High Performance, Cost Effective Waterborne Epoxy Concrete Protection

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INTRODUCTION

High performance, cost effective protection of concrete is a key driver within the construction industry. A system based on waterborne epoxy technology which provides durable and highly aesthetic surface protection will be presented. A waterborne curing agent has been designed which exhibits excellent adhesion to concrete, including damp concrete with no carbamation at low temperature offering high performance, cost effective protection of all concrete substrates leading to it being the first choice for a concrete primer and coating system. In addition, for high traffic areas, a self levelling system which effectively offers surface protection to heavy loads with high impact resistance. This system offers a very attractive cost-in-use even when compared to epoxy solvent free systems due to significantly reduced resin demand. To complement these developments, a third curing agent, which offers very high aesthetics will be presented. This system offers high transparency, excellent scratch resistance, low colour and very good yellowing resistance and is ideal for highly decorative top-cot applications.

FIRST CHOICE FOR APPLICATION ON TO CONCRETE

SUPERIOR ADHESION

Concrete primers offer 2 primary functions. Firstly, a concrete primer should offer excellent adhesion to the substrate it is being applied offering a limited amount of protection. Secondly, the primer should offer a sound surface which can readily be coated with further protective or decorative coatings to produce a finished flooring system. Waterborne epoxy systems based on water soluble amines are well known for having excellent adhesion onto a wide range of substrates. A waterborne curing agent, WBCA-1, has been designed to be used in high performance primer system while giving a very low cost-in-use. Systems based on this curing agent provide excellent adhesion to all mineral substrates such as concrete, anhydrite, ceramic and old epoxy coatings. In addition to this the systems based on WBCA-1 will provide excellent adhesion on to damp concrete which is often encountered when coating industrial concrete floors. The adhesion data presented here clearly demonstrates that compared to traditional solvent free and solvent borne primer systems the adhesion to damp concrete is superior with the mode of failure with WBCA-1 being cohesive, indicating that the adhesion to the concrete is greater than the strength of the concrete itself. The primer systems shown are based on stoichiometric use of the curing agents with an unmodified bisphenol A diglycidylether epoxy resin. The following figure shows the pull-off adhesion testing of WBCA-1 compared to a standard cycloaliphatic system when applied to damp concrete.

Curing agent technology	Standard Dry Concrete	Standard Damp Concrete
WBCA-1 curing agent	1200 PSI – concrete failure	1200 PSI – concrete failure
Solvent free Cycloaliphatic	1200 PSI – concrete failure	60 PSI – adhesive failure
Solventborne polyamide	1200 PSI – concrete failure	145 PSI – partial adhesive failure

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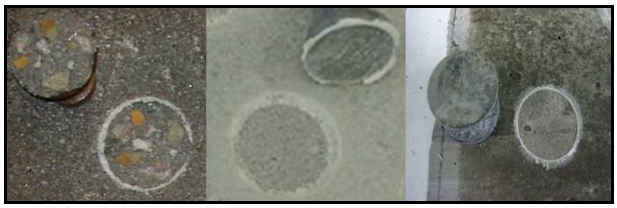

WBCA-1 Primer System | **Solvent free Cycloaliphatic** | **Solventborne Polyamide**

The robust nature of the adhesion of WBCA-1 based primer systems ensures that the risk of failures due to delamination from the substrate is minimised. The confidence in adhesion over a wide range of substrates is a key driver to make WBCA-1 systems the first choice for primer applications.

PERFECT FOUNDATION FOR MULTI-COAT APPLICATIONS

Now we have established the excellent adhesion to the substrate the other key requirements for a primer system is to provide a surface which can readily be overcoated with a further protective or aesthetic topcoat. Many coating applications consist of a number of coatings to increase the protective properties and also to provide a highly decorative system. WBCA-1 based systems exhibit excellent recoatability, with the surface presented offering the ability to recoat immediately or after several months with epoxy, polyurethane or other coating technologies. The intercoat adhesion data clearly demonstrates that there is no intercoat adhesion failure when overcoating the WBCA-1 primer with a further coating of a WBCA-1 system.

Primer and Coating Curing agent technology	After 1 day	After 3 days	After 1 month
WBCA-1	Cohesive failure	Cohesive failure	Cohesive failure
Solvent free Cycloaliphatic	Cohesive failure	Partial intercoat failure	Intercoat failure
Solventborne polyamide	Cohesive failure	Partial intercoat failure	Intercoat failure

A primer system based on WBCA-1 curing agent will be touch dry after 3-5 hours and can be overcoated with the following topcoat or self-levelling flooring system. Also as the system is not susceptible to the formation of carbamation under any circumstances the intercoat adhesion is not adversely affected due to applications at low temperature or high humidity.

DECORATIVE AND PROTECTIVE HIGH FILM BUILD APPLICATIONS

LOW ODOUR, PLASTICISER FREE SYSTEMS

A further waterborne system has been developed which is based on similar technology to WBCA-1, but unlike WBCA-1 it is designed to be used in high film build applications such as self levelling floors. High film build systems offer a high level of protection to the floor which will reduce the requirements for repairing the floor and ensure the longevity of the concrete substrate. Flooring systems based on WBCA-2 are low odour and can be formulated free of volatile organic compounds (VOC) offering VOC compliant systems. The application of coatings in confined spaces limits the use of solvents and other volatiles, due to odour and regulatory constraints. This is equally important for sensitive application areas such as schools, offices or hospitals which can stay occupied during application.

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	Self-Levelling Floor – 3K
A-Component	
1. WBCA-2	10.00
2. Defoamer	0.70
3. Pigment TiO_2	3.70
4. Thixotropic Agent	0.07
5. Water	10.53
	25.00
B-Component	
6. Epoxy resin	**9.00**
C-Component	
7. Fine Quartz Powder	12.00
8. Quartz Powder	28.00
9. Quartz Sand (0.1-0.3)	35.00
	75.00
Total	**109.00**

In Europe increasingly stringent regulations will further limit emissions from flooring systems during the life of the coating. Coating systems containing non-reactive components, such as benzyl alcohol, have shown high emission levels which are above the proposed limits. Self levelling coatings based on WBCA-2 are fully reactive and contain no plasticisers or solvents and therefore offer a compliant system. The WBCA-2 self levelling flooring formulation, as described in the section opposite, has been evaluated for emission levels according to the stringent German AgBB standards for the evaluation of emissions from building products on a 2.5 mm floor applied on concrete. The test results highlight that the WBCA-2 self levelling formulation exceeds the criteria to be categories as a low emission flooring system. This demonstrates that the system will meet the stringent future regulations in Europe and will have low emissions ideal for applications in the electronics industry or where low odour and tainting is of importance.

Furthermore, as the coatings are fully reactive with no plasticisers or solvents there are fewer concerns of flame spread and smoke generation in the case of fire, this is an increasing demand in building construction and offshore and marine environments.

THE IDEAL ROUTE TO HIGHLY DECORATIVE AND FUNCTIONAL FLOORING SYSTEMS

Self levelling coatings based on WBCA-2 curing agent provide a desirable satin/matt finish to lessen the visibility of floor defects and reduce scratch sensitivity. However, the surface is highly adaptable and can be modified to produce highly decorative surface appearances. Due to the inherent good overcoatability the self levelling floor can be readily coated with a transparent sealer or topcoat to produce a high gloss or decorative finish with improved chemical resistance and cleanability. The surface can be easily modified by broadcasting sand or pigment effects and then sealed with a transparent topcoat such as industrial two component polyurethane coatings, waterborne polyurethane / acrylic hybrid dispersions two component waterborne epoxy systems to offer highly decorative or non-slip flooring.

The WBCA-2 self levelling system also offers a high level of protection to the substrate, protecting it from abrasion, impact and chemical attack. The following table shows the physical properties of a self levelling system based on WBCA-2 curing agent compared to the typical properties of a solvent free cycloaliphatic system.

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Physical Properties	WBCA-2	Cycloaliphatic (50phr)
Surface Appearance	Satin / Matt	High Gloss
Compressive Strength (28 days)	5,800 PSI	8,700 PSI
Compressive Modulus (28 days)	110,000 PSI	220,000 PSI
Water Vapour Transmission ( )	500-1,000	30,000
Adhesion to Concrete	650 PSI	580 PSI
Impact Resistance	180-200 kg.cm	< 100kg.cm
Abrasion Resistance (Taber C17)	300mg	260mg
Plasticiser Free	Yes	No

Table 1 – *Typical Properties of Self Levelling Floor Systems*

In addition, this system provides high resistance to impact, e.g. from falling heavy objects. Upon impact a 'dent' but no cracking will occur so that concrete will be further protected without extensive repair works.

TIME IS MONEY

The self levelling flooring system based on WBCA-2, as described earlier, offers very fast property development allowing for a very fast return to service. The fast property development is demonstrated at 75°F and 50°F indicating that even at low temperatures the system will produce a walk-on hardness after 24 hours, the system will withstand light traffic after limited cure time allowing for the floor to be back in service after application or overcoated with a further decorative surface finish much quicker than competitive technologies. This has the advantage of reducing the time a floor will be out of service which has economic and logistical advantages.

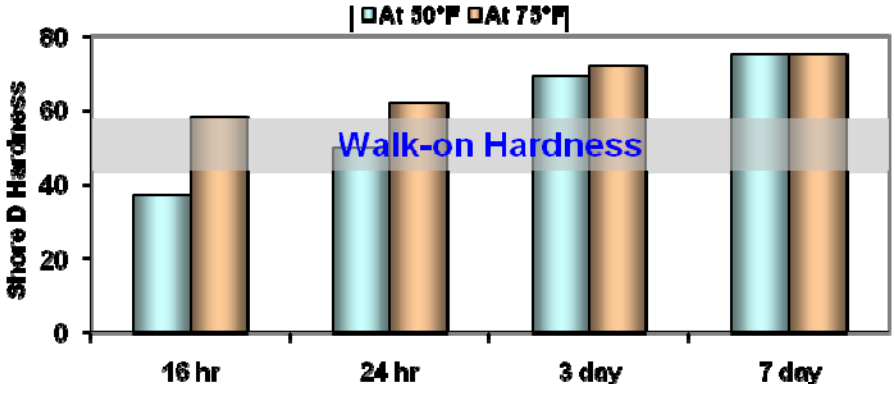

Figure 1 – *Shore D Hardness Development as a Function of Time of Cure for WBCA-2 Self Levelling Formulation.*

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AESTHETIC TOPCOAT APPLICATIONS

In the previous sections, functional primer and high build systems have been described using WBCA-1 and WBCA-2. These curing agents are based on water soluble polyamines which offer the best properties for these applications. For highly aesthetic low colour coatings and clear sealers a different technology is employed which offers easy handling and long working time to allow for easy application. The key to obtaining all of these properties is the use of dispersion technology.

EASY TO MIX AND EASY TO APPLY

Dispersion curing agent technology, (product WBCA-D) addresses the need for low viscosity, low colour, good colour stability and long pot-life. This technology is a stable amine functional dispersion based on a polymeric amine of hydrophobic nature that exhibits low solubility in water with an average particle size of 800 nm. The dispersion is non-ionically stabilised and exhibits freeze-thaw stability as well as storage stability. Dispersion technology has been applied to yield an ultra low viscosity curing agent, unlike any other waterborne currently produced. As is typical for an aqueous dispersion, viscosity is independent of molecular weight. The viscosity of 200 cP (55% solids) is more than an order of magnitude lower than conventional water soluble polyamine curing agents, which have viscosities of 10,000–20,000 cP at similar solid levels. This offers obvious advantages in handling and formulation development, providing handling characteristics comparable to well established solvent free technology based on cycloaliphatic curing agents. It can be utilized for transparent sealers without further processing, thereby achieving cost savings for curing agent formulation and re-packaging. In pigmented systems, WBCA-D shows very easy application by brush or roller with no roller pick-up due to low viscosity and the hydrophobic nature of the curing agent. This benefit translates into faster paint application, allowing for the same surface area to be coated in less time.

The low curing agent viscosity also translates into low mix viscosity at same solids, or in other words the ability to use higher solids in a waterborne system at the same viscosity. Between 25 – 50% more solids can be applied compared to other waterborne technology at the same application viscosity, thereby lowering cost by reducing the number of coats and the time necessary to yield the desired film thickness. As less water is required to evaporate from the system, a higher film build can be achieved. Unfilled systems have cured up to a dry film thickness of 500μm with high transparency and without any signs of water entrapment, thus providing application security and the possibility to apply transparent high film build water-based coatings. Coupled with this ability to cure in thick films are the low initial colour and good yellowing resistance, so that very transparent and clear epoxy coatings are achievable. Yellowing upon UV exposure is a commonly known shortcoming of epoxy technology and is inherent to the nature of the chemistry. Accelerated weathering benchmarking with QUVA exposure shows that the newly developed dispersion technology exhibits better UV stability than established waterborne and solvent free systems. This opens new water-based epoxy applications, such as clear top coats on decorative flooring systems, where traditional waterborne epoxy technology could not have been utilised and solventborne 2K polyurethane systems have been the preferred systems.

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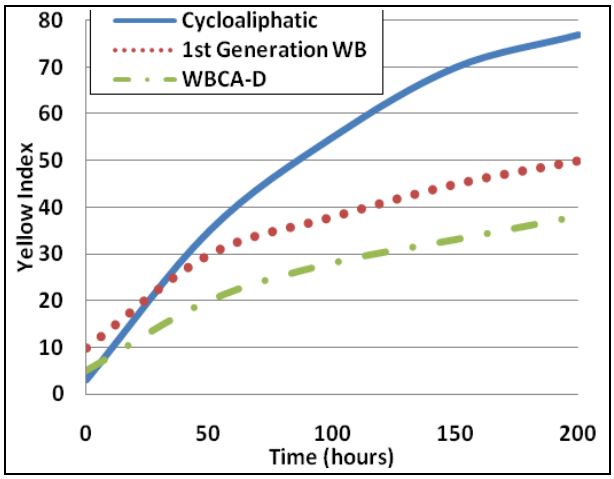

Figure 2 – *Yellow Index as a Function of Time of QUVA exposure*

A-Component	**1.2.3.10/AQ100**
1. WBCA-D	40.00
2. Dispersant	1.50
3. Defoamer	0.05
4. Titanium dioxide	26.00
5. Barytes	10.00
6. Filler	4.00
7. Talc	4.00
8. Curing Agent	6.00
9. Defoamer	0.50
10. Rheology modifier	2.00
11. Water	5.95
	100.00
B-Component	
1. Epoxy Resin	**25.00**
Total	**125.00**

Cycloaliphatic curing agents have been used for a number of years in top coat applications and have become an industry standard for highly durable top coats. The following table shows the formulation for a standard white top coat paint based on WBCA-D which can be brush, roller or spray applied. This formulation shows very good colour stability on exposure to UV light as shown in Figure 2 compared to similar formulations with a cycloaliphatic curing agent and a water soluble polyamide. The paint has a PVC of 20.5% and shows stable gloss at a value of 80 measured at 60° through the pot life, which is in excess of 6 hours.

Another interesting feature of WBCA-D, which is illustrated in the previous paint formulation, is the exceptional working time after mixing with epoxy resin. When cured with standard liquid epoxy resin a pot life of up to 8 hours is achievable; the system offers a very stable viscosity profile over a 6 – 8 hour period with excellent film formation properties such as high and constant gloss and hardness. Traditional waterborne curing agent technology for liquid epoxy resins only provide a pot life of 1-2 hours, whereas conventional cycloaliphatic systems exhibit pot lives of less than 1 hour (Figure 3). This provides an economic route to long pot life water-based systems that currently can only be achieved utilizing pre-dispersed resin systems.

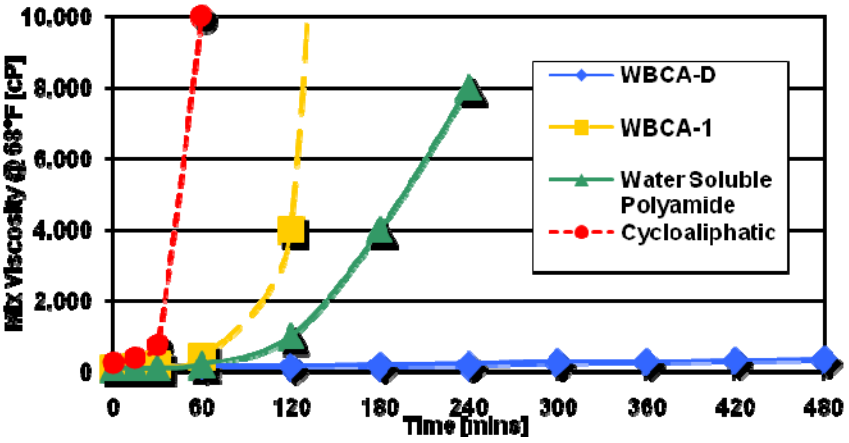

Figure 3 – *Viscosity Increase During Pot Life Using a Standard Epoxy Resin.*

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The long pot life offers an application window of a full working day, allowing for the mixing of one batch of material at the start of the day and then the continued application of this same material all day, optimizing the efficiency of applicator work crews. Additionally, the longer pot life is beneficial for wall coating application and usage in warmer climates, such as southern Europe and the Middle East. The high molecular weight of WBCA-D provides rapid drying and crosslinking with a lacquer dry on evaporation of water. The touch dry time of the system is very fast with the hard dry being similar to conventional waterborne systems such as WBCA-1 and solvent free cycloaliphatic systems as depicted in Figure 4.

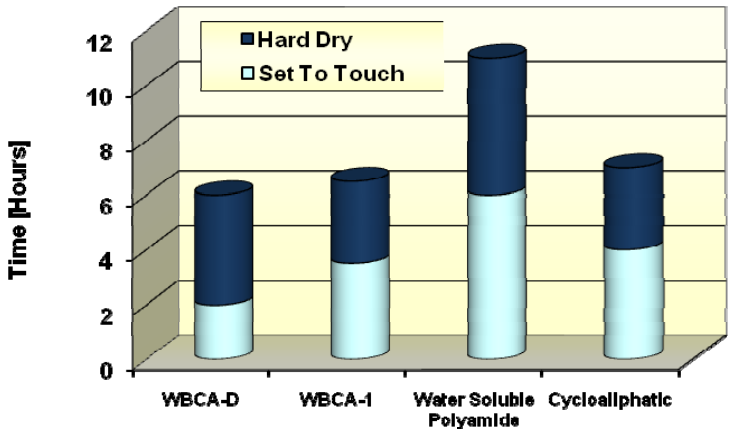


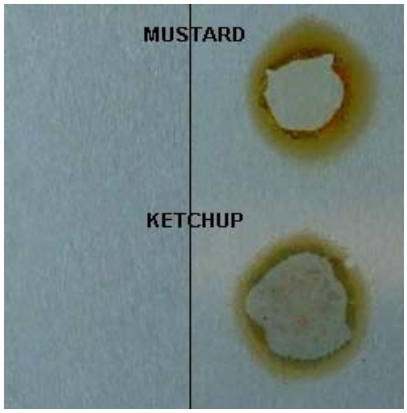
Figure 4 – *Drying Times of Waterborne and Solvent Free Systems at 77°F.*

For top coat applications it is important for coatings to retain their high quality aesthetic finish. Benchmarking of top coats for chemical and stain resistance against conventional water-based technology has again highlighted improvements. Good solvent resistance is observed for all water-based systems, however, a marked improvement in acid resistance is noticeable with WBCA-D. Organic acid resistance has always been a severe limitation of water-based epoxy coatings. Results of the benchmarking show coatings based on the new dispersion remain intact upon exposure to dilute acetic acid (3%) contact whereas other water-based systems show severe failures, leading to blistering and delamination from the substrate.

The improved acid resistance translates to improved stain resistance against common foodstuffs, especially those containing low levels of acetic acid such as mustard, ketchup and red wine. A summary of the results is outlined in Table 2. Coatings featuring the dispersion based curing agent are virtually unaffected after exposure whereas other waterborne systems show significant signs of attack.

Table 2 – *Stain Resistance 18h Exposure*

	WBCA-D	***Water Soluble Polyamine***
Coffee	no change	slight stain
Ketchup	no change	yellow stain
Mustard	no change	yellow stain
Red Wine	slight stain	yellow stain



WBCA-D **Water Soluble Polyamine**

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The increased chemical and acid resistance and the ability to cure in transparent low colour films suggests that films based on this technology can be utilised in more decorative coatings where contact with foodstuffs may occur, such as emerging coating applications in institutional areas or top coats in food preparation areas.

In addition to good compatibility with standard liquid epoxy resins, that are preferred for cost effectiveness, WBCA-D also exhibits exceptionally good compatibility with pre-dispersed solid epoxy resins. Use of pre-dispersed solid resins provides exceptionally fast dry speed and walk-on time, with touch dry times recorded at less than 1 hour for very fast return to service.

SUMMARY

In summary, WBCA-1, WBCA-2 and WBCA-D provide comprehensive waterborne systems with significant technical advantages over competitive technologies to provide high aesthetic durable protection of concrete. Their ability to ensure performance over a wide range of substrates while offering a cost effective solution to problematic applications make these systems the first choice for a wide range of end uses, including primers, water vapour permeable build coats and decorative top coats. In a market where ever increasing legislation and stringent regulatory requirements are being strengthened and enforced this system will provide a long-term solution whilst maintaining the high performance associated with epoxy flooring technology.

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