NCC Meeting
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Performance Cements

Focus on Sustainability

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Cementitious materials and *Sustainability*

- Formula for sustainability:
  - Minimize the clinker content in concrete
  - Minimize the transport of materials
  - Maximize the beneficial re-use of byproducts
  - Maximize use of materials with low associated CO_2 emissions
- Blended cements versus separate components
- Limestone in cement

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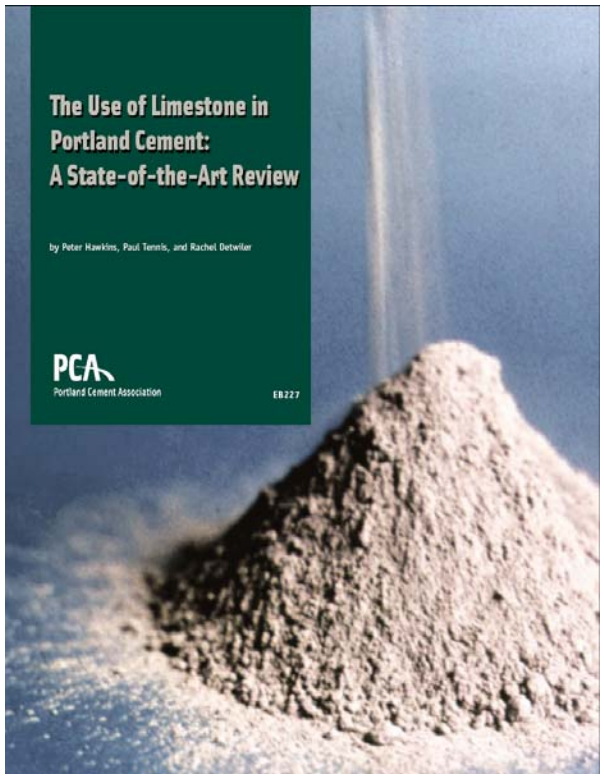
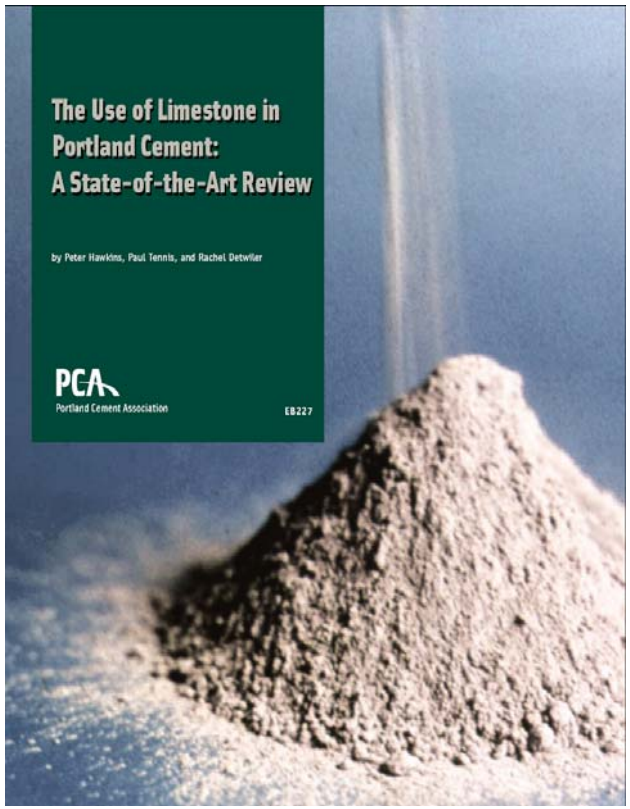
- Blended cements versus separate components
- **Limestone in cement** 

Background: experiences with up to 5% limestone



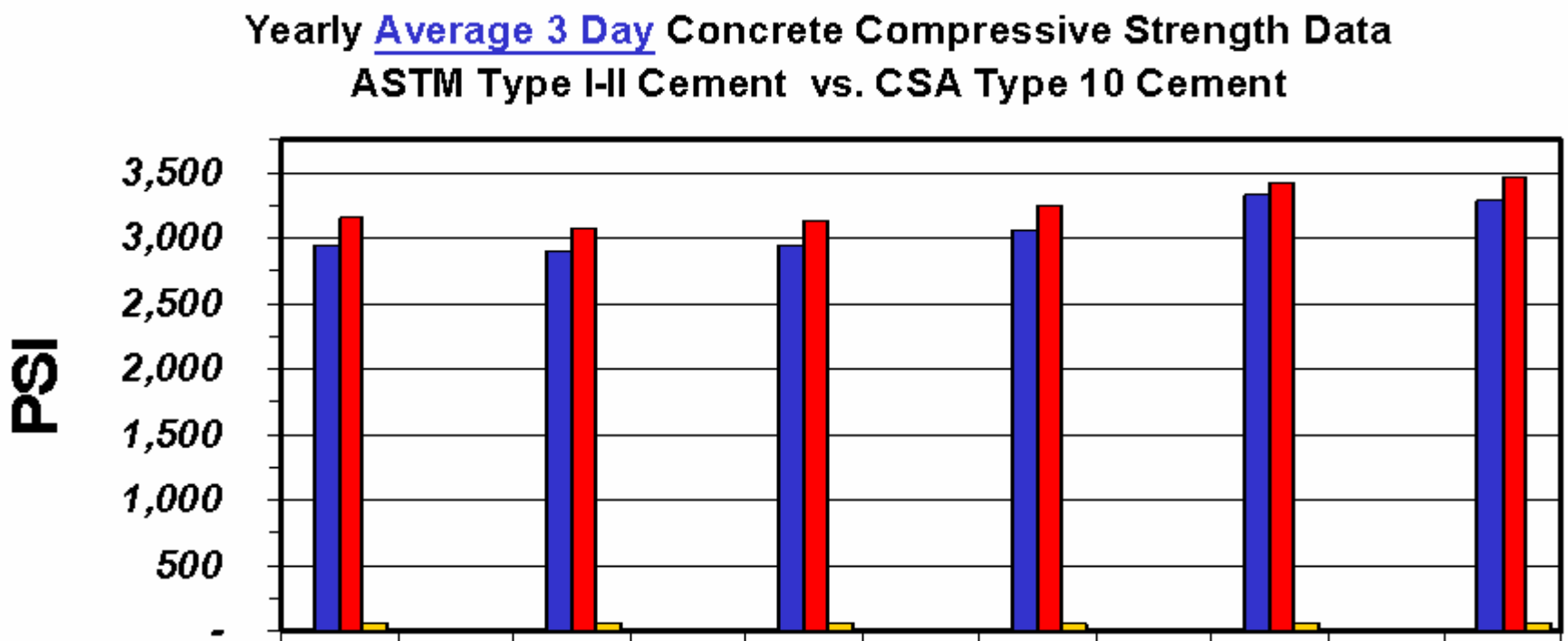
- Limestone is typically fed in metered proportions to the finish grinding mill
- Allowed in many countries for years
  - In Canada since early 1980s
- Only recently allowed in the US
  - ASTM C 150 in 2004
  - AASHTO M 85 in 2007
- Negligible effects
- Some slight performance benefits

Performance of cement with 5% limestone



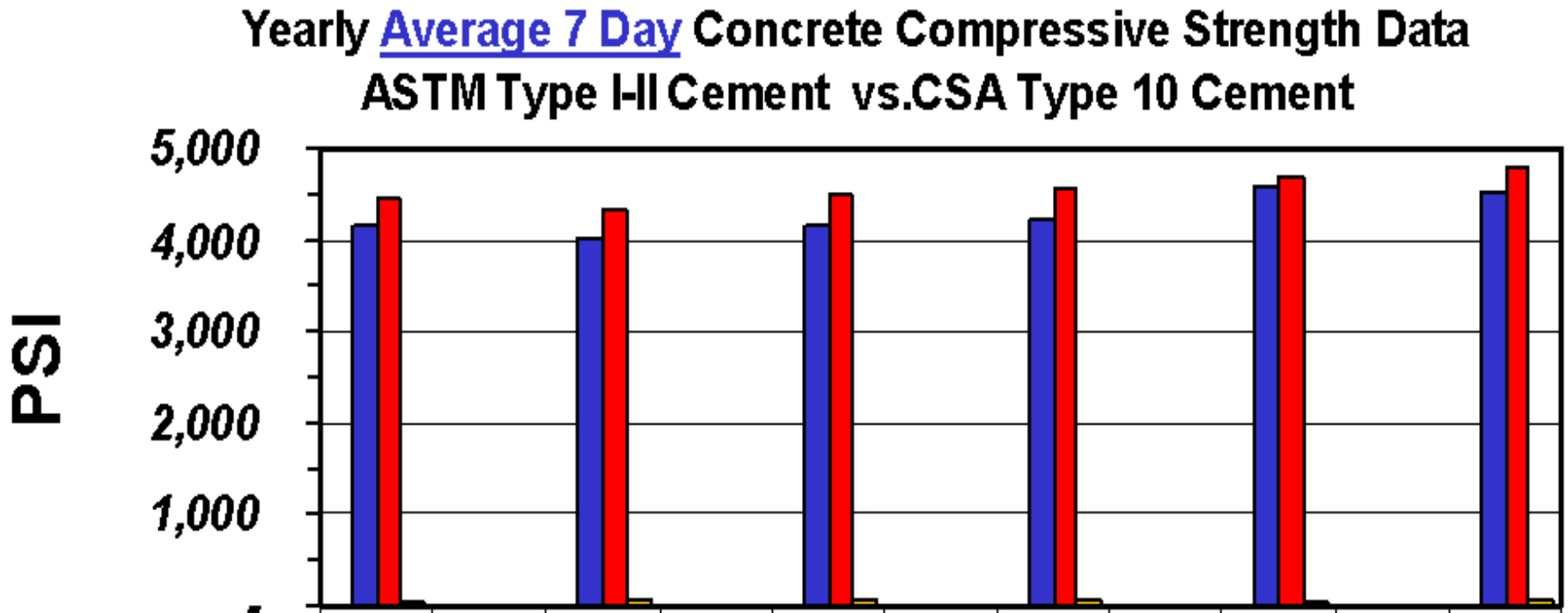
- Enhanced particle size distribution
  - Improved concrete workability
  - Less bleed water
  - Lower water demand
  - Higher density and strength
- Reduced heat of hydration
- Possible permeability, sulfate resistance improvements
- Setting time effects variable
- No impact:
  - Drying shrinkage
  - Resistance to freeze/thaw, deicer salts
  - ASR susceptibility
  - SCM & admixture interaction

Concrete data – ASTM vs. CSA cements, 3 days



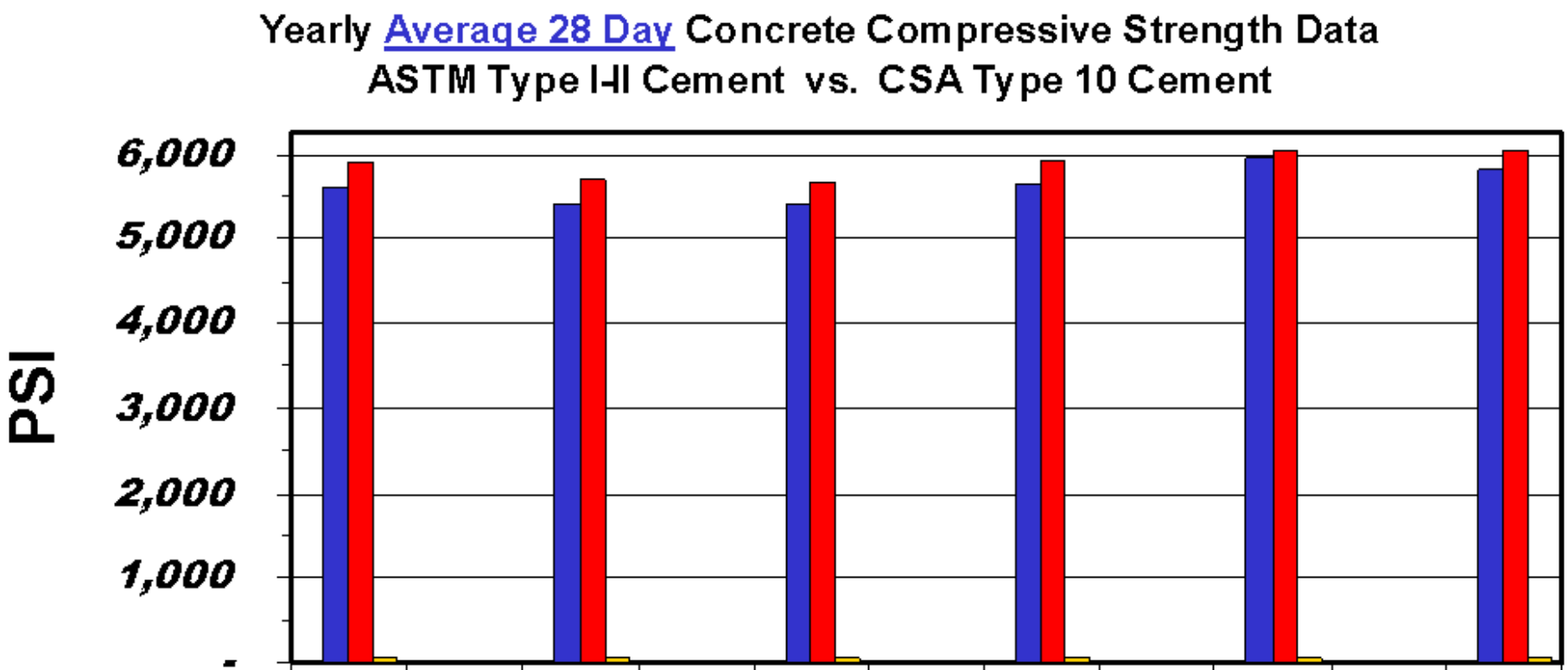
**** Years ****	-											
ASTM Type I-II	2935		2907		2943		3050		3331		3295	
CSA Type 10	3153		3079		3134		3254		3414		3452	
Tests Per Year	49		53		53		52		50		52	

Concrete data – ASTM vs. CSA cements, 7 days



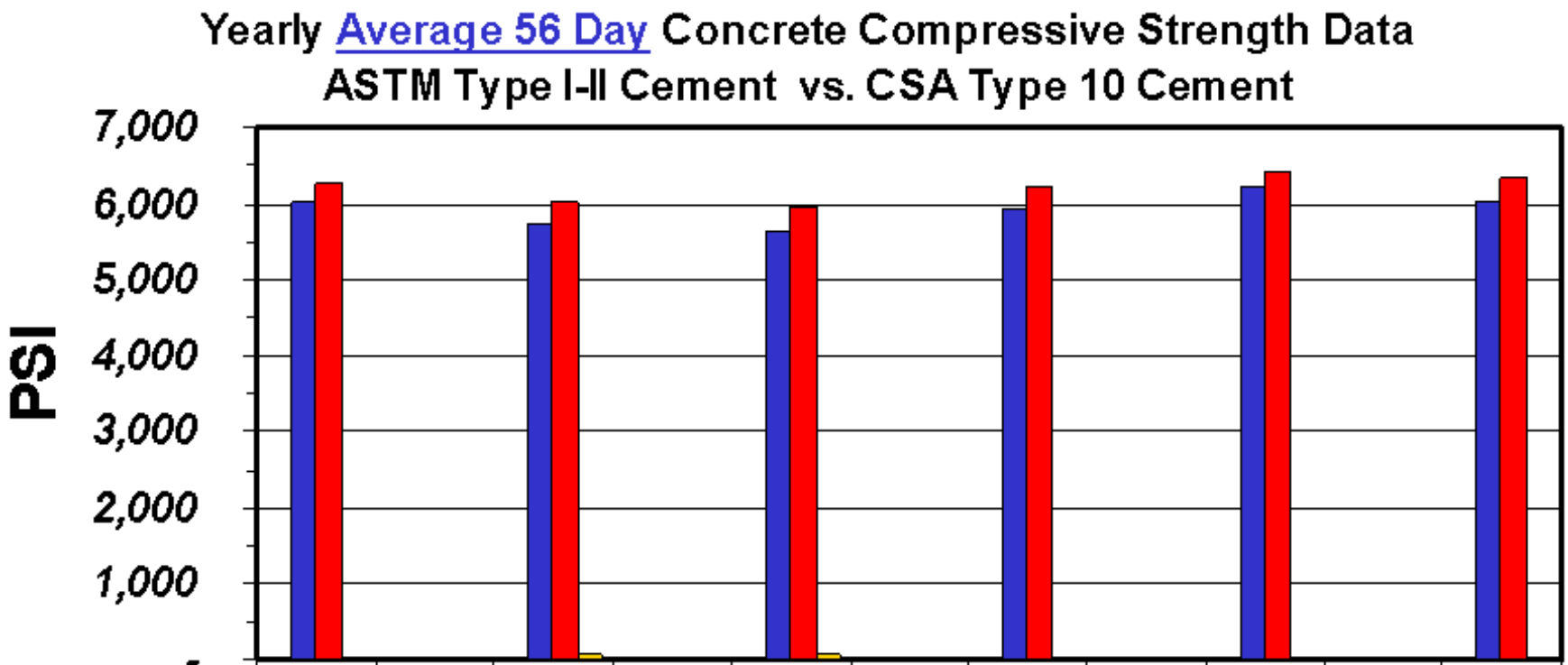
**** Years ****	1997		1998		1999		2000		2001		2002
ASTM Type I-II	4140		4029		4148		4224		4608		4539
CSA Type 10	4457		4321		4491		4556		4710		4796
Tests Per Year	49		53		53		52		50		52

Concrete data – ASTM vs. CSA cements, 28 days



**** Years ****	1997	1998	1999	2000	2001	2002
ASTM Type I-II	5628	5420	5408	5642	5961	5830
CSA Type 10	5905	5700	5662	5923	6046	6038
Tests Per Year	49	53	53	52	50	52

Concrete data – ASTM vs. CSA cements, 56 days



**** Years ****	1997		1998		1999		2000		2001		2002
ASTM Type I-II	6016		5726		5623		5915		6238		6020
CSA Type 10	6265		6003		5957		6225		6401		6333
Tests Per Year	49		53		53		52		50		52

Sustainability implications of limestone @ up to 5%

- At a realistic assumed use of 2.5%, reductions of:
  - Raw materials use, 1.6 million tons
  - Energy use, 11.8 trillion BTUs
  - CO_2 emissions, 2.7 million tons
  - Solid wastes, 190,000 tons
- Equivalent to the environmental impact from two average-sized US cement plants

Specifications for limestone use @ > 5%

European standard EN 197-1

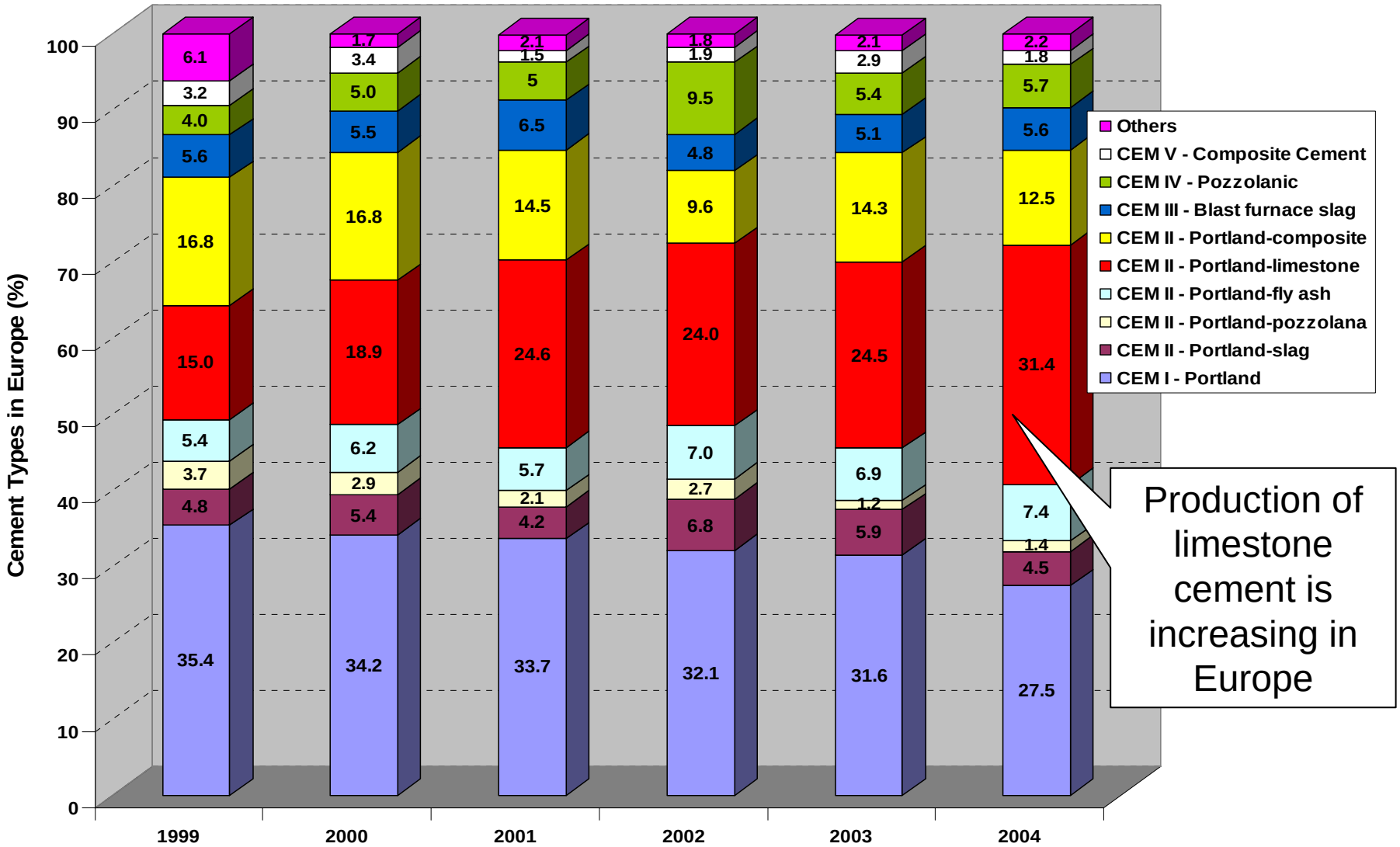
- Portland cement – CEM I: up to 5%
- Portland limestone cements –
  - CEM II/A-L: 6% to 20%
  - CEM II/B-L: 21% to 35%

US specifications

- No special limestone categories
- Possible under ASTM C 1157
  - Portland cement – processing additions only
  - Modified portland cement – up to 15% of a mineral ingredient
  - Other blended hydraulic cement – more than 15% of two or more mineral ingredients

Specifications for limestone use @ > 5%

European use of cements with 6% - 35% limestone



Production and quality control of limestone cements

- Limestone grinds more easily than clinker
- Overall fineness & Blaine will typically increase
- For equivalent strengths constant 45-µm (No. 325) sieve fineness may be appropriate
- 1-day strengths may be higher when 7- and 28-day strengths are similar
- Additional grinding energy required is offset by other energy savings

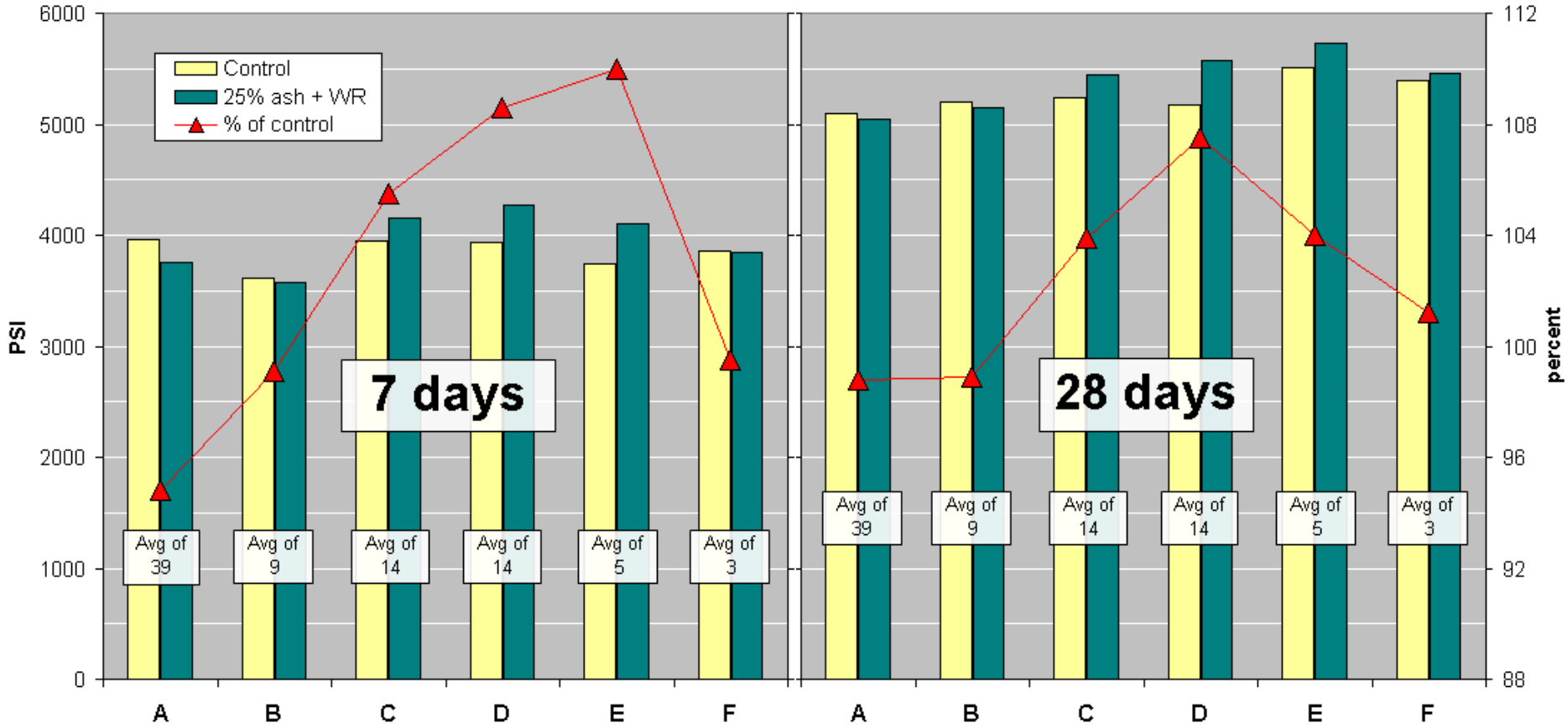
Experience with cements containing > 5% limestone

- ASTM C 1157 (GU, MS, HE)
  - 8-10% limestone
  - Several Holcim (US) plants
  - Not yet approved by many state DOTs
- General performance
  - Higher early strengths
  - Comparable or better later strengths
  - Similar or slightly longer set times
  - Excellent concrete finishing properties
  - Lower bleeding and slump loss
  - Highly successful in products plants
  - No differences in water demand
  - Excellent response with SCMs and chemical admixtures

Experience with cements containing > 5% limestone

- Durability testing of 8-10% limestone C 1157 cements
- Essentially equivalent performance to that of non-limestone cements from the same plants:
  - C 1012
  - C 1567
  - C 666
  - C 672
  - C 157
  - C 1202
- Slightly improved sulfate resistance in some cases

Enhanced performance with Class C fly ash



- Concrete data – 84 samples of non-limestone cements from 6 sources in 2 standard lab mixes (including a control mix with no SCMs or admixture)
- 2 of the 6 have characteristically poor response in the concrete mix with Class C fly ash and a common water reducing admixture

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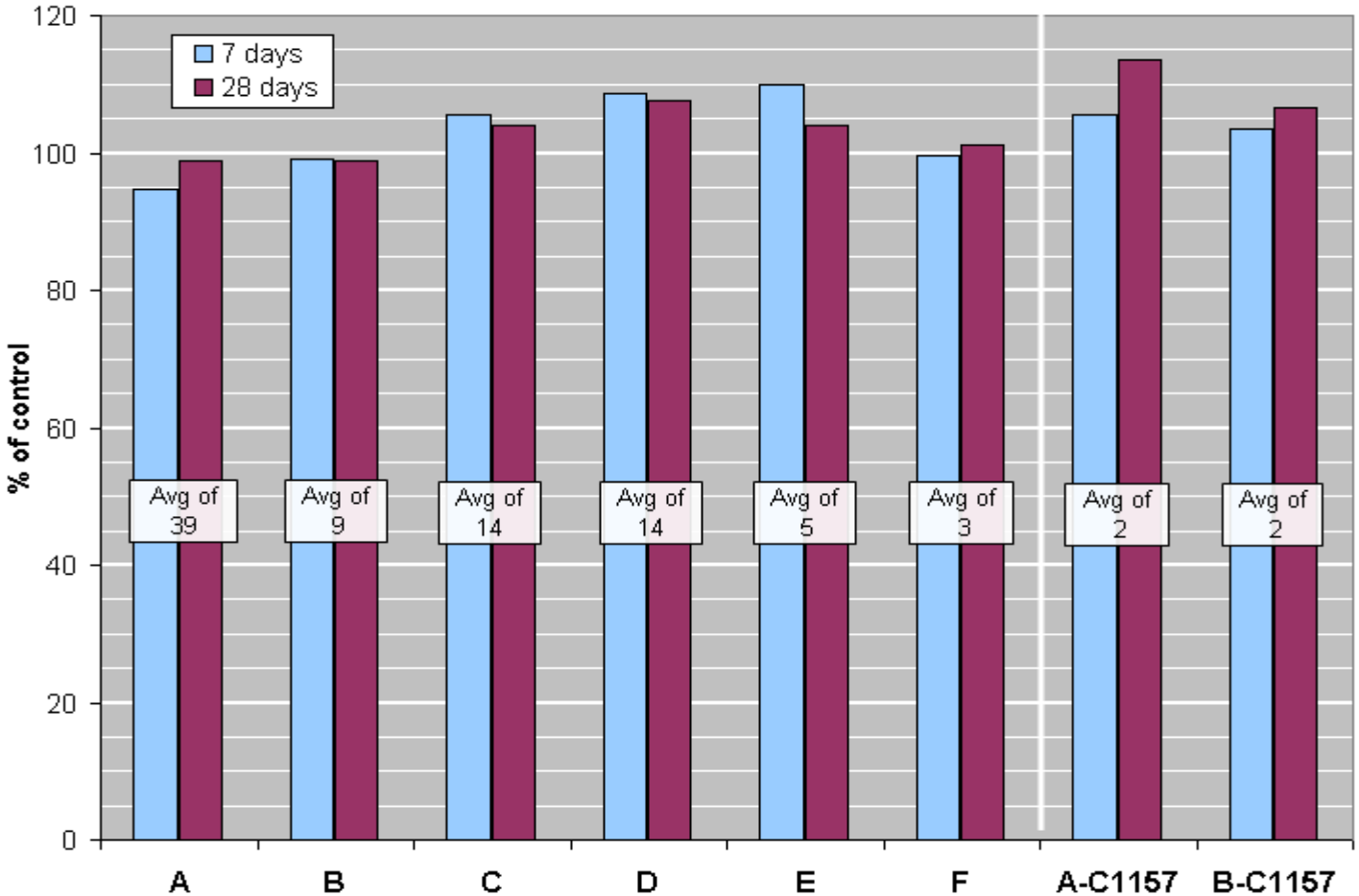

- 7- and 28-day % of control (strength of the mix with C ash + admix divided by control mix strength) for all 6 sources with data for 8-10% limestone C 1157 cements made at plants A and B added

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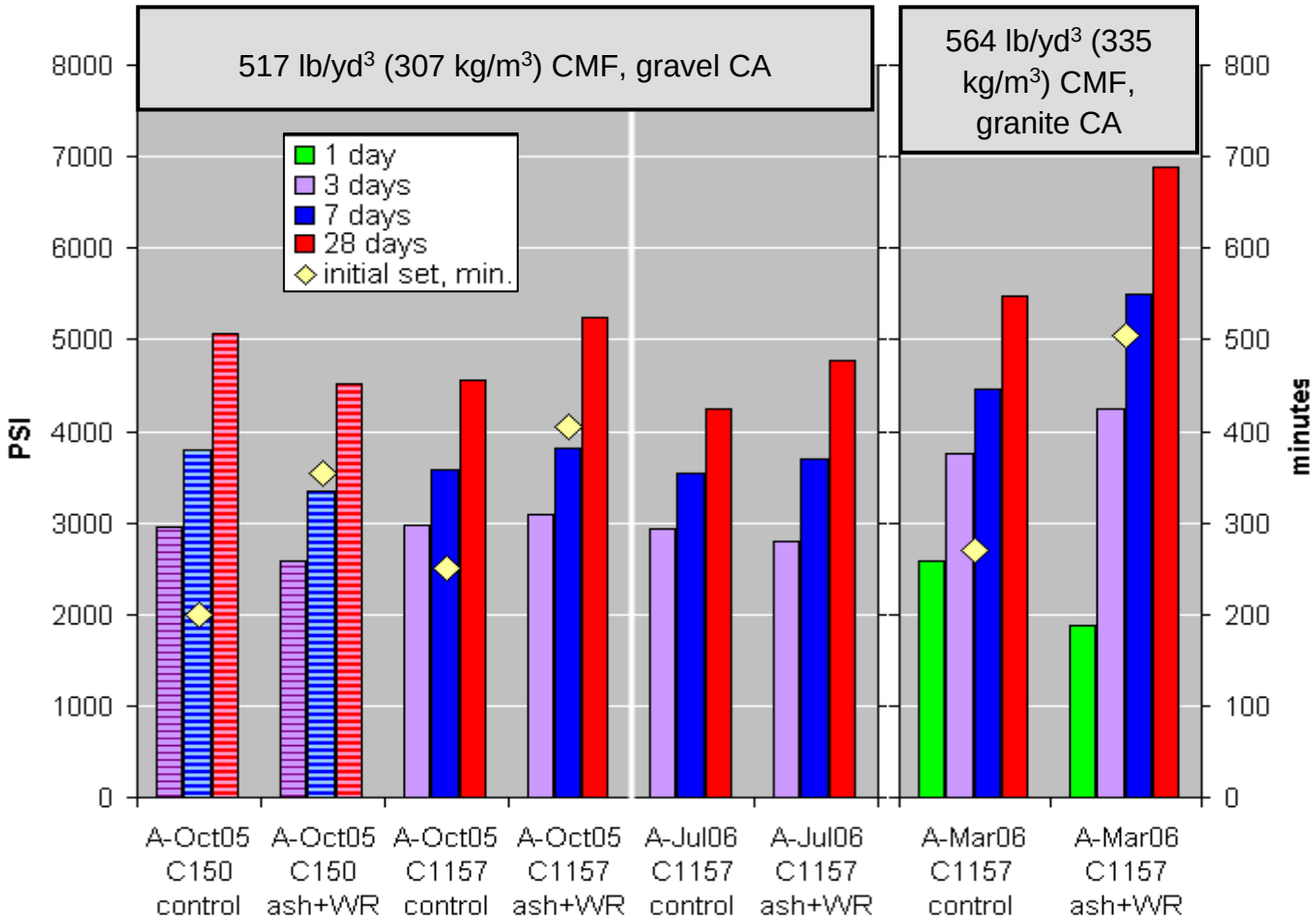
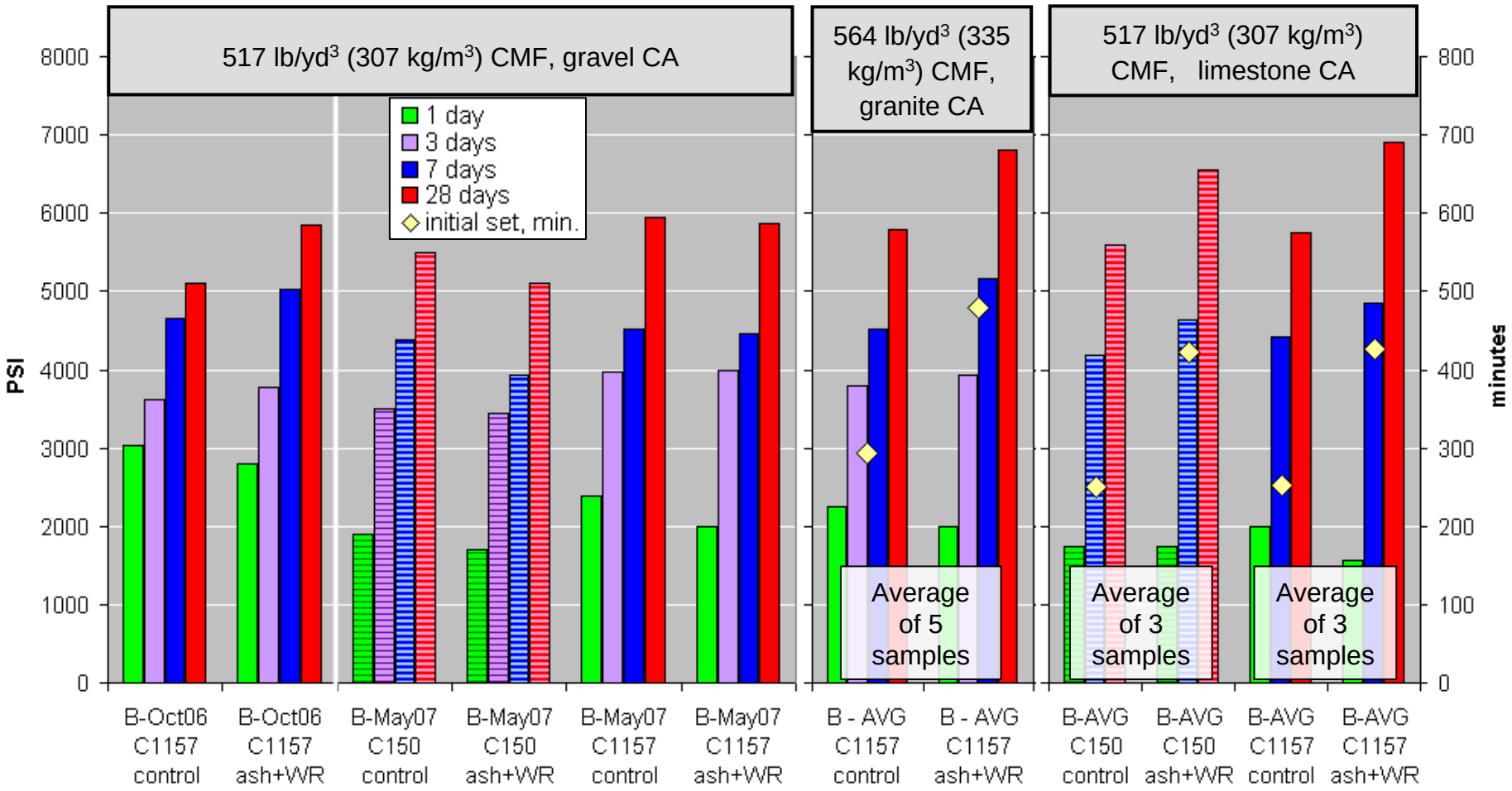


- Additional concrete data from plant “A”, non-limestone C 150 and 8-10% limestone C 1157 cements, control mixes vs. mixes with C ash + admix

Enhanced performance with Class C fly ash



- Additional concrete data from plant “B”, non-limestone C 150 and 8-10% limestone C 1157 cements, control mixes vs. mixes with C ash + admix

Observations from concrete data

- Reactivity of 8-10% limestone cements from plants “A” and “B” with Class C ash and water reducer is clearly better than for non-limestone cements from those plants in gravel mixes
  - Very good fly ash / admix response for the limestone cements regardless of the aggregate
- Set time effects slightly longer for plant “A”, similar for plant “B”
- Strengths generally higher with limestone cements at all ages

Sustainability & specifications considerations

- 10% limestone is a realistic level under C 1157
  - Up to 4 times the reductions of CO2 emissions, energy use, use of resources, solid wastes
- SCMs can still be used in concrete to the maximum extent possible with any cement
- Should a special category for higher limestone cements be included in US specifications?

Conclusions and recommendations

- Performance in concrete of ASTM C 1157 limestone-modified portland cements with 8-10% limestone content is equivalent to or in some cases better than that of traditional non-limestone cements:
  - Strength development overall is at least equivalent
  - Strengths in combinations with Class C fly ash and typical water reducing admixtures may excel, especially with gravel aggregates.
  - Some plastic concrete properties are improved.
  - Durability performance as indicated by common test methods is equivalent or better.

Conclusions and recommendations

- Potential environmental and sustainability influences of cements containing 8-10% limestone are significant
- Barriers to the use of higher limestone content cements should be removed:
  - State DOTs should consider acceptance of ASTM C 1157 cements.
  - State governments and state and local building officials should assure that modern building codes that recognize ASTM C 1157 are in place.
  - Provisions for special categories of higher limestone content cements should be considered by US specification organizations (ASTM, AASHTO).

Questions?

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