Vinyl Acetate Ethylene (VAE) Polymers in Pervious Concrete Applications

QAW, February 2018

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NRMCA NATIONAL READY MIXED CONCRETE ASSOCIATION

MIDDLE TENNESSEE STATE UNIVERSITY.

OZINGA

Over 100 Years of Success

Wacker Chemie AG

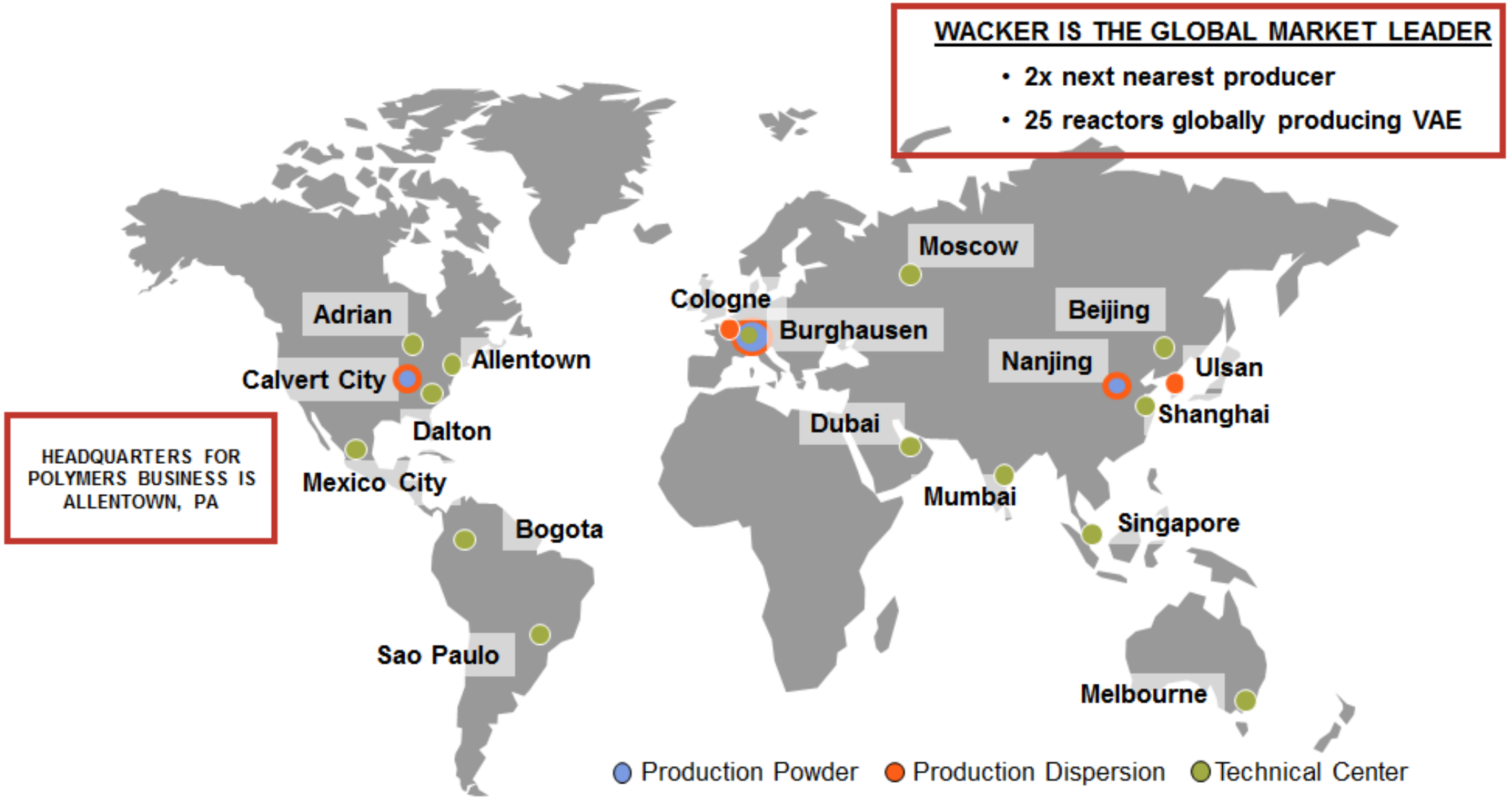
- Founded in 1914 by Dr. Alexander Wacker
- Headquartered in Munich

WACKER Group (2016)*

- Sales: €4.63 billion
- EBITDA: €956 million
- R&D: €150 million
- Investments: €338 million
- Employees: 13,448

* Adjusted in accordance with IFRS 5

Global Polymer Production Footprint – Local Technical / Sales Teams



WACKER POLYMERS: Dispersion and Powder Production

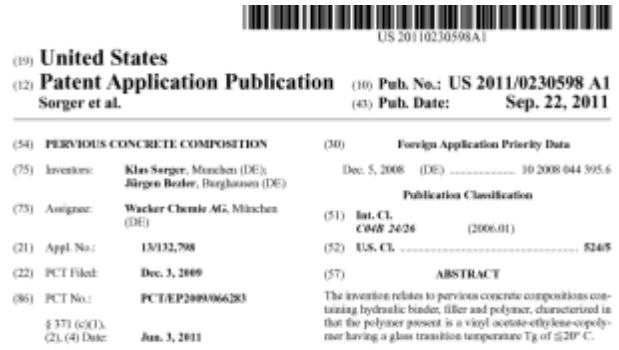
Dispersible Polymer Powder

Dispersion (Latex)

Vinyl Acetate Ethylene in Pervious Concrete

Wacker Pervious Concrete Experience

2011: Patented the use of VAE copolymers in pervious concrete **(US9670094)**
2012: Began commercial testing of various mix designs in Europe
2013: US market study and needs assessment
2014: Began investigating and testing of various mix designs in Allentown parking lot
2015: Expanded and optimized mix designs
2016: Field trials in Tennessee
2017: Commercialization



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(19) **United States**
(12) **Patent Application Publication**
Sorger et al.

(10) **Pub. No.: US 2011/0230598 A1**
(43) **Pub. Date: Sep. 22, 2011**

(54) **PERVIOUS CONCRETE COMPOSITION**

(75) Inventors: **Klas Sorger**, München (DE); **Jürgen Bezler**, Burghausen (DE)

(73) Assignee: **Wacker Chemie AG**, München (DE)

(21) Appl. No.: **13/132,798**

(22) PCT Filed: **Dec. 3, 2009**

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§ 371 (c)(1), (2), (4) Date: **Jun. 3, 2011**

(30) **Foreign Application Priority Data**

Dec. 5, 2008 (DE) 10 2008 044 395.6

Publication Classification

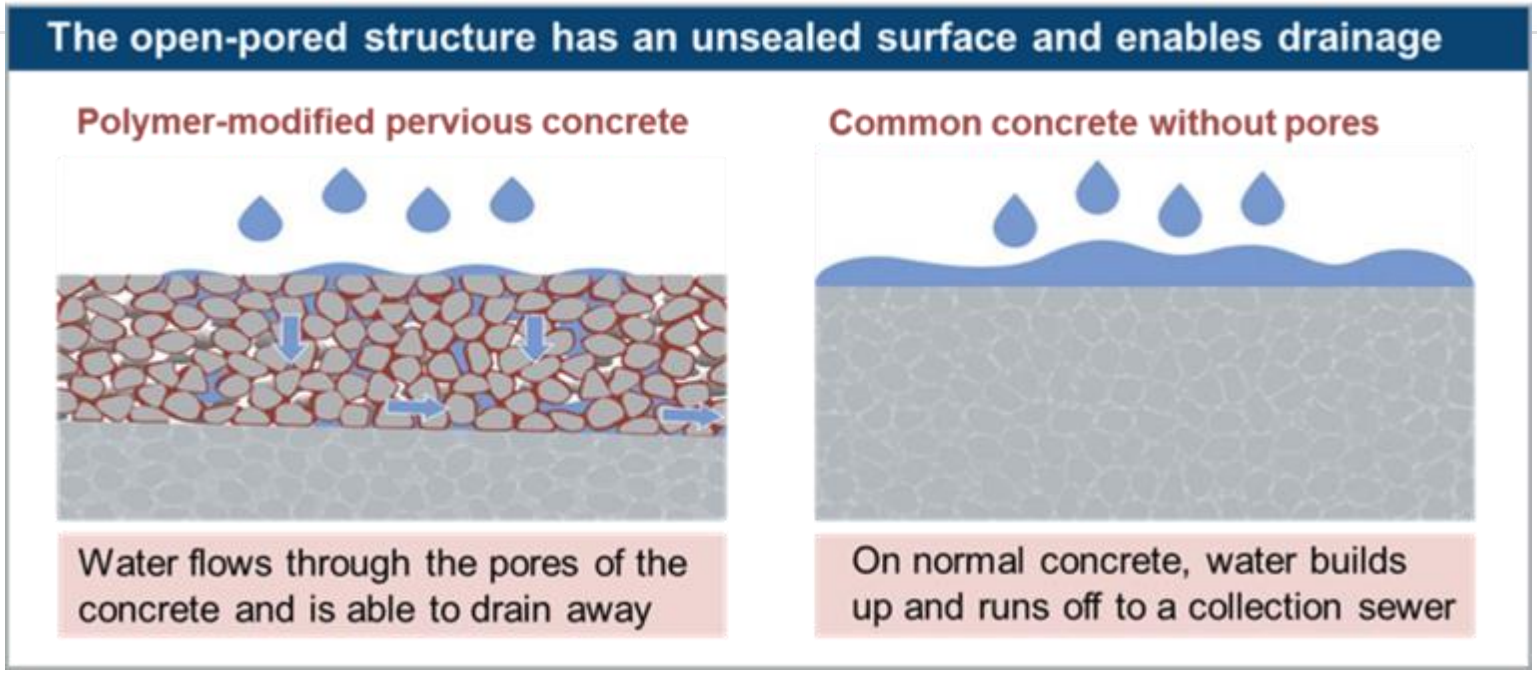
(51) **Int. Cl.**
C04B 24/26 (2006.01)

(52) **U.S. Cl.** **524/5**

(57) **ABSTRACT**

The invention relates to pervious concrete compositions containing hydraulic binder, filler and polymer, characterized in that the polymer present is a vinyl acetate-ethylene-copolymer having a glass transition temperature Tg of ≦20° C.

What is Pervious Concrete?



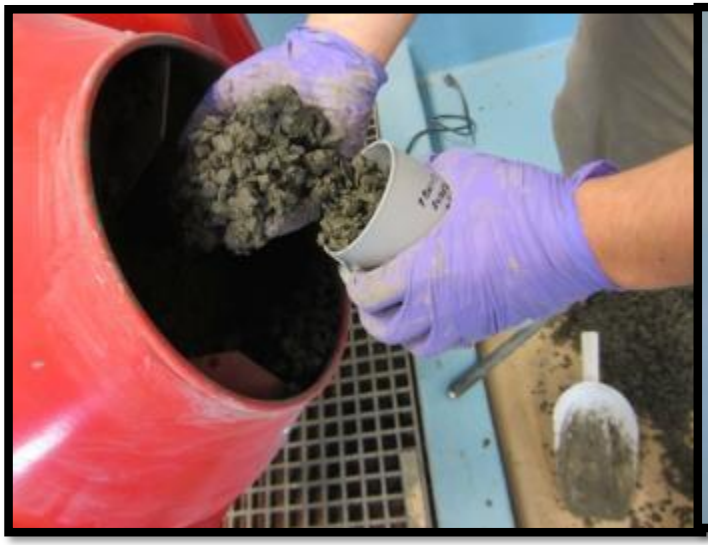
- Pervious concrete utilizes aggregate stones that are roughly the same size so the stones cannot be densely packed, creating a pervious, open matrix of defined void content (15-20%)
- Just enough cement paste is used to bind the aggregate together without filling the space / voids between the packed stones
- Deemed as a “first flush” when it rains
- “Naturally” recharges the underlying Aquifer

Potential Benefits of Pervious Concrete

- Meets or satisfies a variety of government drainage mandates
- Lowers maintenance costs
- Minimizes drainage system requirements
- Lowers storm water impact fees
- Recyclable
- Improves pavement or road safety - elimination of water puddling
- Improves pavement aesthetics
- Superior durability compared to asphaltic pavements

source: http://www.perviouspavement.org/benefits/economic.html

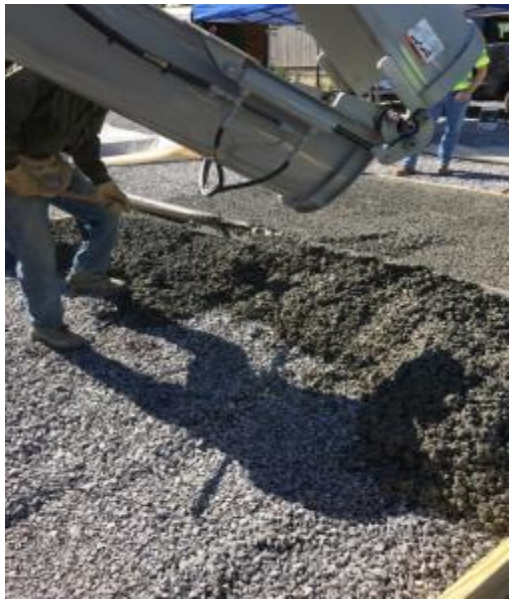
Formulating Capability

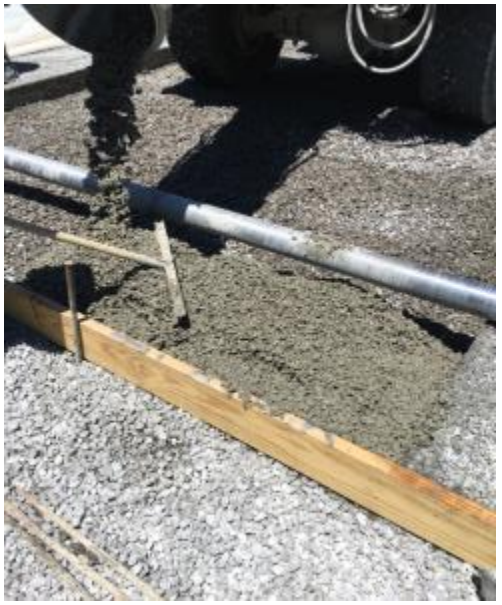






Job Site Experience – Tennessee, Maryland, New York





- > 28 truckloads of VAE-modified pervious concrete (~200 CY)

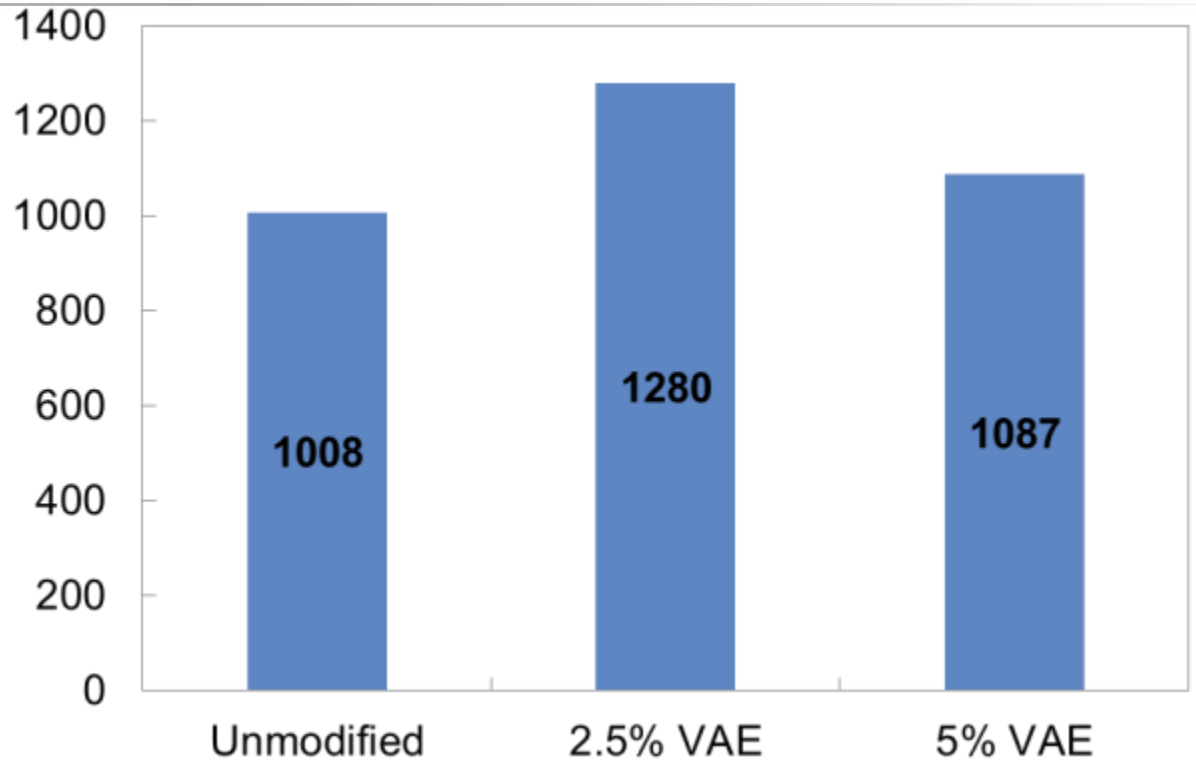
Pervious Concrete Mix Design – Starting Formula

Lb./yd3	Unmodified	VAE Modified
Cement	500	500
Aggregates	2500	2500
Water w/c = 0.33	165	165
Wacker VAE (1.5, 2.5 and 5.0% o.c.w)	--	7.5; 12.5; 25
Mid Range Water Reducer	50 oz	50 oz
Hydration Stabilizing Admixture	60 oz	60 oz

- Optimal cement factor ~ 500 lb./CY
  - 20% cement can be replaced by pozzolan
- w/c ~ 0.33 for optimal workability and strength
- Hydration stabilizing admixture dosage dependent on:
  - Weather
  - Distance between ready mix station and job site
  - Do not use retarder instead
- VAE products were evaluated at various dosages

Infiltration Results, inches/hour

Infiltration Ring Test (Bunyan Industries)

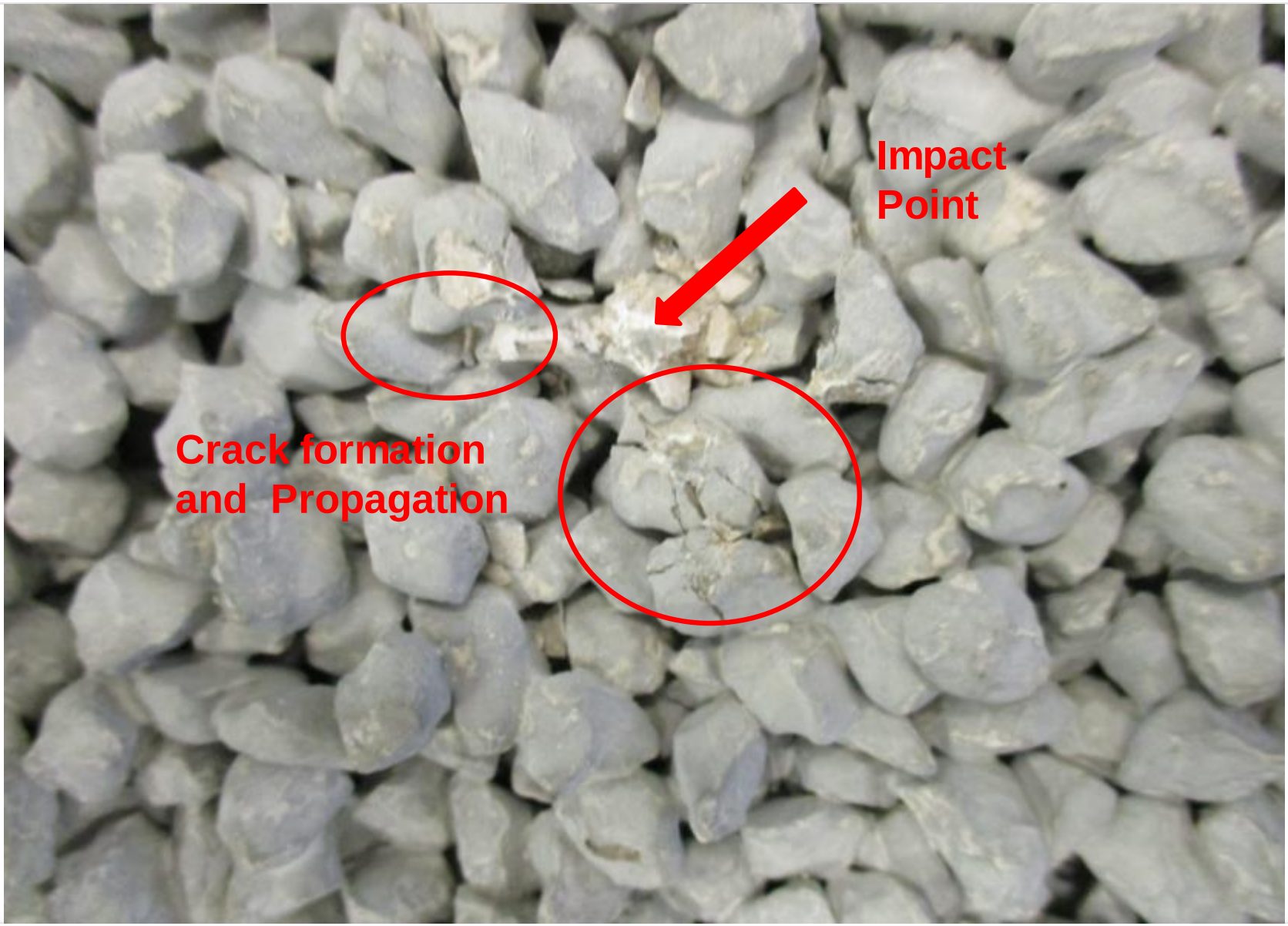


- Industry standard > 500 inches / hour = pass
- VAE-modification has little impact on infiltration
- Infiltration rate can be optimized by aggregate sizes and other components in mix designed

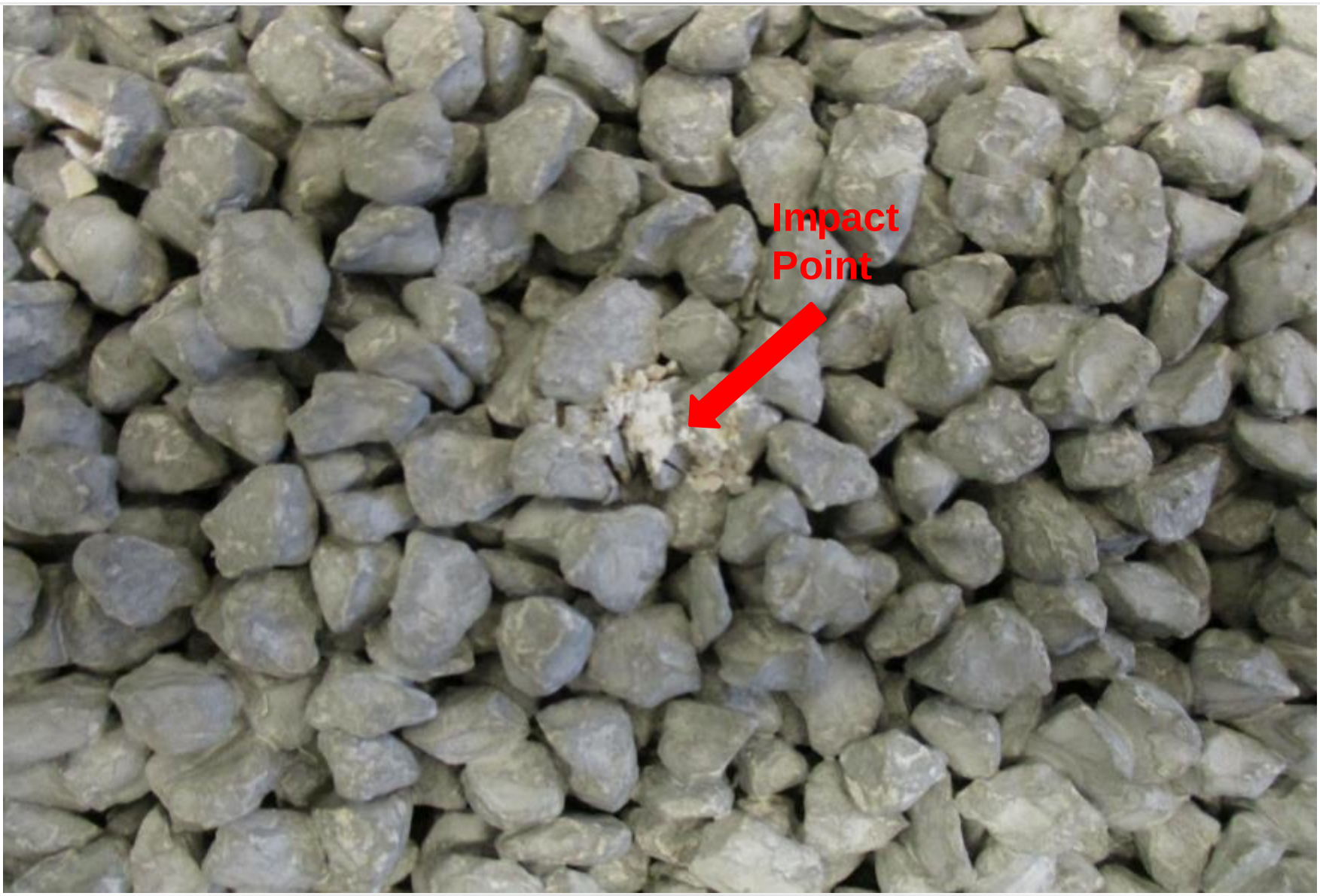
Impact Resistance Testing (Surface Raveling)

- Surface raveling is caused by cracking of the cement paste that bonds the aggregate
- Pervious concrete blocks (12” x 12” x 3”) are cured for 28 days before testing
- A metal ball (1045g) is dropped from a calibrated height (2 ft.) to impart a consistent impact energy (6J)
- The extent of cracking and raveling is then visually evaluated

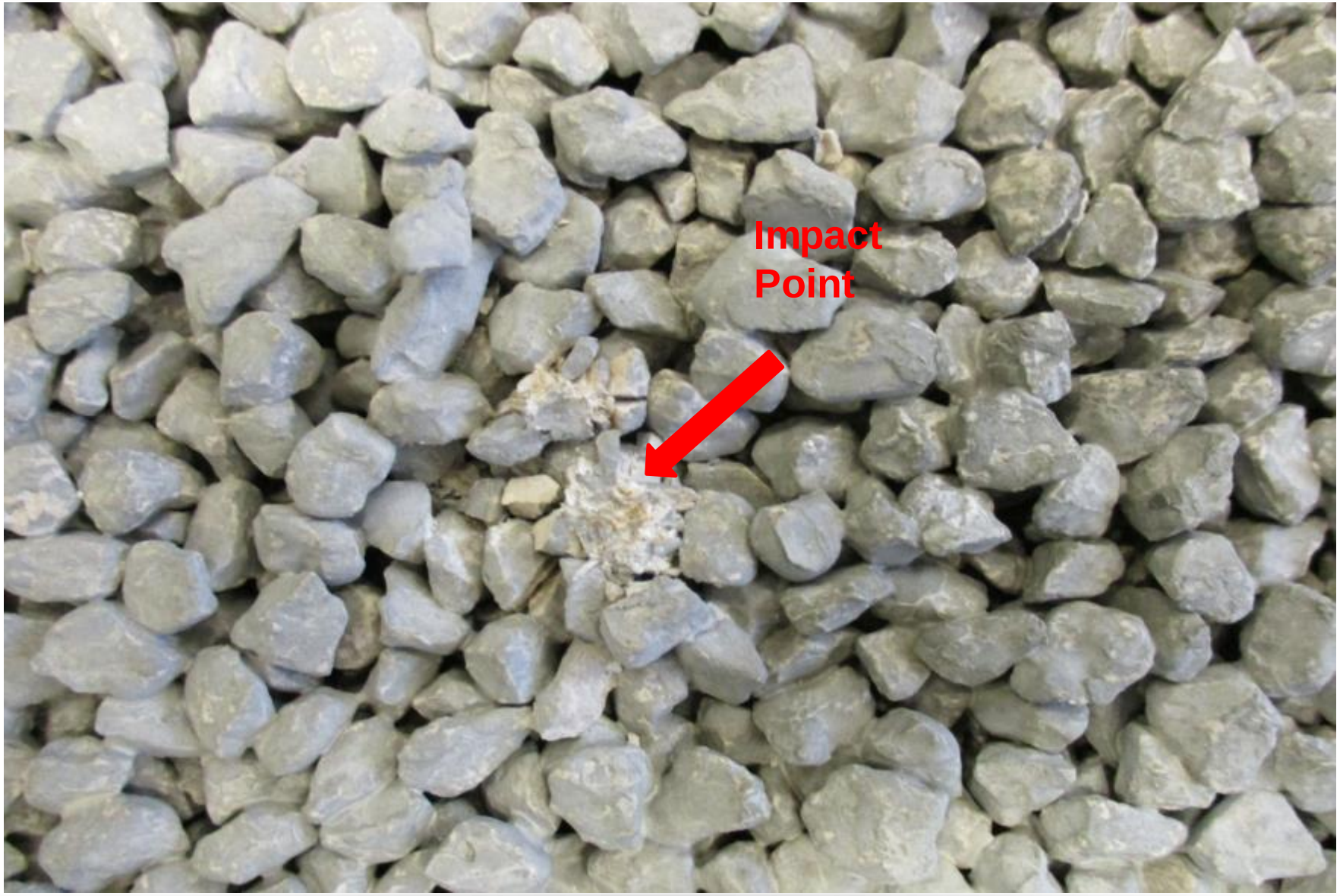
Unmodified Pervious Concrete



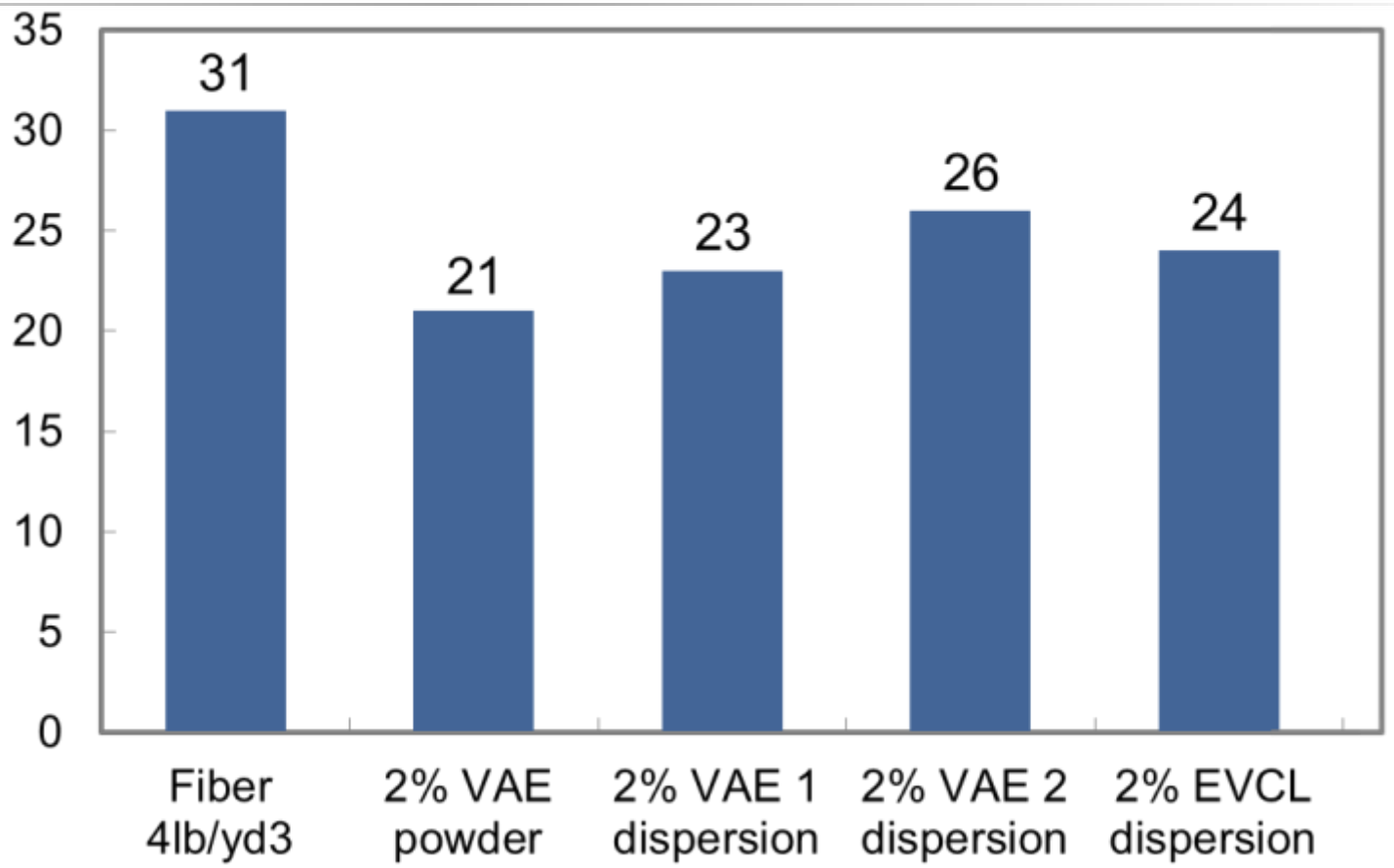
VAE-Modified Pervious Concrete – 2.5% o.c.w.



VAE-Modified Pervious Concrete – 5.0% o.c.w.

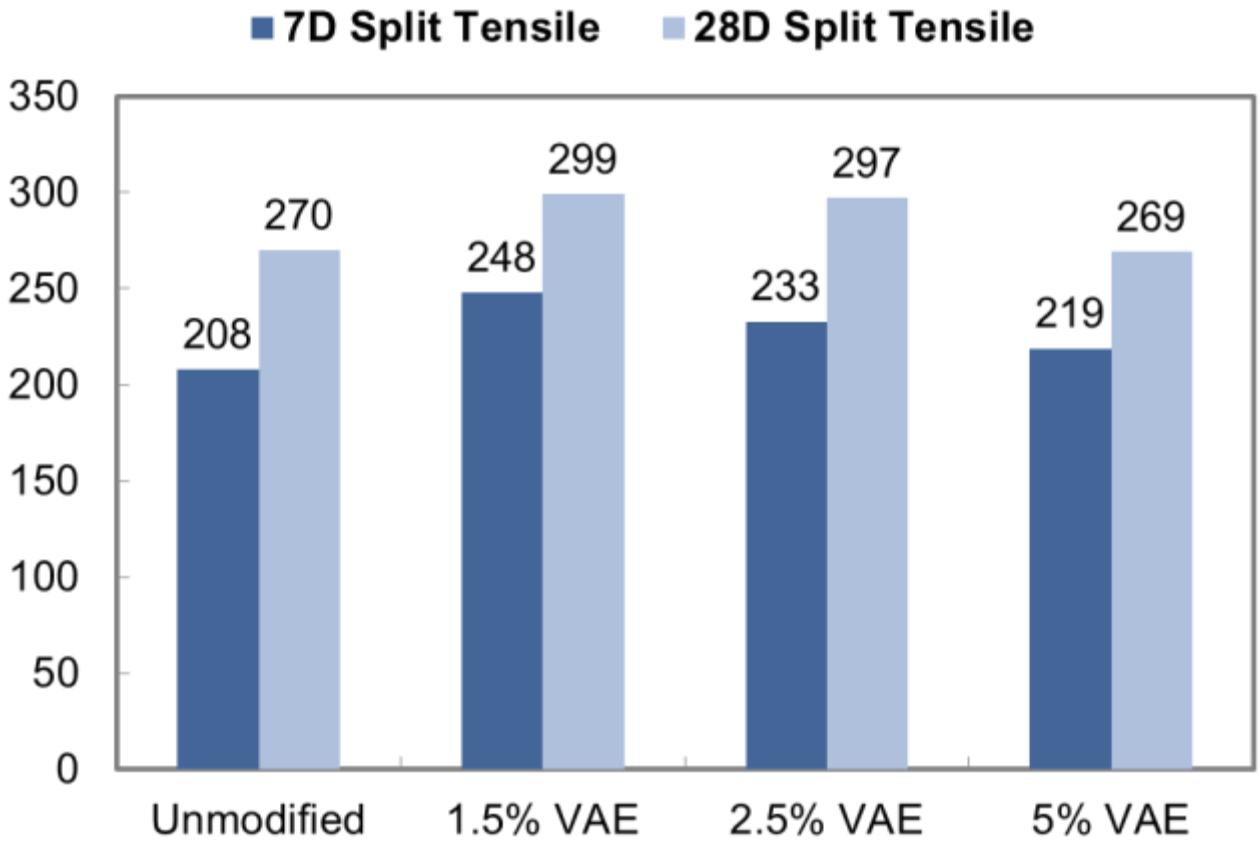


LA Abrasion, % Weight Loss, 500 revolutions



- All grades of VAE are more effective than fiber in improving abrasion resistance
- 2% of VAE powder exceeds fiber modification by 30%

Split Tensile Tests, psi



Sample Size = 3” x 6” Cylinder

10 – 20% increase in split tensile strength

Evaluation of Cement Paste in Pervious Concrete

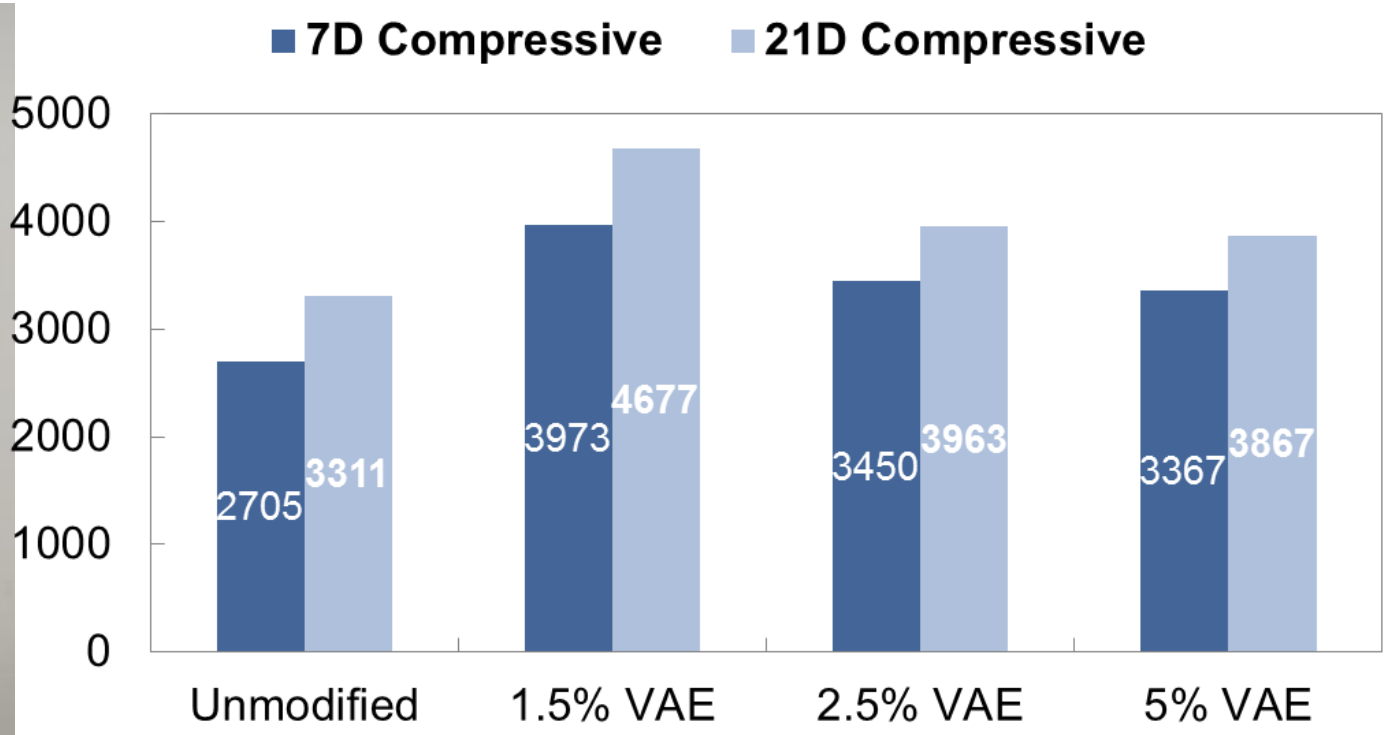
- One challenge of evaluating pervious concrete mix designs is the lack of standard test methods
- High void and aggregate content often yield inconsistent test results
- The properties of the cement paste in pervious concrete are key to determine performance

VAE-Modified Cement Paste Evaluation Method

Per standard C109	
Cement	1 part
Sand	2.75 part
Water	w/c = 0.5
Wacker VAE	1.5%, 2.5%, 5% by weight of cement

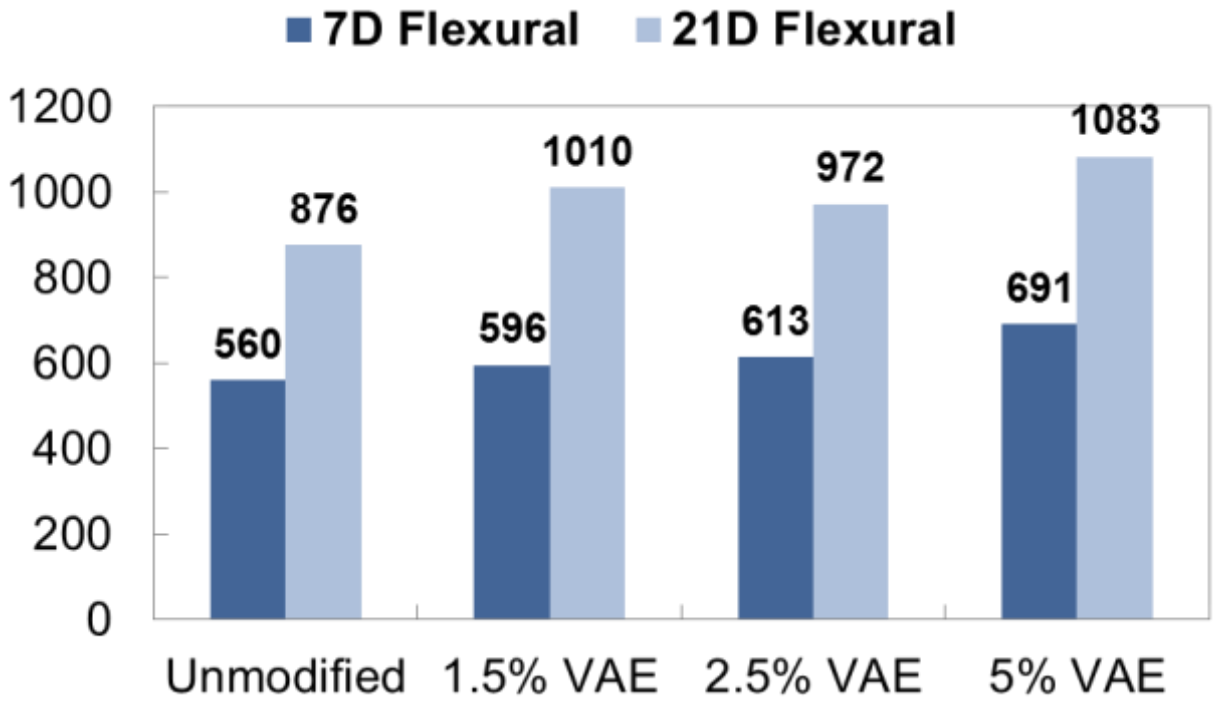
- **ASTM C109** compressive strength of hydraulic cement mortars
  - 2” x 2” cube specimens
  - Cured at standard condition for 7D and 21D
- **ASTM C348** flexural strength of hydraulic cement mortars
  - 40mm (1.57”) x 40mm (1.57”) x 160mm (6.3”) prism specimens
  - Cured at standard condition for 7D and 21D

VAE-Modified Cement Paste Compressive Strength, psi



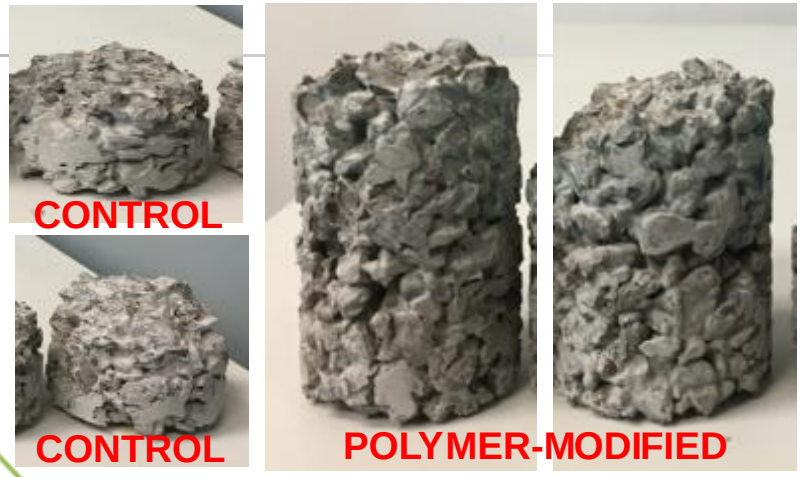
- VAE-modification increases the compressive strength by ~ 30 - 50%
- Increased compressive strengths = stronger cement paste = improved durability of pervious concrete

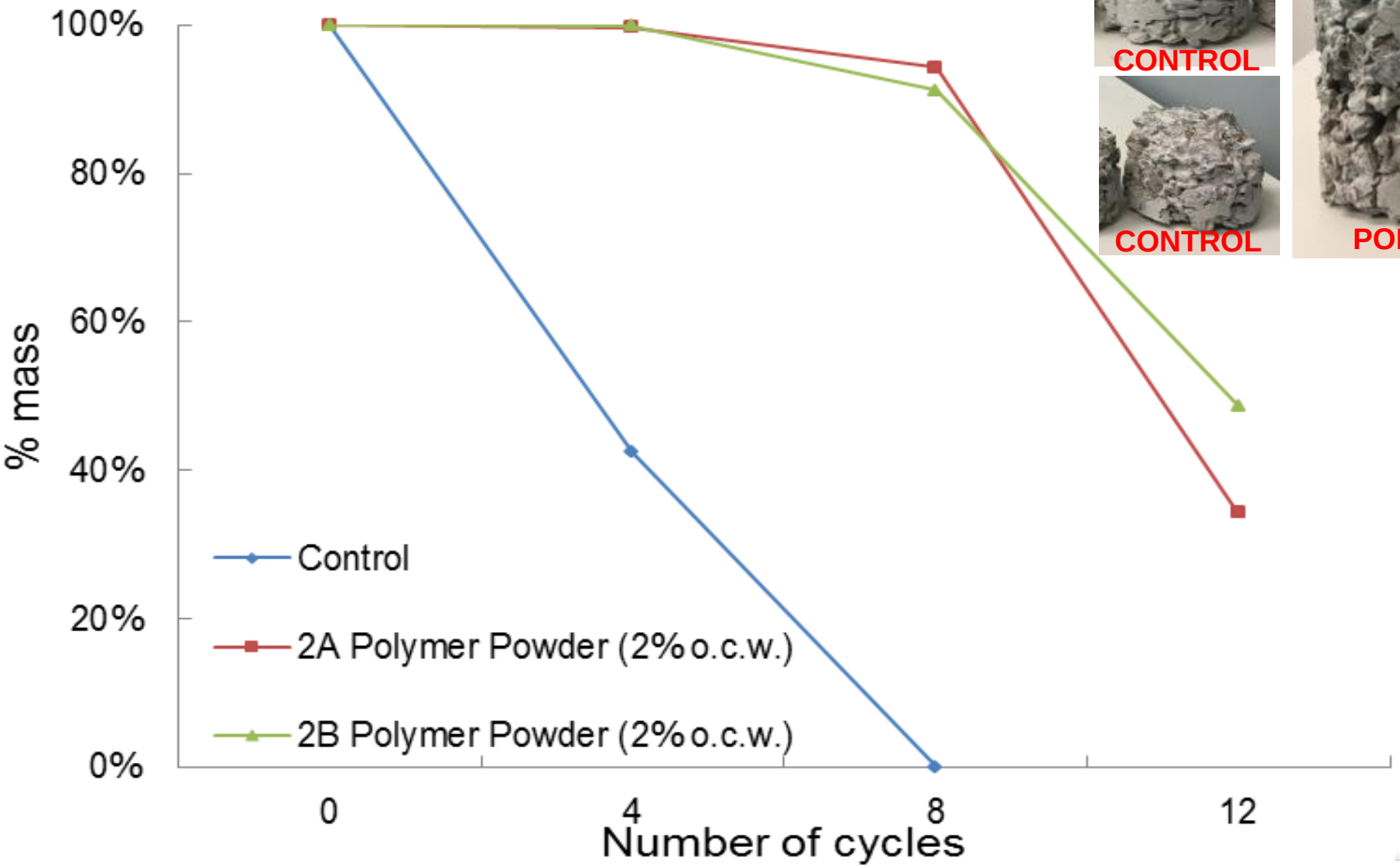
VAE-Modified Cement Paste Flexural Strength, psi



- VAE-modification increases the flexural strength by ~15 - 20%
- Increased flexibility = improved bonding = reduced cracking and surface raveling

Chemical Resistance – TNCA Field Trial



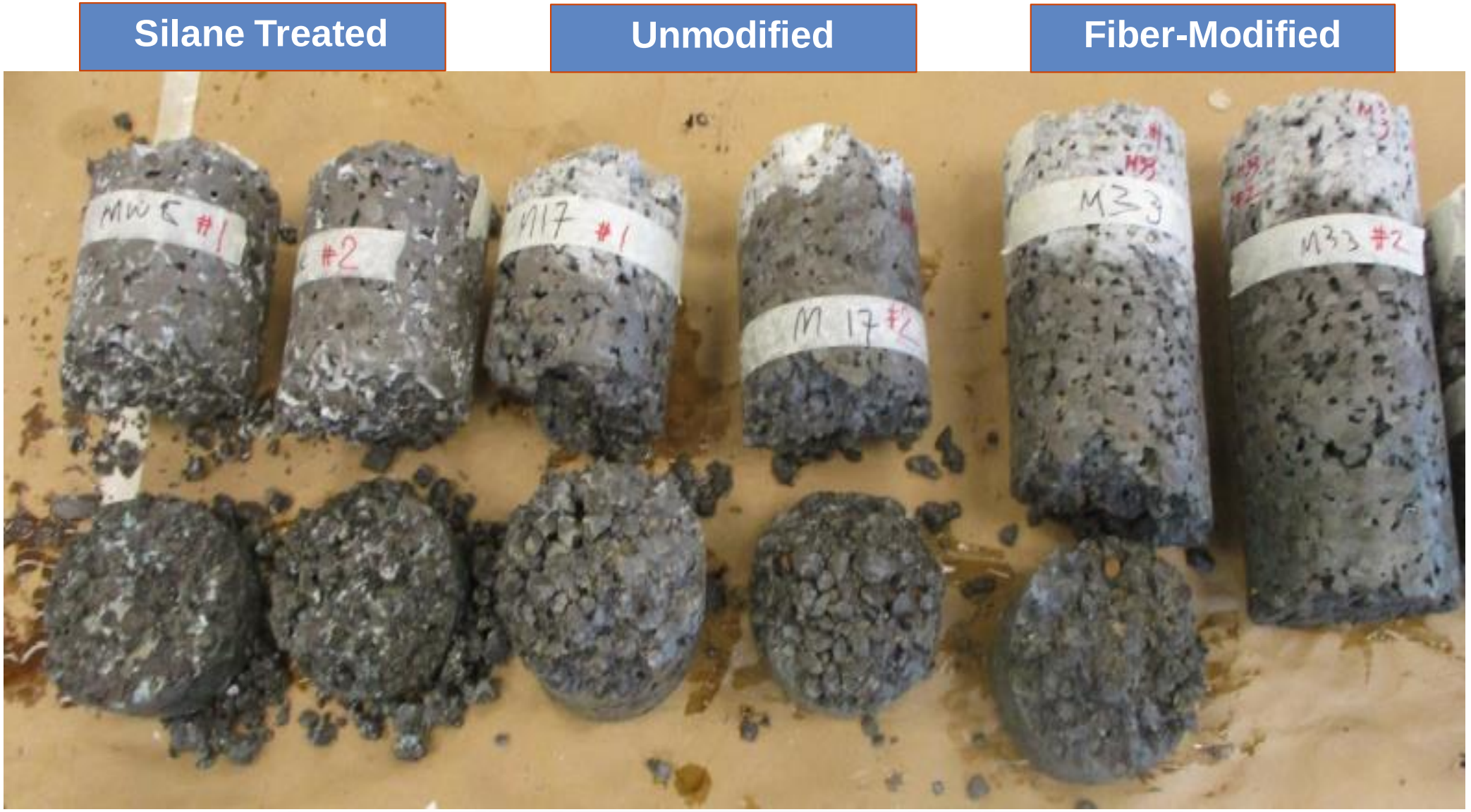


Chemical Resistance – TNCA Field Trial One Year Later

- 2 cores per mix were taken from the field
- Cores are partially immersed in 10% MgCl solution then undergo F/T cycles
- 2 control samples and 1 of the fiber + sand sample failed after 7 cycles; the second fiber + sand sample failed after 17 cycles
- 1% VAE samples lasted 40 cycles
- 2% VAE samples are still going now passing 60 cycles….

➢ VAE modification is the solution to chemical resistance + F/T resistance

Chemical Resistance – TNCA Field Trial
One Year Later - 7 cycles



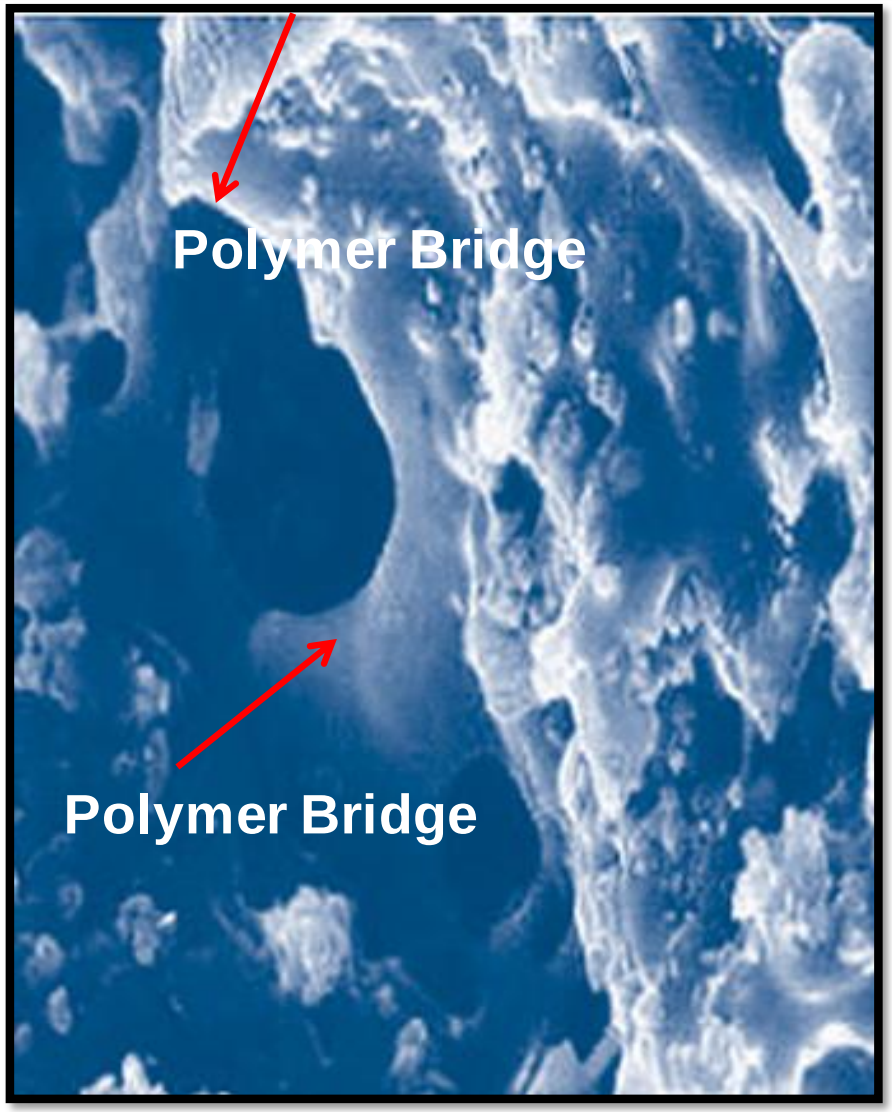
Chemical Resistance – TNCA Field Trial
One Year Later - 7 cycles

1% VAE

2% VAE

Chemical Resistance – TNCA Field Trial
One Year Later - 17 cycles

Microstructure of VAE-Modified Cement Paste



- SEM image of a VAE-polymer modified system shows large continuous areas of polymer film
- VAE-polymer forms films and bridges around the cement paste; acting to enhance the bond between the cement and aggregate, leading to improved compressive and flexural strengths
- VAE-polymer films “over-bridge” cavities around/near the cement paste which deters crack propagation
- VAE-polymer films and bridges help “shield” and protect the cement paste from chemical attack

Conclusions

- VAE-modified pervious concrete shows superior overall durability and resistance to raveling and cracking
- VAE-modified pervious concrete exhibits excellent chemical resistance to deicing salts
- VAE-modified cement paste shows outstanding compressive and flexural performance
- All VAE grades out perform unmodified and fiber modified products

Thank You for Your Attention