POLYMER MODIFIED DRY-MIX TILE ADHESIVES

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Abstract: Modern ways to install ceramic tile is by so called thin-bed dry-mix tile adhesives. In order to achieve the vital requirement for cementitious tile adhesive, a modification by redispersible powder – powder form dispersion polymer is necessary. The new international standard ISO13007(draft) or the EN12004 showing that without certain polymer binder inside, the requirements can not be meet. Tests showing the up-to-date redispersible technology with high pressure Vac/E copolymer, can outperform than the Vac/VeoVa copolymer, mainly on heat stability and durability. By testing deformability with EN12002, showing flexibility of tile adhesives highly rely on the dosage of polymer, and the low glass transition Vac/E copolymer provide a high deformation ability also at low temperatures.

Introduction: Pre-packed polymer modified dry-mix mortars are widely used in the modern building industry, e.g. as adhesives for fixing tiles and the installation of thermal insulation materials, as tile grout mortars, mineral decorative finishes and stuccos, self-leveling screeds and underlayments, waterproofing sealing slurries, repair mortars, jointing compounds, key-coats, masonry adhesives etc. Due to the high diversification of modern building materials, these mortars must meet various technical requirements like good adhesion on all kind of substrates, high deformation ability (flexibility) and excellent durability even under extreme climatic conditions all over the world.

The outstanding performance and durability of such dry mortars is achieved by combining the mineral binder Portland cement with organic binders in form of dry synthetic polymers, the so-called redispersible powders. Cement based mortars provide some outstanding characteristics, like high strength, excellent long-term water resistance and extremely good durability. But even if cement mortars are modified with cellulose ethers in order to improve the workability and the water retention, they will adhere poorly to many of the substrates found in the modern construction industry (e.g. concrete, polystyrene panels, wood panels, non absorbing substrates such as old tiles etc.). In addition cementitious mortars are very hard and brittle materials, but many applications demand more flexible or deformable mortars. In all these cases, the modification of cementitious mortars with polymers becomes a must. In dry-mix mortars, the two binder systems, namely the mineral binder cement, and the polymer binder redispersible powder, are ideal partners. This combination of mineral and polymer binder yields outstanding synergistic properties and characteristics of the dry-mix mortar which cannot be achieved by either one of these binders being used exclusively.
Redispersible powders are polymer binding agents being produced by a spray drying process of special water based dispersions mostly based on Vinyl acetate/Ethylene polymers. These are often also referred to as re-dispersible powders, because after the mixing or re-dispersion with water, these powder-form polymer binders can be returned to their original water based dispersion with all their typical characteristics and functions as polymer binders. The polymer film is formed after partial evaporation of the water by coalescence of the individual polymer particles. This polymer film acts as an organic binder, gluing together the filler particles, reinforcing the mortar structure and providing an excellent adhesion at the mortar – substrate interface.

In so-called dry-mix mortar plants, the redispersible powder is precisely and automatically dosed and homogeneously mixed together with cement, fillers and additives needed for specific types of dry-mix mortars. Thus the composition, the polymer content and consequently the quality and the performance of these polymer modified dry-mix mortars can be guarantied. This is not true for all kind of two-component or two-pack systems, where a liquid or a paste-form system is mixed with a dry-mix mortar or cement, which is a permanent source and occasion for mixing and application errors.

In contrast to two component or two-pack systems, exclusively the use of polymer-modified dry-mix mortars allows a safe, quality controlled and in addition also a highly efficient application of all kind of mortars.

The role and function of the redispersible powder as a polymer binder in cement based mortars is demonstrated based on two typical examples for the application of polymer modified dry-mix mortars: ceramic tile adhesives and mortars for the installation of the exterior thermal insulation systems.

**Ceramic tile adhesives**

One of the most important applications for polymer modified cement based mortars is tile fixing using the so-called thin-bed method. After mixing the pre-packed dry-mix at the job-site with water, the cementitious adhesive mortar is spread with a notched trowel onto the wall or floor and the tiles are laid into the fresh mortar bed. Typical requirements for such a thin layer adhesive are: good workability, long open time, high anti sag or anti slip resistance and after curing of the mortar: high tensile adhesion strength, sufficient deformation ability (“flexibility”) and durability under all relevant conditions.

Tests according to international standards like ISO 13007 (draft) or European Standard EN 12004 (chart 1) show that the minimum requirements can not be achieved without using a polymer binder (redispersible powder)(figure 1), especially after the so-called heat ageing
storage condition. According to these international standards, the tensile adhesion strength of a ceramic tile adhesive using stoneware tiles must be higher than 0.5 N/mm² for all storage conditions given (additional requirement: 1.0 N/mm²) (figure 2).

The very critical heat ageing test imitates the development of stresses which occur during temperature changes between the tiles and the substrate due to their different coefficients of thermal expansion. These internal stresses are compensated by the polymer incorporated in the cement matrix, providing a certain deformation ability, thus preventing failures and damages of the tiles fixed with the adhesive mortar.

Very porous tiles (earthenware tiles, water absorption approx. 15 to 30%; not specified in the international standards) can be fixed on porous substrates in principle with pure cement based mortars due to a mechanical anchoring of the cured mortar in the pores and cavities of the tile and the substrate (picture 1). As soon as less porous tiles (e.g. stoneware tiles as specified in the international standards, or the very popular even less porous porcelain tiles with water absorption < 0.01%) have to be fixed, the polymer binder is essential to provide a good bond on these glass-like tile materials. Pure cement based mortars will not be able to bind to these glass-like materials. In this case the bonding to the tiles is mainly provided by the polymer binder, as can be seen on pictures taken by the scanning electron microscope (picture 1). This mechanism of adhesion also applies for non-porous substrates (e.g. very smooth concrete, old glazed tiles, steel, etc.).

Results based on tests according to the European Standard EN 12002 demonstrate that the polymer modification not only improves significantly the adhesion (tensile adhesion strength) but in addition significantly the deformation ability (“flexibility”), depending on the polymer dosage. Special polymers based on Vac/E (vinyl acetate/ethylene copolymers) with a low Tg (glass transition temperature) provide a high deformation ability also at low temperatures (figure 3).

Testing cement based ceramic tile adhesives under more extreme and more practice orientated climatic conditions compared to the conditions given in the international standards, the role of the polymer binder for a reliable and durable fixing of tiles can be demonstrated even more impressively. In figure 4, data for the tensile adhesion strength of cement based ceramic tile adhesives are given. The higher the dosage of the redispersible powder, the higher the tensile adhesive strength values at low or high temperatures, especially if compared with a non-polymer modified mortar.

Comparing different polymer bases under various harsh test conditions with cyclic
temperature variations (temperature variation between -20°C and +70°C) prove that polymers based on vinyl acetate/ethylene provide the best over-all mechanical performance (data given in figure 5).

**Summary:** The combination of Portland cement as a mineral binder with redispersible powders as synthetic polymer binders allows the production of pre-fabricated and pre-packed high quality dry mortars. Depending on their composition, the polymer content and the type of polymer used, these mortars not only meet the requirements of international standards for the building industry, but also under very harsh and extreme laboratory testing conditions. For more then 45 years the redispersible powders have proven their reliability and durability in different kind of mortars and applications even under extreme practical application and climatic conditions all over the world. From the above discussion, it is demonstrated that polymers based on vinyl acetate/ethylene provide the best technical performance even under extreme conditions.

**Supplement:**
VINNAPAS® is the commercial name for thermoplastic polymer binding agents produced and supplied by WACKER POLYMERS. In combination with mineral binders (mainly cement), VINNAPAS® redispersible powders are used in the construction industry with great success for more than 45 years.

Typical applications for polymer modified dry-mix mortars are:
- ceramic tile adhesives and building adhesives,
- jointing and grouting mortars,
- special masonry mortars
- thermal insulation adhesives and base-coat mortars,
- self levelling mortars and screeds,
- concrete repair mortars and mortars for concrete rehabilitation systems,
- all types of plasters, renders and mineral finishing coats,
- lime-cement paints and cement-free powder paints,
- sealing slurries,
- joint fillers,
- trowelling and smoothing compounds.

VINNAPAS® redispersible powders are polymer binding agents that are produced by a spray drying process of special water based polymer dispersions. The redispersible powder was invented 1953 by WACKER Chemie. Today WACKER POLYMERS is the world-wide largest producer of redispersible powders.
The polymer modification of dry-mix mortars with VINNAPAS® redispersible powders will, depending on the dosage, improve:

- the adhesion on all kind of substrates,
- the flexibility and deformability of the mortar,
- it’s flexural strength and
- abrasion resistance,
- it’s toughness,
- cohesive strength and
- density (impermeability).

In addition, special VINNAPAS® redispersible powders can confer a hydrophobic effect making the mortar strongly water repellent.

Redispersible powders used in the tests of the presentation above:

- Vac/E, Tg 18°C: VINNAPAS® RE 5010N
- Vac/E, Tg 12°C: VINNAPAS® RE 5028 N
- Vac/E, Tg -8°C: VINNAPAS® RE 5044 N
- VC/E/VL, Tg 0°C: VINNAPAS® RI 554 Z
- Vac/VeoVa, Tg 18°C: market product

Special technical literature and technical information regarding applications with VINNAPAS® redispersible powders and their performance are available on request.

References:
1. “Polymer modified ceramic tile adhesives” Dr. Hermann Lutz
2. “Polymer modified factory-made dry-mix mortars as modern building materials” Dr. Hermann Lutz
3. “先进的瓷砖粘贴技术和先进的瓷砖胶粘剂” Dr. Christian Kober
Fig. 1: Determination of the tensile adhesion strength for ceramic tile adhesives by a pull-off test

**Storage conditions** according to EN 1348 (EN 12004) and ISO 13007 (tests performed at 23°C):

- **Standard storage:** 28 d sc (23°C/50% R.H.)
- **Water immersion:** 7 d sc + 21 d in water
- **Heat ageing test:** 14 d sc + 14 d at 70°C + 1 d sc
- **Freeze/thaw:** 7 d sc + 21 d in water + 25 cycles (2 h -15°C + 2 h in water at +23°C)

**Minimum requirement for all storage conditions:**
- Normal ceramic adhesives: 0.5 N/mm²
- Additional requirement: 1.0 N/mm²
Fig. 2: Tensile adhesion strength [N/mm²] of a cement based ceramic tile adhesive according to EN 12004 depending on the polymer dosage (% redispersible powder); comparison between stoneware tiles and porcelain tiles; polymer based on Vac/E, Tg 12°C

![Graph showing tensile adhesion strength](image)

- Minimum requirement: 0.5 N/mm²
- Materials: Stoneware (low porosity) tiles, Porcelain (non-porous) tiles
- Conditions: 28 d standard conditions, Water immersion, Heat ageing, Freeze/thaw

Fig. 3: Deformation ability [mm] of a cement based ceramic tile adhesive according to EN 12002 depending on the polymer dosage (% redispersible powder based on Vac/E = vinyl acetate/ethylene), the glass transition temperature (Tg) of the polymer and the testing temperatures (+23°C and –10°C)

![Graph showing deformation ability](image)

- Vac/E: Tg = -8°C (test at -10°C)
- Vac/E: Tg = +16°C (test at -10°C)
- Test at +23°C
Fig 4: Tensile adhesion strength [N/mm²] of a cement based ceramic tile adhesive according to EN 12004 depending on the polymer dosage (% redispersible powder based on Vac/E = vinyl acetate/ethylene) and the testing temperatures (23°C; +70°C and -20°C).

Fig 5: Tensile adhesion strength [N/mm²] of a cement based ceramic tile adhesive according to EN 12004 depending on the polymer dosage (% redispersible powder based on Vac/E and Vac/VeoVa) after the standard heat ageing test and cyclic temperature variations (100 cycles [+70°C/- -20°C, 24 hours each]).
Pict. 1: SEM (scanning electron microscope) pictures of a cement based ceramic tile adhesive on different type of tile materials

Earthenware tile (high porosity; water absorption 15 – 30%); mechanical anchoring of the cement based mortar within the pores and cavities is possible

Porcelain tile (1) (no porosity; water absorption < 0.01%); no mechanical anchoring possible; adhesion through the polymer film (2) at the interface tile/cement mortar

Chart 1 requirements of EN12004:2001 for cementitious tile adhesives

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<th>Class</th>
<th>Tensile adhesion strength [N/mm²] acc. EN 1348</th>
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<th>Open Time: Tensile adhesion strength [N/mm²] acc. EN 1346, after 20 min</th>
<th>Open Time: Tensile adhesion strength [N/mm²] acc. EN 1346, after 30 min</th>
<th>Tensile adhesion strength [N/mm²] acc. EN 1346 after storage 24 h acc.</th>
<th>Slip resistance [mm] acc. EN 1308</th>
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