1K Water-Based CONCRETE COATINGS: Achieving Top Performance

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This article discusses the current available water-based acrylic, styrene acrylic, and modified epoxy acrylic; one-component technologies for concrete coatings; and low VOC technologies and options. With environmental regulations and advances in dispersion and emulsion technologies, chemists and formulators are confronted with several, possibly confusing choices. This study will help provide chemists and formulators with a better understanding to assess performance balance for concrete substrates. Benefits and performance properties of current and newer technologies are presented together with several practical options.

INTRODUCTION

Concrete coatings is an extensive subject that encompasses a wide variety of protective, functional, and decorative coatings. The choice of coating is determined by the substrate (concrete) condition, environmental issues, and the desired performance properties. Whatever the ultimate purpose of the coating may be, it is crucial that we understand concrete as a substrate as well as its proper surface preparation.

Concrete is the most commonly used building material. It is a mixture of water, portland cement, aggregates (sand, gravel), pozzolans (soda ash) and air (added on purpose). Water in this mixture combines with cement to form a rigid mass called concrete. Usually concrete is strong; however, environmental elements like water and UV radiation attack the surface both physically and chemically. Physical attacks cause failure; concrete being porous, water is absorbed and released within the concrete and causes spalling or cracking. Therefore, it is necessary to protect its surface from deterioration and contamination by applying a coating. Surface preparation is also of prime importance to the durability and adhesion of applied coatings.

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This article will mainly focus on horizontal concrete surfaces that require one-component (1K) protection.

There are several reasons to coat these surfaces:

- To seal from moisture and help reduce dust
- To impart longer life and better wear
- To improve chemical resistance
- To impart functional properties—non-skid surfaces, static control, etc.
- To improve abrasion resistance
- To protect from corrosion
- For aesthetics

There are various technologies used to provide concrete coatings. They are:

- Acrylics (solventborne and waterborne)
- Epoxy
- Urethanes
- Polyurea
- Hybrids

These coatings serve functional, protective, and decorative purposes. In recent years, decorative coatings for concrete have gained popularity and are primarily based on acrylic emulsions. Emulsions include pure acrylic, acrylic styrene, epoxy acrylic, and vinyl acrylic. This technology also provides protective and functional value: chemical resistance, good corrosion and weathering resistance, alkali resistance, abrasion resistance, dirt pick-up resistance, and good gloss. Most of the 1K pigmented commercial coatings fall into this category.

DISCUSSION

The concrete market has two main user segments: professional contractors and homeowners or "do it yourself" (DIY). These two types of users have different needs; the contractor needs a product that can be applied fast for quick job turnaround, and meets minimum performance properties to avoid warranty claims. Since skill levels of contractors vary, the product must also be easy to use. Paint formulators face different challenges with homeowners since they may have minimal application skills, do not prepare the surface properly, and often skip instructions.

Health and environmental issues are a big concern, as increasing government regulations limiting organic solvents (volatile organic compounds or VOCs) continue to be severe. It is a challenge to formulators and resin producers to bring user friendly products that meet the performance level that the market demands.

These concerns led to certain restrictions in technologies for this market. While high solids, solventborne and two-component (2K) systems can be used by contractors, products for the DIY market are limited to 1K waterborne systems. This article limits its focus to 1K waterborne coatings for direct-to-concrete applications.

For this market there are three different product classes—paints, stains, and sealers. All three can be pigmented or clear. Paint is designed to form a continuous film over the concrete to protect it and is usually pigmented. A stain is lower in viscosity than paint and is formulated to penetrate the concrete. Stains can be transparent, semitransparent, or opaque, and are usually pigmented. Sealers, as their name implies, seal the concrete and are generally clear.

While the product classes are different, they all share the same performance requirements. These are:

- Water resistance and wet adhesion
- Hot tire resistance
- Chemical resistance
- Stain resistance
- Abrasion resistance
- Hardness

The main differences in performance would be dependent on the application where it is being used. Garage floor products and other coatings that see automobile traffic require hot tire resistance, water resistance, abrasion resistance, and chemical resistance to household chemicals and automotive fluids. Patio stains, sealers, and paints need water and abrasion resistance and good anti-stain properties. Porch and floor coatings require water resistance and need to have good wear properties. Thus, the end use of the coating determines what balance of properties are needed (*Figure* 1).

For this study, the following properties were tested with regard to pigmented coatings:

- Water resistance and wet adhesion
- Taber abrasion resistance
- Pendulum (Koenig) hardness
- Hot tire resistance
- Chemical and stain resistance to household chemicals and automotive fluids

Figure 1—Physical properties needed for different coating types.

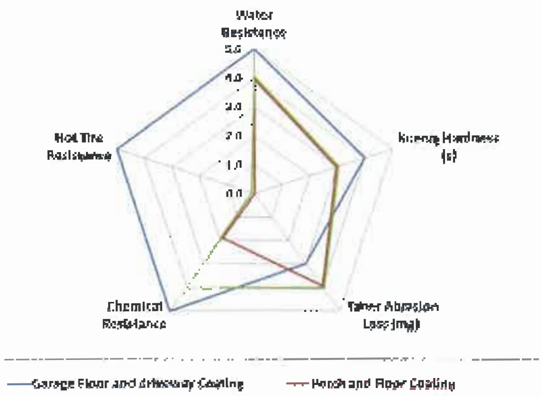


Table 1—Surfactant Influence on Coatings Properties

Test Property/Coating	Coating A	Coating B
Surfactant level	1	0.1
Minimum film forming temperature (°C)	19	23
Hot tire resistance[a]	4	3
Water resistance and wet adhesion[a]	1	3
Taber abrasion resistance (mg lost)	127	192
Koenig hardness (sec)	34	37
Chemical and stain resistance[b]	32.5	31

(a) Results are based on a 1–5 rating with 5 being best.
(b) Results are based on a 1–5 rating as above for eight chemicals (maximum 40).

For clear sealers, the following properties were tested:

- Water resistance
- Hot tire resistance
- Chemical and stain resistance to household chemicals and automotive fluids

Influence of Surfactant Level in the Emulsion

Water-based coatings contain emulsions which are dispersed discrete particles in a hydrophilic surfactant. This surfactant plays an important role in end film properties. In testing of two coatings with the same formulation, with the exception of surfactant level, there were marked differences observed. In the example in *Table* 1, Coating A had the surfactant suppliers optimal surfactant level. Coating B was made at 10% of that level to see how lower surfactant levels change coatings properties due to changes in hydrophobicity as well as other properties.

The coating with less surfactant showed a more hydrophobic nature and was harder. This translates to better water resistance and poorer hot tire resistance. A picture of the hot tire resistance of coating A (left) and Coating B (right) is shown in *Figure* 2.

Figure 2—Hot tire resistance of coating A (left) and coating B (right).

PIGMENTED PAINTS, STAINS, AND SEALERS

Hot Tire Resistance Testing

As there is no ASTM test method for hot tire pickup resistance, test methods have been improvised. Hot tire resistance of coatings is difficult to perform in a reproducible manner that also represents what will happen in real life situations. The test procedure developed used a vehicle to park on the coatings under controlled temperature conditions. Tests were conducted using a standard coating to check if there is a difference between the four tires on the vehicle (front/rear and left/right). Tests were also conducted right after driving the vehicle at highway speeds for 30 min and under controlled temperature conditions (72°F, 22°C). In all cases there was no difference in the hot tire test results. Thus, all testing was conducted in an interior location at 72°F. The vehicle was a 4500 lb SUV with Maxxis Bighorn off-road tires. The softer off-road tires tended to stain the coatings easier than other tires tested, producing a more sensitive test. Since tires contain tall oil, most tire staining is a result of the migration of this brownish oil. The more hydrophobic the film is, the greater the staining. Also, the softer the film, the greater tendency there is for discoloration and deformation from the tire. Coatings were applied on test blocks at constant film weight and dried at 72°F for 72 hr before being parked upon for eight hours under the same conditions (*Figure* 3). The coatings were rated on a 0-5 scale, with 5 being best (see rating criteria in Appendix 1).

Coatings were tested for solids and a given solid level was applied to the test substrate with a paint brush to simulate real life conditions. In all cases a standard coating was included in each test run to confirm reproducibility.

Water Resistance and Wet Adhesion Testing

The coatings were applied on standard concrete blocks, using the same method as in hot tire testing. After 16 hr air cure, dry adhesion was tested using an x scribe and tape pull-off (Permacel tape). All coatings rated a 5. The block was then immersed in water for one hour and another tape pull off in another location was conducted after a towel dry of the film, and then rated again. Also rated was level of blistering (% area and size of blisters.) Testing was also conducted after 72-hr and 24-hr immersion (*Figure* 4). The ratings were 0 to 5 with 5 being best (see rating criteria in Appendix 1).

Figure 3—Hot tire resistance results for pigmented coatings.

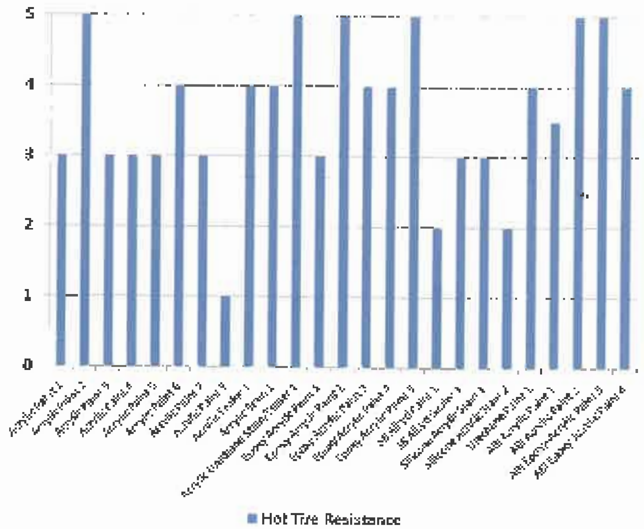


Figure 4—Water resistance results for pigmented coatings.

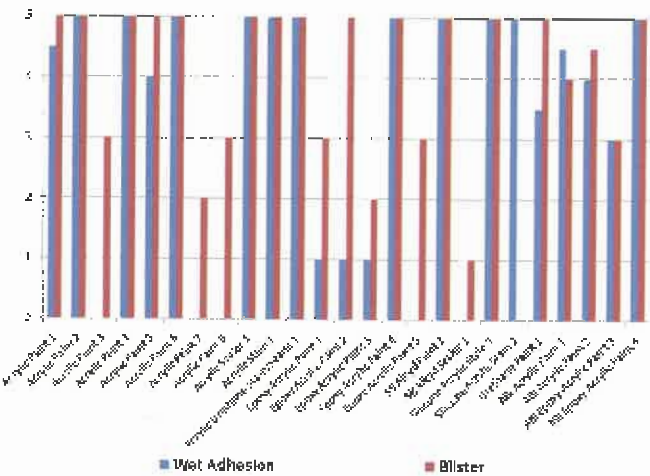


Figure 5—Chemical resistance for pigmented coatings.

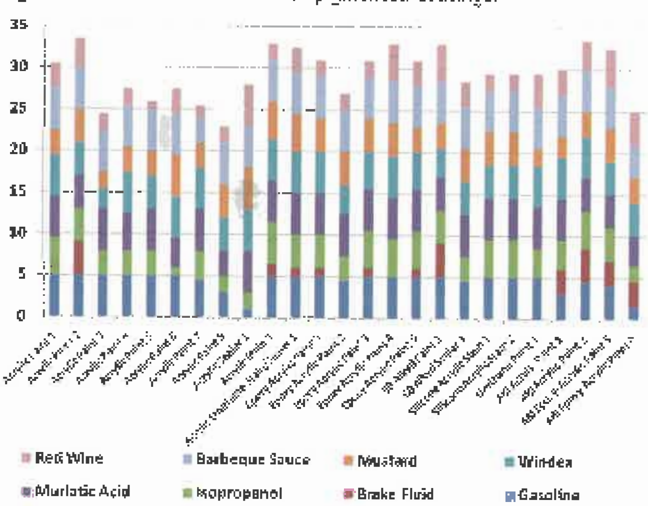


Figure 6—Koenig hardness for pigmented coatings.

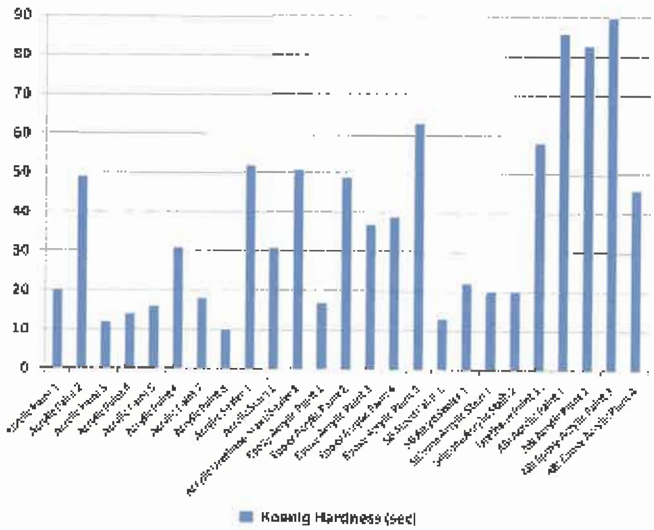


Figure 7—Taber abrasion for pigmented coatings.

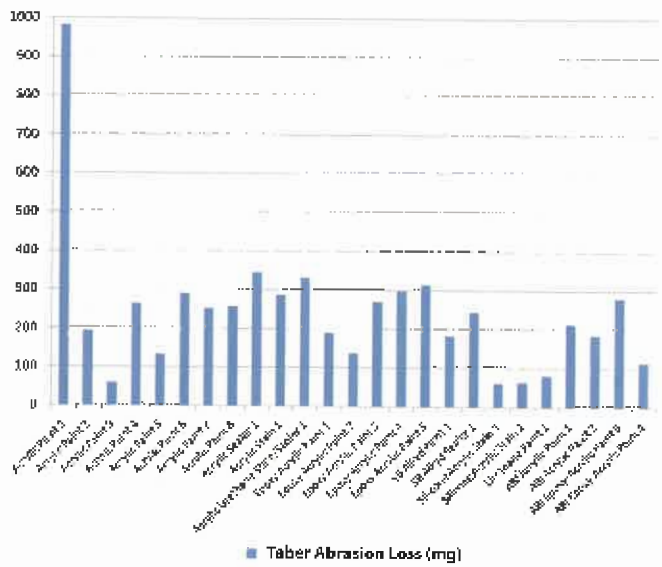


Figure 8—Overall results for pigmented coatings.

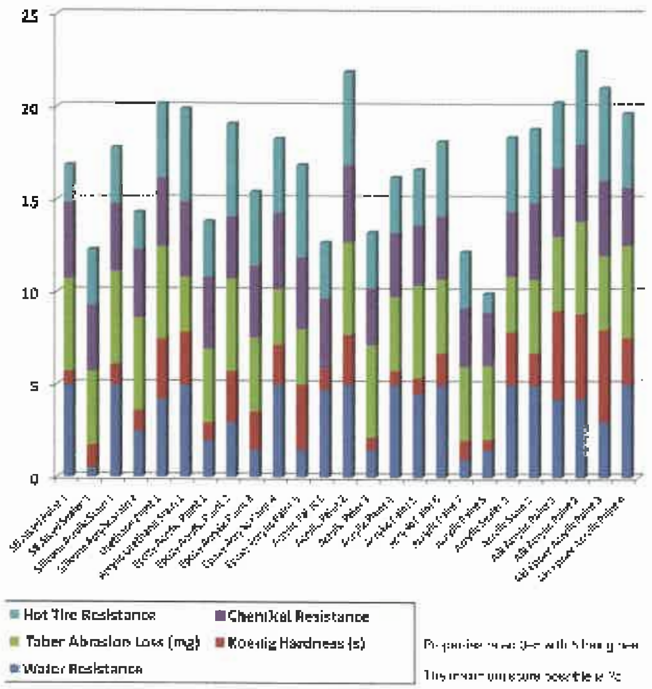


Figure 10—Overall results for pigmented epoxy acrylic coatings.

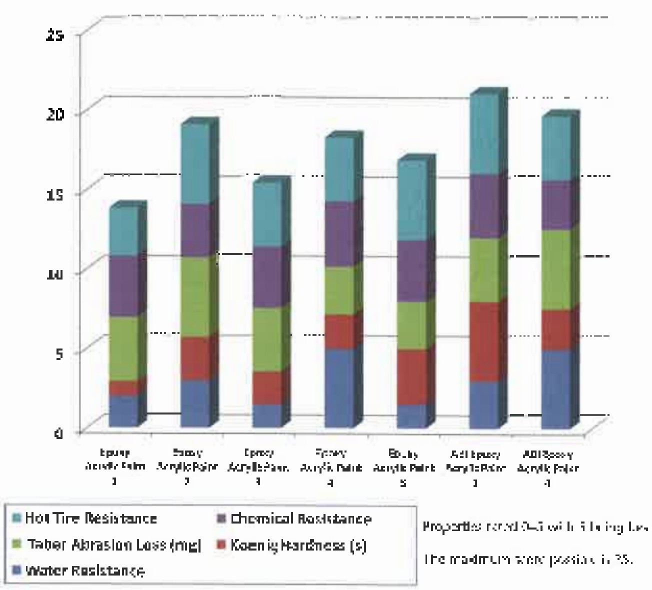


Figure 9 -Overall results for pigmented acrylic coatings.

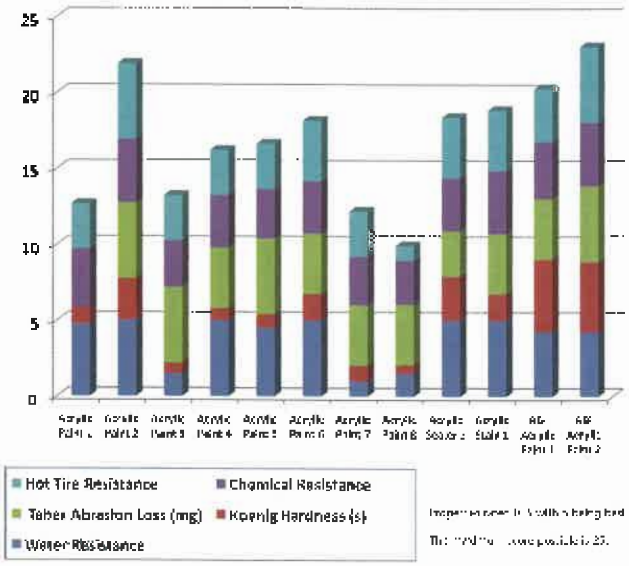


Figure 11 Overall results for pigmented modified acrylics and non-acrylic coatings.

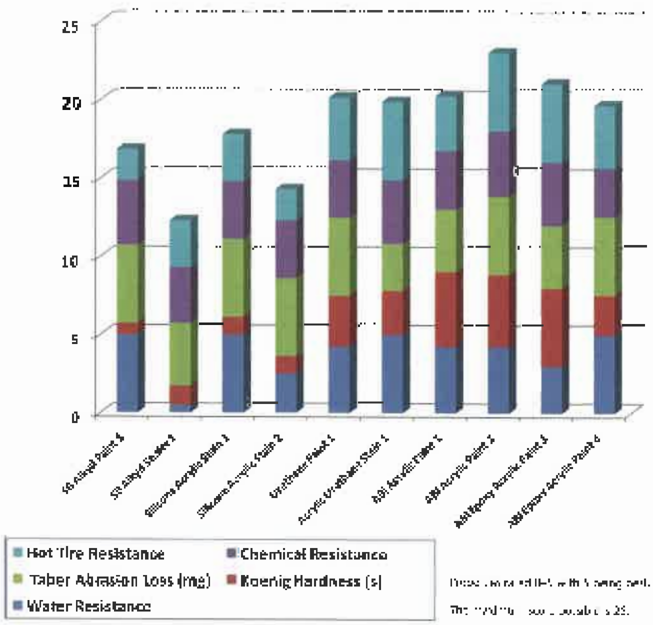
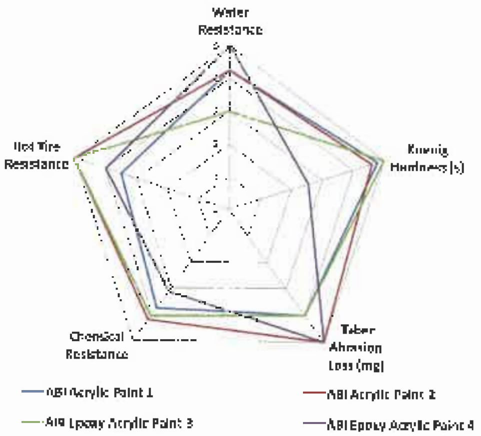


Figure 12—Comparison of coatings results.



Chemical and Stain Testing

Chemical and stain resistance tests for the following chemicals are reported (*Figure* 5):

- Mustard
- Red wine
- Barbeque sauce
- Brake fluid (DOT 3)
- Gasoline
- Isopropyl alcohol
- Muriatic acid
- Windex®

Also tested and not reported were: radiator fluid, power steering fluid, coffee, and Formula 409. All the coatings showed the same resistance and thus there was no differentiation.

The coatings were drawn down and allowed to dry for seven days at room temperature. Spot tests were conducted for one hour and then the coatings were rated 0–5 for each chemical with 5 being the best. Results were then added, giving a total rating with a maximum of 40.

Koenig Hardness

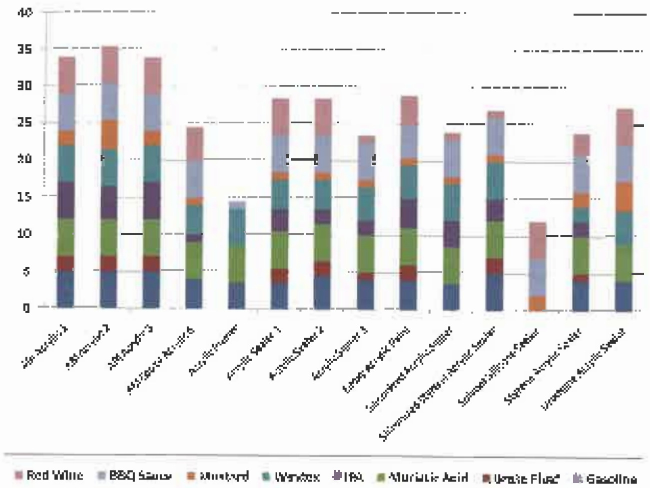
The coatings were drawn down 8 mils wet on glass and allowed to dry for seven days (*Figure* 6).

Taber Abrasion

The coatings were drawn down 10 mils wet on scrub charts. They were then run 1000 cycles with 1000-gram weights using CS-17 wheels (*Figure* 7).

All properties were then rated 0–5 with 5 being the best. The results are charted in *Figure* 8. To facilitate viewing, the products have been broken out by resin technology (*Figures* 9–12).

Figure 13—Chemical resistance for clear coatings.

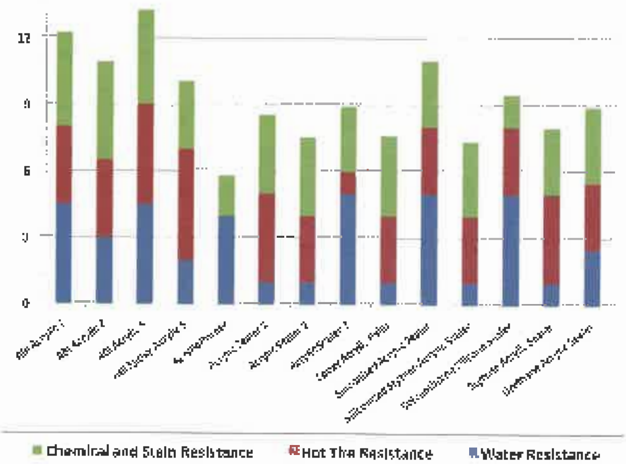


CLEAR PAINTS AND SEALERS

Clear coatings used on concrete have many properties, and these are both functional as well as aesthetic in nature. Newer trends in concrete coatings have increased the use of clear coatings as stand-alone products as well as topcoats on stained or coated concrete. This results in coated concrete being used in architectural and industrial applications where other materials were used in the past.

As a result of the different ways clear coatings are applied and used on concrete, their properties are not the same as pigmented coatings. They tend to have very low viscosity and solids to better penetrate the concrete substrate. The low viscosity of the coating prevents consistent film formation on the nonporous substrates

Figure 14—Overall results for clear coatings.



used for testing. This makes it difficult to test for hardness and abrasion resistance. Due to these difficulties the more applicable tests are: water resistance, hot tire resistance, and chemical/stain resistance.

Testing was conducted the same way as the pigmented coatings and is reported in *Figures* 13 and 14.

The coatings were drawn down and allowed to dry for seven days at room temperature. Spot tests were conducted for one hour and then the coatings were rated 0–5 for each chemical with 5 being the best. Results were then added, giving a total rating with a maximum of 40 (*Figure* 13).

The coatings were rated 0–5 for chemical and stain resistance, hot tire resistance, and water resistance with 5 being the best. Results were then added, giving a total rating with a maximum of 15 (*Figure* 14).

CONCLUSION

One-component concrete coatings need different properties depending on their intended application and end use. Because of the different requirements from professional contractors and consumers, there are limitations on which technologies work for both. The most cost-effective solution for coatings companies is one coating that can be used for different applications by different types of users. CT

APPENDIX 1: RATING SYSTEM FOR TESTS

Hot tire resistance:

5—No impact on the film
4—Very light discoloration and no film deterioration
3—Moderate discoloration and no film deterioration
2—Heavy discoloration and/or light film indentation or deformation
1—Heavy film indentation or deformation and/or little loss of adhesion
0—Complete deterioration of the film

Water resistance, wet adhesion, and blistering:

5—No impact on the film
4—Less than 5% loss of adhesion or blistering and/or light softening
3—Less than 20% loss of adhesion or blistering and/or light softening
2—Less than 50% loss of adhesion, severe softening or heavy blistering
1—Heavy little loss of adhesion; over 50%
0—Complete deterioration of the film

Chemical and stain resistance testing:

5—No impact on the film
4—Very light discoloration and no softening or film deterioration
3—Moderate discoloration and/or light softening and no film deterioration
2—Heavy discoloration and/or moderate film softening allowing easy deformation
1—Heavy film softening with little loss of adhesion
0—Complete deterioration of the film

Koenig Hardness

The coatings were rated versus the hardest coating with a hardness of 90 seconds, to give a value of 0–5. Rating = (coating hardness / 90) * 5

Taber Abrasion:

The coatings were rated versus the coating with the highest abrasion loss to give a value of 0–5, with 5 being the best.