A NEW LOOK TO AN OLD POZZOLAN

CLINOPTILOLITE – A PROMISING POZZOLAN IN CONCRETE

DIPAYAN JANA
Construction Materials Consultants, Inc. &
Applied Petrographic Services, Inc.
Greensburg, PA USA

PRODUCTIVE ZEOLITE DEPOSITS IN THE USA

Eyde & Holmes 2006

Commercial Applications

- Clinoptilolite
- Mordenite
- Erionite
- Chabazite
- Phillipsite

Common Sedimentary Zeolites

- Analcime
- Heulandite
- Ferrierite
- Laumontite

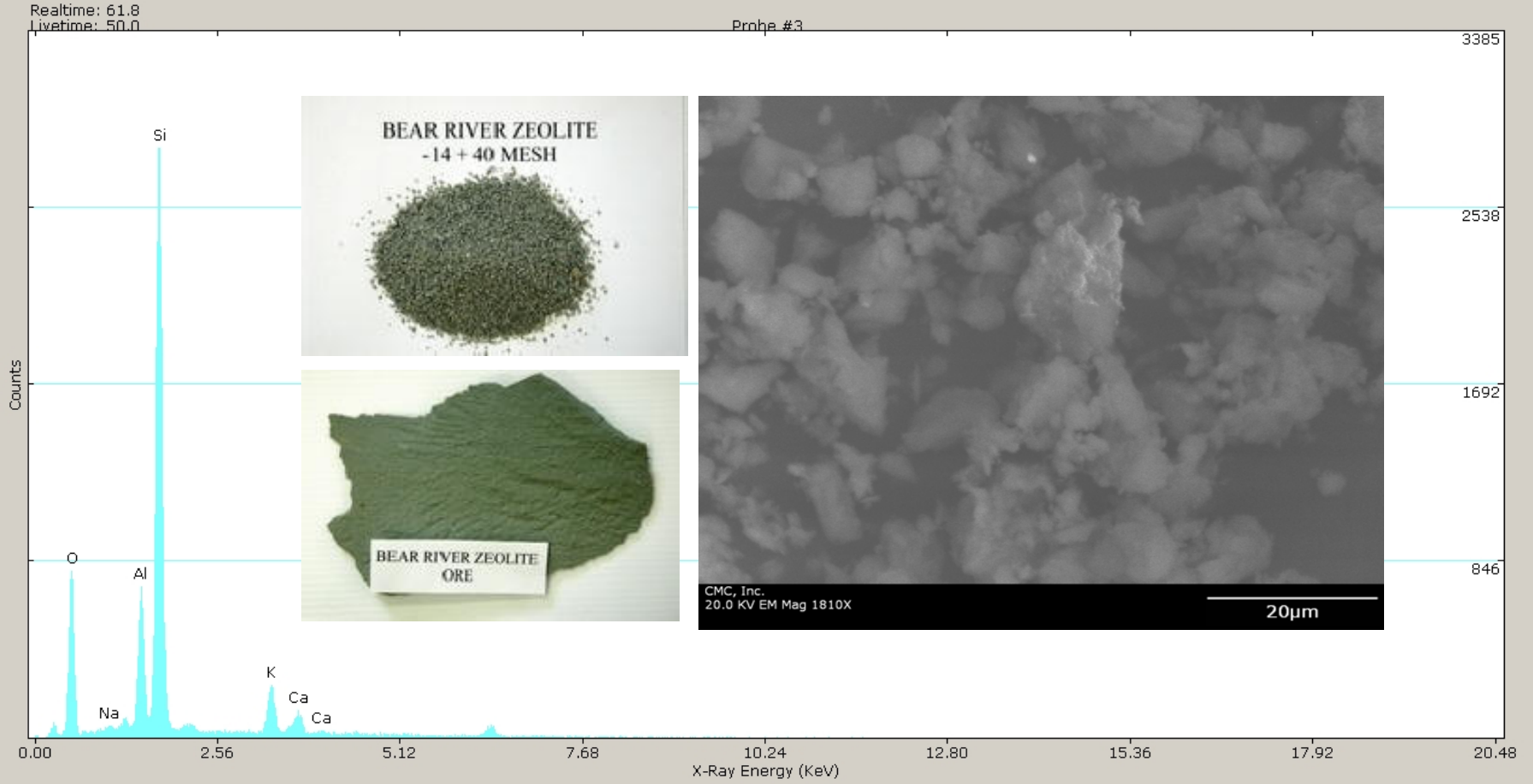
0 250 500 kilometers

Lacustrine Volcanoclastic Sedimentary Deposits (Tertiary Age)

THE BEAR RIVER ZEOLITE, PRESTON, IDAHO

- A wholly owned subsidiary of U.S. Antimony Corporation

CLINOPTILOLITE $[(Na_4K_4)(Al_8Si_{40}O_{96}).24H_2O]$

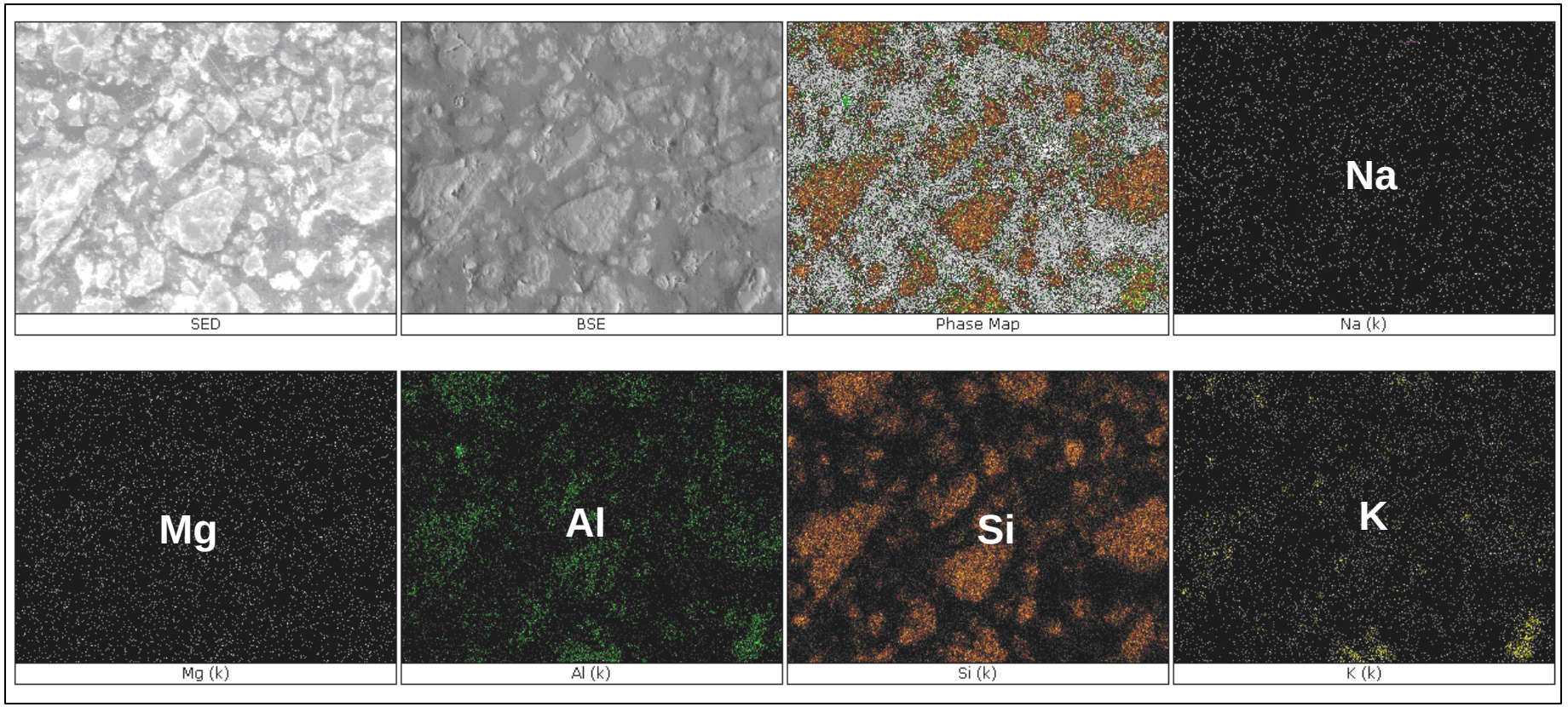


Quantitative Results for Probe #3
Analysis: Bulk Method: Standards
Acquired 26-Mar-2007, 20.0 KeV @10 eV/channel

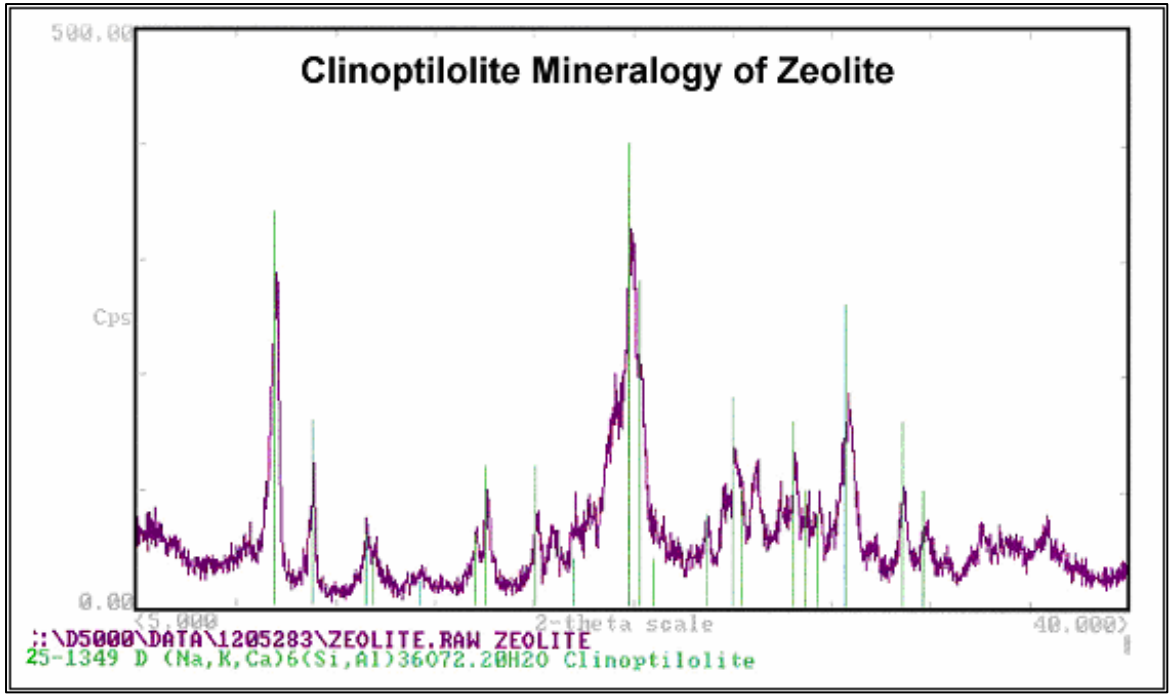
Element	Weight %	Atomic %	Oxide %		Intensities
O §	50.67	64.62	0.00		0.0
Na	0.51	0.45	0.69	(Na2O)	107.7
Al	8.33	6.30	15.75	(Al2O3)	4680.1
Si	36.76	26.71	78.65	(SiO2)	20158.3
K	1.50	0.79	1.81	(K2O)	2063.2
Ca	2.22	1.13	3.10	(CaO)	1001.2
Total	100.00		100.00		

§ Element by standardless analysis.

CLINOPTILOLITE $[(Na_4K_4)(Al_8Si_{40}O_{96}).24H_2O]$

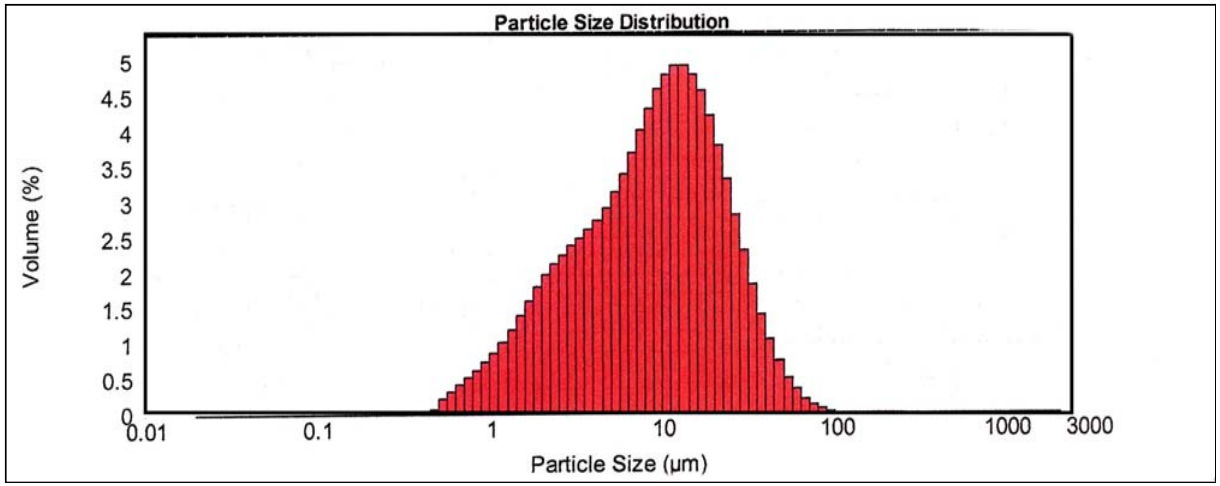


BEAR RIVER ZEOLITE – 85-90% CLINOPTILOLITE



XRD Pattern of BRZ Deposits

Mean Particle Size = 12.2 µm



Malvern Mastersizer Laser Diffractor

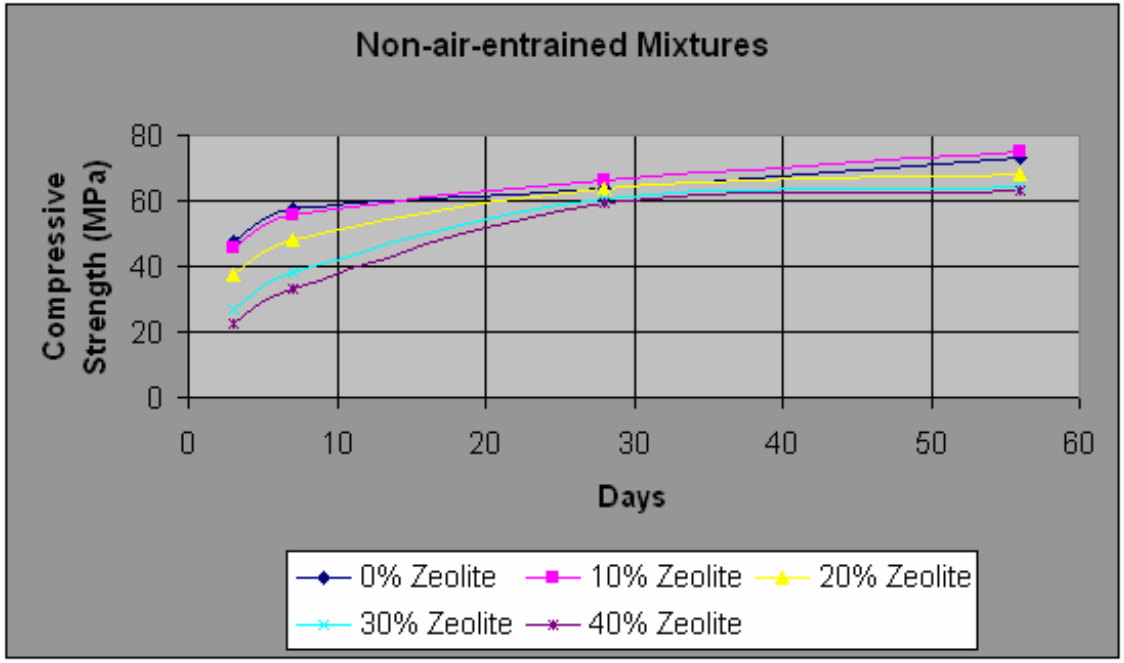
ZEOLITE MEETS THE TYPE N SPECIFICATION OF ASTM C 618

Properties	Zeolite (Clinoptilolite) used in this study	ASTM C 618 Type N Pozzolan
Silicon Dioxide (SiO_2)	70.32	-
Aluminum Oxide (Al_2O_3)	12.55	-
Ferric Oxide (Fe_2O_3)	3.38	-
$SiO_2 + Al_2O_3 + Fe_2O_3$	86.25	70 (min)
Sulfur Trioxide (SO_3)	0.02	4 (max)
Calcium Oxide (CaO)	3.05	-
Magnesium Oxide (MgO)	0.48	-
Sodium Oxide (Na_2O)	0.03	-
Potassium Oxide (K_2O)	5.50	-
Equivalent Alkali – Sodium Oxide (Na_2O_{eq})	3.65	-
L.O.I. (loss of ignition)	4.63	10 (max)
L.O.I. @ 110°C	3.00	3 (max)
L.O.I. @ 110° - 750°C (for cements @ 950°C)	4.63	-
Density, g/ml @ 20°C	2.19	-
Blaine Fineness, m^2/kg	1107	-
Zeolite Color	Pale Green	-
Mohs Hardness of zeolite	4	-
Percent retained on 325 sieve (45-µm), as received	26.94	34 (max)
Percent retained on 45-µm sieve, after grinding by hand	3.22	-
Autoclave soundness	0.02	+0.8 (max)
Strength Activity Index	See below:	See Below:
- Water (percent of control)	110.0	115 (max)
- 7-day (percent of control)	75.5	75 (min)
- 28-day (percent of control)	111.90	75 (min)
Free Moisture Content	3.0	3 (max)

CONCRETE MIX DESIGN & FRESH CONCRETE PROPERTIES

Mixtures	Non-air-entrained Mixtures					Air-entrained Mixtures		
Percent Zeolite Replacement	0	10	20	30	40	0	10	30
Mixture Proportions Per Cubic Yard								
Portland Cement, Type I, kg.	356	320	285	249	214	356	320	285
Zeolite Ultrafine, kg.	0	36	71	107	142	0	36	71
Coarse Aggregate, #67 Limestone, kg. (SSD)	1068	1068	1068	1068	1068	1068	1068	1068
Fine Aggregate, Sand, kg. (SSD)	893	879	867	854	842	776	762	737
Aggregate-to-Cementitious Materials Ratio	5.5	5.5	5.4	5.4	5.4	5.2	5.1	5.1
Water, kg.	134	134	134	134	134	134	134	134
MB-VR (A.E.A.), L	-----	-----	-----	-----	-----	0.19	0.27	0.58
Polyheed 997, (MRWR), L	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33
Rheobuild 1000 (HRWR), L	2.01	4.03	5.73	8.05	14.6	1.32	2.90	6.85
Mixture Water-Cementitious Ratio (*w/cm*)	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Total Water-Cementitious Ratio * - (*w/cm*)	0.39	0.39	0.39	0.40	0.41	0.39	0.39	0.40
Total Batch Weight, kg., ASTM C 192	2457	2446	2437	2426	2422	2340	2328	2308
Fresh Concrete Properties								
Concrete Temp., °C, ASTM C 1064	20.0	21.1	21.1	21.1	19.4	20	20	19.4
Slump, mm, ASTM C 143	100	100	88	94	100	100	94	94
Air Content, %, ASTM C 231	2.9	2.4	2.3	2.2	2.4	5.5	6.5	5.5
Unit Weight, kg/m^3, ASTM C 138	2426	2429	2419	2406	2377	2348	2313	2332
Yield, m^3, ASTM C 138	1.013	1.007	1.007	1.008	1.019	1.00	1.006	0.99
Initial Time of Set, ASTM C 403	7 hr. 45 min.	7 hr. 14 min.	6 hr. 17 min.	5 hr. 50 min.	11 hr. 13 min.	7 hr. 35 min.	7 hr. 42 min.	6 hr. 13 min.
Bleeding, %, ASTM C 232	0.44	0	0	0	0	0	0	0

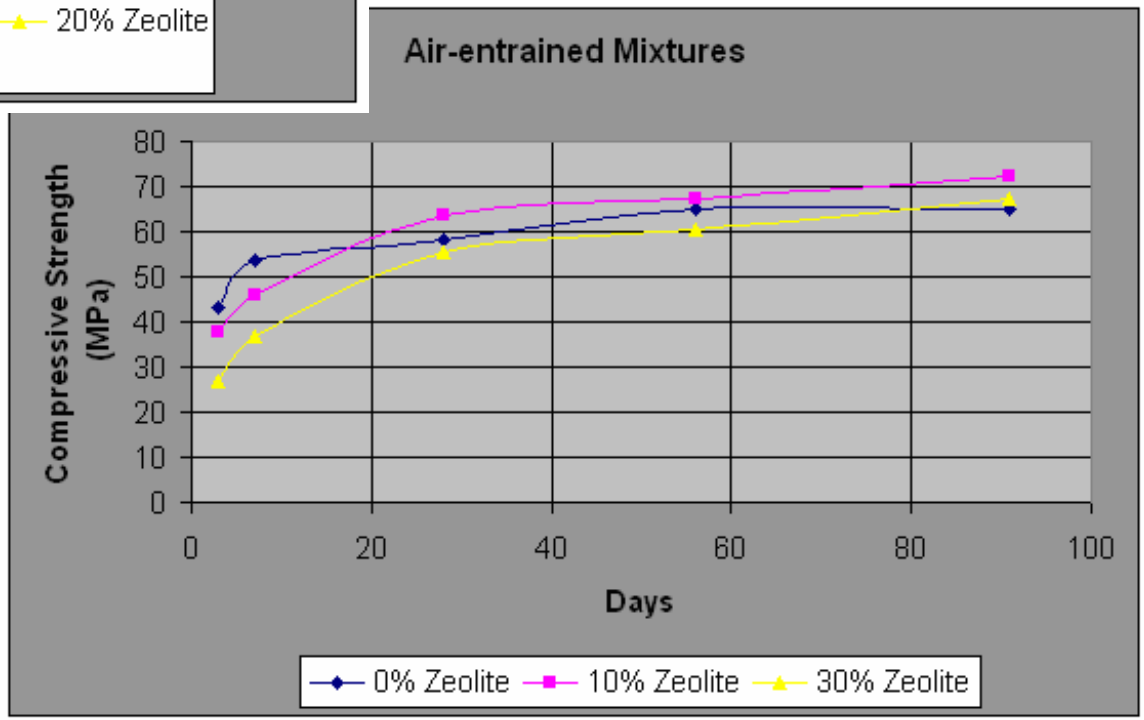
COMPRESSIVE STRENGTH [ASTM C 39]



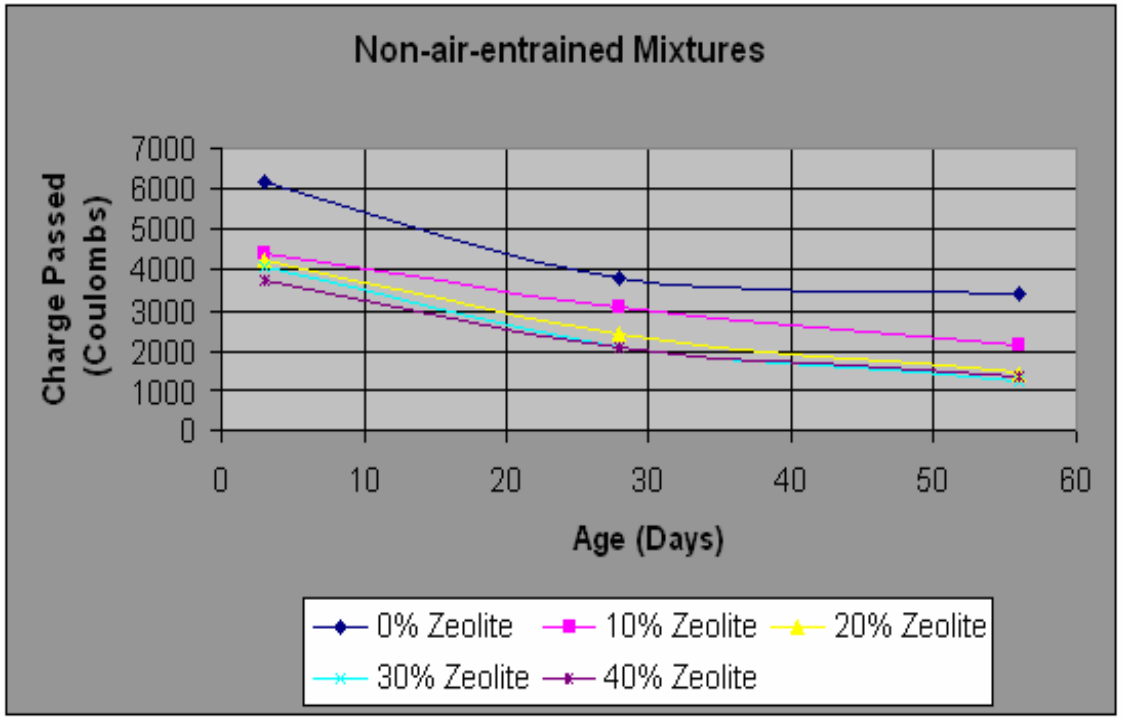
Neither a major strength benefit

Nor a major strength loss

-Not a major loss, even at 30% zeolite is a gain!

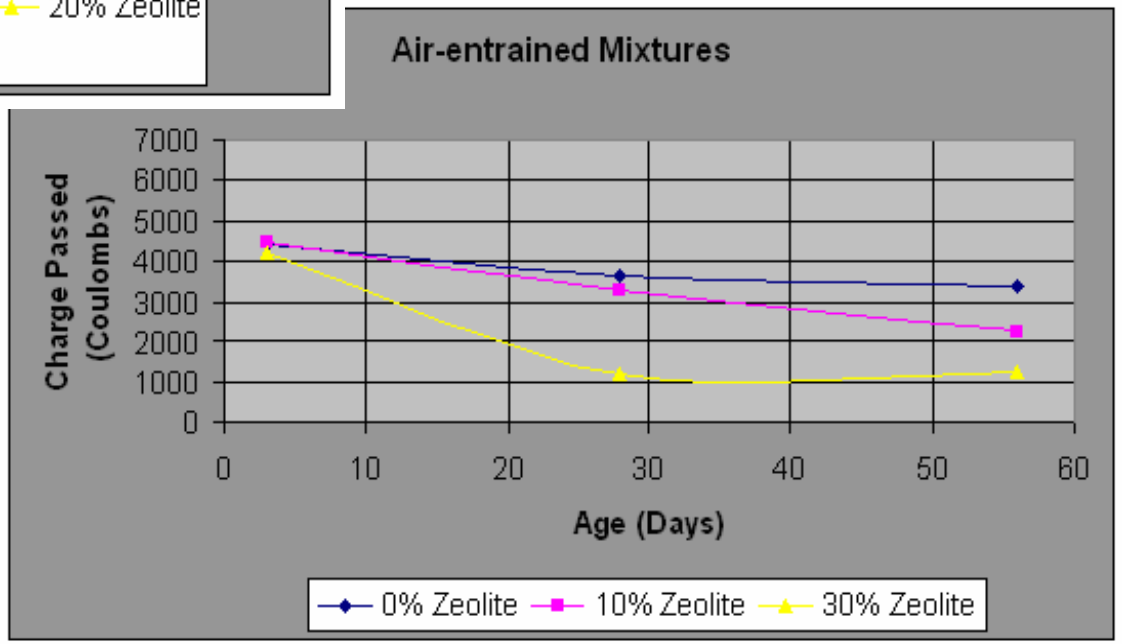


RAPID CHLORIDE PERMEABILITY [ASTM C 1202]

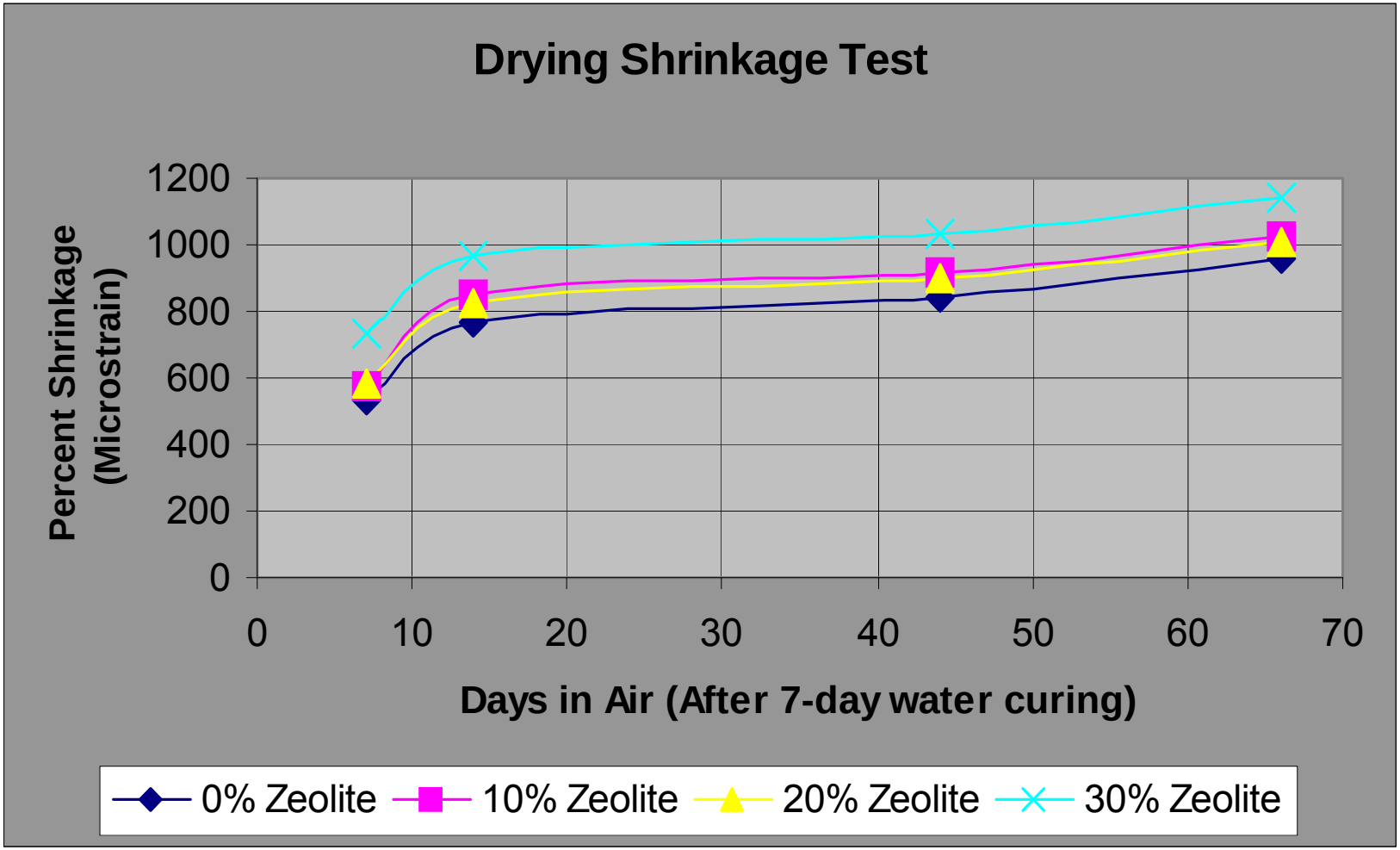


Now we are talking!

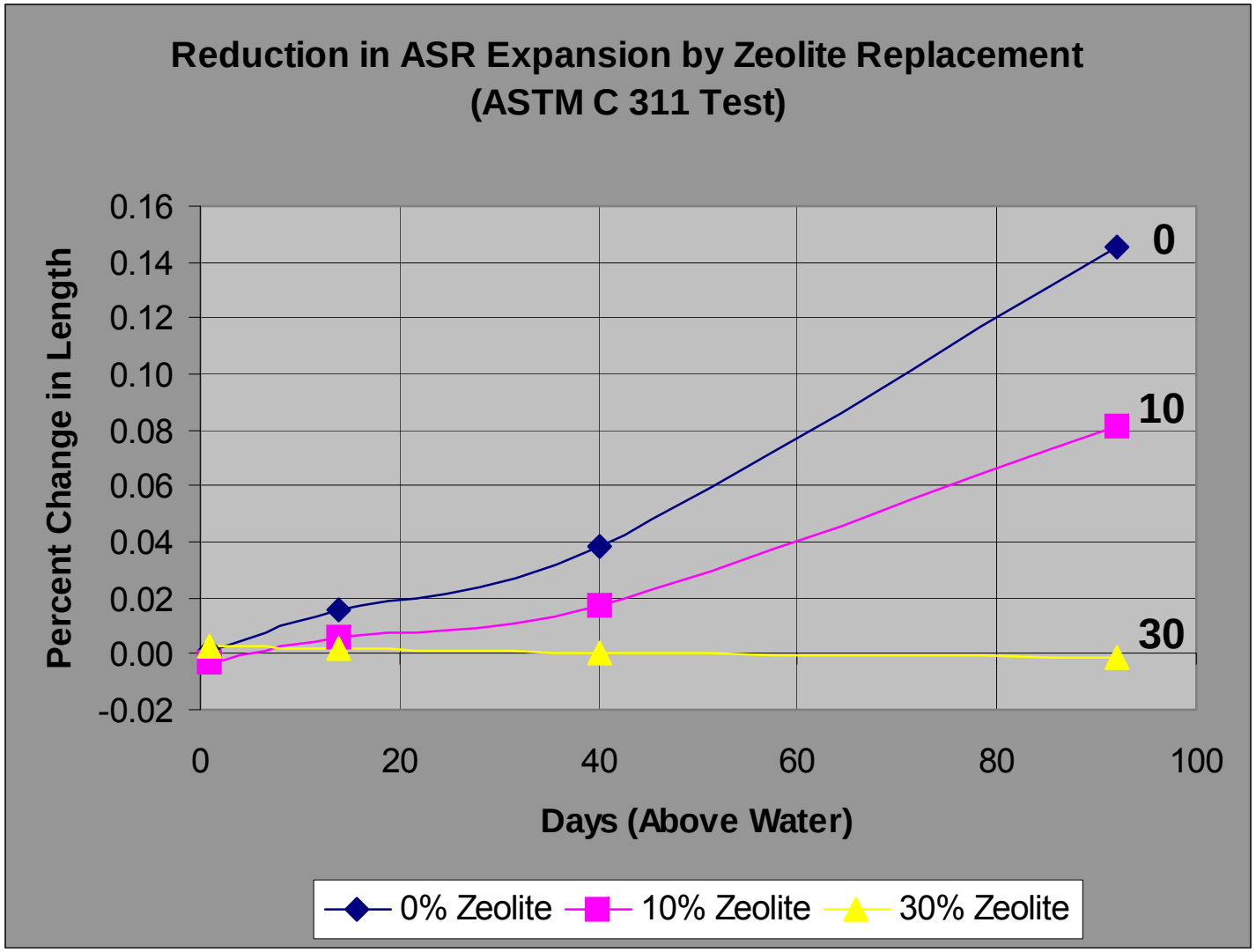
A significant reduction
In chloride permeability!



DRYING SHRINKAGE [ASTM C 311]

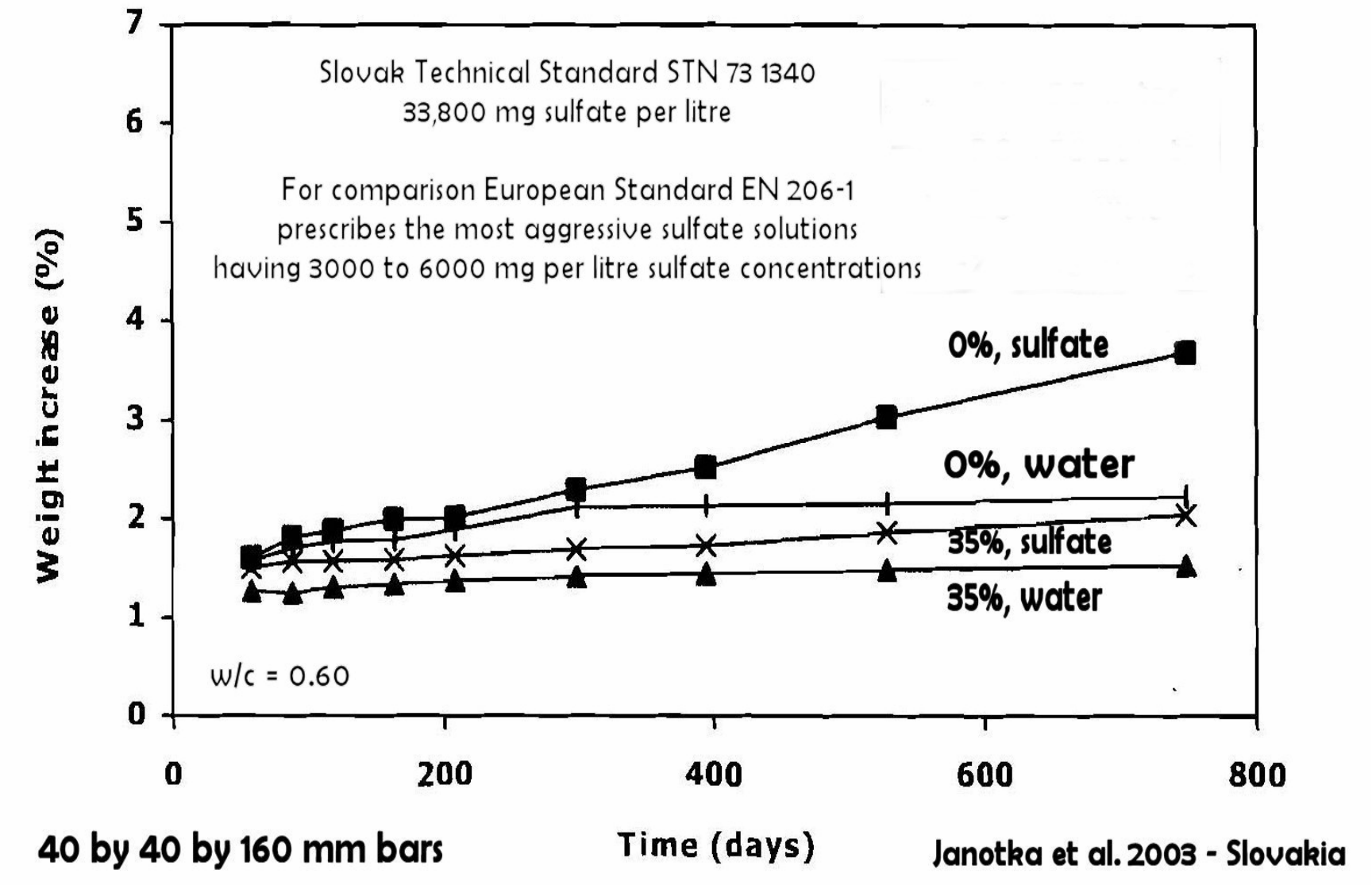


ALKALI – SILICA REACTION [ASTM C 311]

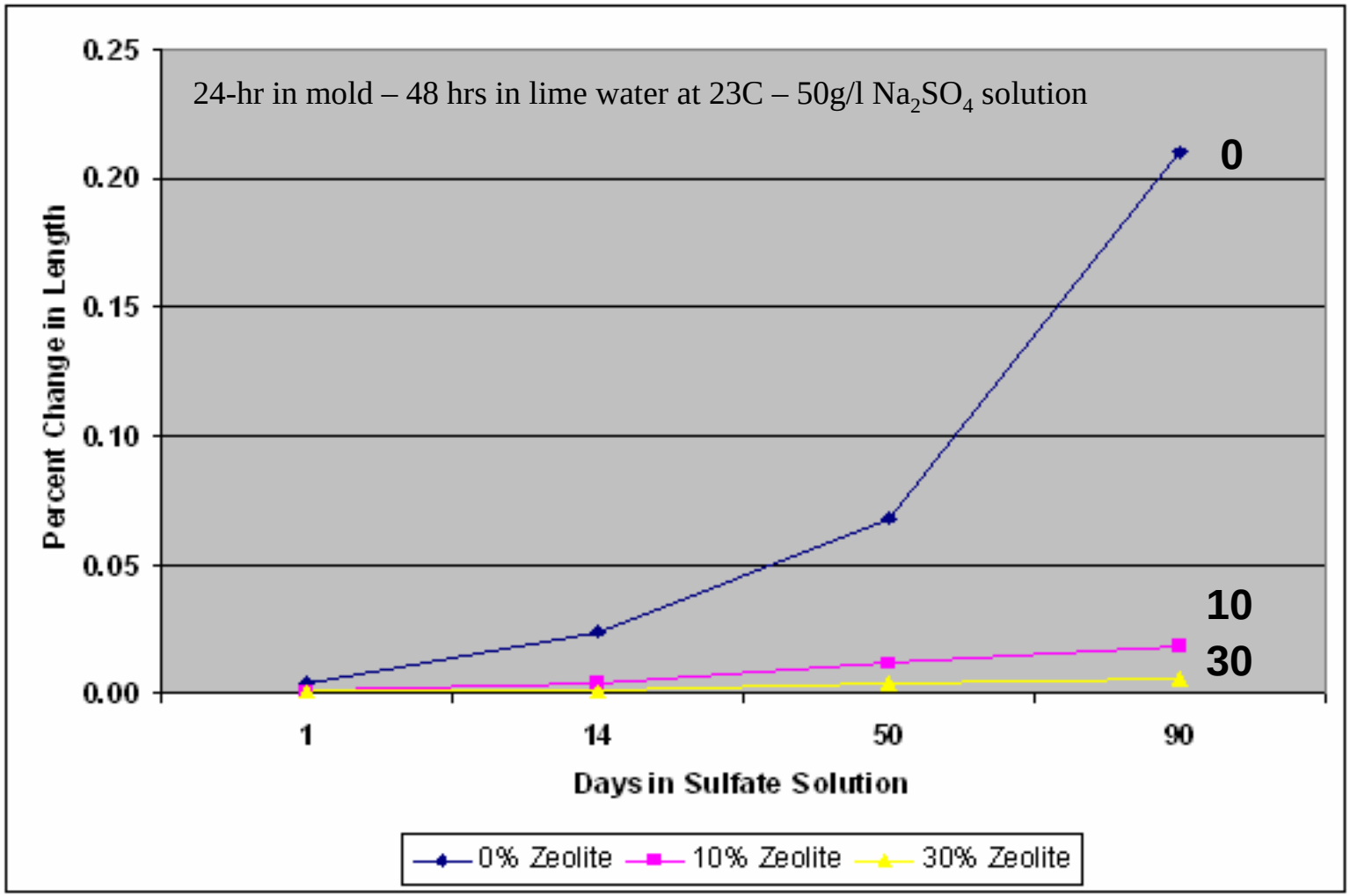


We are talking again – Now a Big Time!

ACID & SULFATE RESISTANCE – A BIG BONUS



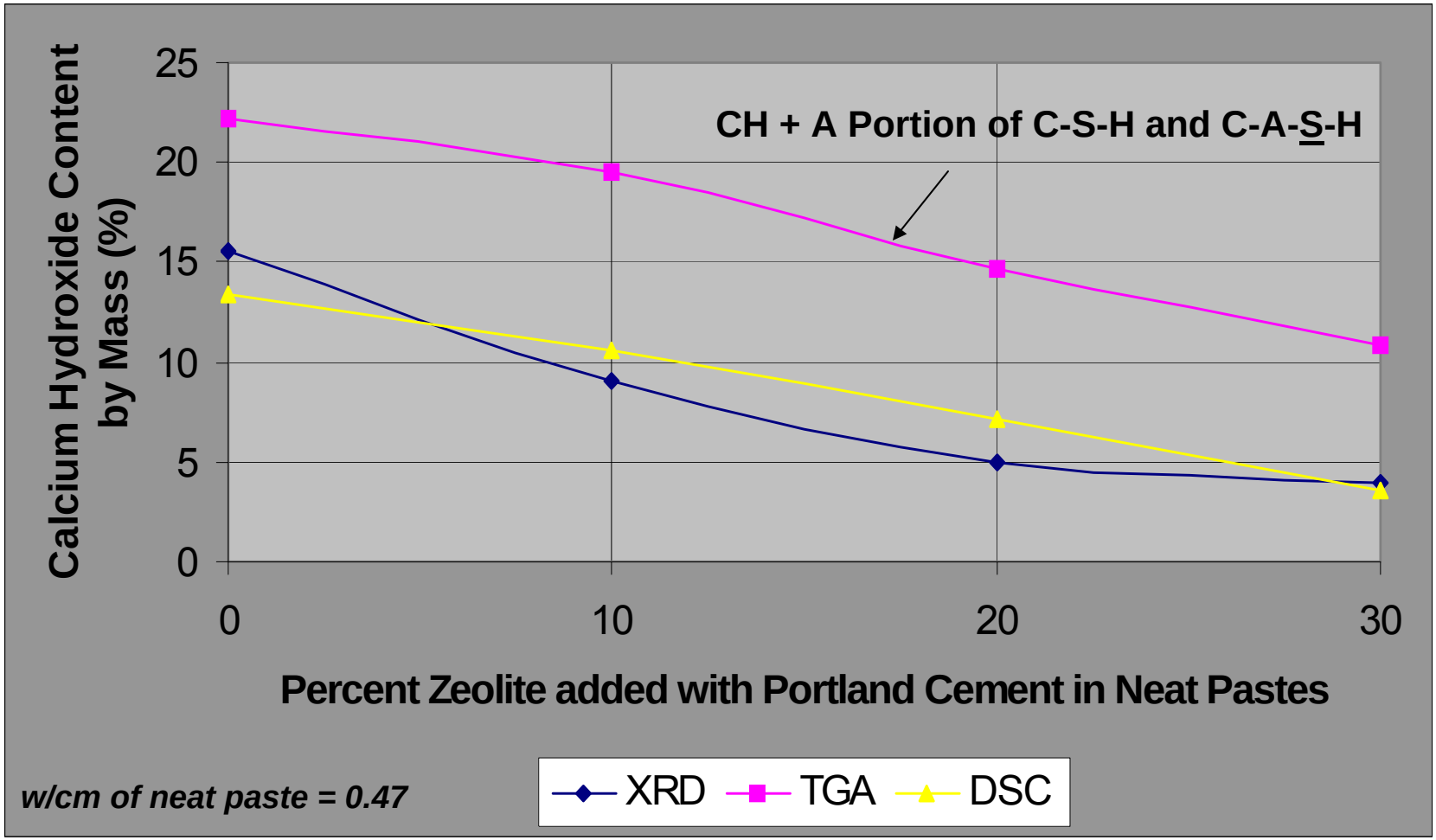
SULFATE RESISTANCE [ASTM C 1012]



25 × 25 × 285 mm Mortar Bars

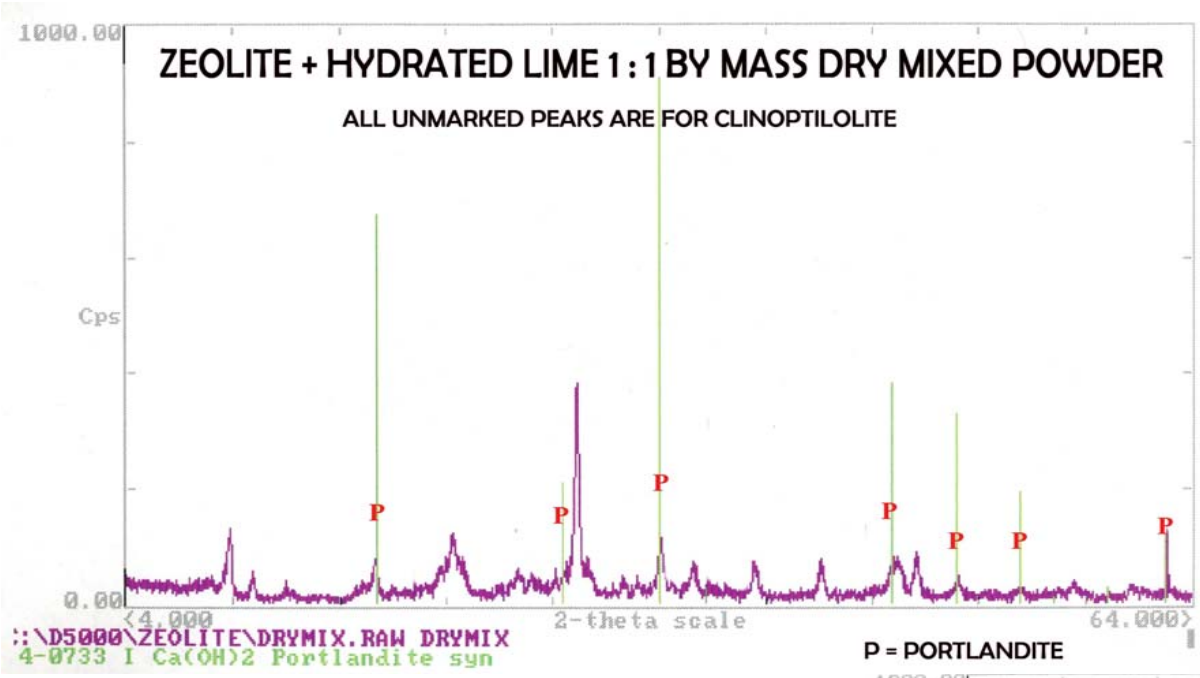
POZZOLANIC REACTION

- The Secret Behind the "Magic" of Zeolite in Concrete



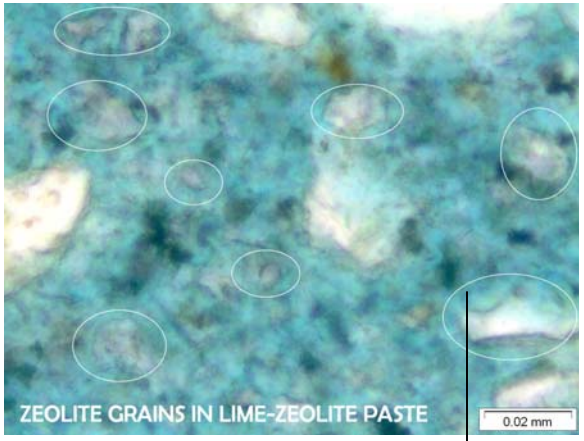
Clinoptilolite + Calcium Hydroxide → Calcium Silicate Hydrate

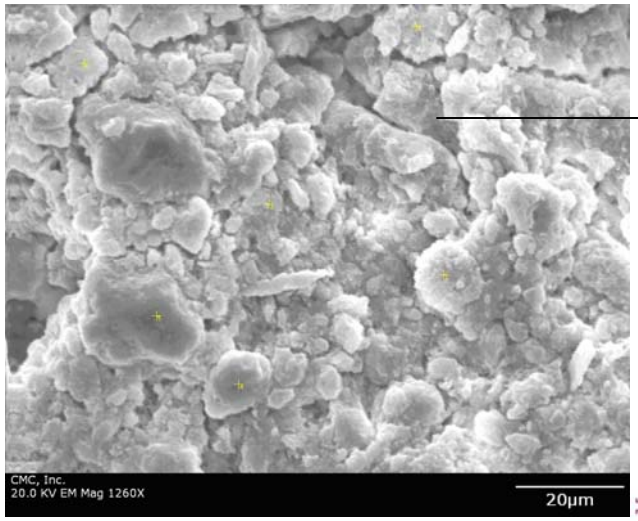
POZZOLANIC REACTION – ANOTHER EXPERIMENT

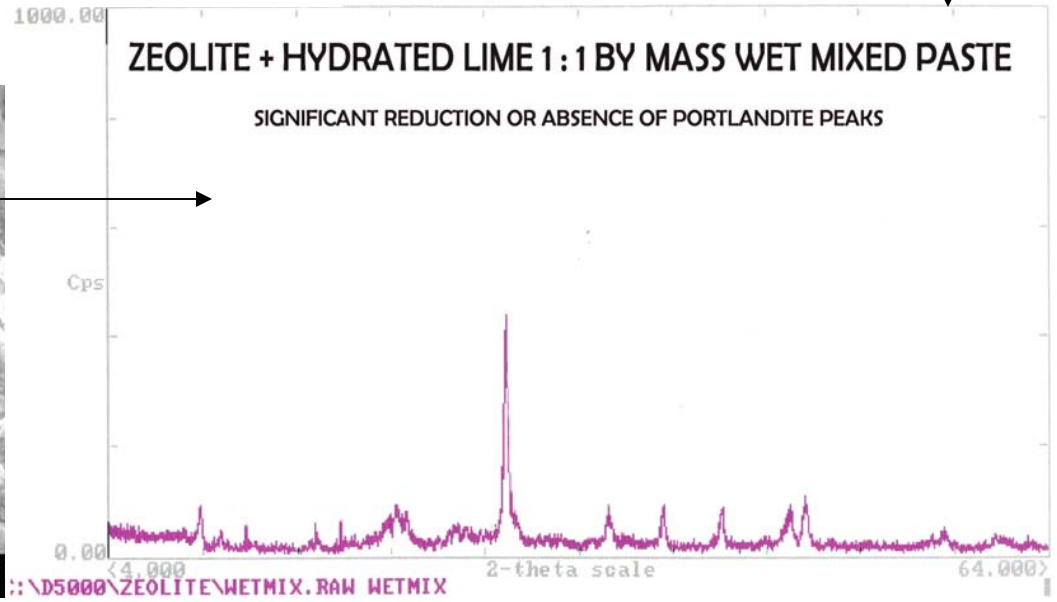


P = PORTLANDITE

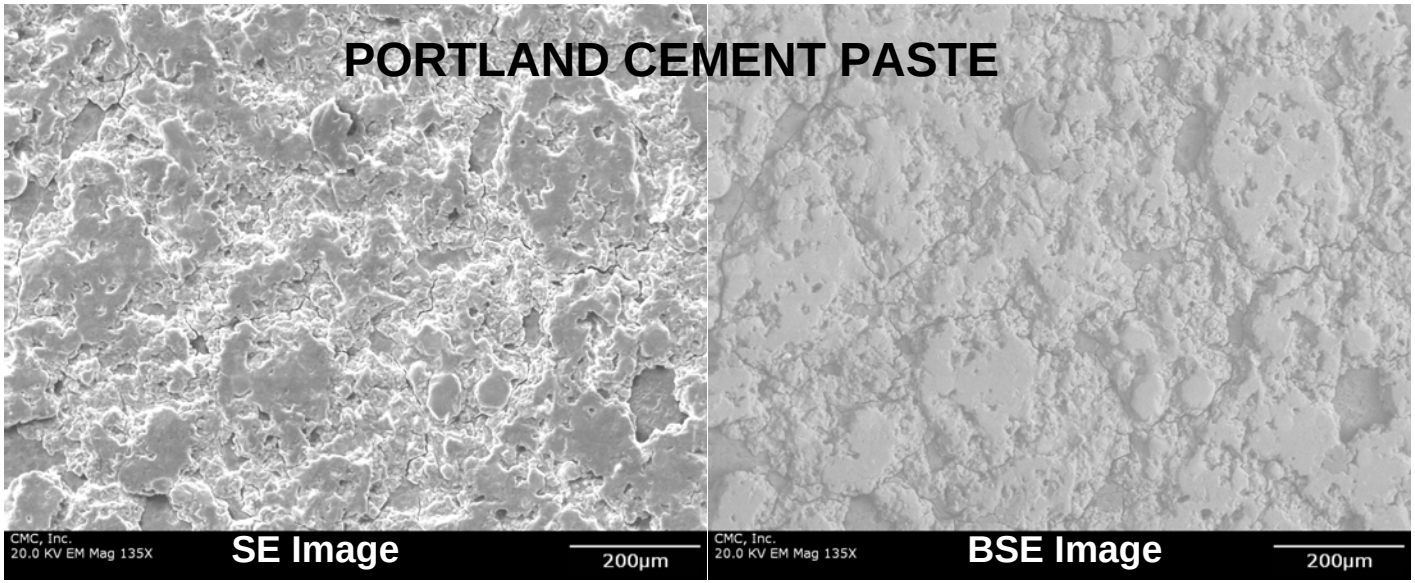
Zeolite – Lime Mix = Ancient Mortar Recipe

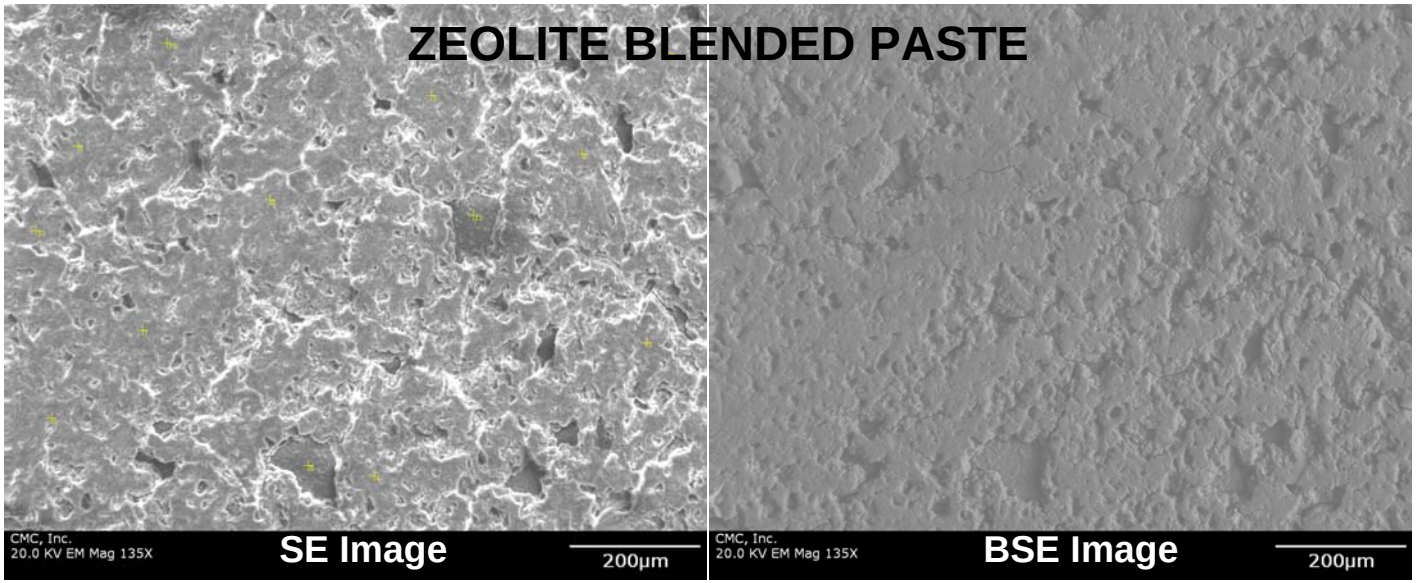






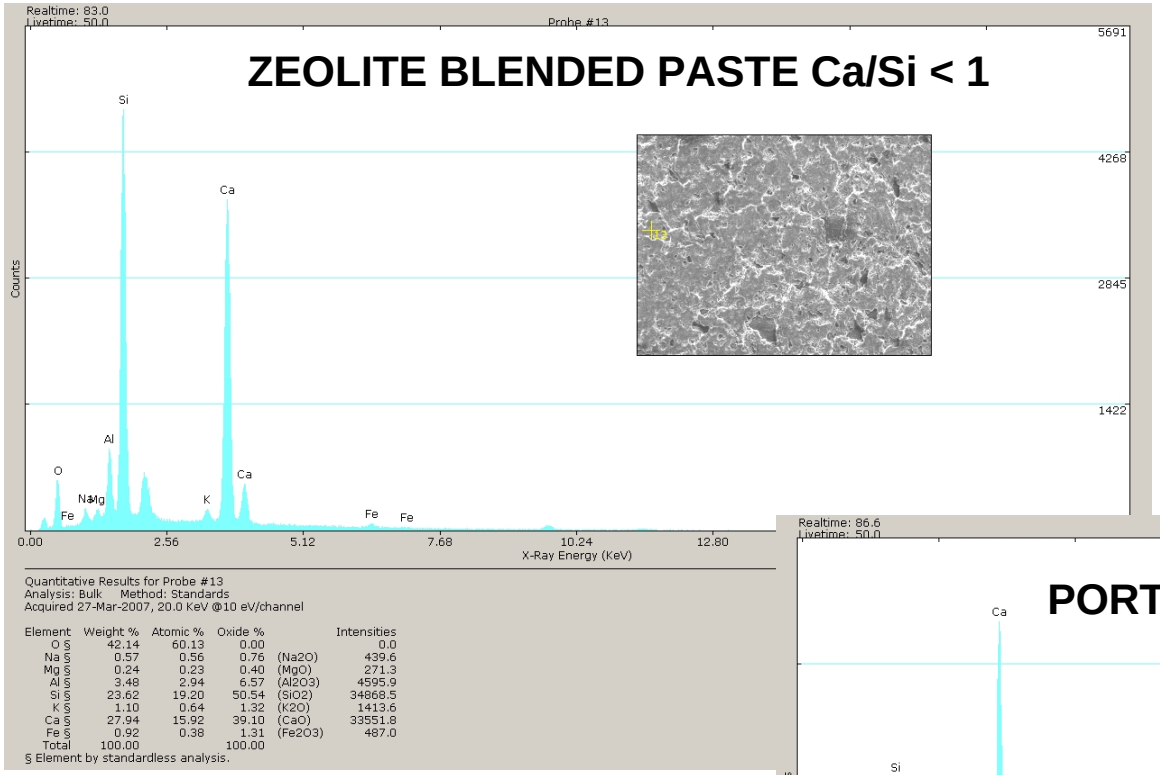
ZEOLITE-BLENDED PASTE





Densification of paste by pozzolanic reaction

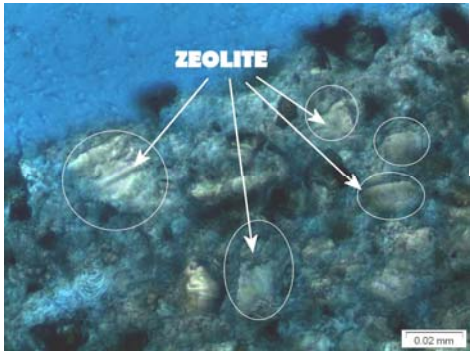
ZEOLITE-BLENDED PASTE

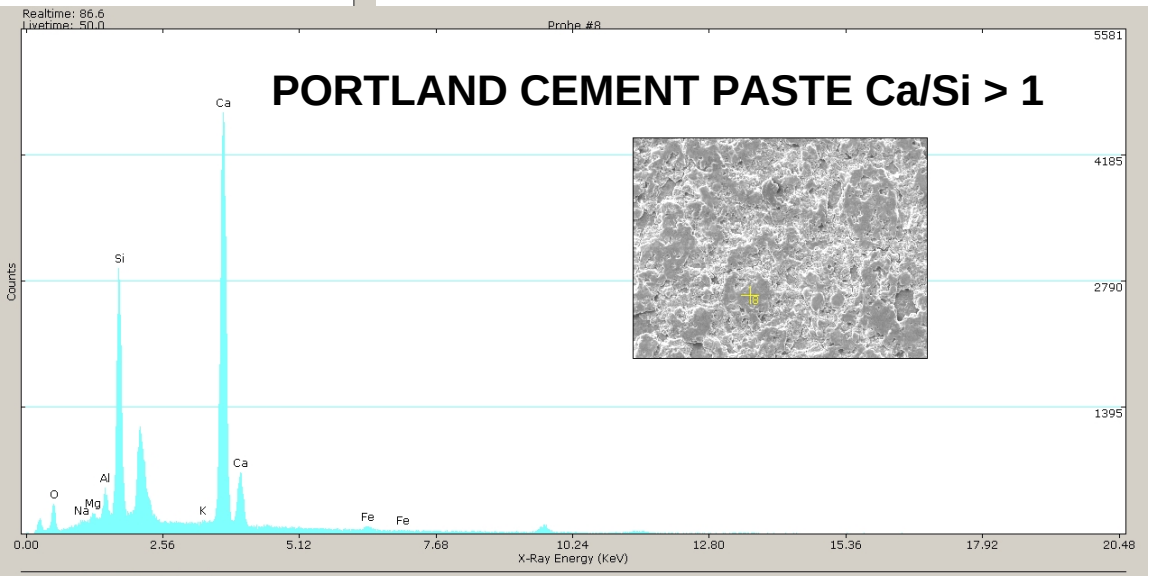


Quantitative Results for Probe #13
Analysis: Bulk Method: Standards
Acquired 27-Mar-2007, 20.0 KeV @10 eV/channel

Element	Weight %	Atomic %	Oxide %		Intensities
O §	42.14	60.13	0.00		0.0
Na §	0.57	0.56	0.76	(Na2O)	439.6
Mg §	0.24	0.23	0.40	(MgO)	271.3
Al §	3.48	2.94	6.57	(Al2O3)	4595.9
Si §	23.62	19.20	50.54	(SiO2)	34868.5
K §	1.10	0.64	1.32	(K2O)	1413.6
Ca §	27.94	15.92	39.10	(CaO)	33551.8
Fe §	0.92	0.38	1.31	(Fe2O3)	487.0
Total	100.00		100.00		

§ Element by standardless analysis.





Quantitative Results for Probe #8
Analysis: Bulk Method: Standards
Acquired 27-Mar-2007, 20.0 KeV @10 eV/channel

Element	Weight %	Atomic %	Oxide %		Intensities
O §	35.91	56.16	0.00		0.0
Na §	0.16	0.17	0.21	(Na2O)	72.4
Mg §	0.27	0.28	0.46	(MgO)	236.3
Al §	0.90	0.84	1.71	(Al2O3)	1060.1
Si §	13.27	11.82	28.38	(SiO2)	21186.3
K §	0.19	0.12	0.23	(K2O)	168.4
Ca §	48.33	30.17	67.63	(CaO)	42918.1
Fe §	0.97	0.43	1.38	(Fe2O3)	367.0
Total	100.00		100.00		

§ Element by standardless analysis.

CONCLUSIONS

- Zeolite meets the ASTM C 618 specification for a Type N Pozzolan
- A reduction in Workability – Need for a High-range water-reducer
- Strength – A modest improvement at 10% & reduction at 20-30% @ 56d
  Overall not a significant improvement or impairment in strength
- Durability – Significant improvements in resistance to:
  - Chloride Permeability
  - ASR Expansion
  - Acid/Sulfate Attacks
- Densification of the microstructure by pozzolanic reaction
- Zeolite Deposits in the Western USA
  – A Possible "Gold Mine" for the Construction Industry

ACKNOWLEDGMENTS

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- **Ted H. Eyde**
- **George Desborough, USGS**

Two nationally & internationally recognized experts who have written numerous articles on zeolites

Thank You.