Fast-Cure Amine Technologies Enable Rapid Return to Service in Floor Coatings

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INTRODUCTION

Concrete is one of the most used construction materials due to its strength, durability, resilience, safety, and low cost. In the flooring applications, demand for concrete for interior and exterior use in residential and commercial settings is growing significantly thanks to the strong construction market around the globe.

Coatings for concrete floor not only protect concrete from wear, deterioration, and contamination, but also enhance the physical performance, provide chemical resistance, and improve aesthetics. Today, architects, specifiers, and end-users can select from a broad range of technologies and finishes to protect and enhance the aesthetics of the concrete floor. Each technology or finish brings specific benefits and introduces trade-offs in other areas. Polymer technology is among the most popular choices for concrete flooring and include thermoset chemistries such as amine-cured epoxy, urethane, urea, methacrylate, and acrylic. The preferred option depends on the type of application and the required performance properties.

High-performance floor installation using polymer technology requires at least two stages (primer and topcoat), and preferably three (including a midcoat) as shown in *Figure 1*. With each stage needing time to cure, fast-cure speed to reduce the total installation time translates into minimum downtime and fast return to service. This has been a key market driver across the coating industry. Yet, fast-cure speed often comes as a trade-off for short working time. Balancing fast cure and good working time remains a challenge for coating industry. This article describes fast-cure amine technologies using a system approach that enables the installation of a multistage floor system within one day while maintaining good working time at each stage and high-performance of the entire system.

As shown in *Figure 1*, the concrete primer serves to penetrate and seal the concrete pores because concrete is a porous and permeable material. Primer establishes good adhesion and bonding between the concrete substrate and the polymer overlayment. Cured concrete traps various amounts of moisture, about 1% to 2% in ambient dry concrete, and 4% to 5% in damp and wet concrete; however, the corresponding relative humidity inside concrete is as high as 75% to 95%. When a primer is applied at low temperature, applicators also need to consider the dew point to avoid moisture condensation during or shortly after the application of the primer. Two-part amine-cured epoxy primers have proven to tolerate the challenges introduced by concrete as a substrate and provide good adhesion to dry and damp concrete even at low temperature and high humidity. In addition, advancement in waterborne technology equips the formulators with waterborne epoxy system as a new tool to meet performance, low volatile organic components (VOC) and low emission requirements.[1–3] It has gained wide acceptance as an environmentally friendly alternative to the solventborne system due to the improved performance made during the past two decades.

Coated on top of the primer is the polymer midcoat and then topcoat. Until recently, topcoats have been dominated by two key technologies: amine-cured epoxy and polyurethane based on polyol-cured isocyanate. Lately, another two-component (2K) aliphatic polyurea, referred to as polycarbamide or polyaspartic technology, has been developed to practical industry use. It is derived from polyamine cured isocyanate chemistry.[4–7]

This relatively new polycarbamide technology utilizes a partially blocked amine to react more slowly with the aliphatic isocyanates to produce a modified aliphatic polyurea as illustrated in *Figure 2*. A diamine is reacted with dialkyl maleate via the Michael Addition reaction to convert primary amine to hindered secondary amine as the resulting polycarbamide curing agent, which is also often referred to polyaspartic ester. As the curing agent is a much bigger molecule, less of the isocyanate is needed based on 1:1 stoichiometry between isocyanate and curing agent. This could result in an overall lower system cost per applied coating thickness since the aliphatic isocyanate is often the most expensive component of the system. The polycarbamide curing agents are developed to provide formulators with good balance of fast cure speed and working time or pot life. In addition, polycarbamide coatings offer excellent UV and light stability and have a very low yellowing tendency. As concrete floor

FIGURE 1—Representative examples of a high-performance flooring system.

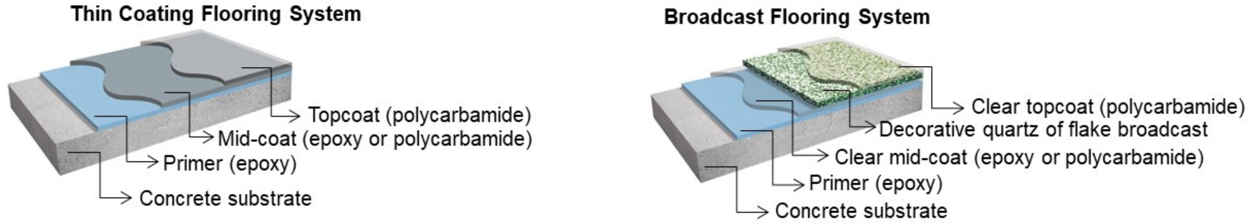
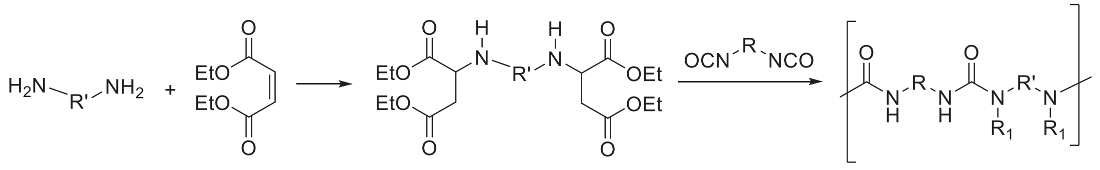


FIGURE 2—Polycarbamide technology.



coating, polycarbamides can be installed in both clear and pigmented form, and broadcast media such as quartz and/or vinyl paint chips, and metallic pigments can also be incorporated to enhance the aesthetics and add personalization. This article will discuss polycarbamide technology as topcoats in detail.

Each technology offers a unique set of features and benefits in cost, handling, formulation latitude, property development, emission compliance and mechanical and chemical properties. Which technology to use in a floor system will depend on the application and the target performance requirement. This paper presents a system approach for a complete floor system and demonstrates the synergy when utilizing high-performance epoxy primers, both solvent-free and waterborne systems, in conjunction with polycarbamide topcoats. The end-result of the system approach is a high-performance floor with a unique combination of enhanced properties, rapid return to service, and good working time while also meeting the demand for low emissions.

TABLE 1—Standard Test Methods

PROPERTY	ASTM TEST METHOD
Specular gloss	D523
Gardner color	D1544
APHA color	D1209
Thin film set time	D5895
Dry hard time (thumb twist)	D1640
Carbamation resistance	ISO2812
Water spotting	D1308
Gel time (150 g mass)	D2471
Pot life	ISO9514
Persoz pendulum hardness	D4366
Shore D hardness	D2240
Intercoat adhesion	D3359
Impact resistance	D2794
Taber abrasion	D4060
QUV accelerated weathering	G154
Tensile properties	D638
Concrete adhesion	D7234
Moisture vapor transmission	E-96

EXPERIMENTAL

The standard test methods listed in *Table 1* were used to evaluate clear-coating and casting performance. Curing agent and resin with designated stoichiometry were mixed in a speed mixer for one minute at 3000 rpm. The mixture was drawn down on a substrate at ~150 μm (6 mil) wet thickness unless otherwise specified. The coatings were typically cured at 23 °C/50% relative humidity (RH) or 10 °C/50% RH for 7 days before testing.

A carbamation-resistance test was carried out on a Leneta chart. After the coating was cured under the designated condition and time duration, a 1″ x 1″ cotton patch saturated with water was placed on the coating and covered with a watch glass to prevent water evaporation. After 24 hours, the cotton patch was removed, and the coating was dried with a clean tissue. The appearance of the coating was examined and rated in a scale of 1 to 5, with 5 being the best showing no effect from cotton patch, and 1 being the worst with a white surface.

Samples for Shore D hardness of the clear casting were prepared by using about 35 g of the curing agent and resin mixture poured into a circular metal or plastic lid with a diameter of 2.75 inches to produce about 0.4-inch thickness. Shore D hardness was measured using a Shore D Durometer with scale 0 to 100 after having been cured under the designated condition and time duration.

Water-vapor-transmission rate was determined using a modified ASTM E-96 method. Curing agent and resin with designated stoichiometry were mixed with a speed mixer for one minute at 3000 rpm. The mixture was drawn down on a Teflon film at 20 mil wet thickness using a bird bar. The coatings were cured at ~23 °C and ~50% RH for 7 days. The dry-film thickness was 11–12 mil. The coatings were cut into 2-inch diameter circles for testing. The test was run using a 4-oz plastic jar with the plastic lid diameter of $2^3/_4$ inches. The lid has a soft plastic liner. A circular hole of $1^3/_8$-in. diameter was cut with a Carver press. The coating was inserted between the lid and the liner to cover the hole. The coating was glued and sealed to the lid with a thin layer of epoxy glue along the edge. About 100 g of water was placed in the plastic jar and the lid was sealed with tape. The jar was placed in a temperature and humidity control room of ~23 °C and ~50% RH and the weight change was monitored over time.

RESULTS AND DISCUSSION

Primer Application to Concrete: Fast Cure and Excellent Adhesion

The amine curing agents used as primer in this study and their basic handling properties are summarized in *Table 2* and designated as WB-1 for waterborne and MVB-1 for solvent-free system respectively. The performance of the epoxy primers is shown in *Table 3,* and the advantages of these systems are exemplified by comparing with a typical solvent-free cycloaliphatic curing agent and a commercially available fast-cure, two-part waterborne primer system.

Waterborne Primer

WB-1 is a newly developed waterborne curing agent incorporating a novel crosslinkable fast-cure polyheterocyclic amine accelerator to facilitate fast cure speed at low temperature and high humidity.[9–10] WB-1 can be used with standard liquid epoxy resin and solid resin dispersion, and it is designed to be both a primer and a topcoat. The cure mechanism of the polyheterocyclic amine was investigated in detail, and the results show that polyheterocyclic amine accelerator promotes fast crosslinking and complete property development within short period of time compared to typical amines. In addition, the polyheterocyclic amine has been demonstrated to enhance adhesion to various substrates. Incorporating this polyheterocyclic amine into WB-1 curing agent enables ultrafast cure speed at low temperature and high humidity especially in combination with solid-epoxy-resin dispersion while maintaining excellent adhesion to concrete.

Data presented in *Tables 2* and *3* show WB-1 is low color, has medium viscosity and zero VOC, and can be diluted down to 20–25% and remains stable, which offers formulators the flexibility to add needed water to curing agent and make a 2K system instead of 3K system when water has to be added in the field. The low-mix viscosity of WB-1 primer system allows for easy handling and spreading. In addition, WB-1 maintains good working time of almost an hour with ultrafast cure speed of 1 hour at ambient temperature and 2 hours at 10 °C. For comparison, a commercially available fast-cure waterborne primer showed much higher neat viscosity and mix viscosity when used with solid resin dispersion, and had a short pot life. Furthermore, the cure speed of this comparative system at 10 °C lengthened significantly from 2 hours at room temperature to 7 hours at 10 °C.

For a primer, concrete adhesion is one of the most critical performance criteria. The WB-1 primer demonstrated excellent adhesion on dry and damp concrete at both ambient and low temperature. In contrast, the commercially available fast cure primer only adhered to dry concrete, and had limited adhesion on damp concrete at room temperature. It mostly peeled off from concrete at low temperature on damp concrete. The difference in appearance and performance is illustrated in *Figure 3*. The comparative primer showed whitish coating appearance likely due to trapped water and/or poor coalescing of solid resin particles.

TABLE 2—Basic Handling Properties of Curing Agents[8] Used for Primer

	WB-1	MVB-1
Color Gardner	≤ 4	≤ 5
Viscosity (mPa.s at 25 °C)	6,000–9,000	400–700
AHEW	250[a]	70
PHR	33[b]	36[d]
Gel time/pot life (min. at 25 °C)	50–60[c]	28[d]
Mix viscosity (mPa.s at 25 °C)	100–300	1050[d]
BK Phase III Time (h at 25 °C)	1	3
VOC (g/L)	0	0

[a] as supplied:- WB-1 contains 55% solid in water
[b] used with solid resin dispersion Ancarez AR555, 55% in water, EEW = 550 as supplied
[c] pot life determined by loss of coalescence with solid resin dispersion Ancarez AR555
[d] bisphenol-A resin such as Epon 828 diluted with C12-C14 glycidyl ether at 90/10 weight ratio, EEW 195

FIGURE 3—Adhesion of WB-1, left, and comparative primer on damp concrete at 10 °C/50% RH.

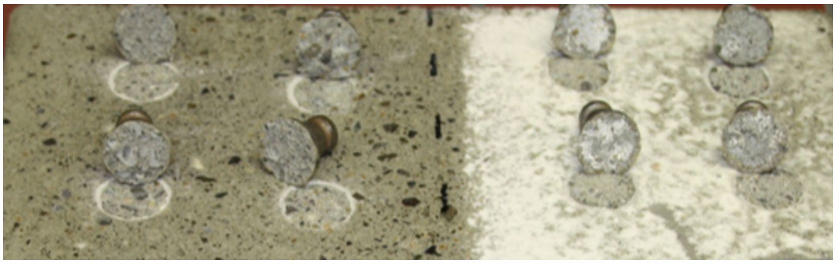


TABLE 3—Performance Properties of Epoxy Primers for Concrete

PROPERTIES	WB-1	COMMERCIAL WB WITH SER[a]	MVB-1	SOLVENT-FREE EPOXY[b]
Mix viscosity (mPa.s at 25 °C)	100–300	1000–2000	900–1100	450–550
Pot life or gel time (min. at 25 °C)	50–60	20–30	25–30	30–45
VOC (g/L)	0	0	0	0
Formulation solids %	25–45%	25–45%	> 95%	> 95%
Wet film thickness (µm)	200–600	200–300	300–500	300–500
Dry hard time (h at 25 °C)[c]	1	2	3	6–8
Dry hard time (h at 10 °C)[c]	2	7	6	24
Carbamation resistance[d]				
• 1d at 25 °C	5	4	4	4
• 2d at 10 °C	5	3	3	3
Concrete adhesion[e]				
• Concrete condition	Dry/Damp	Dry	Dry/Damp	Dry
• Adhesion strength	> 500 (damp)	> 450 (dry)	> 500 (damp)	> 400 (dry)
• cohesive failure at 25 °C on damp concrete	100%	70%	100%	100%
• cohesive failure at 10 °C on damp concrete	100%	5%	100%	50%

[a] a commercially available fast-cure waterborne system using solid resin dispersion
[b] representative average example of a two-pack epoxy primer, solvent-free system
[c] ASTM D1640
[d] ISO 2812
[e] ASTM D7234

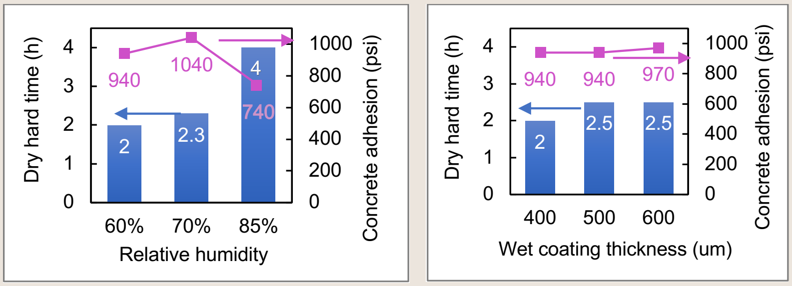


FIGURE 4—Left, WB-1 Primer performance at 10 °C on dry concrete vs various relative humidity at (400 µm (15.7 mil) wet coating thickness. Right, versus wet coating thickness at 50% RH.

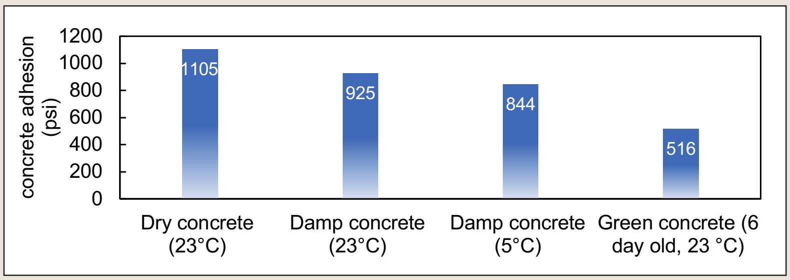


FIGURE 5—Concrete adhesion of MVB-1 under various conditions.

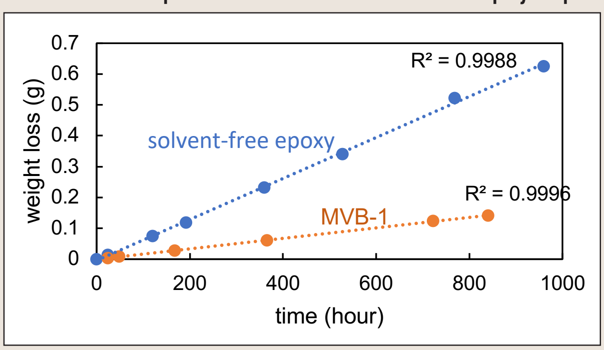


FIGURE 6—Moisture vapor transmission of MVB-1 and solvent-free epoxy comparison.

The outstanding performance of WB-1 is further exemplified in *Figure 4* where the effects of relative humidity and coating thickness did not show a strong impact on the cure speed and adhesion of the primer. In general, humidity can have significant impact on drying time and adhesion strength of the coating in waterborne systems. High humidity prevents water from evaporating therefore not only slows down the cure speed but also traps and retains water in the coating. The adverse effect is longer drying time and entrapped water resulting in poor coating appearance and inferior coating properties such as poor adhesion. Even at high humidity, the WB-1 primer continued to deliver dry speed of 4 hours and maintained excellent (>700) psi concrete adhesion. An additional key feature of WB-1 primer is the ability for high film buildup to about 600 µm (23.5 mil) wet-film thickness in one pass. *Figure 4* clearly shows the retention of fast drying time and excellent adhesion (>900) psi at higher film builds. This is contrary to the typical waterborne systems, where it is more difficult for water to evaporate from thick coating, especially at low temperature and high humidity. The slow water evaporation leads to longer drying time and entrapped water, as clearly shown in the data in *Table 3* and picture in *Figure 3* for the comparative commercially available fast-cure waterborne primer. Moreover, WB-1 provides good adhesion to green concrete where a fresh-poured concrete contains significant amount of moisture, and the properties of the concrete are not yet fully developed.

Primer WB-1 is designed for fast cure speed on both dry and damp concrete even at 10 °C with excellent adhesion, and can be overcoated within 2 hours. The easy handling (low mix viscosity and good working time) combined with rapid cure and excellent adhesion establishes WB-1 as top choice for fast-cure, high-performance flooring system, such as one-day floor where the entire system is installed and ready to return to service within one day.

Solvent-free Primer as Moisture Vapor Barrier

Solvent-free curing agent MVB-1 in *Table 2* is a modified polyamine curing agent designed also as moisture vapor barrier and intended for use with diluted liquid epoxy resin at ambient and low temperature application. As reported previously, concrete is a permeable material and allows the moisture originating from below the concrete or trapped in the concrete itself to migrate as a vapor phase to concrete surface.[11] Moisture transfer phenomenon accounts for many flooring failures resulting in significant financial losses annually. A moisture-vapor-barrier coating is proven to be an effective solution to address flooring failures by minimizing moisture vapor transmission when applied before installing the resilient floor covering or a seamless multiple-layer flooring system, e.g., broadcast floors. Well-designed epoxy coating of MVB-1 serves as a primer and also a moisture vapor barrier due to its excellent barrier property.

Table 3 compares the performance of MVB-1 with a typical solvent-free cycloaliphatic curing agent. The cycloaliphatic primers typically provide good adhesion to dry concrete substrates but are relatively slow to cure at the lower temperature condition (about 24 h at 10 °C) and exhibit poor adhesion to damp concrete. MVB-1, on the other hand, provides fast cure speed at ambient and 10 °C and affords excellent concrete adhesion even to damp concrete at 10 °C while maintaining a good working time of about 30 minutes. *Figure 5* illustrates the excellent adhesion of MVB-1 to concrete under various test conditions, including freshly poured green concrete.

Additionally, MVB-1 does not contain typical plasticizer such as benzyl alcohol making it a top choice in low-VOC floor coating formulations and in emission-compliant systems. The cycloaliphatic primers often contain benzyl alcohol to facilitate full cure over time. The presence of benzyl alcohol increases the water-vapor-transmission rate, which makes them less effective as a moisture vapor barrier. *Figure 6* compares the water-vapor transmission (WVT) of clear coatings of MVB-1 with a typical benzyl alcohol containing solvent-free cycloaliphatic curing agent. MVB-1 have much lower WVT rate than the solvent-free epoxy system. MVB-1 is certified by third-party testing lab to meet ASTM F3010 <0.1 Perms rating requirement. Such rating has been adopted by architects and specifiers for flooring jobs and is often a must-have for new floor installation. In addition to the nice balance of fast cure speed with good working time and excellent concrete adhesion, the outstanding moisture vapor barrier property of MVB-1 makes it a preferred primer for a fast-cure floor system where good moisture vapor barrier is required.

Carbamation Resistance to Ensure Good Intercoat Adhesion

As primer serves as the bonding layer between concrete substrate and the subsequent layers applied on top, intercoat adhesion between the primer and the overlayment is crucial for a high-performance multi-layer floor system. One of the fundamental tests to ensure good intercoat adhesion is carbamation resistance test. Carbamation occurs when low molecular weight amines from a curing agent migrate from the bulk of the coating to the surface, where they react with carbon dioxide and moisture in the air to form ammonium salts. This process is highly undesirable as it competes with the needed amine-epoxy reaction, and is more likely to occur at lower temperature and high humidity and manifests itself as haziness, reduced gloss, and white salt on the surface. Carbamation reduces the visual appeal of the coating, more importantly leads to poor intercoat adhesion. The carbamation resistance test result of WB-1 and MVB-1 is summarized in *Table 3* and benchmarked against the commercially available waterborne primer and a typical cycloaliphatic primer, with relative rating scales of 1 to 5, with 5 being the best, showing no signs of carbamation. A minimum rating of 3 is required as the fundamental assurance for good intercoat adhesion. Both WB-1 and MVB-1 show good carbamation resistance at ambient temperature and 10 °C. WB-1 exhibits outstanding carbamation resistance with rating of 5 even after only 1 day at 10 °C.

Topcoat Application: High Performance and Ultimate Aesthetics

After the primer is applied, it is either overcoated with a thin coating (< 500 µm) directly as a topcoat or a midcoat followed by a topcoat as shown in *Figure 1*. The option for specific floor system depends on the target end-use. The two-coat system offers benefits of economics and good aesthetics for applications where mechanical wear and load bearing properties are not critical attributes such as in retail outlets. For industrial flooring, these properties are essential requirements to ensure protection of concrete integrity, therefore a midcoat is typically required. The choice for midcoat is largely determined by the end function of the floor and can be any of the polymer technology (epoxy, polyurethane, or polyurea), and applied at various coating thicknesses (a thin coating of <500 µm or a filled high build self-leveling of >1 mm). Any polymer technology as a midcoat for a fast-return-to-service floor installation will fall in the realm of being able to provide fast cure speed.

Topcoats are typically applied between 75 and 500 µm depending on the floor system. In general, a thin topcoat is applied over a high-performance industrial floor to improve appearance (gloss or satin finish), UV durability, and abrasion resistance. A thicker coating as a seal coat is necessary for a broadcasted epoxy floor to provide improved protection to the underlying decorative features of the epoxy floor as shown in *Figure 1*. For a fast-return-to-service floor system, one of the key requirements for the topcoat is fast cure speed to make a one-day floor installation possible when in combination with fast primer and midcoat. Equally critical attributes for topcoat are high aesthetics and UV stability. The option for topcoat becomes more limited when fast cure speed is coupled with good UV stability and high aesthetics.

Among the polymer technologies with good UV stability, aliphatic isocyanate-based topcoats (2k solventborne polyurethane, 1K polyurethane dispersion, and polycarbamide) and methyl methacrylate are the top choices. The comparison of performance properties for each technology is summarized in *Table 4*. Although fast cure and low VOC, methyl methacrylate (MMA) technology suffers from short working time, matte-only finish, limited abrasion, and organic solvent resistance, low flexibility, and impact resistance. Another key drawback of MMA technology is the strong odor, which further limits its application. This leaves the option for high aesthetics and good UV and wear resistance to aliphatic isocyanate-based topcoats.

TABLE 4—Comparison of UV Resistant Polymer Technologies

PROPERTY	POLYCARBAMID[a]	SOLVENT-BASED 2K PUB	1K PUD[b]	MMA
Working time (open time) (minute)	15–25	>30	nd	15
Mix Viscosity (mPa.s)	350-1300	2,000	<250	<250
VOC (applied) (g/L)	<100	140–500	140–500	<5
Spreading rate (g/m^2)	200–500	100–200	80–100	200–500
Dry film thickness	200–500	75–125	50–75	200–500
Walk on (dry hard) time at 25 °C (h)[c]	2–7	12–24	12–24	2–4
UV durability (ΔE)	Excellent	Excellent	Excellent	Excellent
Tensile elongation (%)	25	>25	10–25	<5
Abrasion Resistance (CS17, 1000 cycle) (mg loss)	40–50	60	60	80

[a] HDI Trimer isocyanate, 21.8 wt % NCO; η 2,500 mPa.s at 25 °C
[b] Representative average examples
[c] Thumb twist test

Table 4 compares the performance properties of three types of aliphatic isocyanate-based topcoats: polycarbamide technology, a 2K polyurethane (PU), and a 1K polyurethane dispersion (PUD). Typically, both PUD and PU are solvent-based systems with 140-500 g/L VOC. The 1K PUD is applied in thinner coatings to avoid problems with solvent retention and film formation. The low dry-film thickness limits a long service life in industrial environments. The 2K PU coatings provide similar benefits to the 1K PUD with improved flexibility and slightly higher dry-film thicknesses. However, high film thickness is still not achievable due to potential defects caused by bubble formation and solvent retention. In addition, the cure speed of 2K PU is slow especially at low-temperature condition, which can result in poor early water-spot resistance.

Compared with 1K PUD and 2K solventborne polyurethane systems, polycarbamide-based topcoats deliver attractive fast-cure speed, excellent early water-spot resistance, in combination with good UV stability and high resistance to abrasion and impact. The polycarbamide formulations offer low-mix viscosity and can be formulated without solvents for low-to-zero-VOC and odor-free application. High film buildup to 500 µm per coat is also achievable while retaining fast cure speed and remaining defect free. Both high humidity and higher application temperature will accelerate the cure process in these systems, which can significantly impact pot life and cure times. Conversely, lower temperature and humidity will extend working time and return to service time. Thanks to the advanced formulated polycarbamide technology, coating systems can be tailored for various cure conditions.

Table 5 summarizes three polycarbamide curing agents that are designed for customized need. All three curing agents are low in color and viscosity, and they have a mix ratio of 2:1 when used with standard HDI trimer isocyanate. The curing agents have fast cure speed and provide excellent water-spot resistance in less than 4 hours. All demonstrates excellent flexibility, high hardness (Shore D and Persoz), and good UV and abrasion resistance. The low viscosity and mix viscosity allow for easy handling and flexibility to formulate zero-to-low-VOC applications without the need for additional solvent to reduce viscosity.

As shown in *Table 5*, IC-1 provides the fastest cure speed and is recommended to be used for low-temperature and lower-humidity application, while IC-2 is slower in cure speed and more suitable for higher temperature and higher humidity cure condition. *Figure 7* illustrates the temperature and humidity effect on working time and cure speed of IC-1, IC-2, and IC-3. IC-3 provides similar cure speed to IC-2, in addition, the gloss of the coating can be uniquely customized to satin finish with a specially selected matting agent. The satin finish is achievable at various thickness. For example, the 60° gloss of 37 GU was retained regardless of thickness from 125 µm (5 mil) to 500 µm (20 mil). A starting point formulation is shown in Appendix.

The slower cure IC-2 and IC-3 can be accelerated by blending with the fast cure IC-1 to meet cure speed requirement under various application conditions. *Figure 8* illustrates how the open time and walk on time can be adjusted at different ratios of IC-1 and IC-2.

Excellent Intercoat Adhesion Between Epoxy Primer and Polycarbamide Topcoat

It has been demonstrated that primer WB-1 and MVB-1 provides fast cure speed and excellent adhesion to dry and damp concrete under ambient and low temperatures, and topcoat polycarbamides offers outstanding aesthetic and fast cure speed. One important parameter for a successful high-performance multistage floor installation is the intercoat adhesion between the primer and topcoat. There are two test methods to assess intercoat adhesion. The standard test method is the concrete pull-off test based on ASTM D7234. The topcoat was applied 4 hours after the primer was coated at ambient temperature and 8 hours at 10 °C. The test data is summarized in *Table 6* to illustrate the good intercoat adhesion between epoxy primer and polycarbamide topcoat. At ambient temperature, both WB-1 and MVB-1 can be topcoated within 4 hours with polycarbamide, and only 8 hours at 10 °C. *Figure 9* shows the cohesive failure of concrete for both WB-1 and MVB-1 systems. Test method based on ASTM D3359 is a simpler way to evaluate intercoat adhesion. The results were

TABLE 5—Polycarbamide Curing Agents[8] to Deliver Fast Cure Speed and Excellent Aesthetics

PROPERTIES	IC-1	IC-2	IC-3
Color (APHA)	< 100	< 100	< 100
AEW	376	379	373–385
Viscosity (mPa.s, 25 °C)	350	225	90–120
Mix Viscosity (mPa.s, 25 °C)	1300	1000	350–500
Viscosity build (min. to 12,000 mPa.s)	22	55	50–70
Thin film set time, phase 2/3 (h)	0.5 / 2	1 / 6	1 / 6
Shore D (7 days)	>70	>70	n/a
Persoz Hardness (1 day /7 day)	192 / 250	73 / 235	88 / 247
Gardner impact (in.lbs) Direct/Reverse	>160 / >160	>160 / >160	>160 / >160
Taber abrasion (mg loss) (1000 cycles, CS17)	42	40	50
Elongation at break (%)	10%	25%	n/a
QUV-A (500hrs)	4.4	2.2	3.5
VOC/emission of cured coating (g/L)	0	0	< 100
Water spotting at 25 °C (h)	2	4	4

FIGURE 7—Humidity and temperature effect on, left, open time, and, right, walk-on time.

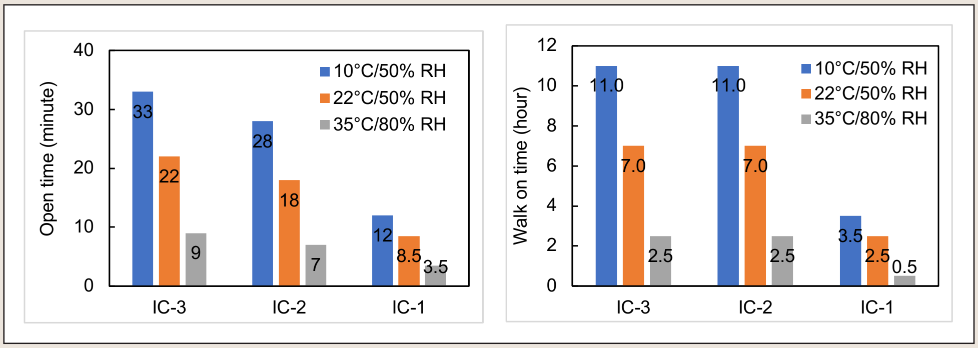


FIGURE 8—Open time and walk-on time are adjusted by IC-1 and IC-2 blends.

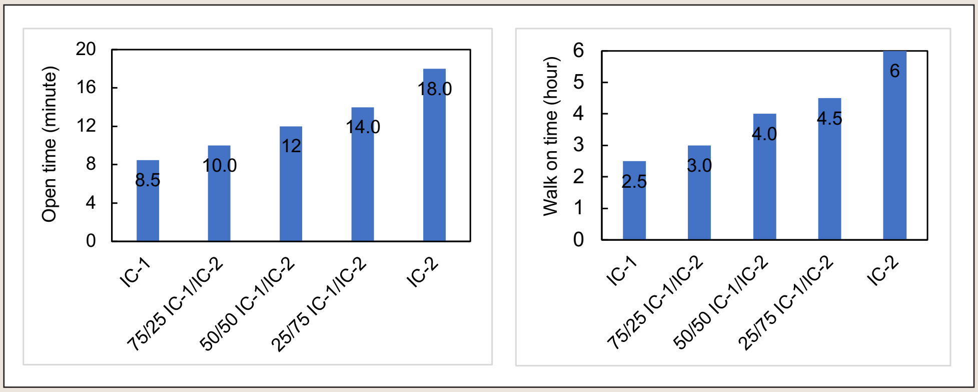
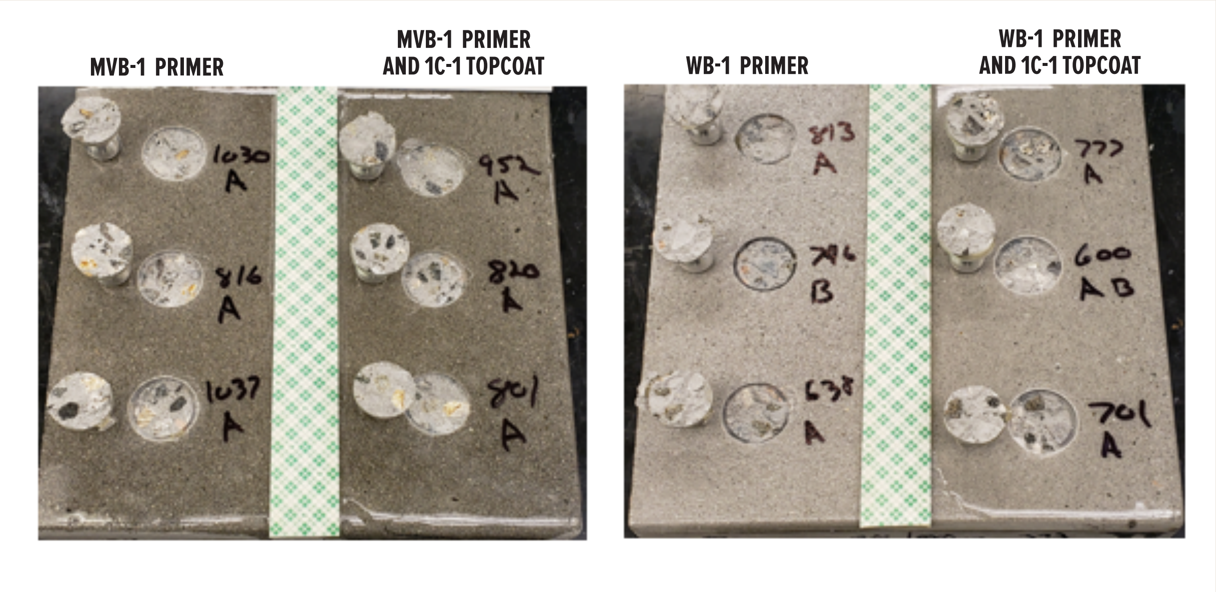


TABLE 6—Excellent Intercoat Adhesion Between Fast Cure Primer and Polycarbamide Topcoat

TOPCOAT	IC-1	IC-2	IC-1	IC-2
	PRIMER MVB-1		PRIMER WB-1	
ASTM D3359	23 °C/50% RH		23 °C/50% RH	
Topcoated at 4 h	5A	5A	5A	5A
Topcoated at 24 h	5A	5A	5A	5A
ASTM D7234 (psi)	23 °C/50% RH		23 °C/50% RH	
Topcoated at 4 h	637	582	852	854
	10 °C/50% RH		10 °C/50% RH	
Topcoated at 8 h	858	717	692	548
Topcoated at 24 h	nd	nd	648	764

FIGURE 9—Intercoat adhesion on concrete, topcoated at 8 hours at 10 °C/50% RH.



recorded as a relative scale of 1A-5A as 5A being best, no visible peeling or removal of coatings. The same combination of primer and topcoat was assessed as test matrix. Primer was coated on a metal substrate, and after 4 hours the topcoat was applied. All IC topcoats showed excellent adhesion to primer from 4 hours to 24 hours after primer was applied. Longer overcoat window was not tested in this study.

One-Day Floor System—Epoxy-Polycarbamide Synergy Delivers High Performance

For a floor system using the MVB-1 or WB-1 epoxy as primer, polycarbamides as topcoat and optionally an epoxy or polycarbamide midcoat, average cure time for primer is 2 to 3 hours at ambient temperature, 2 to 6 hours for epoxy or polycarbamide midcoat, and 2 to 6 hours for polycarbamide topcoat. In total, it would take 6 to 15 hours to install a 3-stage high-performance floor system and have it return to service within 24 hours. Such fast cure one-day floor system delivers attractive fast cure speed, good working time, excellent early water-spot resistance, combined with good UV stability, and high resistance to abrasion and impact. The ability of polycarbamide technology to deliver high film build also offers formulator flexibility to construct a thick coating for longevity and durability of a floor system. The entire floor installation can be made into zero- to low-VOC and in low-emission-compliant system while maintaining good working time at each stage.

CONCLUSIONS

Fast return to service and productivity improvement are key market trends for flooring industry that drive new product innovation. This requires fast cure speed of the coatings without sacrificing performance and low emission compliance. Development in polymer technology enables multistage (primer, midcoat, and topcoat) high-performance flooring system to be installed within one-day using a system approach combining epoxy primers with aliphatic polyurea/polycarbamide topcoats and delivers fast cure speed and excellent aesthetic.

Two-component epoxy systems have proven track record as concrete primer due to its good adhesion to concrete substrate even under adverse cure conditions. Waterborne epoxy primer based on curing agent WB-1 is designed to deliver ultra-fast cure speed even at low temperature and under high humidity. It can be applied either as a thin coating or at thicker build up to 600 µm in one pass which commonly is not achievable for waterborne system due to trapped water. In addition, it delivers excellent adhesion to green concrete. WB-1 primer system provides an attractive combination of zero VOC, easy handling, fast dry speed, good working time, and excellent adhesion in low-emission-compliant formulations.

Solvent-free epoxy primer based on MVB-1 provides a nice balance of fast cure speed with good working time and excellent concrete adhesion. Its outstanding moisture-vapor-barrier property makes it a first-choice primer for a fast-cure floor system where good moisture-vapor barrier is required by architects and specifiers. MVB-1 is certified to meet ASTM F3010 <0.1 Perms rating requirement. MVB-1 provides an additional feature of not containing typical plasticizer such as benzyl alcohol, an excellent choice in low-VOC floor coating formulations and in emission compliant systems. On top of the good adhesion to concrete substrate, both waterborne epoxy primer WB-1 and solvent-free MVB-1 show good carbamation resistance and provide excellent intercoat adhesion to topcoat.

For midcoat, both fast-cure epoxy and polycarbamide (aliphatic polyurea) can be used for a fast-track floor system to enable fast return to service. For high aesthetic topcoats equipped with fast cure speed, polycarbamides have become the obvious choice owing to its excellent appearance, good UV and abrasion resistance, and high impact resistance. A portfolio of polycarbamide curing agents IC-1, IC-2, and IC-3 offers formulators options to tailor cure speed, working time, and customized sheen under various cure temperature and humidity. Furthermore, coatings based on IC-1, IC-2, and IC-3 can be formulated without solvents for low- to zero-VOC and odor-free application in high film builds up to 500 µm per coat that can't be achieved in 1K PUD and 2K PU systems.

Applying a system approach, the synergy of fast-cure and high-performance epoxy primers in conjunction with aliphatic polyurea/polycarbamide topcoats delivers a unique combination of enhanced properties and fast cure speed. Such synergy provides formulators a solution to one-day flooring system where a multistage flooring system can be installed within 24 hours and ready to return to service the next day.

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APPENDIX

Summaries of the formulation compositions; for start formulation recipes, see Reference 8

	PRIMER WB-1	PRIMER MVB-1	HIGH GLOSS TOPCOAT IC-1 to IC-3	SATIN TOPCOAT IC-3
Amine curing agent and additives (pbw[a])				
WB-1 amine curing agent	100			
MVB-1 amine curing agent		100		
IC-1 to IC-3 amine curing agent for isocyanate			100	100
Defoamer, air-release agent	1.0	0.5	1.1	1.1
Wetting agent			1.1	1.1
Dispersant				1.1–2.1
Molecular sieve 3A				1.1–1.6
Matting agent[b]				15.0–19.5
Water	100			
Resin				
Diluted bisphenol A epoxy resin[c]		270		
Solid resin dispersion[d]	300			
HDI Trimer isocyanate resin[e]			53.5	53.5
Total Weight	**500.1**	**370.5**	**155.7**	**172.9-178.9**

[a] pbw–parts by weight
[b] Acematt® 3600
[c] bisphenol A epoxy resin 90 wt%, diluted with 10 wt% glycidyl ether of C12-14 alcohol
[d] Ancarez® AR555
[e] HDI Trimer, 21.8% isocyanate content, viscosity ~ 2,500 mPa.s