FAST CURE, HIGH UV RESISTANT AND EHS FRIENDLY EPOXY COATINGS

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ABSTRACT

Fast-cure floor coatings that reduce downtime and boost productivity, offering high-performance, protection against contamination and wear, while ensuring long-lasting quality and aesthetics, remain a top priority in the flooring industry. However, historically, fast curing has often been accompanied by trade-offs in performance, including issues related to durability, UV resistance, adhesion, working time, and environmental, health, and safety (EHS) requirements. For instance, in order to achieve rapid curing, accelerators such as phenolic compounds are commonly added to two-component epoxy systems, which speed up the curing process but often raise concerns about worker safety due to the use of non-EHS-friendly substances. Additionally, other accelerators like phenolic tertiary amines can significantly compromise UV resistance.

This paper introduces a fast cure, high UV resistance curing agent designed for epoxy systems, addressing both performance and EHS gaps in current commercially available systems. This innovative curing agent enables a rapid return to service, delivering coatings with exceptional aesthetics at ambient and low temperatures, outstanding UV resistance, and extended working times. When this fast-curing coating is used as a topcoat in conjunction with a rapid primer, it offers a one-day flooring solution where both primer and topcoat can be applied on the same day and are ready for service within 24 hours. Furthermore, when combined with hydrogenated resin, the coating maintains rapid cure speed and excellent UV resistance, achieving results not attainable with current available systems. The paper will also delve into key performance attributes and provide comparisons with benchmark epoxy systems.

BACKGROUND

The coating industry is constantly innovating to meet the challenges of increasingly stringent environmental regulations and demand for worker and end-user safety, while fulfilling the need to improve productivity and reduce downtime. Technology advancement has equipped the industry with epoxy systems that deliver fast cure speed and improved EHS (environment, health, and safety) profile. Two-component epoxy systems are well-known for their excellent mechanical properties, chemical resistance, and adhesion to substrates. They have been widely used as protective coatings for concrete, metal, and wood surfaces. The protective coatings provide an impermeable barrier, improve aesthetics, and enhance chemical resistance to various chemicals. For these reasons, epoxy systems are frequently chosen over other technologies as a floor coating material.

Two-component epoxy systems are thermoset polymer networks formed by crosslinking epoxy resin(s) and curing agent(s) (also known as hardener), and the properties of these systems depend on both resin and curing agent. Curing agents are typically based on amine chemistry. Commercially available epoxy resins are limited to bisphenol-A, bisphenol-F, and novolac. On the contrary, there is a wide range of curing agent options to optimize a coating system. The curing agent plays a critical role in defining the cured epoxy network, and is often designed to tailor cure speed and coating performance, thus providing a toolbox for formulators to meet performance target and EHS requirements.

When it comes to curing agent design, fast cure to improve productivity often comes with trade-offs in performance such as durability, UV resistance, chemical resistance, and working time, and compromise EHS requirement. The cure speed of amine-epoxy systems is accelerated by using accelerators such as phenolic compounds for example t-butylphenol, bisphenol A, and salicylic acid.[1] Phenolic accelerators are usually not EHS-friendly, and pose health and safety hazards to the workers and the environment. In addition, these accelerators often degrade the UV resistance of the coatings. This paper presents a fast-cure, high UV resistance curing agent that addresses both performance and EHS gaps in the current commercially available systems. This new curing agent enables a rapid return to service and delivers coatings with exceptional aesthetics at ambient and low temperatures, outstanding carbmation and UV resistance, and extended working times.

EXPERIMENTAL

A new curing agent, Ancamine® 2880 was developed based on a proprietary amine chemistry. Two commercially available curing agents BM-1 and BM-2 were used as benchmark products for their known good UV resistance and cure speed. However, both have unfavorable EHS rating. All coatings or castings were prepared with standard bisphenol A epoxy resin or diluted with a glycidyl ether of C12-14 alcohol[2] at 1:1 stoichiometry. Curing agent and resin were mixed with a speed mixer for one minute at 3500 rpm before testing. All the test methods in this paper are listed in Table 1.

The cure speed or thin film set time (TFST) was evaluated in accordance with ASTM D5895. A coating was drawn down at 6 mil wet film thickness (WFT) on 1″ x 12″ glass substrate, and placed on a Beck-Koller

TABLE 1: Standard Test Methods

PROPERTY	ASTM TEST METHOD
Viscosity	D2196
Specular Gloss	D523
Gardner color	D1544
Thin film set time	D5895
Carbamation resistance	ISO2812
Persoz hardness	D4366
Gel time (150 grams mass)	D2471
Shore D hardness	D2240
Tensile properties	D638
Compressive properties	D695
Flexural properties	D790
Taber abrasion	D4060
QUV accelerated weathering	G154
Adhesion, dry and wet Tape	D3359
Adhesion pull off test on concrete	D7234

recorder at a specific scale of travel time under the designated environmental conditions.The carbamation-resistance test was conducted on black Leneta charts according to ISO2812 method. The coating was drawn down at 6 mil WFT and allowed to cure under the designated environmental condition and time duration. A water saturated 1″ x 1″ cotton patch was placed on the cured coating and covered with a watch glass to prevent water evaporation. The cotton patch was removed after 24 hours, and the wet coating surface was dried with a tissue. The appearance of the coating was judged in a scale of 1 to 5, with 5 being the best showing no effect, and 1 being the worst with a white surface.

The viscosity profiles were generated on a Brookfield viscometer at 23 °C using about 20 grams of mixed material. Gel time of a 150 grams mixture of epoxy resin and curing agent was recorded using Techne GT-3 Gelation Timer as the time when the product components gelled enough to arrest the free movement of disposal plungers operated at one cycle per minute.
Persoz hardness was determined in accordance with ASTM D4366 method. The coatings were applied at 6 mil WFT on 3″ x 4″ glass substrate, and allowed to cure under the designated environmental conditions and time duration. Shore D hardness was performed according to ASTM D2240. 35 g of epoxy resin and curing agent was poured in 2.75 inch diameter circular metal lid to get a 0.4 inch thick clear cast.

Intercoat adhesion test was established by two methods. ASTM D3359 method measures adhesion by tape (Test method A – X Cut Tape Test). The epoxy primer was coated on a steel substrate, followed by application of a topcoat on to the primer after a specified time. The coatings were cured at ambient conditions for 7 days before testing. The results were noted in a scale of 1A-5A, with 5A being best, showing no peeling or removal of coatings. The other method was ASTM D7234. A 1.5 inch thick concrete block was sand blasted to CSP 3 surface profile prior to applying 10 mil WFT of epoxy coat. The coatings were cured for 7 days under the designated environmental conditions, before performing dolly pull-off test using a portable adhesion tester. The adhesion strength and mode of failure were documented.

Differential scanning calorimetry (DSC) was utilized to determine degree of cure. About 5~10 mg sample of stoichiometric mixture of epoxy resin and curing agent was probed by TA Instruments DSC Q20 at a heating rate of 10 °C/minute. The sample was heated in the temperature ranging from -50 °C to 250 °C at 10 °C/minute, cooled back to -50 °C and the test was repeated.

The abrasion resistance was tested per the ASTM D4060 standard test method. In this method, various epoxy-curing agent system was coated at 6 mil WFT on 4-5 steel coupons of the size of around 4″ x 4″ x 0.125″, allowed to cure for 7 days at ambient conditions. Then a 0.25″ diameter hole was drilled out of the center of each test specimen. The test specimens were weighed prior to abrading them. A CS-17 harsh abrading wheel with a 2000 gram load was placed on the coatings. The specimens were then abraded with up to 500 cycles each and they were weighed after abrasion. The average weight loss in milligrams (mg) were then calculated for all of the systems tested.

For measurement of mechanical properties in tensile, flexural and compressive modes, stoichiometric mixture of bisphenol A resin and curing agent was casted and cured for 7 days at ambient conditions. Test for tensile properties was conducted as per ASTM D638 at a crosshead speed of 0.2″/min until failure. Mechanical properties in compressive mode was determined according to ASTM D695. The test was conducted on 1″ cube at 0.05″/minute cross-head test speed. Test was stopped at yield point or 0.25″ displacement. Flexural test was performed in accordance with ASTM D790 on 0.12″ x 0.5″ x 3″ specimens using 3-point-bend tests with a crosshead speed of 0.5″/min. The test is stopped when the specimen reaches 5% deflection or the specimen breaks before 5%.

RESULTS AND DISCUSSION

Handling Properties

The new curing agent, Ancamine® 2880 was developed based on a proprietary amine technology without using the substance of high concern such as bisphenol A, alkylphenol or salicylic acid. Unlike the two benchmark products BM-1 and BM-2 with unfavorable EHS rating, Ancamine® 2880 offers fast cure speed with favorable EHS rating. Table 2 summarizes the important handling and performance properties of the newly developed curing agent Ancamine® 2880 and two commercially available benchmark product BM-1 and BM-2. Ancamine® 2880 offers a low neat viscosity as compared to BM-1 and BM-2. The performance was evaluated by mixing the curing agents with bisphenol A resin at 1:1 stoichiometric ratio. The low-mixed viscosity of Ancamine® 2880 system allows for easy handling and application. It maintain similar gel time as offered by BM-1 and BM-2 at ambient conditions.

Rapid Property Development

The new curing agent provides fast cure speed and property development as evident from Table 3. Ancamine® 2880 delivers fast cure speed similar to BM-1, but faster than BM-2. Rapid early mechanical property development of thick casting and thin coating is an outcome of fast cure speed. As can be seen from Table 3 that Ancamine® 2880 exhibits faster Shore D and Persoz hardness development as compared to BM-2.

TABLE 2: Comparison of Handling Properties

PROPERTY	ANCAMINE® 2880	BM-1	BM-2
Color, Gardner	1	2	2
Neat viscosity (cPs)	210	450	600
AHEW (Wt/[H])	95	95	115
PHR	50	50	60
Gel time (minutes)	37	35	40

TABLE 3: Comparison of Performance Properties

PROPERTY	ANCAMINE® 2880	BM-1	BM-2
Mixed viscosity (cP)	2,000	3,000	4,000
Dry hard time at 23 °C (hour)	4.5	4.5	5.5
Dry hard time at 10 °C (hour)	10	10	14
Shore D hardness (day1 at 23 °C/10 °C)	80/75	80/75	80/60
Persoz hardness (day7 at 23 °C/10 °C) (second)	335/252	326/225	319/215

Cured with standard bisphenol A liquid epoxy resin, EEW=190.

Rapid property development is demonstrated by cure viscosity built-up. Figure 1 shows the cure viscosity profiles of the curing agents at ambient condition. Fast viscosity build-up often reflects on high reactivity. As shown in Figure 1 that slowest viscosity build-up by Ancamine® 2880 offers prolonged working time while keeping the cure speed similar or faster compared to the benchmark products.

High degree of cure is a very important feature in industrial flooring application in terms of coating's performances on mechanical, chemical and thermal resistance properties. Degree of cure is directly related to the reactivity of epoxy-curing agent systems and was determined by DSC. Figure 2 displays the degree of cure of epoxy-curing agent systems cured at ambient and 10 °C environments. At ambient conditions, Ancamine® 2880 displayed similar reactivity compared to BM-1, but faster reactivity than BM-2. On the other hand, it provided fastest reactivity at 10°C conditions. Additionally, Ancamine® 2880 reaches almost 100% degree of cure on day 1 at ambient and on day 7 at 10 °C conditions.

Ancamine® 2880 Offers Best Coating Appearance

One of the important performance attributes of epoxy coating system is carbamation resistance which is frequently related to amine blushing or blooming. The chemical component of the epoxy coating system, responsible for the blushing or blooming, is the amine curing agent. The hygroscopic low molecular weight amines migrate from the bulk of the coating to the surface and react with atmospheric carbon dioxide and moisture to form an ammonium carbamate salt. The outcome of the above undesirable side reactions is that some amine is consumed, which results in compromised stoichiometry in epoxy-amine reaction. Ultimately, the under cure epoxy coating appears as greasy, tacky, hazy, reduced gloss, or white salt on the surface. And most importantly, carbamation leads to poor intercoat adhesion. The result of carbamation resistance of Ancamine® 2880, BM-1 and BM-2 is summarized in Table 4, and the photographs are shown in the Figure 3 as well. The results shown in the table are with relative rating scales of 1 to 5, with 5 being the best, showing no signs of carbamation. Ancamine® 2880 exhibits excellent coating appearance and outstanding carbamation resistance with rating of 5 even after only 1 day at 10 °C. At lower temperature, reactivity of epoxy and amine decreases. During this period, reaction of amine with carbon dioxide and moisture can be favored over that with epoxy, which consequences into carbamation. The new curing agent Ancamine® 2880, designed by a proprietary chemistry, shows outstanding carbamation resistance at 10 °C compared to benchmark products.

FIGURE 1: Viscosity profiles at 23 oC, 50% relative humidity (RH) with standard bisphenol A resin (EEW 190)

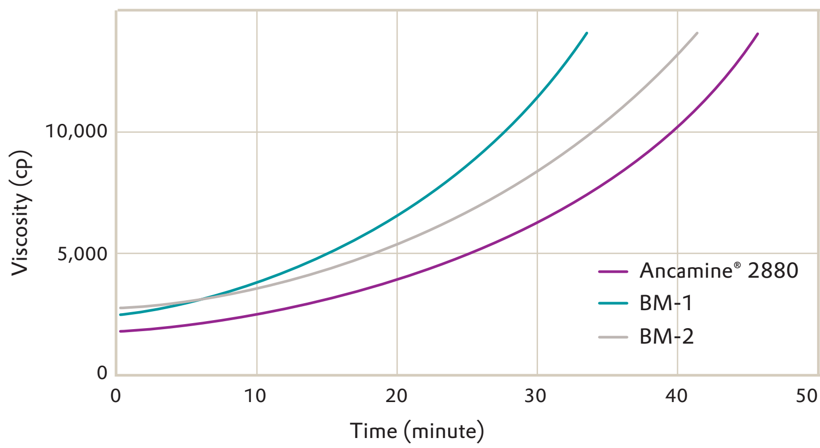
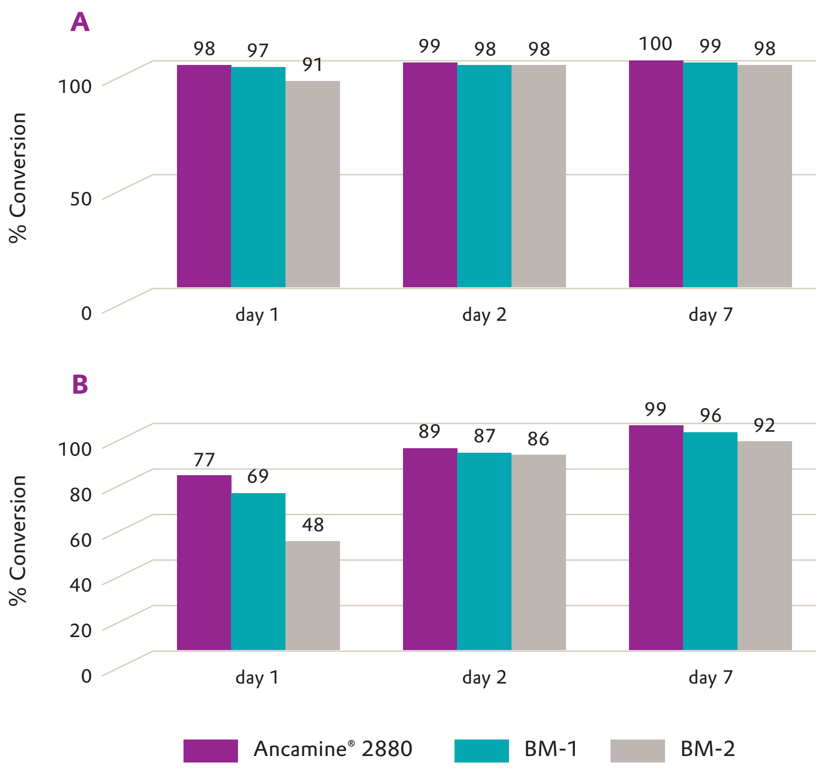


FIGURE 2: Degree of cure (A) at 23 °C, 50% RH and (B) at 10 °C, 60% RH using standard bisphenol A resin diluted with 10% Epodil 748.



Effect of Humidity on Performance of Coating

Two major factors which may impact on coating's performance are humidity and temperature. At high relative humidity (RH) and low temperature, moisture in the air condensates on the coating surface and the amine on surface reacts with carbon dioxide and moisture to form carbamate. Low temperature slows down the amine-epoxy reaction and increases the carbamate side reaction. High humidity and low temperature negatively affect the cure performance and coating appearance. Table 5 provides a summary of cure speed, carbamation resistance and water spotting resistance of epoxy coatings cured with Ancamine® 2880 at 23 °C, 50% RH and at 10 °C with varying RH. The 6.5 hours cure speed at 23 °C/50% RH was lengthened to 14 hours due to reduced epoxy-amine reactivity at 10 °C/60% RH. The cure speed at 10 °C was not affected by varying the RH ranging from 60% to 85%. The coating retained excellent carbamation resistance and water spotting resistance across the temperature and humidity ranges under consideration.

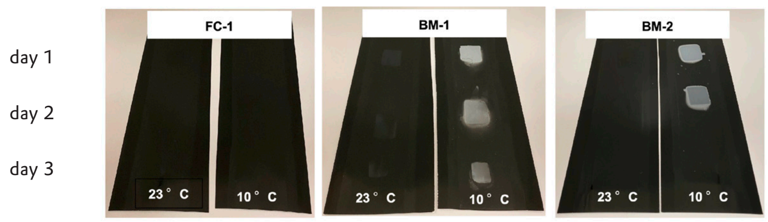
TABLE 4: Comparison of Carabamation Resistance

		ANCAMINE® 2880	BM-1	BM-2
At 23°C, 50% RH	Day 1	5	3	5
	Day 2		4	
At 10°C, 60% RH	Day 1	5	1	1
	Day 2		1	1

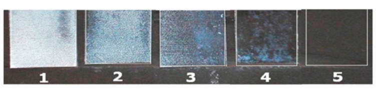
Excellent Intercoat adhesion

High performing floorings have multi-layer systems depending on the target end-use. Flooring with two coat systems is preferred in terms of economics where mechanical properties are not so important. On the other hand, a midcoat is required to maintain concrete integrity for protection against mechanical wear and tear, in industrial floors for example. Generally, a topcoat is applied to improve protection to the underlying epoxy midcoat. Intercoat adhesion between a primer and a topcoat, a primer and a midcoat, and midcoat and topcoat is an important parameter for a successful high performance multistage floor installation. For a fast return to service multistage flooring system such as a one-day flooring, each stage is required to cure within short period of time, especially for primer. Typically it is a requirement for a primer to cure within 8 hours even at low temperature, so the topcoat can be applied by the same crew and same shift.

FIGURE 3: Carbamation resistance of coatings at 23 °C, 50% RH and 10 °C, 60% RH using standard bisphenol A resin (EEW 190) diluted with 10% Epodil 748.



Carbamation rating reference



The intercoat adhesion test was carried out on concrete and steel substrates. When Ancamine® 2880 was used as a topcoat, a fast cure epoxy was used as primer on both concrete and steel substrate. And when Ancamine® 2880 was used as a primer on steel substrate, a highly UV resistant and fast cure aliphatic polyurea was used as topcoat to provide extra UV stability.

The standard test method for intercoat adhesion on concrete is the pull-off test based on ASTM D7234. The concrete blocks used in this study had a surface profile of CSP 2 or 3. For test with damp concrete, the concrete block was submerged in water for 24 hours, and then removed from water before coating. The fast cure epoxy primer[3] was coated at 6 mil WFT on dry and damp concrete and cured at ambient and 10 °C environment. The 10 mil Ancamine® 2880 topcoat was applied 4 hours after the primer was coated at ambient condition and after 8 hours at 10 °C. The test result in Table 6 demonstrates the excellent intercoat adhesion between a fast cure epoxy primer and Ancamine® 2880 topcoat on both dry and damp concrete. At ambient temperature, Ancamine® 2880 system can be topcoated within 4 hours, and only 8 hours at 10 °C onto the fast cure primer to achieve a one-day flooring system with excellent intercoat adhesion. Figure 4 shows the cohesive failure of concrete for both primer and topcoat.

The intercoat adhesion was also evaluated on steel substrate according to ASTM D3359. The X-cut and cross-cut results were recorded as a relative scale of 1A-5A as 5A being best, no visible peeling or removal of coatings. Two sets of experiments were conducted using two different coating systems. The first set of the two-coat system is the same as on concrete substrate, the fast cure epoxy primer was coated at 6 mil WFT on steel substrate, and after 4 hours the Ancamine® 2880 topcoat was applied at 10 mil WFT. In the second set of experiment, the Ancamine® 2880 was used as primer and coated at 6 mil WFT on steel substrate, and after 6 hours a commercially available aliphatic polyurea[4] topcoat was applied at 10 mil WFT. Both systems were cured at controlled ambient condition for 7 days. The test result is shown in Table 6. The result of the first set experiment collaborates with the data on concrete substrate where Ancamine® 2880 showed excellent adhesion to the epoxy primer. Similarly, when used as primer on steel panel, Ancamine® 2880 demonstrates excellent adhesion to polyurea topcoat. The fast cure and outstanding intercoat adhesion of Ancamine® 2880 offers a solution for fast return to service where multiple layers can be applied within 24 hours.

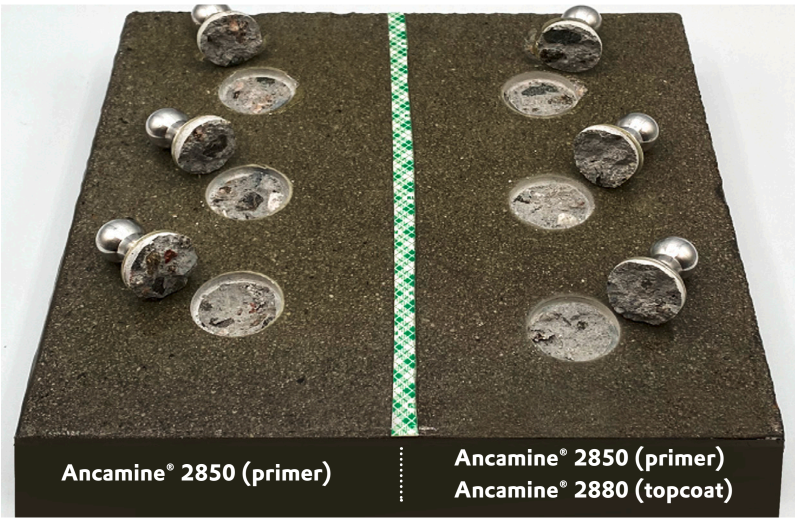
TABLE 5: Effect of Humidity on Performance Properties of Epoxy Coating using standard bisphenol A resin diluted with 10% Epodil 748

PROPERTIES	23 °C, 50% RH	10 °C, 60% RH	10 °C, 80% RH	10 °C, 85% RH
Cure Speed	6.5 h	14 h	13 h	13 h
Carbamation resistance day1	5	5	5	5
Water spotting resistance day1	5	4	5	5

TABLE 6: Intercoat Adhesion of Primer to Ancamine® 2880 Topcoat

Intercoat adhesion on concrete (ASTM D7234): Ancamine® 2880 Topcoat over Epoxy Primer	**on dry concrete**	
	At 4 h, 23 °C, 50% RH	951 psi
	At 8 h, 10 °C, 60% RH	829 psi
	on damp concrete	
	At 4 h, 23 °C, 50% RH	837 psi
	At 8 h, 10 °C, 60% RH	888 psi
Intercoat adhesion on steel panel (ASTM D3359)	**Ancamine® 2880 Topcoat over Epoxy Primer**	
	At 4 h, 23 °C, 50% RH	5A
	Polyurea Topcoat over Ancamine® 2880 primer	
	At 6 h, 23 °C, 50% RH	5A

FIGURE 4: ASTM D7234, all samples show cohesive failure using standard bisphenol A resin diluted with 10% Epodil 748.



Abrasion Resistance

The abrasion resistance was tested per the ASTM D4060 standard test method. The curing agents mixed with different epoxy resins, were coated at 6 mil WFT on steel substrates, and cured for 7 days at ambient conditions. The abrasion test was conducted using the CS-17 harsh abrading wheel with a 2000 gram load for 500 cycles. The average weight loss in milligrams given in the Table 7, illustrates excellent abrasion resistance of Ancamine® 2880 in all the resin systems tested. This makes it an ideal candidate for a flooring to withstand wear and tear in high traffic areas.

TABLE 7: Comparison of Abrasion Resistance Using Different Epoxies

	Weight loss after 500 cycles/2 Kg wheel (mg)		
CURING AGENT	RESIN 1*	RESIN 2**	RESIN 3***
Ancamine® 2880	27	42	30
BM-1	38	42	37
BM-2	33	42	32

*Resin 1: Bisphenol A epoxy (EEW = 190)
**Resin 2: 90% Bisphenol A epoxy – 10% Epodil 748
***Resin 3: 50% Bisphenol A epoxy – 50% Novolac epoxy

TABLE 8: Mechanical Properties of Ancamine® 2880 and Benchmark Products

PROPERTIES	ANCAMINE® 2880	BM-1	BM-2
Compressive strength (MPa)	81	76	80
Comressive modulus (kpsi)	284	225	260
Tensile strength (psi)	9670	9488	9008
Tensile modulus (kpsi)	405	406	396
Flexural strength (MPa)	94	88	87
Flexural modulus (kpsi)	454	438	439

Cured with standard bisphenol A liquid epoxy resin, EEW=190.

Mechanical Properties

Mechanical characteristics of a through-cure epoxy is critical in flooring application to prevent structural disintegrations. The tests in tensile, compression and flexural modes were evaluated to ensure that the cured epoxy material maintains its high mechanical properties. The details of sample preparation and test method are described in the experimental section. Table 8 presents a summary of mechanical properties of curing agents Ancamine® 2880, BM-1 and BM-2 cured with standard bisphenol A epoxy resin. The test data show that epoxy material cured with Ancamine® 2880 maintains high mechanical characteristics by providing high load bearing capability, stiffness, resistance to deformation and resistance to cracking.

Chemical Resistance

Two component epoxy coating protects the underlying substrates from chemical attack by creating a highly crosslinked impermeable barrier layer between the substrate and environment. Study of chemical resistance was conducted as per ASTM D1308. Curing agent and epoxy were blended and coated on 4" x 12" steel panels at 6 mil WFT, and cured for 7 days at ambient conditions. Cotton patches of different class of chemicals were placed on 7-day cured films, and covered with a watch glass. Patches were removed after 24hrs exposure, followed by pat dry with paper towel. The coatings were visually inspected and evaluated. The results were recorded as the film appearance on a relative scale of 5-1 as 5 being excellent, no effect on coating surface. Summary of the test results is given in Table 9. Ancamine® 2880 provides good to excellent resistance to most of the selected chemicals of different classes, such as organic solvent, alkali, inorganic and organic acid. Good chemical resistance is a requirement for flooring application to withstand daily cleaning chemicals and accidental spillage or leakage of chemicals in industrial settings. The good appearance, high aesthetics and good chemical resistance properties of Ancamine® 2880 makes it an ideal candidate not only for institutional and decorative flooring but also for industrial and commercial flooring such as factory and commercial kitchen.

UV Resistance

Epoxy coatings provides excellent chemical resistance, strong mechanical properties and good adhesion to avariety of substrates. However, epoxy coatings degrade when exposed to UV light in outdoor conditions resulting in discoloration, reduced gloss,

TABLE 9: Chemical resistance of Ancamine® 2880

CHEMICALS	ANCAMINE® 2880	BM-1	BM-2
Acetone	4	5	4
Methanol	5	5	3
Ethanol	5	5	4
Methyl ethyl ketone	4	5	1
Xylene	5	5	5
Toluene	4	5	5
30% Ammonium hydroxide	4	2	3
50% Sodium hydroxide	5	5	5
6% Sodium hypochlorite	5	4	5
10% Nitric acid	4	4	4
10% Hydrochloric acid	4	5	4
50% Sulfuric acid	4	4	4
10% Acetic acid	3	3	4
10% Lactic acid	4	3	4

5: Excellent, 4: Good, 3: Fair, 2:Poor, 1: Not recommended

FIGURE 5: δE over time for epoxy coatings under UV Irradiation, cured with standard bisphenol A resin diluted with 10% Epodil 748.

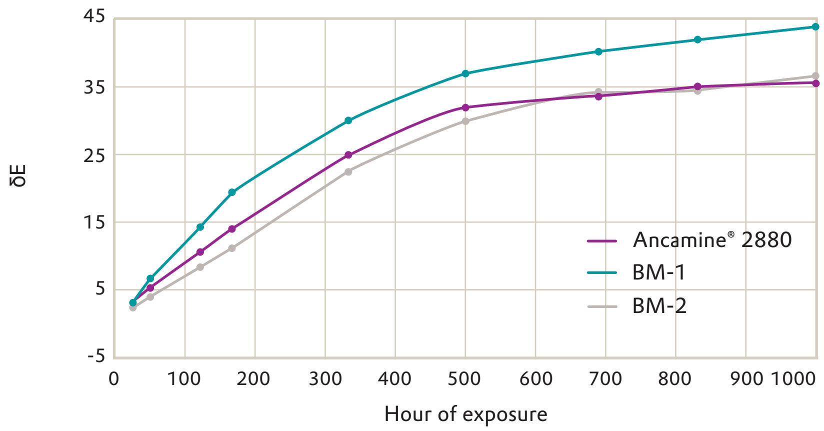


TABLE 10: Performance properties of Ancamine® 2880 Curing Agent with Hydrogenated Bisphenol A Epoxy Resins

PROPERTIES	HE-1	HE-2	HE-3
PHR	43	48	57
Gel Time (150g mix at 77F) (minute)	80	45	35
TFST, Phase-3 (6mil @ 77F) hour)	14	7	11
TFST, Phase-3 (6mil @ 50F) (hour	28	20	28
Shore D Hardness 77F (Day 1)	70	75	65
Shore D Hardness 50F (Day 1)	30	50	30

TABLE 11: Chemical resistance of Hydrogenated Bisphenol A Epoxy Coatings Cured with Ancamine® 2880 Curing Agent

CHEMICALS	HE-1	HE-2	HE-3
Acetone	5	5	5
Methanol	5	5	5
Ethanol	5	5	5
Methyl ethyl ketone	5	5	5
Xylene	5	5	5
Toluene	5	5	5
30% Ammonium hydroxide	5	4	3
50% Sodium hydroxide	5	5	5
6% Sodium hypochlorite	5	5	5
10% Nitric acid	5	2	1
10% Hydrochloric acid	5	1	1
50% Sulfuric acid	5	5	1
10% Acetic acid	1	1	1
10% Lactic acid	1	1	1

5: Excellent, 4: Good, 3: Fair, 2:Poor, 1: Not recommended

chalking and delamination. One of the biggest challenges in the coating industries to formulate epoxy coating with high UV resistance for outdoor applications. In the present study, photostability was studied in accordance with ASTM D4587. 6 mil of curing agent-epoxy coating was applied on precoated white polyurethane steel panels, and allowed to cure for 7 days and ambient conditions. The cured epoxy panels were exposed to UV irradiation in the accelerated weathering QUV machine equipped with fluorescent ultraviolet lamp apparatus (340 nm bulbs, 0.89 W/m2.nm irradiance at 50 °C temperature) operated in accordance with ASTM G154 for 1000h, without condensation. The data for δE, yellowness index (YI) and gloss retention were collected before and after exposure to UV irradiation on a regular interval. Figure 5 describes the UV resistance of epoxy coating cured with Ancamine® 2880 and the benchmarked products BM-1 and BM-2. The benchmarked products are known for their good UV resistance in epoxy coatings. Ancamine® 2880 exhibits good UV resistance similar to BM-2, and better than BM-1. The UV resistance can be further improved by using hydrogenated epoxy resin in place of standard bisphenol A resin, which will be described in the following section of this paper.

Performance Evaluation of Ancamine® 2880 with Hydrogenated Epoxy Resins

The major cause of yellowing in bisphenol epoxy resin system is the oxidation of the aromatic ring. There are different chemical approaches to mitigate such chemical structure degradation, for example using silicon-based epoxy hybrids[5], doping standard epoxy system with UV-resistant additives, and hydrogenation of bisphenol epoxy resins.[6, 7] Of these solutions, the hydrogenation of bisphenol epoxy offers the best techno-economic viability. Hydrogenated bisphenol A epoxy resin does not contain double bonds in the molecule, and has the advantages of good weather resistance for outdoor use, excellent electrical properties, low viscosity, and good processability. Compared to bisphenol A, hydrogenated bisphenol A improves the UV resistance performance to maintain color stability thus prolong the service life.

Three hydrogenated bisphenol A epoxies (HE-1, HE-2 and HE-3)[8] were selected for

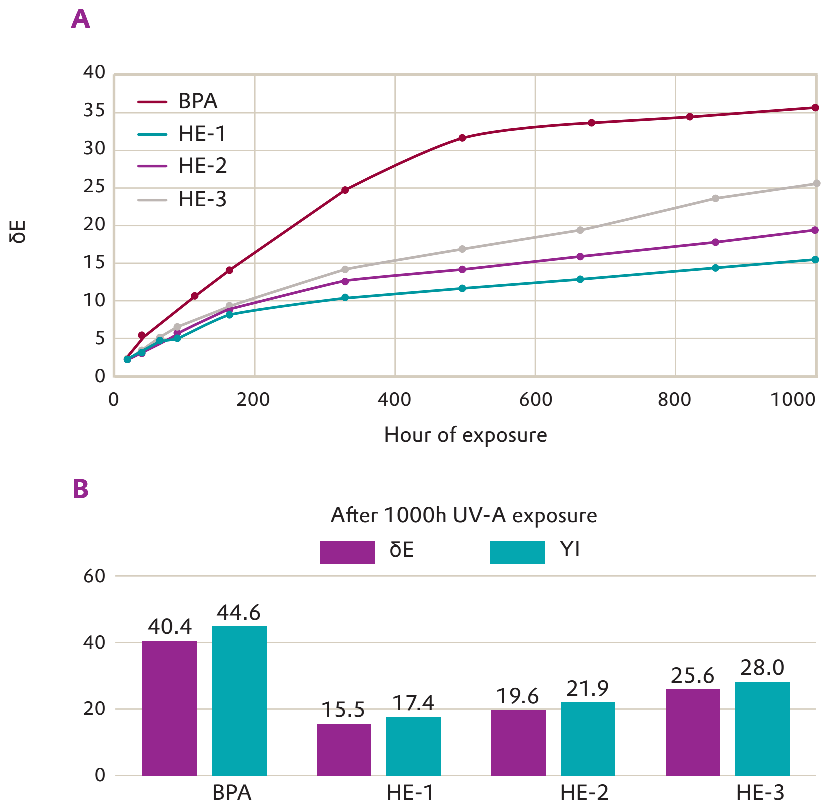


FIGURE 6: (A) δE over time of coatings under UV irradiation, (B) δE and yellowness index (YI) under UV irradiation after 1000 hours. Coatings were cured with standard bisphenol A resin diluted with 10% Epodil 748 (BPA) and hydrogenated bisphenol A resins (HE-1, HE-2 and HE-3).

performance evaluation with the curing agent Ancamine® 2880. The handling and performance properties of the three resins with Ancamine® 2880 curing agent are summarized in Table 10. Ancamine® 2880 in combination with HE-2 resin provides the fastest cure speed with long working time, and offers walkable floor on one day even at 10 °C. The study of chemical resistance was performed in the same manner as mentioned in the previous section, and the result are shown in the Table 11. Ancamine® 2880 curing agent in combination with HE-1 hydrogenated resin exhibits better resistance to different class of chemical compared to HE-2 and HE-3 resins.

UV resistance study of the coatings, prepared by mixing Ancamine® 2880 with bisphenol A epoxy (BPA) and the three hydrogenated epoxy resins was conducted by following the same procedure as described in previous section. The bisphenol A resin was included to compare its UV stability with that with hydrogenated bisphenol A resin. The color retention and yellowness index (YI) are shown in Figure 6A and 6B, respectively. Ancamine® 2880 curing agent in combination with HE-1 hydrogenated resin delivered the best UV resistance compared to HE-2 and HE-3 resins. All three hydrogenated resins out-performed BPA resin as expected. It is also notable that the HE-1 resin exhibited greater than two times better UV resistance as can be concluded from color retention and yellowness index values after 1000 hours of exposure.

CONCLUSIONS

Fast return to service and productivity improvement is a key market trend for coatings industry that drives new product innovation. This requires fast cure speed of coatings without sacrificing performance and EHS requirement. Two-component epoxy systems have proven track record in coatings application owing to its good adhesion to various substrates and excellent chemical resistance and mechanical properties. To achieve fast cure speed, epoxy systems are often accelerated with phenolic compounds to improve cure speed, however, these compounds are typically not EHS-friendly due to their health hazard rating and/or degrade the UV resistance.

Fast curing agent Ancamine® 2880 was developed to close the performance gaps and improve the EHS profile. This new curing agent delivers fast cure speed with good working time. The resulting coatings exhibit exceptional aesthetics at ambient and low temperatures, and good abrasion, UV and chemical resistance. In a multiple coat system, Ancamine® 2880 demonstrates excellent intercoat adhesion with epoxy primer and with aliphatic polyurea topcoat. The fast cure speed in combination with superior coating appearance and excellent mechanical properties renders Ancamine® 2880 an ideal candidate for one-day flooring solution where both primer and topcoat can be applied on the same day and are ready for service within 24 hours. Furthermore, when cured with hydrogenated resin, the coating maintains rapid cure speed and excellent UV resistance, achieving results not attainable with current available systems. This opens the possibility for using Ancamine® 2880 epoxy system for outdoor application where high UV durability is a requirement for long service life.

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