Novel Technology for Water Vapor Permeable Floor Coatings

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Overview

- Background
  - Epoxy floors

- Development of Novel Curing Agent Technology
  - Unique properties
  - Advantages

- Self-Leveling Formulation
  - Components
  - Physical and mechanical properties
  - Moisture vapor transmission

- Adhesion to Green Concrete
  - Bond strength and mode of failure

- Conclusions
Epoxy Floor Advantages

- High Mechanical Properties
- Excellent Appearance
- Good Adhesion to Concrete
- High Chemical Resistance
- Excellent Wear Resistance
- Cost Effective
Epoxy Floors
Epoxy Floors
Blisters and De-lamination

Blister

De-lamination
Causes for Blistering, Delamination

- **Hydrostatic water pressure**
  - Differential between highest elevation of water column and lowest point of structure
  - Becomes an Issue with Below-grade slab or high water table

- **Osmotic Pressure**
  - Spontaneous flow from dilute to concentrated solution through a semi-permeable membrane
  - Three requirements: presence of water, salts and semi-permeable membrane
  - Orders of magnitude greater than hydrostatic pressure
Osmotic Blistering

- Semi-permeable membrane
  - Primer (concrete pores are not fully filled)
  - Microstructural differences between upper and lower portion of slab

- Water and water soluble salts
  - No complete removal
  - Higher salt concentration in top concrete layer
  - Ground water

Result
Problem

Impermeable Floor

Solution

Water Vapor Permeable Floor

Water Vapor

Water

Blister

Self-Leveller Primer Partially-sealed Concrete
Novel Curing Agent Technology

- Curing agent emulsion of ultra high molecular weight
  - High compatibility with epoxy resin
  - Removal of unreacted by-products
- Faster drying at ambient and adverse conditions
- Applicable in high film build coatings: self-leveling and mortar floors
Novel Curing Agent - Advantages

- Zero VOC
- No benzyl alcohol
- Non-corrosive labelling
- No carbamation
- Low odor
- Heat resistant
- Easy clean up with water
- Moderate chemical resistance

- Matte Finish
- Water Vapor Permeable Floors
- Adhesion to Green Concrete
# Novel Curing Agent - Properties

<table>
<thead>
<tr>
<th>Physical Form</th>
<th>Emulsion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Pale Yellow</td>
</tr>
<tr>
<td>Solids</td>
<td>55 % in Water</td>
</tr>
<tr>
<td>Viscosity @ 25°C, mPa.s</td>
<td>5,000 – 10,000</td>
</tr>
<tr>
<td>AHEW</td>
<td>300</td>
</tr>
<tr>
<td>Recommended Use Level (phr, EEW=190)</td>
<td>140-170</td>
</tr>
</tbody>
</table>
Reactivity

Dying Time BK Recorder

Hardness Development

TFST @ 20°C (hrs)

Persoz Hardness

<table>
<thead>
<tr>
<th>Generation</th>
<th>1st</th>
<th>2nd</th>
<th>3rd (New)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Day</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>7 Days</td>
<td></td>
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<tr>
<td>14 days</td>
<td></td>
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</table>
Pot Life

Formulations based on Novel Technology Exhibit a Visible End of Potlife

![Chart showing the comparison of First Generation and Novel Technology products over time and viscosity. The chart highlights the end of potlife for each formulation.]
**Dilution Profile**

Solids [%] at 1,000 mPa.s with Diluted Liquid Epoxy Resin

<table>
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<th>1st</th>
<th>2nd</th>
<th>3rd (New Technology)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27.5</td>
<td>43.5</td>
<td>52.3</td>
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</table>
Novel Curing Agent
Self-Leveling Floor Formulation

Component A
Novel Curing Agent 11.0
Anquamine® 401 2.5
BYK-045 0.7
Ti-Pure R-960 TiO2 3.8
Water 9.1
Cimbar 325 36.0
Sil-Co-Sil 63 18.0
Quartz Sand (150μ) 9.3
Quartz Sand (300μ) 9.2
Xanthan Gum (3% in water) 0.4
Total 100.0

Component B
Epoxy Resin (EEW190) 10.0

<table>
<thead>
<tr>
<th>Shore D</th>
<th>1 day</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 days</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>7 days</td>
<td>82</td>
</tr>
</tbody>
</table>

Walk on time (20°C) 24 hrs

Solid Content 85% (wt), 70% (vol)
Self-Leveling Floor
Performance Properties

Basic Properties
Flow out (cm)* 15.9
Hardness (shore D) 82
Surface appearance Matte
Abrasion (mg/1000 cycles) 156
*50 x 25 mm disc - 2 min flow out

Mechanical Properties
Tensile Strength (psi) 1,233
Compressive Strength (psi) 5,076
Flexural Strength (psi) 1,595
Wet Cup Permeability Test

ASTM E96-95 (wet cup)

- Standard system:
  - No significant weight change over time.
  - Impermeable Coating

- Novel system:
  - Weight reduction over time.
  - Permeable Coating
# Water Vapor Permeability

<table>
<thead>
<tr>
<th></th>
<th>Floor based on the new technology</th>
<th>Floor based on a standard cycloaliphatic amine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Vapor Permeance, WVP</td>
<td>$6.67 \times 10^{-7}$</td>
<td>$4.69 \times 10^{-9}$</td>
</tr>
<tr>
<td>(g/s/m²/Pa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeability, $\delta$</td>
<td>$1.44 \times 10^{-7}$</td>
<td>$1.17 \times 10^{-9}$</td>
</tr>
<tr>
<td>= WPV X Sample Length</td>
<td></td>
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</tbody>
</table>

Floor based on *new technology* offers permeability 100 times greater than a standard floor.
SEM Images of Floor Specimens

- Cycloaliphatic
- New Curative

Factor 20,000 x
Shrinkage

- Very low shrinkage of \(~1.3\%\) at 70\% volume solids
- Water is driven out very quickly (within one day)

Hypothesis: Microporous floor structure that is water vapor permeable
Heat Resistance

Hypothesis: No plasticizer in the formulation

Candidate for Heat Resistant Flooring
Suggested Application Areas

- Areas known to be prone to hydrostatic or osmotic pressure
  - Underground water
  - Blistering is likely to occur
  - New concrete
- Renovation of industrial floors where existence of waterproof membrane cannot be guaranteed
- Clean room applications
  - No outgassing of plasticizer
- Conductive Self-Leveling Floor
  - Incorporation of 0.25% carbon fiber (resistance to earth $10^{-4} - 10^{-6}$ Ω)
Adhesion to Green Concrete

- Market trend: Faster return to service (minimize down time)
- The majority of current systems require a 28 day cure of the concrete before application
- Limited availability of systems for use over green concrete
- Self-leveling floor formulation based on the novel technology was evaluated on green concrete for adhesion
Test Protocol

Concrete Formulation 1 *
- Cement: 470 lbs
- Fly ash: 100 lbs
- Fine Aggregate: 1420 lbs
- Coarse Aggregate: 1850 lbs
- Water: 30.8 gal
- Admixture: 17.1 oz

W/C ratio = 0.45

Concrete Formulation 2 **
- Cement: 470 lbs
- Fine Aggregate: 1450 lbs
- Coarse Aggregate: 1900 lbs
- Water: 34 gal

W/C ratio = 0.60

- Concrete Slabs Poured into Forms with Bottom Plastic Liner
- Slab Finished by
  - Steel Trowel *
  - Broom Finish **
  - Mild Shot Blast After Three Days**
- Slabs Cure 24 Hours, Forms Removed, Sides Sealed, Epoxy Formulation Applied (Application in 3 Days for Shot Blast Finish)
- Bond Strength to Concrete Slab Determined
Bond Strength Testing

Coring

Bond pull-off test
Bond Strength After 7 Days of Epoxy Cure

![Bar Chart]

- **Steel Trowel**: Bond Strength
- **Broom**: Bond Strength
- **Shot Blast**: Bond Strength

**Concrete Finish**
- **Concrete Control**
- **New SL Floor**

Bond Strength, psi

0 50 100 150 200 250 300 350 400 450
Mode of Failure After 7 Days of Epoxy Cure

![Bar chart showing mode of failure after 7 days of epoxy cure for different concrete finishes.](chart.png)

- **Steel Trowel**: Over 50% failure rate, with mostly cohesive epoxy and concrete paste failure.
- **Broom**: Close to 100% failure rate, primarily concrete failure.
- **Shot Blast**: Approximately 90% failure rate, mostly concrete paste failure.

Legend:
- Black: Cohesive Epoxy
- Light gray: Concrete/Paste
- Dark gray: Concrete

Concrete Finish:
- Steel Trowel
- Broom
- Shot Blast
Bond Strength After 30 Days of Epoxy Cure

Concrete Finish

Bond Strength, psi

Steel Trowel   Broom   Shot Blast

Concrete Control
New SL Floor
Mode of Failure After 30 Days of Epoxy Cure

![Bar chart showing mode of failure after 30 days of epoxy cure for different concrete finishes: Steel Trowel, Broom, Shot Blast. The chart compares cohesive epoxy, concrete/paste, and concrete finishes.]

Concrete Finish
Conclusions

- Hydrostatic and Osmotic pressure cause synthetic floor de-lamination
- Novel curing agent technology has been developed to address market need for *fast return to service* and coating *high MVT concrete*
- Self-leveling floor formulations based on the novel curing agent exhibits
  - Excellent handling properties
  - Excellent mechanical properties
  - Very high moisture vapor transmission and
  - Excellent adhesion to green concrete
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