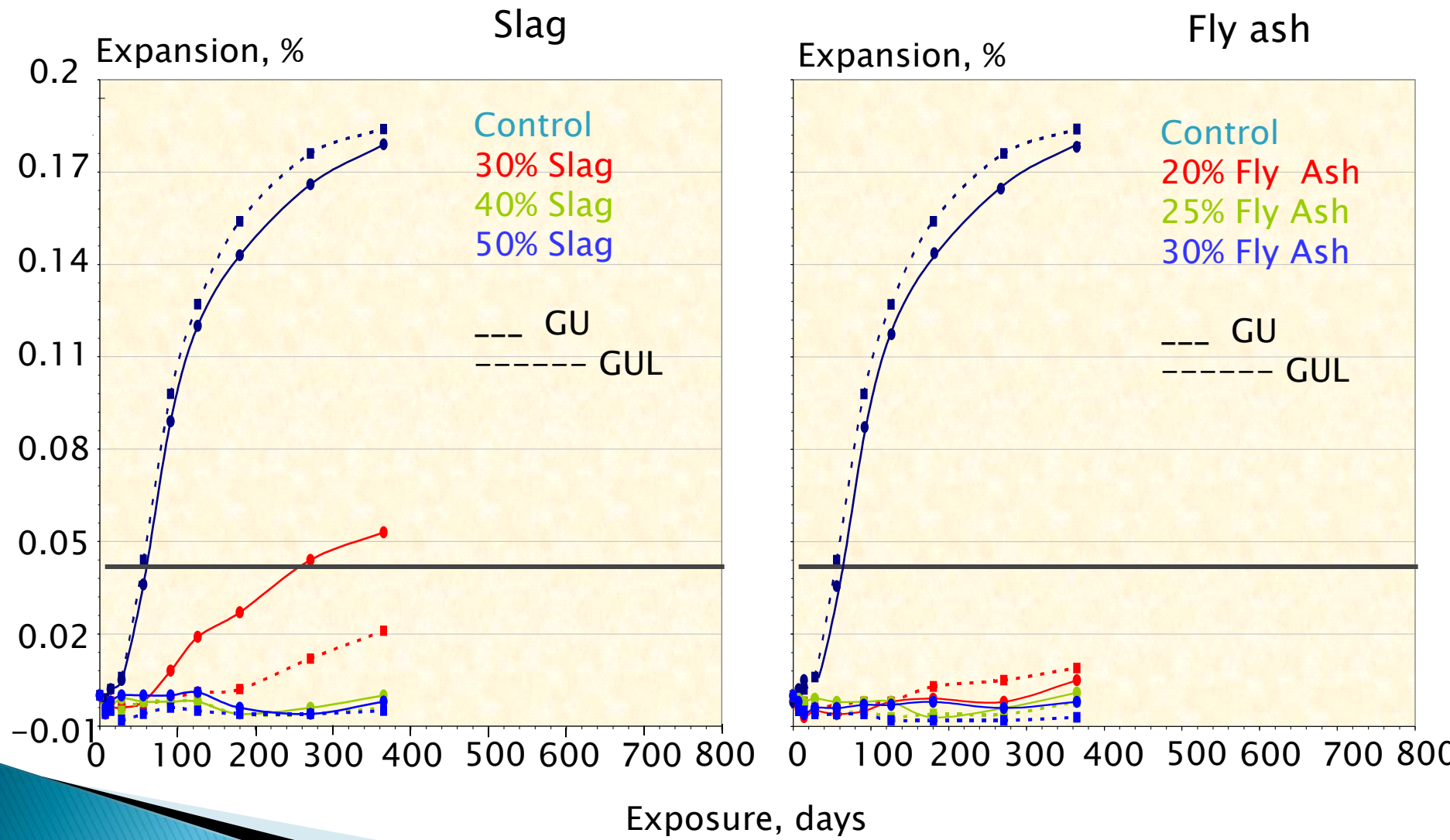
The Trend – Type IL Performance

- ASR (Spratt Aggregate)



Source PCA SN 3148

ASR – Concrete Prism Test

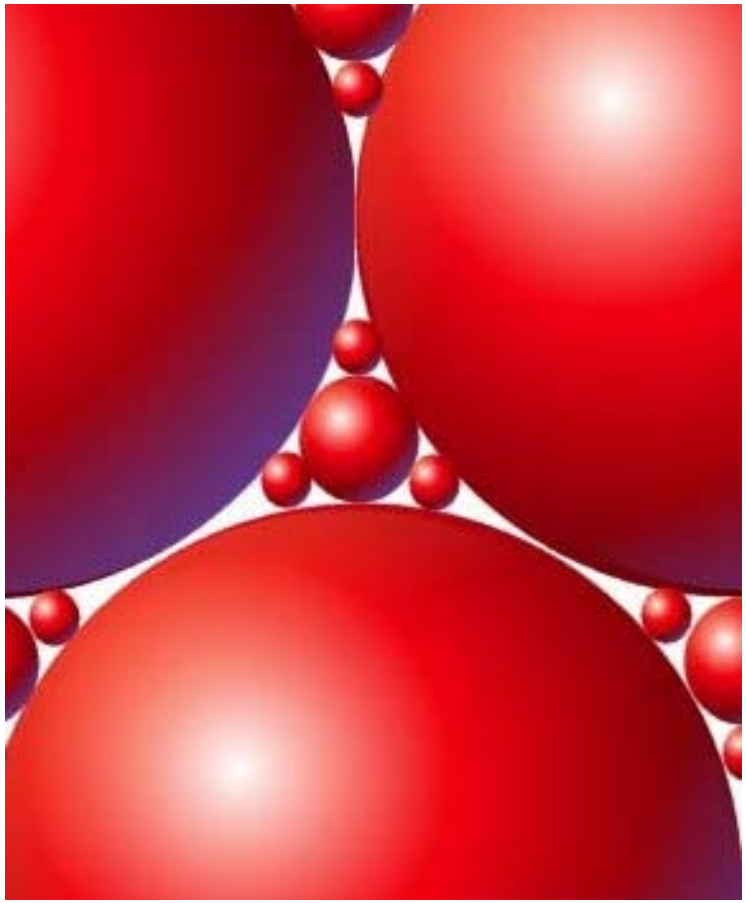


F ash

How Limestone Works

How Limestone Works

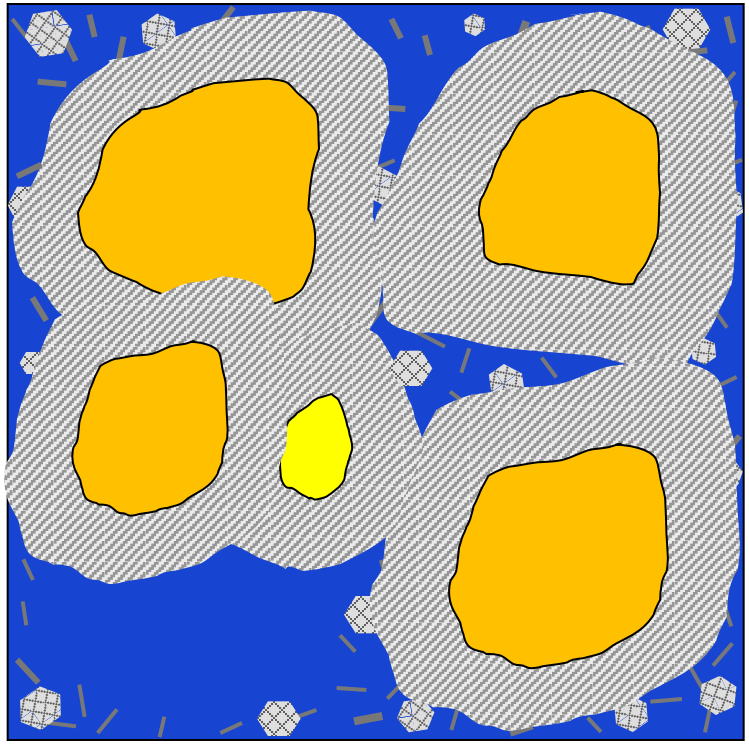
- Particle packing
  - Improved particle size distribution



How Limestone Works

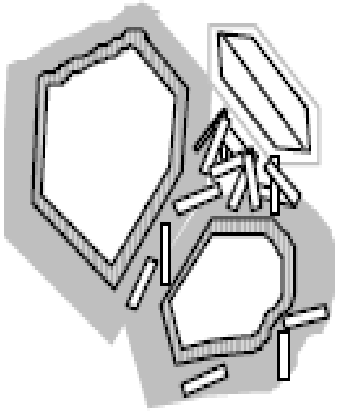
- Particle packing
  - Improved particle size distribution

- Nucleation
  - Surfaces for precipitation of C–S–H



How Limestone Works

- Particle packing
  - Improved particle size distribution
- Nucleation
  - Surfaces for precipitation of C–S–H
- Chemical reactions
  - Only a small amount
    - Carboaluminate



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

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

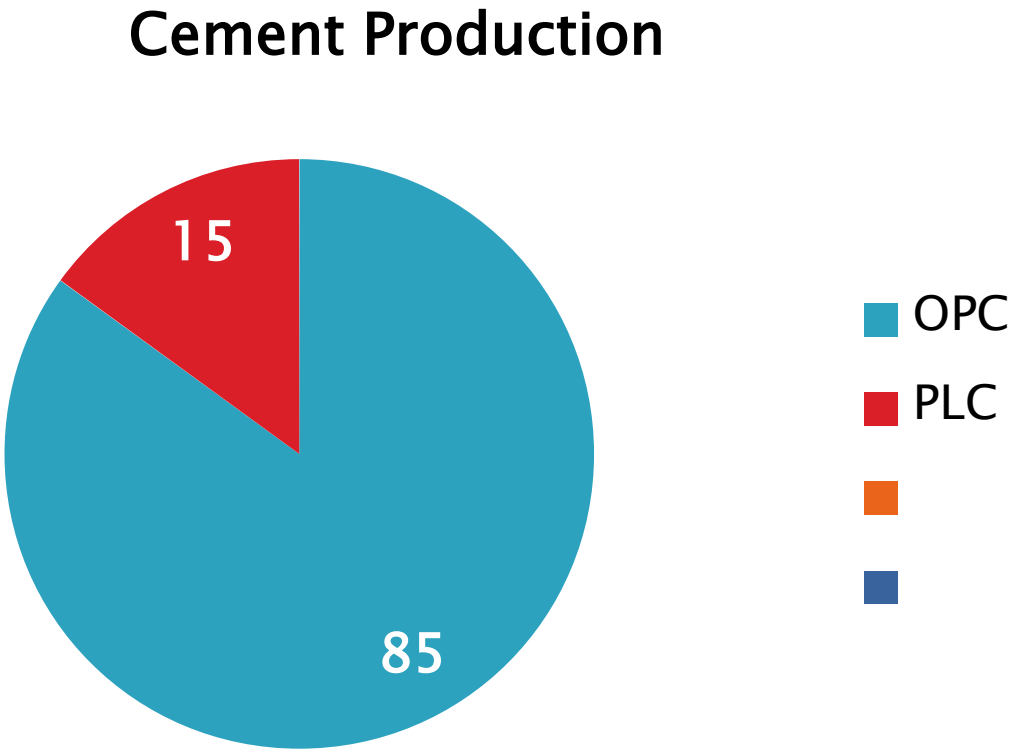
CO_3^{2-}

The Trend – Type IL

- Acceptance
  - **Europe**
    - 2000: EN 197-1, CEM II/A-L {6-20% limestone}
  - **Canada**
    - 2008: CSA A3002 PLC {5-15% limestone}
  - **U.S.**
    - 2012: ASTM C595 Type IL {5-15% limestone}

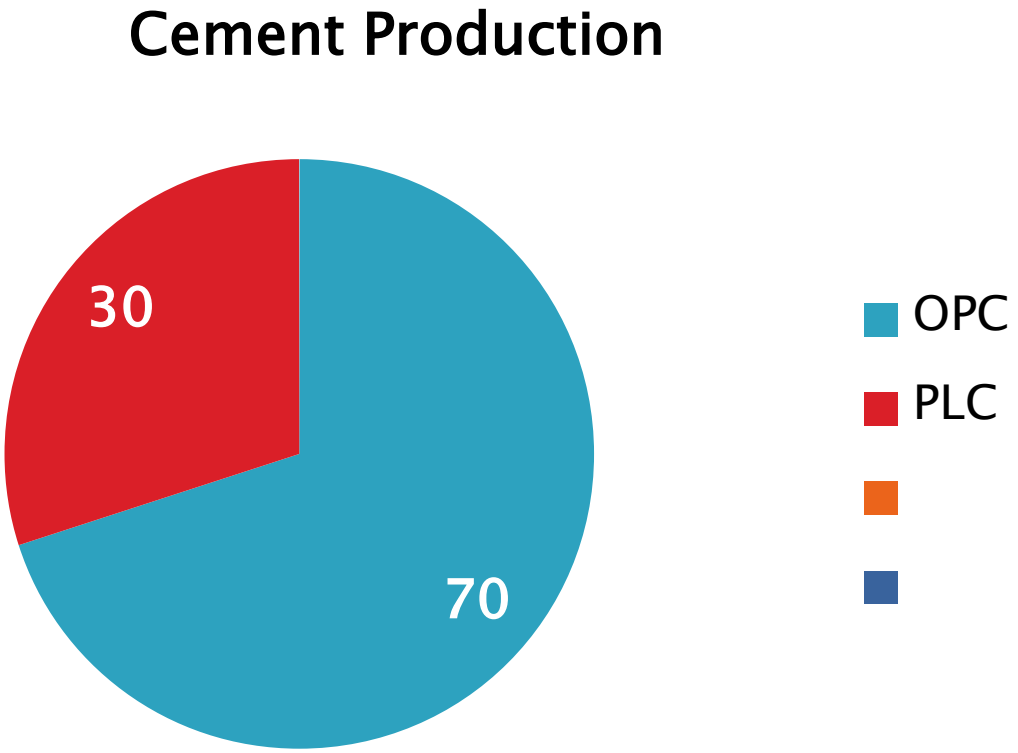
The Trend – Type IL Performance

- European Usage: 1999



The Trend – Type IL Performance

- European Usage: 2004



The Trend: Resources

PCA
Portland Cement Association

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

©Portland Cement Association 2011
All rights reserved

5420 Old Orchard Road
Skokie, Illinois 60077-1083
847.966.6200 Fax 847.966.9481
www.cement.org

PCA
Portland Cement Association

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

©Portland Cement Association 2010
All rights reserved

5420 Old Orchard Road
Skokie, Illinois 60077-1083
847.966.6200 Fax 847.966.9481
www.cement.org

Concrete Mix Components: Trends & Challenges

Thanks to the Organizing Committee

Virginia Concrete Conference

Concrete Mix Components: Trends & Challenges

Questions/Discussion

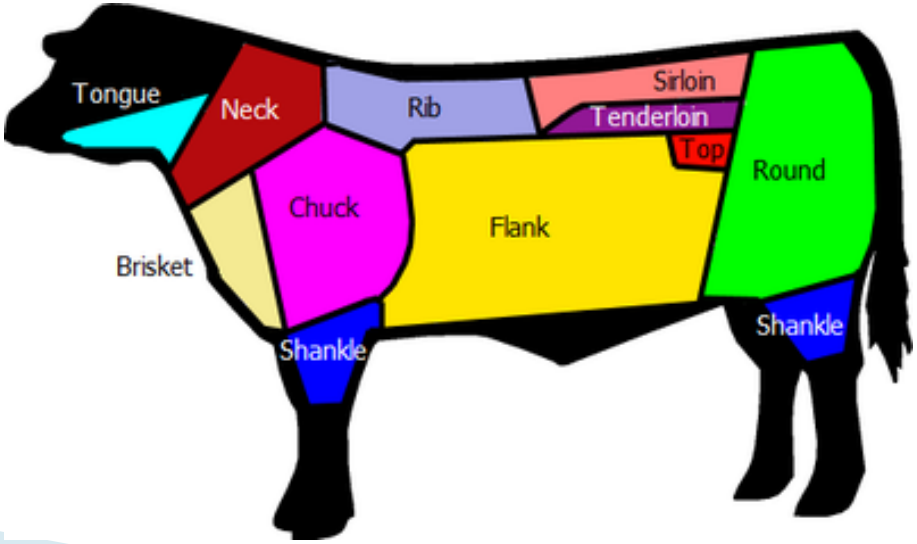
Concrete Mix Components: Trends and Challenges

Aggregate Production
Kevin Vaughan
Vulcan Materials Company

Product Balance

- Balancing the products made versus those sold

- Quarries can't just produce coarse aggregate
  - Make aggregate base and fines as well



Example from One Quarry

Production	Sales
Base: 27%	Base: 23%
Clean Stone: 54%	Clean Stone: 61%
Screenings: 18%	Screenings: 14%
Misc: 1%	Misc : 2%

Quarry Example

- Driving product for this quarry is the clean stone
- Assume the quarry needs 1,000,000 tons of clean stone to meet sales demand

	Sales (tons)	Production (tons)	Difference (tons)
Clean	1,000,000	1,000,000	0
Base	377,049	500,000	122,951
Screenings	229,508	333,333	103,825
Misc.	32,787	18,519	-14,268

Added to the stockpiles each year

Results in Excess Inventory

Screenings

Base

Base & Fines in Virginia

- In Virginia alone, the industry has the following:
  - 6,184,000 tons of aggregate base
  - 910,000 tons of manufactured sand
  - 5,942,000 tons of screenings
- These quantities grow every year as coarse aggregate sales accelerate
- This is not a *sustainable* way to do business
  - Bad for the environment
  - Bad for future aggregate costs

Base & Fines in Virginia

- Recycling also worsens this problem
  - Recycled Asphalt Pavement – less fines sold to asphalt industry
  - Recycled Crushed Concrete – less base sold for pavements
  - In Place Road Recycling – less base sold and less fines for pavement

- As more “green” technologies are used, it causes our industry to be less “green” by creating excess product

Aggregates & The Concrete Industry

- We're all in this together
- Excess inventory has a cost associated with it
  - Crushing and screening products that aren't sold
  - Handling those products
  - Stockpiles covering reserves (may need to be moved)
- Excess costs for the aggregate industry will end up being a cost for its customers
- How can the concrete industry help?

Manufactured Sand

- Quality concrete fine aggregate
  - Researched by many organizations
  - Already in use in many areas
- Effect on concrete
  - Depends on gradation and geology
  - May have no effect
  - Use of admixtures
- Natural sand deposits are being depleted
- Allowed by ASTM C33

Roller Compacted Concrete

- Good product for aggregate balance
- Tends to use high percentage of man sand
- Recent example
  - 18% #67
  - 28% #78
  - 54% Manufactured Sand

Aggregate Base

- Aggregate base is a beneficial part of concrete pavement
  - Increased support
  - Less cracking, faulting, and better ride
  - Less maintenance
- Used extensively under asphalt pavements

Aggregate Base

- VDOT typically uses it under all pavement types
- Some lower volume concrete pavements may not use aggregate base
- Using aggregate base under <u>all</u> pavement types will help product balance and price

Concrete Mix Components: Trends and Challenges

Ready-Mixed Concrete Production

George Kuhn
Chandler Concrete

Challenges & Trends

- SCM Availability
  (Supplemental Cementitious Materials)
- Workforce Labor Pool
- Mix Design Technology

Benefits of SCMs

- Benefits of SCMs to the Mix
  - Better Economics
  - Improved Performance
- Benefits of SCMs to the Environment
  - Lower CO^2 Emissions
  - Recycling of Wastes & Byproducts
  - Reduction of Raw Material Consumption
  - Extends Quarry Life

Availability of SCMs

- 3 Major Types of SCMs:
  - Flyash
  - Slag
  - Silica fume

Availability of SCMs

- Historical Cost Relationship
  - $ Flyash
  - $$ Slag
  - $$$ Silica fume

Availability of SCMs

- Pressures on Coal (Power Producers)
  - Moral Arguments

BEFORE

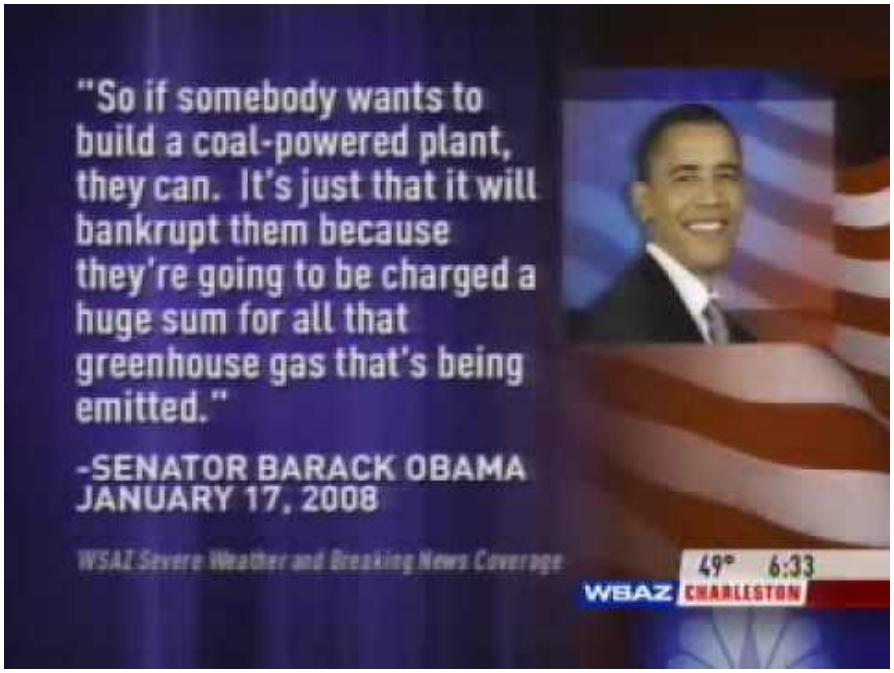
MOUNTAINTOP REMOVAL COAL MINING

AFTER

MOUNTAINTOP REMOVAL COAL MINING

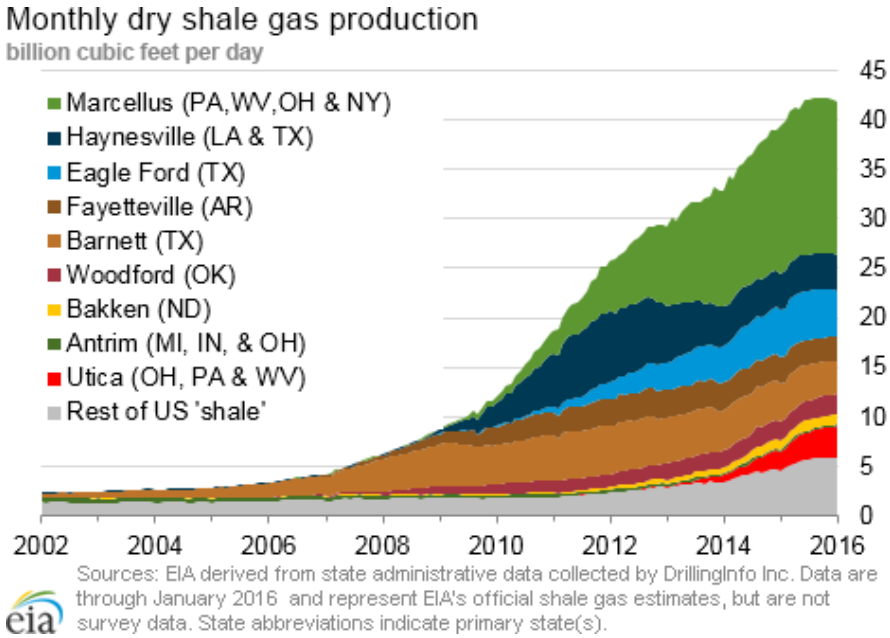
Availability of SCMs

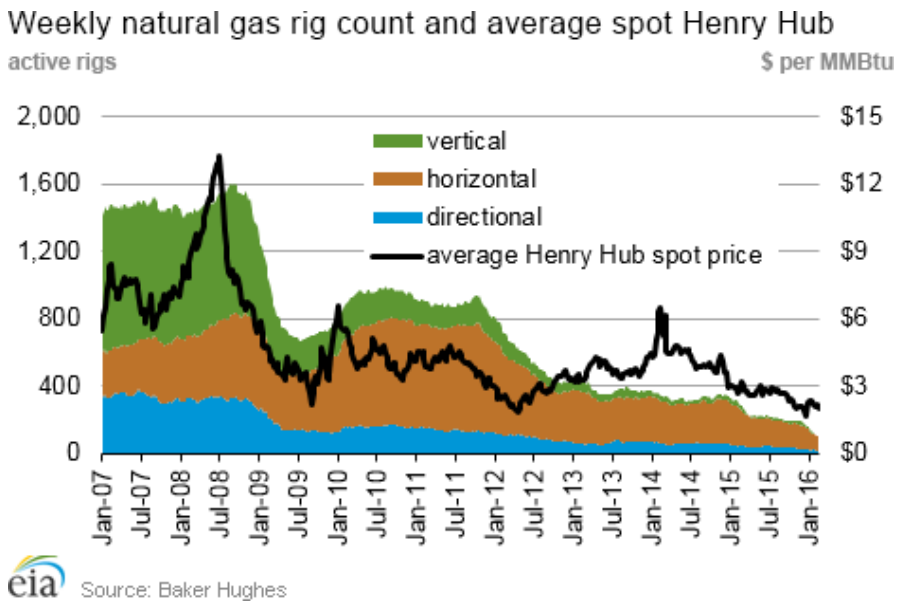
- Pressures on Coal (Power Producers)
  - Moral Arguments
  - Government Regulations


"So if somebody wants to build a coal-powered plant, they can. It's just that it will bankrupt them because they're going to be charged a huge sum for all that greenhouse gas that's being emitted."
-SENATOR BARACK OBAMA
JANUARY 17, 2008
WSAZ Severe Weather and Breaking News Coverage
49° 6:33
WSAZ CHARLESTON

Availability of SCMs

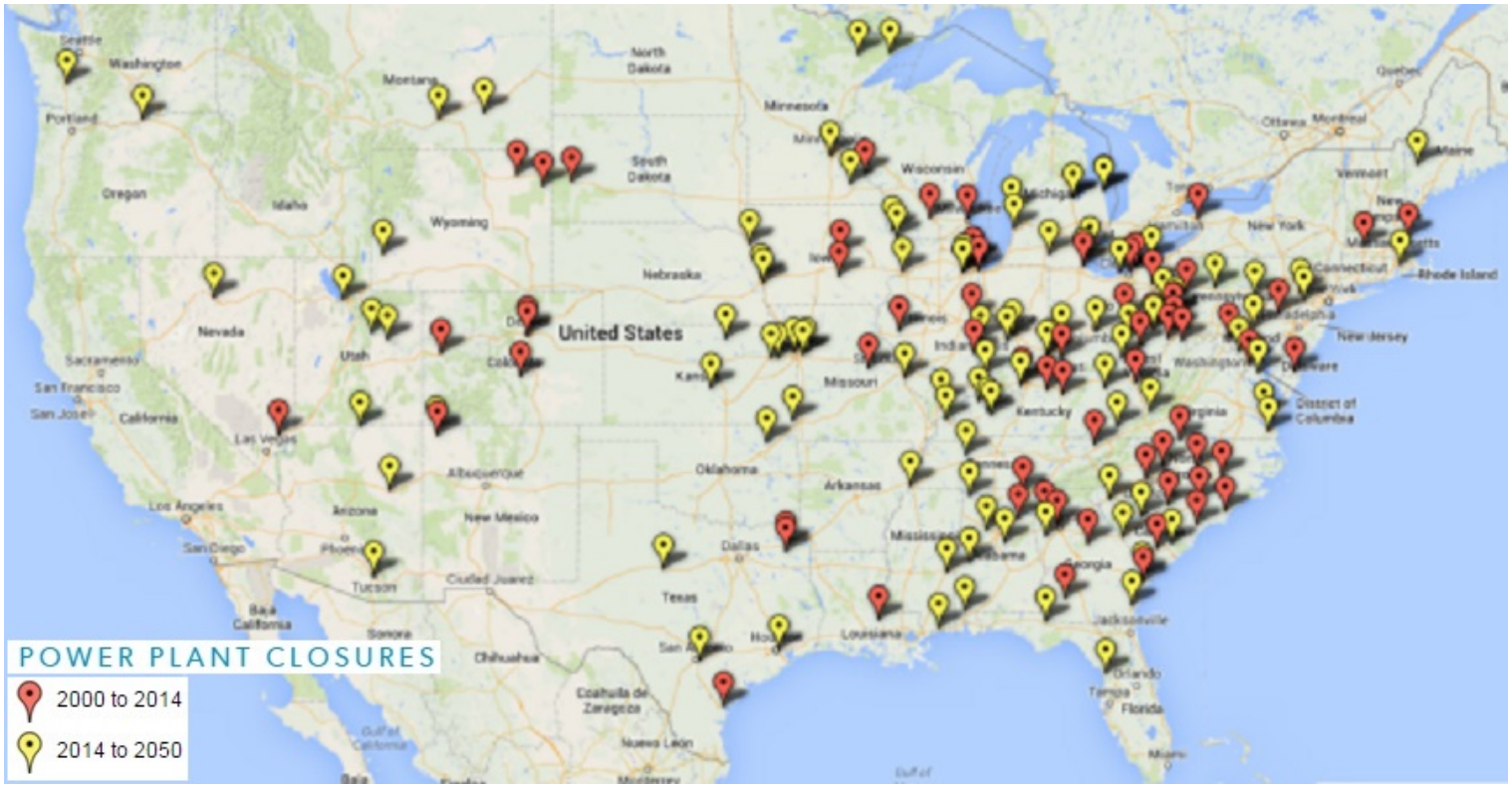
- Pressures on Coal (Power Producers)
  - Moral Arguments
  - Government Regulations
  - Market Forces – Natural Gas Prices

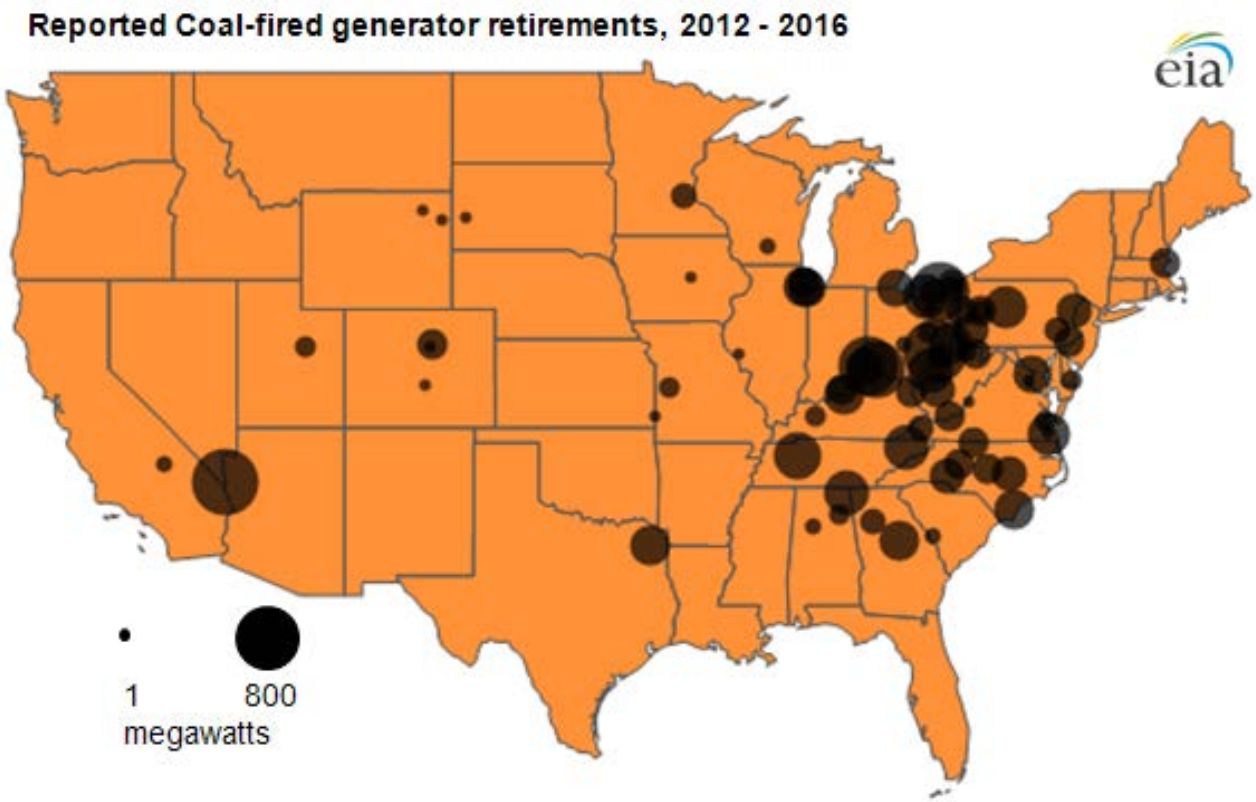

Monthly dry shale gas production
billion cubic feet per day
Marcellus (PA,WV,OH & NY)
Haynesville (LA & TX)
Eagle Ford (TX)
Fayetteville (AR)
Barnett (TX)
Woodford (OK)
Bakken (ND)
Antrim (MI, IN, & OH)
Utica (OH, PA & WV)
Rest of US 'shale'
45
40
35
30
25
20
15
10
5
0
2002
2004
2006
2008
2010
2012
2014
2016
Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through January 2016 and represent EIA's official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).
eia

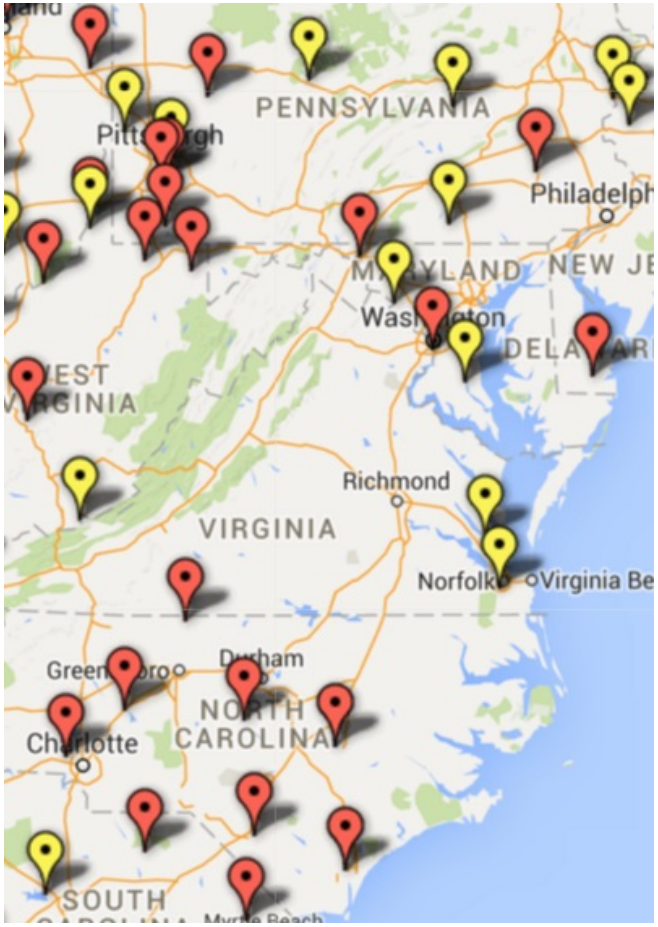

Weekly natural gas rig count and average spot Henry Hub
active rigs
$ per MMBtu
2,000
1,600
1,200
800
400
0
$15
$12
$9
$6
$3
$0
vertical
horizontal
directional
average Henry Hub spot price
Jan-07
Jul-07
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
Jul-15
Jan-16
eia
Source: Baker Hughes

Availability of SCMs

- Pressures on Coal (Power Producers)
  - Moral Arguments
  - Government Regulations
  - Market Forces – Natural Gas Prices
- Reduction in Coal Power Generation
  - Closing of Coal Power Plants


POWER PLANT CLOSURES
2000 to 2014
2014 to 2050
United States


Reported Coal-fired generator retirements, 2012 - 2016
eia
1
800
megawatts


PENNSYLVANIA
Philadelph
NEW JE
Richmond
VIRGINIA
Norfolk
Virginia Be
Durham
NORTH
CAROLINA
Charlotte
SOUTH

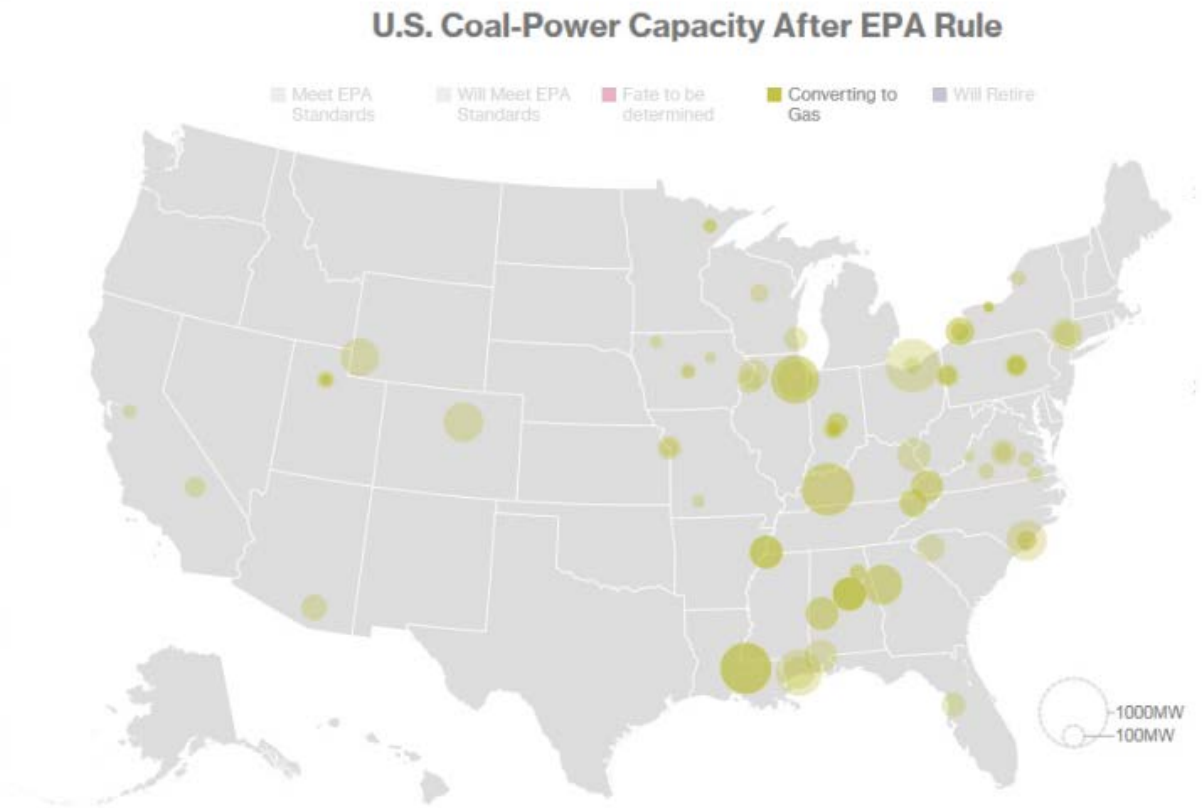
Availability of SCMs

- Pressures on Coal (Power Producers)
  - Moral Arguments
  - Government Regulations
  - Market Forces – Natural Gas Prices
- Reduction in Coal Power Generation
  - Closing of Coal Power Plants
  - Peak vs. Base Load Plants

Availability of SCMs

- Pressures on Coal (Power Producers)
  - Moral Arguments
  - Government Regulations
  - Market Forces – Natural Gas Prices
- Reduction in Coal Power Generation
  - Closing of Coal Power Plants
  - Peak vs. Base Load Plants
  - Conversion of Coal to Gas

Coal Power Plants Converting to Gas



Source: U.S. Energy Information Administration

Availability of SCMs

- Impact on Ready-Mix Concrete (Current and Future)
  - 50% Reduction in Flyash Supply by 2020 (US Energy Information Administration)
  - Allocations or Outages

© 2015 Google
MACK

Availability of SCMs

- Historical Cost Relationship
  - $ Flyash
  - $$ Slag
  - $$$ Silica fume

Availability of SCMs

- Impact on Ready-Mix Concrete (Current and Future)
  - 50% Reduction in Flyash Supply by 2020 (US Energy Information Administration)
  - Allocations or Outages
  - Increased Cost of Raw Materials

Workforce Labor Pool

- 2014 Fall Concrete Works meeting
  Struggles Recruiting & Retaining Drivers
  - Fluctuating Schedules
  - Competitive Pay & Benefits
  - Hours of Service Regulations
  - More Stringent CDL Requirements

Workforce Labor Pool

- Society of Human Resource Management's Workplace Forecast – Employment Trends thru 2023
  - Human Capital – #1 Challenge next 5 years
    - Lack of Skilled Workers
    - Impact of Retirements

Workforce Labor Pool

- Ernst & Young – Global Research Group Study on Millennials (15 – 35 Year Olds) thru 2023
  - Working Millennials
    - Most Unhappy Group
    - Highest Turnover Rate
    - 50% of Workforce by 2020

Workforce Labor Pool

- Today – Drivers
- Tomorrow – Workers in the Field

Mix Design Technology

- Use of "Smarter Mixes"
  - SCC – Easier to Place & Consolidate
    - Drilled Shafts, Restoration
    - Structural Use – ease labor demands
  - Performance Based Mixes (VDOT 217 – Options 2 & 3)
    - Blended & Engineered Aggregates
    - Reduced Cementitious Totals
    - Lightweight – internal curing

Mix Design Technology

- Use of “Smarter Mixes”
  - Increasing Use of Admixtures
    - Superplasticizers
    - Slump Retention
    - Hydration Control
    - Corrosion Inhibiting
    - ASR Mitigation
    - Shrinkage Reducing
    - Waterproofing
  - Fibers – Macro & Micro

Questions?