SPECIAL PUBLICATION FOR WORLD OF CONCRETE 2019
WACKER CHEMICAL CORPORATION

THE BENEFITS OF VINYL ACETATE-ETHYLENE (VAE) POLYMERS IN PERVIOUS CONCRETE MIXES

Introduction

Pervious concrete or permeable concrete is increasingly used in the United States as a means to enable sustainable storm water management and improved water quality. Pervious concrete is a mixture of coarse aggregates, water, cement, and admixtures. The absence of fine particles in this system allows for an open pore structure, thereby making it water permeable (Figure 1).

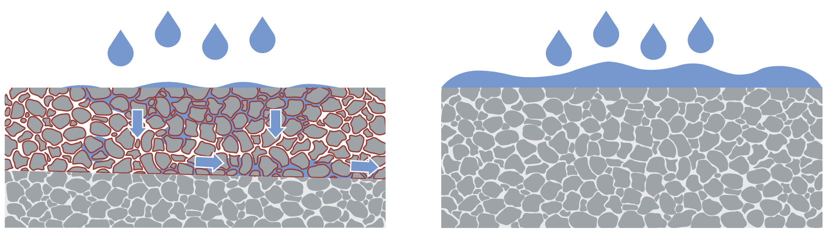
Although pervious concrete has been around for more than thirty years, the application is fairly new in North America. Pervious concrete installations have experienced many challenges in the field.
Raveling resistance, loss of flexibility and degradation by deicing salts and chemical runoff have impeded its wider spread promotion and use. Pervious concrete mix designs require careful thought and an understanding of the additives used along with their function/interactions. Admixtures such as mid-range water reducers and hydration control admixtures are often utilized. Polymers may also be added to enhance the performance of the mix system.

This technical article will focus on the benefits provided to pervious concrete when incorporating Vinyl Acetate-Ethylene (VAE) co-polymers. In addition, recent case studies are presented to illustrate the application of VAE-modified concrete pavement as public infrastructure.

VAE co-polymers come in both solid and liquid forms. VAE polymers are now being used in pervious concrete mixes to provide rheology benefits and improve impact, abrasion, freeze-thaw, deicing salt resistance and overall durability. Typical mix designs with and without VAE polymer are shown in Table 1:

Figure 1. Typical Pervious Concrete Versus Normal Concrete.

Polymer-modified pervious concrete / **Normal, non-porous concrete**



Water passes through the pores in the concrete and recharges the local aquifer.

On normal solid concrete, the water collects on the surface and drains to storm sewers.

Table 1: Typical Pervious Concrete Mix With and Without VAE.

lb/yd3	Unmodified	VAE-modified
Cement	500	500
Aggregate	2,500	2,500
Water	165	165
VAE (1.5, 2.5, 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

Several properties were evaluated and the resulting benefits are detailed discussed in the following sections.

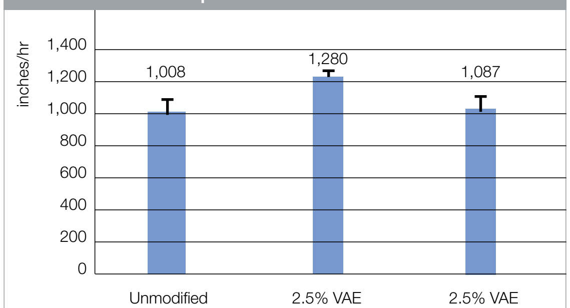
TEST METHODS

Several tests were performed to evaluate VAE-modified pervious concrete mix designs. The tests included: infiltration; impact resistance (to evaluate surface raveling); abrasion resistance; split tensile; compressive strength; flexural strength and chemical resistance to deicing salts in freeze-thaw cycles.

Infiltration:
With VAE, Excellent Water Infiltration Rates Can be Achieved Easily

Infiltration tests were performed per ASTM C1701. VAE modification does not impede water infiltration rate as compared to unmodified pervious concrete (Figure 2). Infiltration rates also depend on the aggregate sizes, admixtures and density of the pervious concrete mix. Excellent water infiltration rates can be easily achieved by manipulating the components/ parameters in conjunction with VAE modification.

Figure 2. Infiltration Per ASTM C1701 of Unmodified and VAE-Modified pervious Concrete.

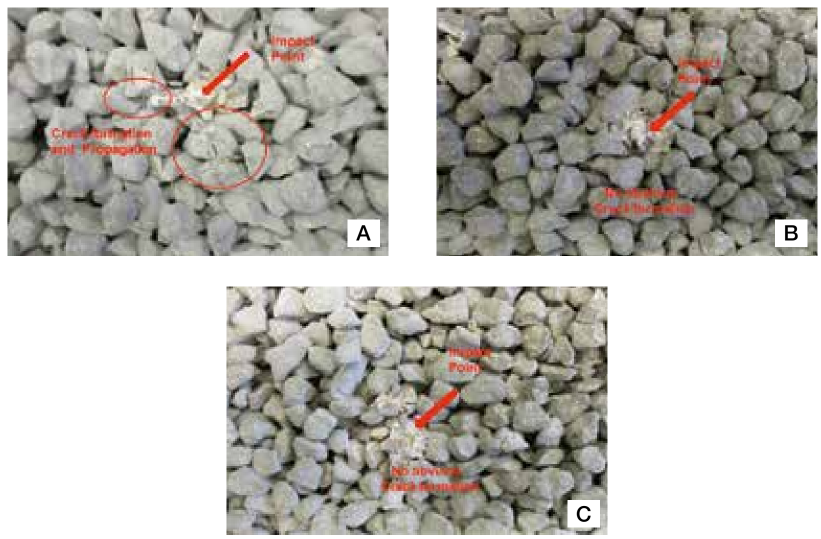


Impact Resistance:
VAE-Modified Samples Showed no Cracking at Various Dosages

Surface raveling is caused by cracking of the cement paste that bonds the aggregate. Susceptibility to cracking was evaluated by performing an impact resistance test. Pervious concrete blocks (305 mm x 305 mm x 76 mm) covered with polyethylene sheets were cured at room temperature for 28 days before testing and a metal ball (1045 g) was dropped from a calibrated height (610 mm) to impart a consistent impact energy (6J). The extent of cracking and raveling was then evaluated visually and via photography/ microscopy techniques.

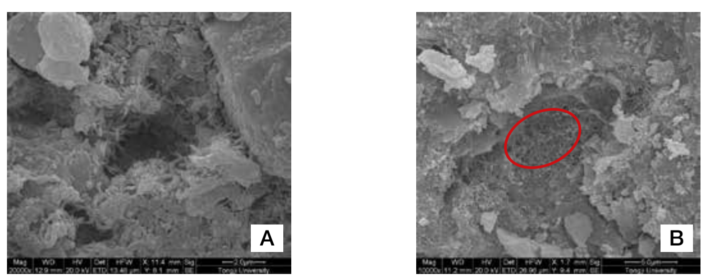
In general, unmodified pervious concrete exhibited cracks propagating from the impact site, whereas VAE-modified showed no cracking at various dosages (Figure 3). Scanning electron microscopy (SEM) images (Figure 4) show VAE-modified pervious concrete forms a densified microstructure of cement hydrates and polymeric membrane, which provides improved mechanical and chemical stability.

Figure 3



A) Unmodified pervious concrete showing crack formation due to impact; B) and C) VAE-modified pervious concrete at 2.5% and 5.0%, respectively, with no crack formation.

Figure 4



SEM images of A) unmodified pervious concrete and B) VAE-modified pervious concrete.

Abrasion Resistance: 30% Less Mass Loss of VAE-Modified Pervious Concrete

Abrasion resistance of unmodified and VAE-modified pervious concrete was evaluated per ASTM C1747 and the percent mass loss at 500 revolutions was measured. Percent mass loss of VAE-modified pervious concrete was 30% lower (better) than the unmodified mix. (Figure 5). With this significant reduction in mass loss, it can be concluded that there is less raveling tendency, thereby improving pavement durability and lifecycle.

Split Tensile: VAE-Modified Samples Exhibited Similar or Increased Split Tensile Strengths

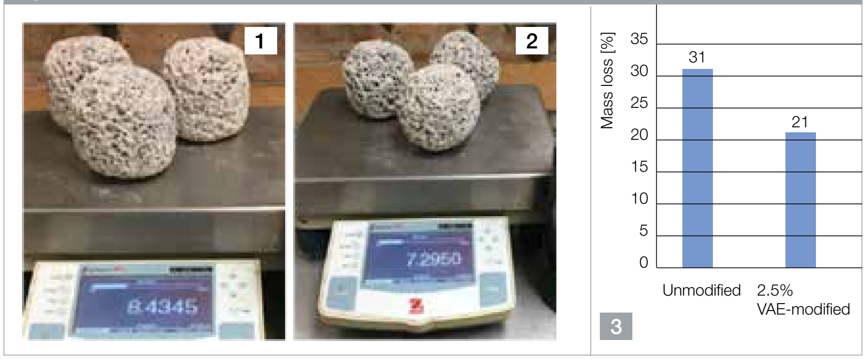
Split tensile tests were performed on 3" x 6" (76 mm x 152 mm) cylinders. Two sets of samples were allowed to cure under polyethylene sheets at room temperature for 28 days and then split at room temperature. Generally, VAE-modified samples exhibited similar or increased split tensile strengths vs. the unmodified samples (Figure 6). VAE-modified pervious concrete exhibits improved flexibility, durability and pavement life cycle.

Chemical Resistance: VAE-Modified Concrete Lasted Nearly Twice as Much Without Any Raveling

In cold regions, deicing salts are often applied onto pervious concrete pavements to treat snow covered areas and prevent icing. Deicing salts are predominately chlorides of sodium, magnesium and calcium and/or acetates of sodium and calcium metals.

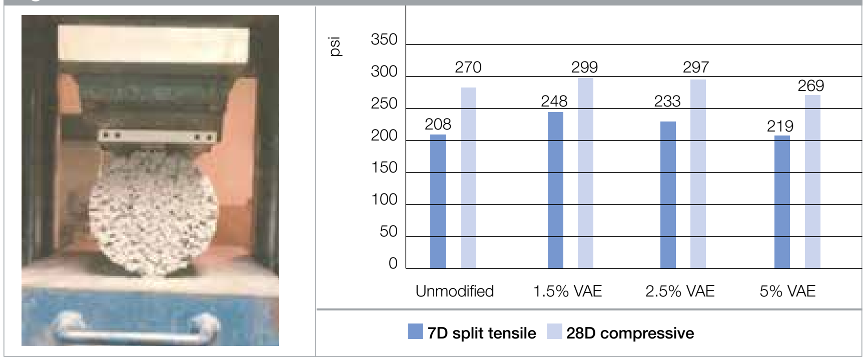
Chemical resistance to deicing salts was evaluated by partially immersing 3" x 6" (76 mm x 152 mm) cylinders in a bucket containing 10% Magnesium Chloride ($MgCl_2$) solution and then placed in a freezer at -20 °C for 12 hours, removed and thawed in the same solution for 12 hours at room temperature (Figure 7, Left). This is perceived as an aggressive test since freezing and thawing in the $MgCl_2$ solution exerts both mechanical and chemical stress on the pervious concrete. A 12 hour freeze and 12 hour thaw was considered one full cycle. Unmodified samples failed after 35 cycles whereas the VAE-modified concrete lasted 60 cycles without any signs of raveling or failure. (Figure 7, right).

Figure 5



Abrasion resistance per ASTM C1747: 1) after abrasion, VAE modified; 2) after abrasion, unmodified; 3) % mass loss of unmodified and VAE-modified pervious concrete

Figure 6



Left: Split tensile test. Right: Split tensile of VAE-modified and unmodified pervious concrete at 7 and 28 days of curing.

Figure 7

Left: Resistance to deicing salts' test
Right: Samples after 35 cycles.

Evaluation of Cement Paste

To further illustrate the value of adding VAE's to pervious concrete, cement paste was evaluated for compressive and flexural strengths. The cement paste was formulated as shown in Table 2.

Compressive Strength: VAE-Modification Increases the Compressive Strength by 30–50%

The compressive strengths of 2" x 2" (50 mm x 50 mm) cement paste cubes were evaluated per ASTM C109 at 7 and 21 day curing at room temperature covered under polyethylene sheets. As shown in Figure 8, VAE-modification increases the compressive strength by 30 - 50% vs. the unmodified cement. Due to the stronger cement paste, the durability of the pervious concrete mix is improved.

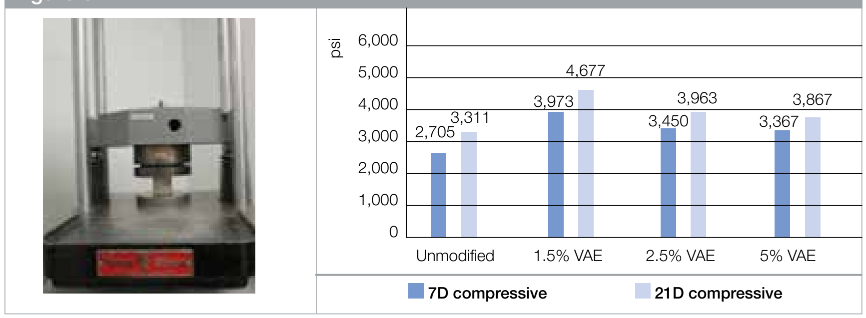
Flexural Strength: VAE-Modification Improves Flexibility by 15–20%

The flexural strength of unmodified and VAE-modified cement paste was evaluated on 1.57" x 1.57" x 6.3" (40 mm x 40 mm x 160 mm) prism specimens per ASTM C348 at 7 and 21 day curing. As shown in Figure 9, VAE-modification increases flexural strength by 15 - 20%. Improving cement paste flexural strength improves the flexibility of the pervious concrete and reduces cracking susceptibility and surface raveling.

Table 2: Cement Paste Formulation

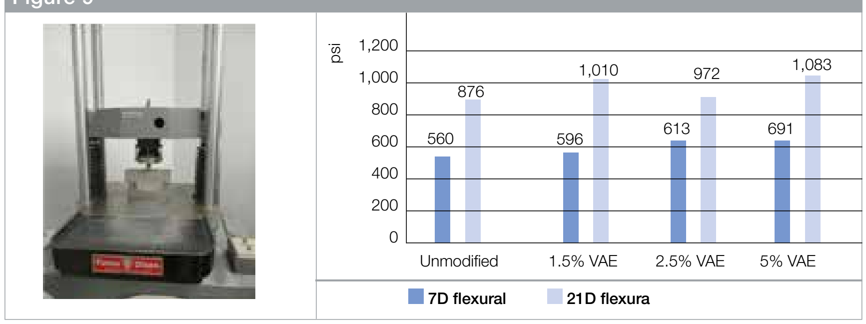
	Dosage
Cement	1 part
Sand	2.75 parts
Water	w/c = 0.5
VAE (1.5, 2,5, 5.0% o.c.w.)	0, 1.5, 2.5 and 5% o.c.w.

Figure 8



Left: Compression test method.
Right: Compressive strength of unmodified and VAE-modified cement paste.

Figure 9



Left: Flexural test method.
Right: Flexural strength of unmodified and VAE-modified pervious cement paste.

CASE STUDIES

The Village of Des Plaines, IL
Alleviating Flooding Issues

Flooding is often an issue in the urban areas. Much of the neighborhood alleys were originally paved with asphalt. To help reduce flooding and recharge local goundwater aquifers, the local government has begun to remedy this issue with permeable surfaces.

In October 2018, a 1300 yard residential alley was paved with VAE-modified Filtercrete™ pervious concrete system. To install the pavement, the village of Des Plaines, IL teamed with Ozinga, one of the first ready mix producers working with pervious concrete.

City of Spokane, WA:
Keeping Pollutants Out of the River

In Spokane, stormwater and sewage share piping to the treatment facility. In some cases, the pipes get overloaded and over flow their contents into the river. To stop this pollution, the city has started a pilot project to test the viability of different permeable pavements. It's a new approach of managing stormwater, naturally allowing the earth below to filter the water before it reaches the river.

In August 2018, a 500 yard area was paved with VAE-modified pervious concrete, including road lanes, parking lanes and a 4-way intersection. Central Pre-Mix Concrete Co, a CRH Americas Materials Company, provided the engineering and construction.

Conclusion

The current study evaluated the use of VAE polymers (solid and liquid) in pervious concrete. The beneficial effects on various properties such as: impact resistance, abrasion resistance, split tensile, chemical resistance (resistance to deicing salts) and cement paste were determined. Generally, VAE-modified pervious concrete exhibited higher impact resistance, abrasion resistance and split tensile strength, which improves overall pavement flexibility, durability and life cycle.

VAE-modification significantly improved resistance to an aggressive 10% $MgCl_2$ solution, which was used to simulate deicing salt attack. In regions where failures of pervious concrete occur due to chemical attack on the cement paste, VAE polymer technology provides significant mitigation. To further prove that VAE technology provides a wide array of performance benefits, cement paste evaluations showed significant improvement vs. the unmodified cement paste for both compressive and flexural strength.

Pervious concrete is a sustainable storm water management tool whose adoption has been slowed due to challenges with field performance. The addition of VAE polymers to the mix design mitigates and/or eliminates these challenges and should be considered for use in all future pervious concrete placements.

WACKER POLYMERS, Headquarters, 6870 Tilghman Street, Allentown, PA 18106-9346, USA, Tel. +1 (610) 336-2700
info@wacker.com, www.wacker.com, www.wacker.com/socialmedia

7663us/01.19