The function of polymer dispersion powder in cement based dry mix products

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SUMMARY
The modern building chemical industry needs dispersion powders as essential components in mineral binder based dry-mix mortars. These dry powder-form polymer binders do not only provide a good adhesion on the substrate, for example ceramic tiles, or improve significantly the impact resistance in the external thermal insulating system or the flexibility of one component sealing slurry mortars, they can improve formulations in different ways. Special dispersion polymer powders providing a water repellent effect used in finishing plaster or ceramic tile grouts, thus leading to a low water absorption and excellent weather resistance. Based on some selected applications and tests according to European Standards it’s demonstrated the high performance, the long working life and long durability. Comparing mortars modified with different amounts of polymer under various test conditions prove that dispersion polymer powders based on vinylacetate-ethylen copolymer provide a very good over-all performance.

KEY-WORDS
Dispersion Powders; Polymer; Dry-mix mortars; Adhesive; Cement;

1. INTRODUCTION
Dispersion polymer powders produced by a spray drying process are used in several applications, the most important are; Ceramic Tile Adhesive; Exterior Thermal Insulation Composite System; Ceramic Tile Grout; Self Levelling Underlayment and Overlayment; Concrete Repair Mortars; Gypsum trowelling compounds; Sealing slurries and Powder Paints.
The polymer binders are especially developed for blending with inorganic binders such as cement, gypsum, and hydrated lime. In the final product dispersion powders have an effect on both, the fresh mortar and eventually on the final product after the setting process. For instance in the fresh mortar the rheological behavior can adjusted for a particular application by dispersion powders with neutral, non-sag or flow rheology, in addition workability and open time can be controlled as well. After cement setting of the final product special properties can be attributed to the dispersion polymers like increased flexural strength plasticity abrasion resistance an if desired hydrophobic character. While mixing the dry mix formulation with water, the dispersion polymer powder becomes finally dispersed and after drying it will become water insoluble. This process is not reversible and it’s the reason for the big success of dispersion polymer powders in the world. The dry mix formulation has several advantages like packaging, transport and handling, costs, freeze resistance, resistance to biological attack.

2. POLYMER DISPERSION POWDERS

2.1 WHAT ARE POLYMER DISPERSION POWDERS?
Polymer dispersion powders are spray dried copolymer dispersions, for the building industry mainly based on vinyl acetate / ethylene monomers figure No. 1. During the spray drying process, the dispersion plus additional protective colloids usually polyvinylalkohol (PVAL), is converted into tiny droplets which are dried in a hot air stream. Powder particles (approx. 100 µm) consist of small resin particles embedded in a matrix of water soluble protective colloid figure No. 2. The powder particles are protected with anti caking agents against blocking and caking.

Figure No. 1 Polymer bases for the vinylacetate-ethylen copolymer are ethylene, with a glass transition temperature (TG) of -93°C and vinyl-acetate with a TG of +33°C. The TG of the polymer is controlled by the structure and composition of the copolymer, where ethylene works as an internal plasticizer, there is no need for a plasticizer.
Figure No. 2
Schematic picture of the spray drying process; dispersion plus protective colloid (PVAL), is dried to powder particles and embedded in PVAL. Adding water to the dispersion powder results again the dispersion.

2.2 THE FILM FORMING PROCESS
The film forming process for a pure dispersion powder is reversible figure No. 3. However, in an e.g. cementitious environment the protective colloid will be deactivated by the alkalinity of the cement and by absorption on the surface of cement and fillers. Thus, the dried film is no longer dispersible in water can built a polymer film and becomes now water resistant. Other mineral binders like hydrated lime, high alumina cement or gypsum will act in the same manner; they make the protective colloid water insoluble.

![Distribution Curve](image1)

Figure No. 3
The spray drying process is reversible, shown in the distribution curve; the dispersion powder can be dispersed in water (down) and will restore the original particle size distribution from dispersion (up).
3. TYPICAL APPLICATIONS

3.1 THIN BED MORTARS
The basic structure of a cement based ceramic tile adhesive for "thin bed application" or "thin set mortar" is cement, sand, a water retaining agent and dispersion polymer powder. The most common used cement is a standard Portland cement, either grey or white. The main area of concern is the sand: cement ratio. A thin set mortar should have approximately 1 part Portland cement to 2-1 parts of sand, depending on the type and quality of the cement and of the grading of the sand. The used sand should be silica sand with a particle size between 0.06 to 0.5mm it should be clean and clay-free. For premixed mortars dried sand has to be used. If the tile adhesive is too rich in cement, the adhesive is not elastic enough to ensure good adhesion bond strength in a test carried out, as recommended in the European Standard EN 12004. The admix contains a dispersion powder (0.5 – 6.0%) to improve the workability and open time, impart anti slip properties and display adequate adhesive strength under varying test conditions. An admix of a dispersion powder is especially vital if the installed tiles are exposed to higher temperatures (sunshine). The used tiles in the following test are very common to use but the most difficult tile to fix, the porcelain tile, becomes more popular and it is more difficult to get good tensile adhesion strength, figure No. 4 and No. 5. The water absorption (WA) for the stoneware test tile according to EN 178 is ≤ 0.2 %, the WA of the earthenware test tile according to EN 159 is 15% (± 3) and for porcelain tile we can calculate the WA next to 0.0%.

![Graph showing variation of polymer content and different types of ceramic tiles. Tensile adhesion strength according to EN 1348, after 28 days standard condition s.c. 23°C / 50% relative humidity. Classification according to EN 12004 measured with stoneware tile C1 = 0.5N/mm² and C2 = 1.0N/mm².]

**Figure No. 4**
Variation of polymer content and different types of ceramic tiles. Tensile adhesion strength according to EN 1348, after 28days standard condition s.c. 23°C / 50% relative humidity. Classification according to EN 12004 measured with stoneware tile C1 = 0.5N/mm² and C2 = 1.0N/mm².
Figure No. 5
Scanning electron micrograph (x1500; Wacker Polymer Systems) of the interface between a dispersion polymer-modified ceramic tile adhesive (left) on a porcelain tile (right). The polymer films at the interface between the surface of the porcelain tile and the cementitious mortar can be seen clearly (arrow).

For special applications the level of dispersion powder can be increased to 6 or even 20 % and these results in very flexible tile adhesives. Such tile adhesives are used to provide reliable adhesion to critical substrates (vitrified tiles, smooth concrete flags, plywood, tiles upon tiles). In cases were a higher deformability of the adhesive is required (e.g. thermal expansion, shrinkage or movement of the substrate), an admix of a dispersion powder reduces the elastic modulus and allows the mortar to flex or creep with the substrate and the tile.
Finally the cellulose ether improves also the water retention, the viscosity and the consistency of the thin set mortar and enables the worker to apply the mortar using a notched or serrated trowel in a uniform thickness. Without cellulose ether the mortar would loose the water too quickly and could not be applied by combing the mortar bed with a notched trowel. The level of cellulose ether for thin bed mortars is usually between 0.25 - 0.50 %.

3.2 EXTERIOR INSULATION AND FINISHING SYSTEMS
Exterior Insulation and Finishing Systems (EIFS), also identified as Exterior Thermal Insulation Composite System (ETICS), have been developed in Europe in the early seventies and since then have themselves proven in millions of square meters. Nowadays EIFS is applied world-wide on external walls of buildings in order to save not only energy costs from 30% up to 70% for heating and cooling systems by air condition (AC), but also to provide a healthier and more comfortable living environment and increased durability. It’s also highly recommended and proved to install the system also in hot climate countries because of the high energy consumption for AC’s during the summer time.
The dominating thermal insulation systems are based on expanded polystyrene panels (EPS) figure No. 6, which are fixed with polymer modified cement based adhesives to the walls. In order to protect the soft EPS against damages, a 3-4 mm thick polymer modified cement based mortar, the so-called base coat, is applied on top, embedding a special reinforcing glass fiber mesh. Finally a 2-3 mm thick finishing plaster is applied in order to provide a decorative and protective surface.

Figure No. 6
Scanning electron micrograph (a = x400; b = x3000, Wacker Polymer Systems) of the interface between a polymer-modified mortar (left side of the picture) on EPS (right side of the picture).

3.2.1 EUROPEAN ORGANIZATION FOR TECHNICAL APPROVALS
The European Organization for Technical Approvals (EOTA), located in Brussels, published the ETAG 04, within Europe it is the regulation for thermal insulating systems and it comparable to a standard. Within the ETAG 04 there are some requirements given for basecoat and adhesive materials shown in table No. 1. The approval for the system includes a so called hydrothermal test and requires a special climate chamber, where it is possible to make a cyclic climate test on wall of ≥ 6m². The cycles are:
HEAT RAIN CYCLES, 20 days;
80 Cycles - 3 hours 70°C / 10 % rel. humidity, than 1 hour spraying water at 15°C after this, 2 hours 20°C.
HEAT COLD CYCLES, 5 days;
5 Cycles - 8 hours 50°C / 10 % rel. humidity than 16 hours - 20°C.
Table No. 1 Requirements for tensile adhesion strength and impact resistance, given by the ETAG 04 = European Technical Approval Guideline 04 for ETICS (Download possible from Internet www.eota.be)

<table>
<thead>
<tr>
<th></th>
<th>dry, standard condition 23°C and 50% relative humidity</th>
<th>wet (+ drying time before test; h = hour, d = days) stored in water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength on polystyrene panel</td>
<td>&gt; 0.08 N/mm²</td>
<td>&gt; 0.03 N/mm² (2h)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 0.08 N/mm² (7d)</td>
</tr>
<tr>
<td>Tensile strength of adhesive on concrete slab</td>
<td>&gt; 0.25 N/mm²</td>
<td></td>
</tr>
<tr>
<td>Ball-falling-test, impact energy normal resistance high resistance</td>
<td>without crack formation standard &gt; 3 Joule, high resistance &gt;10 Joule</td>
<td></td>
</tr>
</tbody>
</table>

The improvement of the tensile adhesion strength and polystyrene pull out figure No. 7 from polymer modified cementitious mortars is shown in table No. 2 and depends on the amount of polymer on EPS used. This can only be achieved by using a sufficient high amount of organic binder and the appropriate type of dispersion powder based on VAc/E (vinyl acetate / ethylene).

Figure No. 7 Sufficient adhesion strength of the mortar on the EPS is basically characterized with the EPS pull out and only given, if the failure after the pull-off test is by 100% within the EPS panel. Adhesion strength in the interface between the polystyrene and adhesive is higher than cohesion strength of the panel itself.

Table No. 2 Tensile adhesion strength according to ETAG 04 of EIFS mortars with different amounts of dispersion powder on expanded polystyrene panel (EPS), quality PS 15 (acc. to DIN 18164 15kg/m³).
<table>
<thead>
<tr>
<th>Dispersion polymer powder</th>
<th>DPP</th>
<th>0 %</th>
<th>1 %</th>
<th>2 %</th>
<th>3 %</th>
<th>4 %</th>
<th>5 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile adhesion strength on EPS 14 days sc. (s.c. =23°C /50%RH)</td>
<td>N/mm²</td>
<td>0.05</td>
<td>0.08</td>
<td>0.12</td>
<td>0.14</td>
<td>0.15</td>
<td>0.14</td>
</tr>
<tr>
<td>EPS pull out (adhesion failure within the styropor)</td>
<td>%</td>
<td>0</td>
<td>8</td>
<td>79</td>
<td>92</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Tensile adhesion strength on EPS, 12 d sc. / 2 d water</td>
<td>N/mm²</td>
<td>0.06</td>
<td>0.08</td>
<td>0.11</td>
<td>0.12</td>
<td>0.14</td>
<td>0.13</td>
</tr>
<tr>
<td>EPS pull out (adhesion failure within the styropor)</td>
<td>%</td>
<td>0</td>
<td>35</td>
<td>61</td>
<td>82</td>
<td>95</td>
<td>98</td>
</tr>
<tr>
<td>Impact test in Joule, on 200x200x50mm³ test specimen, 500g steal ball falling test</td>
<td>J</td>
<td>&lt; 0.5</td>
<td>1.5</td>
<td>2</td>
<td>7</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

3.3 CEMENTITIOUS RIGID AND FLEXIBLE WATERPROOFING SLURRIES

Water, in liquid or in vapour form, is the most destructive weathering element for buildings made out of materials like concrete, masonry, and natural stone. Cementitious waterproofing slurries have been used in Germany for nearly 30 years. To eliminate all possible causes of water intrusion, the exterior walls of a building must be completely covered with waterproof material. A waterproofing must interact as a system to be able in preventing the penetration of water coming from groundwater, rainwater and surface water. A wide variety of waterproofing materials are also used in interior applications such as bathrooms, toilets, swimming pools and water tanks. Some waterproofing systems are used as protection against the detrimental effect of aggressive substances such as salts and acids, transported by water. For the flexibility of such products the type of the resin and the resin / cement ratio are very important. Only a flexible resin will impart flexibility to a cementitious compound. Cementitious systems have a very good adhesion bond strength on inorganic substrates, even after prolonged water absorption and it can be used as a waterproofing membrane on gypsum plasterboards or on floors, prior to the tiling as well. The cement / polymer film has also a load carrying capacity and a good scratch resistance as well. The water permeability is very low but it has good water vapor permeability and therefore there are fewer problems with blistering, if water vapor tries to permeate through the waterproofing membrane.

Today several systems are available in the market:

- Dry premix (component A) based on cement, fillers and other additives. Dispersion (component B) and if necessary some other admixtures like preservatives. Both components, A+B, are mixed on site.
- Wet premix e.g. dispersion, fillers and additives. This premix can be blended on site with the locally available Portland cement.
- Flexible single component system.
For rigid systems it’s possible to work with a high level of cement and a small amount, between 2 and 5%, of dispersion powder.

Rigid and flexible waterproofing slurries require at least 2 mm dry layer thickness, which is generally obtained only with multiple coats. Even if one can apply the slurry by trowelling at 2 mm thickness, at least 2 coats must be applied in order to seal pores and micro cracks of the first coat. Against negative pressure for such application the rigid or semi elastic materials are preferred.

Table No. 3
Fundamental requirements for waterproofing membranes for use beneath ceramic tiles acc. to EN 14891

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Requirement after water contact</th>
<th>Requirement after heat ageing</th>
<th>Requirement after contact with lime water</th>
<th>Waterproofing under hydrostatic pressure (1.5bar / 7d)</th>
<th>Crack bridging ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial tensile adhesion strength</td>
<td>≥ 0.5 N/mm²</td>
<td>≥ 0.5 N/mm²</td>
<td>≥ 0.5 N/mm²</td>
<td>No penetration</td>
<td>≥ 0.75 mm</td>
</tr>
</tbody>
</table>

3.3.1 CRACK BRIDGING ABILITY

Crack bridging ability is a new test and has to be done for flexible sealing slurries. In figure No. 8. The test formulation contained a variation of the dispersion powder, 20-45%, OPC cement 8-11%, some defoamer and filled up to 100% by 0.02 to 0.20mm grain size silica sand. The min. requirement > 0.75mm can be reached with dispersion powder contents higher than 20%, ideal between 25 and 35%. Hydrated cement is a rigid material and in this kind of high polymer modified system, dosages above 10% work against the final flexibility.

Figure No. 8 It shows the crack bridging test and the result of the mentioned formulation. Measurement of
elongation in mm, after two different storage condition; 28 days standard condition s.c. and after 14 days standard condition plus 14 days water storage, wet measured.

3.3.2 TENSILE ADHESION STRENGTH
The tensile adhesion strength given as minimum requirement has to be above 0.5 N/mm². The following figure No. 9 and figure No. 10 show the test condition and good performance for various test condition.

Figure No. 9 The sealing slurry is applied directly on the concrete slab according to the guideline. After the drying time the adhesive material has to be applied by a trowel and a test tile, type V1 according to EN14411, is 30 seconds pressed into the mortar with a 20N weight.

![Figure No. 9](image)

Figure No. 10 Adhesion test according to the EN 14891, after different storage condition; sc=standard condition 50% relative humidity 23°C.

![Figure No. 10](image)

4. ADDITIONAL PROPERTIES FROM SPECIAL DISPERSION POWDERS

4.1 HYDROPHOBICITY OF PLASTERS
The water repellent properties are measured according to the EN 1015-18 for mineral based plasters filled the plaster in the form (160x40x40mm³) followed by various storage condition.
The test specimen is standing in a water bath and the water level is adjusted so that the grid is flooded by 5-10 mm. The water absorption is determined by weighing the samples after 10 and 90 minutes. The results are expressed as the water absorption coefficient C. Years ago, a free weathering test was done to demonstrate the durability and stability of the hydrophobicity, shown in Figure No. 11.

<table>
<thead>
<tr>
<th>Capillary water absorption</th>
<th>W0</th>
<th>Not specified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acc. to EN 998-1</td>
<td>W1</td>
<td>C &lt; 0.40 kg/m².min⁰.⁵</td>
</tr>
<tr>
<td></td>
<td>W2</td>
<td>C &lt; 0.20 kg/m².min⁰.⁵</td>
</tr>
</tbody>
</table>

Figure No. 11. Measured according to the former DIN 62517 standard, shows the durability of hydrophobicity supported by special hydrophobic polymers. Test specimen was laid out 6 years on the free weathering in Burghausen 60°/south.

An admix of a suitable dispersion polymer powder does not only reduce the capillary water absorption considerably, it increases the adhesion bond and the flexural strength of a plaster, which also reduces the risk of crack formation. It allows also applying the plaster more thinly, because it acts also as a second binder.

The water vapor permeability, tested acc. to EN 1015-19, of the whole plaster and render work has also to fit with the wall construction in order to avoid any inadmissible increase of moisture in the wall construction due to internal condensation.

4. REFERENCE
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