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WALK ON PROGRESS

Water-borne amine curing agents for high-performance floor coatings. By Dirk Fuchsmann, Evonik.

Flooring systems must meet an ever-increasing range of demands on their performance and efficiency. To meet these requirements, there have been significant technology advancements of epoxy curing hardeners in recent years. This article presents epoxy curing agents that enable floor coating formulators to comply with low emission and sustainability targets while fulfilling high expectations on processing speed and aesthetics.

Figure 1: Market trends and drivers for epoxy-based floor coatings.

Two-component epoxy systems are well-known for their excellent chemical resistance and mechanical properties, as well as superior adhesion to a wide range of substrates. For that reason, epoxy systems are widely used in concrete floor coatings and protective metal coatings [1]. Driven by environmental and safety regulations, water-borne epoxy systems have become an important technology and have gained wide acceptance across the coatings industry. Key advantages of the water-borne systems span from low emissions measured as VOC (volatile organic compounds) and low flammability, to reduced toxicity and easy cleaning with water. This allows coating formulators and applicators to improve workers safety and air pollution especially during indoor applications, but also to comply with ever more stringent sustainability targets [2].

Besides meeting increasingly stringent low emission requirements, the flooring industry is also asking for improved efficiency and product performance (*Figure 1*). These two additional key market drivers comprise minimising downtime to improve costs and productivity, as well as improved coating robustness and better aesthetics throughout the service life. To meet these requirements, there have been significant technology advancements of epoxy curing hardeners in recent years.

Whereas eco- and user-friendliness is a key demand for all layers of a floor coating, the importance of the other two market trends depends on the respective layer. For instance, aesthetics such as UV and colour stability are essential for topcoats but of less relevance for underlying coating layers. Therefore, formulations and subsequently, curing agents must be tailored to meet the different demands.

RESULTS AT A GLANCE

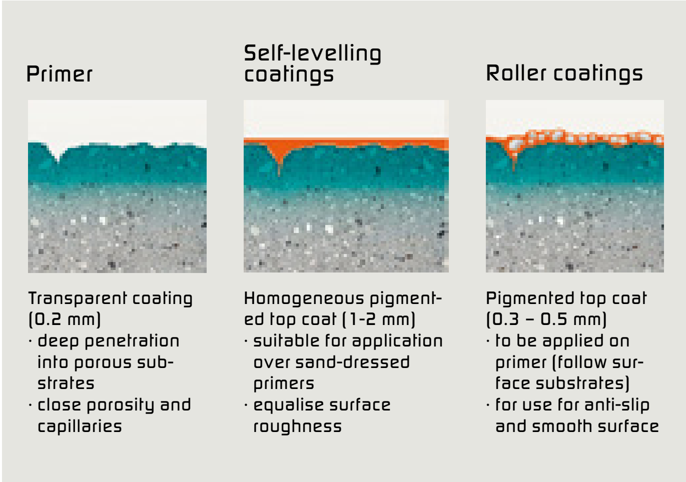
→ The floor coatings industry requires eco-friendly epoxy curing agents that allow for a fast return to service and offer excellent product performance such as outstanding surface properties, high adhesion, and chemical resistance.

→ The newly developed curing agents have been specifically designed to be used in all types of high-performance floor coating layers such as primer, self-leveller, roller coating and clear coat.

→ They enable further improved cure speed even at adverse conditions of low temperatures and on wet concrete.

→ By using these curing agents, floor coating formulators can meet low emission and sustainability targets as well as high expectations on aesthetics and processing.

Figure 2: Typical layers of an epoxy floor coating.



Typically, flooring systems are based on two to three layers. The first layer is a primer which closes pores and capillaries, followed by a thicker self-levelling or thinner roller coating (*Figure 2*). These topcoats are responsible for the functional and decorative features of the final coating. For aesthetic reasons, a final clear coat is also sometimes used.
The "Anquamine" range of products based on our proprietary water-borne technology [3] offers a broad portfolio of water-borne epoxy curing hardeners for flooring systems. They aim to meet the increased requirements of the market and the challenges of the different coating layers. In this article, we will demonstrate that flooring formulations based on these hardeners meet these latest market needs for all three coating layers.

PRIMER CURING SPEED MINIMISES DOWNTIME

Concrete primers are used to seal the pores and capillaries in the surface. In addition, the primer formulation must exhibit good adhesion to the concrete and offer a perfect inter-coat adhesion to the subsequently applied protective, or decorative coating. While it is generally known that epoxy systems show excellent adhesion to dry concrete, flooring systems based on the newly developed water-borne hardeners exhibit high adhesion even on damp concrete.
To demonstrate the good adhesion of the model primer formulations shown in *Table 1*, we carried out adhesion tests according to ISO 4624 on B25 concrete slabs. After cleaning, the slabs were acclimatised at the test temperature of 10 °C for at least 24 hours. The primer was then applied in a wet film thickness of 400 g/m² and the adhesion

Figure 3: Concrete adhesion of primer formulations after curing for 7 days at 10 °C.

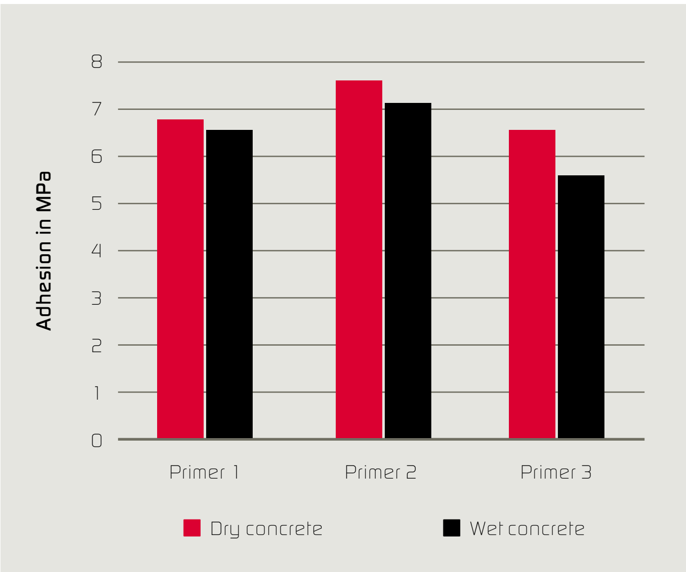


Figure 4: Dry hard test at 10 °C according to ASTM D1640 (thumb twist test).

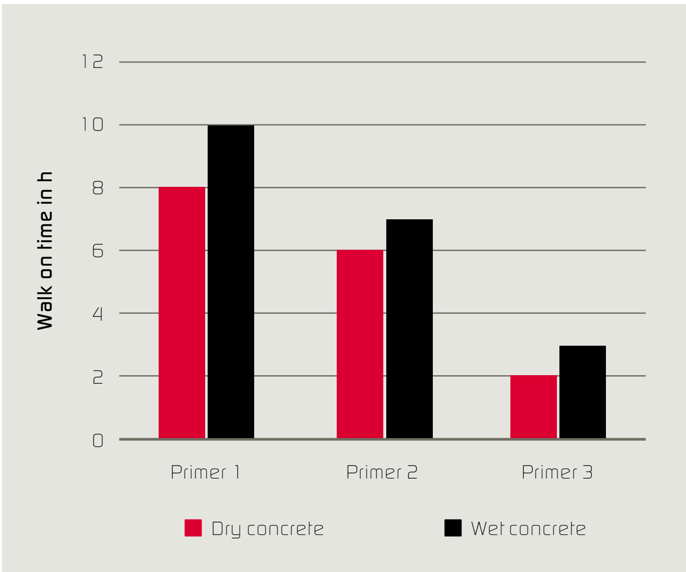


Table 1: Primer formulations.

Components	Primer 1	Primer 2	Primer 3
Part A (pbw)			
Curing agent 721	15.0	-	-
Curing agent 728	-	12.8	13.5
Water	3.8	-	-
Part B (pbw)			
LER; EEW 190	9.0	9.0	-
Reactive diluent	1.0	1.0	-
Solid epoxy resin persion	-	-	40.0
Part C (pbw)			
Water	15.0	22.0	13.0

measured after 7 days. The slabs used for wet concrete testing were kept submerged in water during the test period (2–4 % moisture content). *Figure 3* shows the excellent adhesion of the primer formulations under the extreme conditions of low temperature and wet concrete.
The three primer formulations that are based on a standard liquid epoxy resin (LER) and a solid epoxy resin dispersion exhibit 5–8 MPa bond strength, with a concrete cohesive failure of more than 95 % (*Table 2b*). Whereas adhesion is comparable across all model formulations, Primer 2 and 3 exhibit a much faster curing speed than Primer 1. The hardener used in Primer 1 and 2 has recently been introduced to the market to meet the improved productivity demands of the key market drivers (see *Figure 1*). To estimate walk-on or downtime, we determined the drying speed according to ASTM D1640 (thumb twist test) as shown in *Figure 4*. Using Primer 2 instead of Primer 1 reduces the drying time from 8 to 6 hours on dry concrete. In combination with a solid epoxy resin dispersion, it is possible to further reduce the walk-on time at 10 °C to 2 hours on dry concrete, and 3 hours on wet concrete while adhesion remains above 5 MPa. This short walk-on time allows for the primer to be recoated within one shift and therefore minimises the downtime for the end user.

Figure 5: Chemical resistance of white top-coating from Table 3.

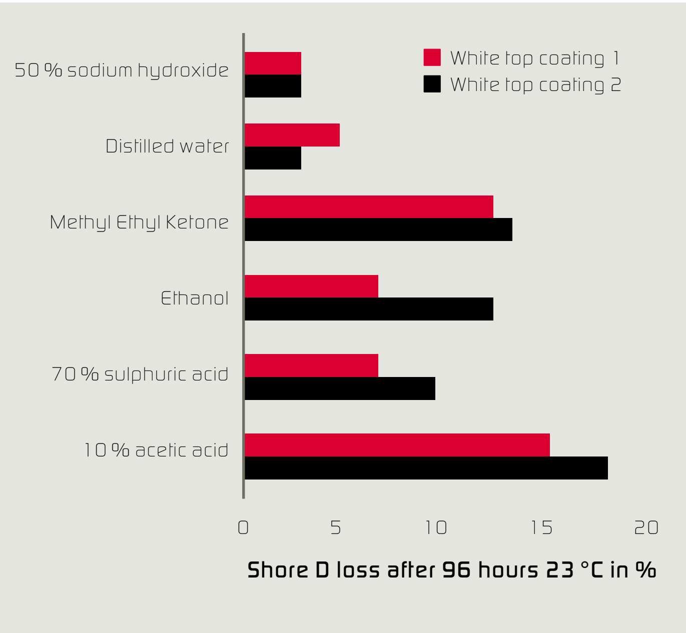


Figure 6: UV-A resistance of water-borne clear coats.

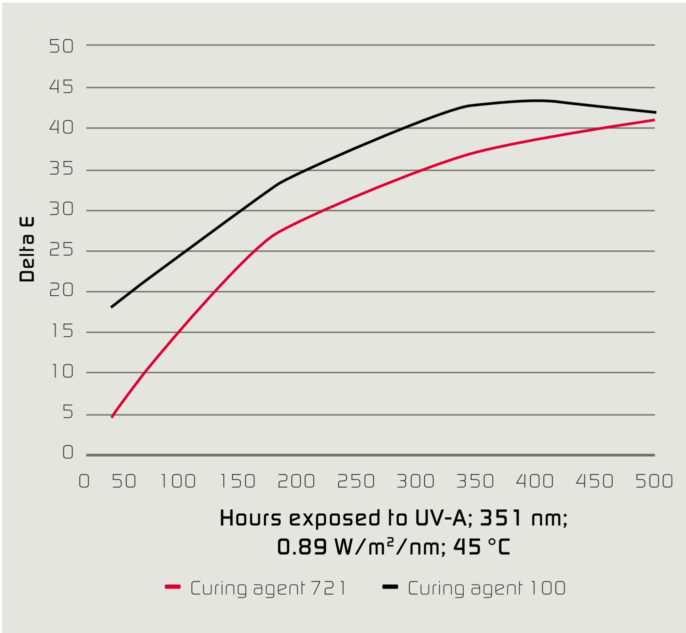
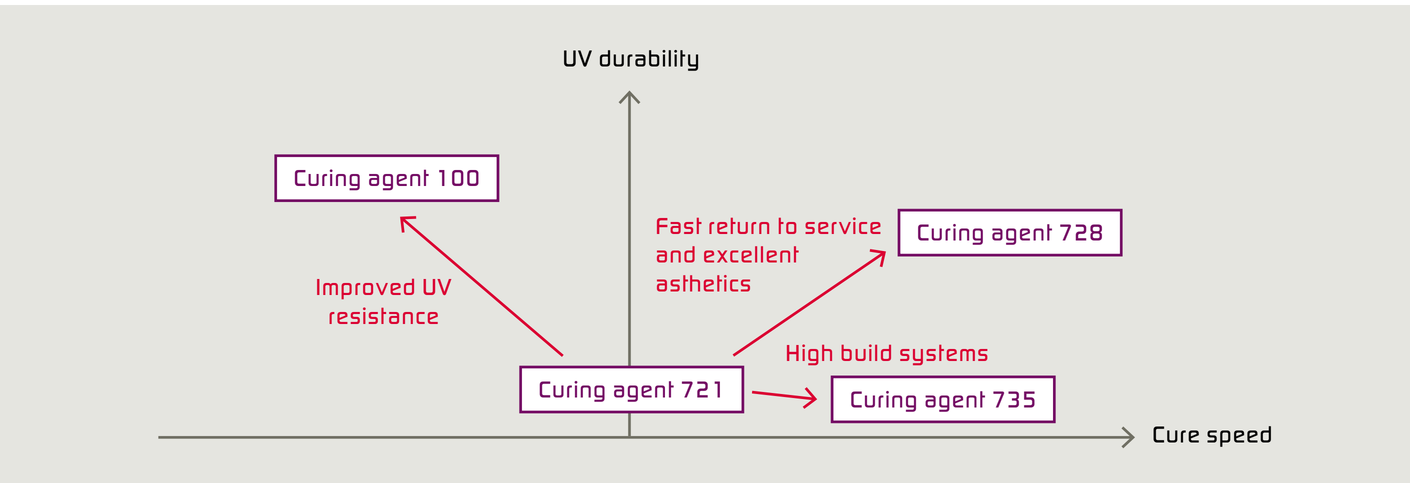


Figure 7: Positioning of water-borne epoxy curing agents for different flooring applications.



SELF-LEVELLING DECORATIVE AND FUNCTIONAL SYSTEMS

For self-levelling applications, we recommend a different hardener type (*Table 2a/b*), which provides a desirable satin or matte finish to minimise the visibility of any floor defects and reduce scratch sensitivity. However, the surface is very adaptable and can be modified to produce highly decorative surface appearances. Due to its good overcoatability, it is possible to additional coat the self-levelling floor with a transparent sealer or clear coat to create a high gloss or decorative finish with improved chemical resistance and cleanability. For instance, the surface can be easily modified by broadcasting sand or pigment effects and then sealing with an epoxy clear coat.
The self-levelling system also provides the substrate with a high level of protection, especially when it comes to abrasion, impact, and chemical spills (*Table 2b*). Conventionally used concrete such as the C25/30 type offers a standard level of performance which is acceptable for general purpose use. Such concretes will require a protective coating to enable a much wider variety of applications such as forklift traffic and chemical exposure. For this purpose, researchers developed a model formulation including additives and pigments (*Table 2a*) which offers excellent resistance to a variety of chemicals and can be cleaned without causing any damage. This formulation exhibits a high level of adhesion as well as excellent mechanical and abrasion properties (*Table 2b*).

TOPCOATS OFFER EQUIVALENT CHEMICAL RESISTANCE

Roller coatings are used for pigmented or clear topcoats. The market demands for high product performance and excellent aesthetics have led to the design of a various water-borne epoxy hardeners. Resistance to chemical spills is essential for many applications in the industrial flooring segment.
In this study, therefore, we evaluated the chemical resistance of model white top coatings. Discs of cured epoxy systems from the two formulations listed in *Table 3* were immersed for 96 hours in different chemicals (acids, bases, and organic solvents) and the effect on Shore D hardness due to swelling or degradation was measured. The results summarised in *Figure 5* show comparably little loss in Shore D hardness for both formulations for all the tested chemicals. Chemical resistance is thus at a comparable level with standard non-water-borne epoxy formulations based on benzyl alcohol.

LONG POT LIFE OF CLEAR COAT IMPROVES FLEXIBILITY

Highly decorative surfaces can be achieved by applying an additional clear coat layer. The key requirement for this application is an enhanced UV stability and transparency of the cured film. Clear coats based on Curing agent 100 exhibit excellent UV stability and transparency when cured with liquid epoxy resins. To investigate UV-A stability, 150 µm wet films were fully cured, dried, and subsequently irradiated for 500 hours. The resulting Delta E development indicating colour differences is a measure of film yellowing. UV stability is considerably improved compared with the standard hardener (*Figure 6*). Furthermore, this clear coat formulation has a long pot life of approximately 8 hours which improves working flexibility. For instance, it can reduce the number of mixing operations for one coating job which leads to a more efficient use of working crews. Additionally, the longer pot life is beneficial for wall coating or applications, and coating jobs at higher temperatures [4].

FASTER PROCESSING AND ENHANCED AESTHETICS

The purpose of this study was to demonstrate that water-borne epoxy hardeners fulfil not only the increasing demand for environmentally friendly, non-VOC formulations, but they can also meet the current trends towards a faster return to service and improved surface qualities. Depending on the specific application requirements, a range of water-borne curing agents is available offering products that are suited to different cure speeds and performance demands in all three flooring layers (*Figure 6*). As an all-round solution, the standard water-borne curing agent exhibits strong primer adhesion even at 10 °C and on damp concrete, and also provides excellent chemical resistance in topcoat applications. Curing agent 728 presents a faster return to service. While maintaining good adhesion and chemical resistance of the standard grade, walk-on times are considerably reduced both on dry and wet concrete. Using solid resin dispersions instead of conventional liquid epoxy resin further optimises these results. The surface appearance of topcoats can be further improved by switching to a dispersion on the hardener side as well. For this purpose, we developed a hardener dispersion that exhibits very low viscosity and thus broader formulation flexibility as an additional benefit. There is also a solution for thicker topcoats with self-levelling properties which is particularly suitable for protecting the concrete substrates against abrasion, impact, and chemical spills.
In summary, the described epoxy curing agents enable floor coating formulators to comply with low emission and sustainability targets while fulfilling high expectations on processing speed and aesthetics.

REFERENCES

[1] Jaap Akkerman + Dirk Mestach et al.; Resins for water-borne coatings; Vincentz Network
[2] Dornbusch + Christ + Rasing; Epoxy resins; Vincentz Network
[3] Klippstein A.H., Cook M.; Proceedings of the 1999 5th Nuremberg Congress, Creative Advances in Coatings Technology, Nurnberg Germany, Volume 1, 12-14 April 1999, 285-300
[4] Technical Data Sheet: Anquamine 100, Evonik

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Table 2a: Self-levelling formulation.

Components	Self leveller 1
Part A (pbw)	
Curing agent 735	10.0
Deaerator	0.5
Defoamer	0.5
Pigment TiO_2	3.8
Filler	12.5
Filler	27.0
Filler	34.0
Thixotropic agent	0.2
Water	11.5
Part B (pbw)	
Diluted LER; EEW 190	9.5

Table 2b: Physical properties of self-levelling formulation.

Physical properties	Self leveller 1
Surface appearance	Satin / matte
Compressive strength (28 days)	40 MPa
Adhesion to dry concrete	4.5 MPa
Adhesion to wet concrete	4.3 MPa
Impact resistance	180-200 kg.cm
Abrasion resistance (Taber C17)	300 mg

Table 3: White top coatings formulations

Components	White top coating 1	White top coating 2
Part A (pbw)		
Curing agent 721	38.0	-
Curing agent 728	-	31.8
Dispersing agent	1.2	1.2
Defoamer	0.1	0.1
TiO_2	28.0	28.0
Rheology modifier	0.7	0.7
Levelling agent	-	0.5
Water	22.0	22.0
Part B (pbw)		
LER; EEW 190	22.5	22.5
Reactive diluent	2.5	2.5