MODIFICATION OF CERAMIC TILE ADHESIVES WITH REDISPERSIBLE POLYMER POWDERS

Dr. Hardy Herold

Technical Service Construction
Polymer Division
L-B-B/TMT04/WB, PK 14, LP 751
Wacker Chemie GmbH
Werk Burghausen
D-84489 Burghausen
phone -8677 83 5398
Fax. -8677 83 5090

ABSTRACT

The traditional bonding system for fixing tiles was basically a simple portland cement mortar. Such adhesives had been applied in the so-called thickbed method e.g. the mortar was first applied (buttered) on the backside of the (prewetted) tiles in a thickness of 10 to 25 mm and the tiles were pressed into their position on the wall or substrate.

This method is more and more substituted by the thin-bed technique which helps to save time and material. A modern ceramic tile adhesive is applied by means of a notched trowel in a thin layer onto a flat and smooth surface.

Afterwards the tiles are pressed onto the ribs of the adhesives with a slightly twisting or sliding action.

The new technique needs sophisticated tile adhesives due to the thin layers applied. In order to guarantee a stable and reliable fixing of the ceramic tiles the used mortars have to fulfil a number of additional demands compared to thickbed mortars. Redispersible polymer powders are used to impart the necessary improvement of adhesion properties and flexibility. They further improve the workability and open time of thinbed ceramic tile adhesives as well as - depending on the type of redispersible powder - thixotropic and hydrophobic behaviour.

INTRODUCTION

Thermoplastic polymer dispersions have been used in the construction industry since the forties as modifiers for cementitious construction materials.

The addition of dispersions significantly improves the properties of cementitious mortars, which otherwise tend to be somewhat brittle.

For example, addition of mortar modifiers markedly improves the adhesion of cementitious mortars to a variety of substrates, especially to problem substrates, such as polystyrene, PVC or steel. The modifiers also have a beneficial effect on mechanical properties, particularly flexural strength (often compressive strength as well), as well as abrasion resistance.

The polymer modifiers reduce the mortar`s modulus of elasticity; that is to say they increase its flexibility. This is important if the bond is to withstand deformations resulting from differential thermal expansion or shrinkage of the substrate. In addition, there is less susceptibility to cracking during hydration of the cement matrix.

The processing properties of the wet mortar are also improved by the addition of a dispersion, making it easier and faster to apply, even to the extent of permitting application with mechanical equipment.

Because of these advantages, polymer-modified cement mortars are becoming established in many new applications. Typical examples include mortars applied in relatively thin layers, such as mineral plasters, repair mortars, filling compounds, construction and tile adhesives.

Polymer modification thus has a long track record and also represents the state of the art.

Since the seventies, there has been an increasing trend towards replacing mortar additives in dispersion form with redispersible polymer powders. To achieve the advantages afforded by polymer dispersions, such redispersible powders must have a range of good technical properties.

The lecture gives an introduction into the application of redispersible powders in ceramic tile adhesives and their influence on the main properties.

APPLICATIONS

Redispersible powders are produced from dispersions by a special spray-drying technology and, after redispersion, have properties in the wet mortar comparable to the original dispersion.

Such polymer powders are extremely versatile, since they can replace aqueous dispersions in most cement applications. Here, too, they are generally also applied in relatively thin layers.

Like dispersions, they have a beneficial effect on important parameters such as adhesion, strength, abrasion resistance, plasticity and workability.

Redispersible powders are added to mineral binders such as cement or gypsum to improve the quality of mortars and concrete in construction adhesives, repair mortars, plasters, filling compounds etc. Redispersible powders can replace separately added mortar dispersions in any application (Table 1).

Application of redispersible powders **Table 1:**

Construction adhesives:	Tile adhesives, adhesives for thermal insulation systems, adhesive sealants, flexible adhesives, adhesive mortars (one- or two-pack)
Plasters:	Mineral plasters, finishing plasters, lightweight plasters, renovating plasters, thermal insulation plasters
Trowelling compounds:	Trowelling compounds for thermal insulation systems, wall and floor trowelling compounds, levelling compounds, joint fillers
Repairs:	Repair mortars, shotcrete, renovating mortars
Wall coatings:	Sealing slurries, wall trowelling compounds
Floor compounds:	Self-levelling compounds, screeds, industrial floors, floor covering adhesives
Primers:	Anti-corrosive coatings, plaster primers, adhesive slurries, bonding courses
Paints:	Limewashes and lime-cement paints, powder paints

Table 1.

HOW REDISPERSIBLE POWDERS WORK

Cement is the most important mineral binder. It must be hydrated with water to form a continous cement matrix. This water of hydration must be available over a long period, since the hardening process is relatively slow.

In the case of solid, thick-walled structures this is usually not a problem, since the surface area is relatively small in comparision to the volume.

The thinner the mortar layer is applied, however, the less favourable is the surface-to-volume ratio. As a result, the water evaporates too quickly or soaks into the substrates, and the cement is insufficiently well hydrated. Strength is poorer, cracks form as a result of shrinkage, and adhesion is inadequate.

In such thin-layer applications, redispersible powder modification is particularly advantageous. The redispersible powder which is produced from suitable dispersions by the spray-drying process can be made into stable dispersions again simply by stirring into water. A similar process is carried out when ready-mixed mortars are made up with water. Redispersible powders thus modify wet mortars in exatly the same way as would polymer dispersions. Unlike cement, the polymer particles form films as the water evaporates and act as a second binder. The two systems -- cement and redispersible powder -- complement each other ideally.

In the hardened cement matrix, the film of polymer particles forms interconnected resin domains between the cement particles and the fillers (Figures 1 and 2).

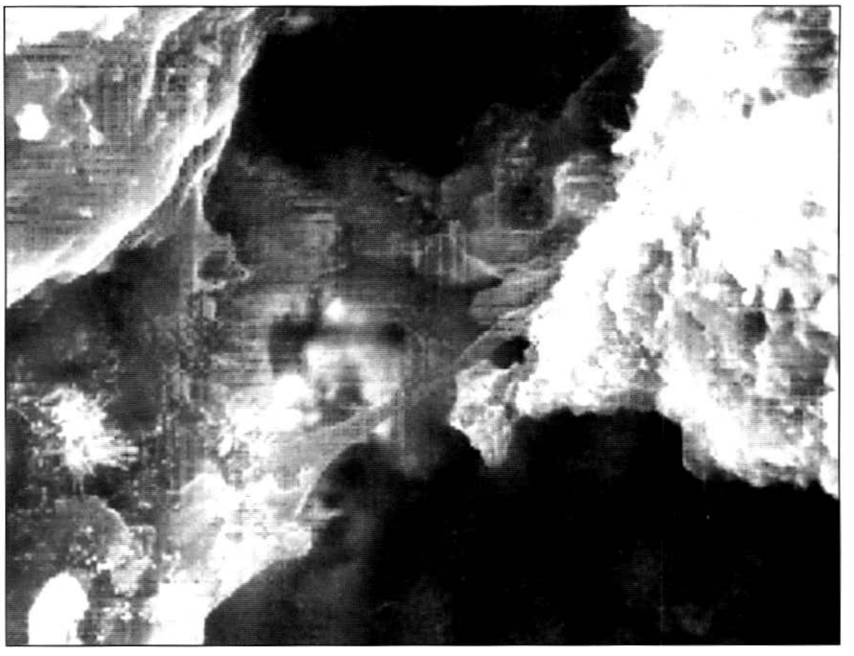

Figure 1.

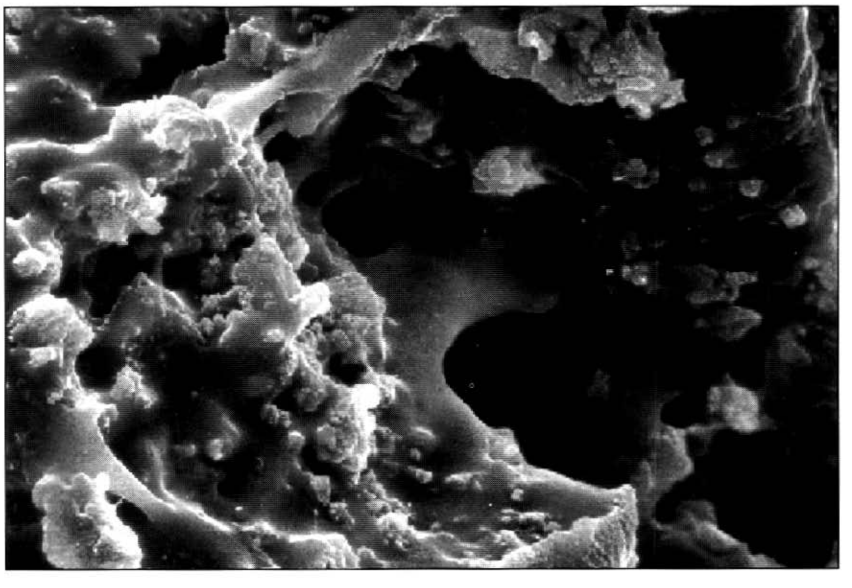

Figure 2.

The redispersible powder binder thus provides additional anchoring of the mineral components of the mortar.

EFFECTS OF MODIFICATION WITH POLYMERS

The improvement of mineral binders (usually cement) with dispersions and redispersible powders has the effect of enhancing a whole range of properties (Table 2).

Some of the benefits of redispersible powders (particularly the improvement of adhesion, plasticity and workability) are very important for tile adhesives, too, and will be discussed in the following.

Enhancing the properties of building products with redispersible powders

Table 2:

- Improved adhesion
- Increased flexural strength
- Reduced E modulus
- Increased plasticity
- Denser structure
- Improved workability
- Improved abrasion resistance
- Increased viscosity and cohesion
- Improved water retention
- Slower rate of carbonation
- Reduced water absorption (hydrophobic redispersible powders)

Table 2.

IMPROVEMENT OF TILE ADHESIVES WITH REDISPERSIBLE POWDERS

Redispersible powders improve the quality of tile adhesives quite significantly. Even a small amount of the modifier provides an improvement in the processing and adhesive properties.

The processing properties include those properties that describe quality, such as plasticity, smooth and easy application of the adhesives to a substrate, less need to "smooth off" the mortar and an increase in its ability to wet the substrates - as well as good water retention and non-slump properties. A suitable redispersible powder can achieve significant improvements and have a beneficial effect on the mechanical properties of the tile adhesives. Parameters such as tensile adhesive strength on different substrates and plasticity depend not only on the powder type but also on the formulation and the amount of polymer in the adhesive. The particular application will determine what requirements are to be made on the adhesive`s adhesion and plasticity - and therefore how much polymer modifier is to be added, i.e. wheather a slightly improved "normal" adhesive is to be used or a flexible adhesive containing typically 5 % powder.

Special adhesives are already available containing over 10 % polymer. Modern building techniques provide substrates that are usually flat, and the adhesives can be applied by thin-bed techniques. They allow a much bigger area to be tiled in the same time, with much lower material consumption. However, such thin-bed mortars of course have to satisfy much more stringent requirements than conventional thick-bed mortars. Because of the low layer thickness, the adhesive mortars also have to show better water retention and plasticity. For this reason, thin-bed adhesives are often significantly more expensive than thick-bed adhesives, but this disadvantage is more than offset by their higher yield, higher quality and more efficient (i.e., faster) application.

Many of the new substrates used in modern building techniques require better tile adhesives. Typical examples include tiles laid on gypsum plasterboard, organic substrates such as wood or PVC, or on old tiles in the course of renovation.

The tiles themselves are increasingly more difficult to bond. Modern high-quality tiles are fired with a very dense structure, and absorb virtually no water. Such tiles require adhesives with outstanding wetting and bonding properties.

This can be illustrated by considering the effect of a redispersible powder based on a VC/E/VL terpolymer (with glass transition temperature of -7 °C) in a tile adhesive. A model experiment was carried out with a formulation containing 35 % Portland cement and 0.4 % cellulose ether (viscosity 25 000 mPa s).

The values for the tensile adhesive strength tests were determined by according to existing European standards (Fig. 3). Stoneware tiles of size 5 x 5 cm, with a water absorption of < 0.5 %, were bonded to concrete slabs. In addition, the plasticity of all the adhesives was determined as specified in the draft standards (flexural tests on mortar strips 280 x 45 x 3 mm) after ageing for 14 days at 100 % relative humidity and then for 14 days under standard climatic conditions (Fig. 4).

Ceramic Tile Adhesives
European standardization

Measurement of the adhesional bond strength values of hydraulic setting tile adhesives

Storage conditions:

A: 28 days standard climate (23 °C/ 50 %)
B: 7 days standard climate (23 °C/ 50 %)
+ 21 days water immersion
C: 14 days standard climate (23 °C/ 50 %)
+ 14 days at 70 °C
+ 1 day standard climate (23 °C/ 50 %)
D: 7 days standard climate (23 °C/ 50 %)
+ 21 days water immersion
+ 25 freeze-thaw-cycles

demands:
adhesional bond strength values > 0,5 N/mm² after all storage conditions

Figure 3.

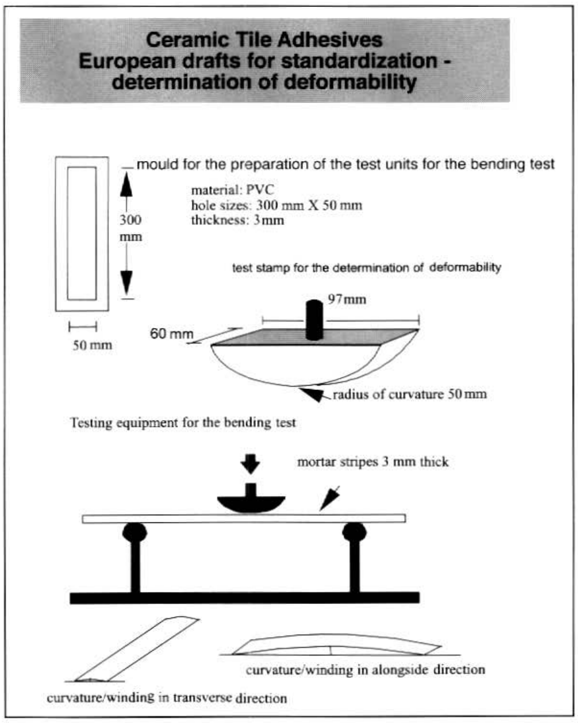

Figure 4.

On the concrete substrate under consideration, even the unmodified tile adhesive shows good adhesion after dry ageing (A). The addition of a (water repellent) redispersible powder further increases this adhesion significantly as a function of the amount added (Fig. 5).

As already mentioned above, the soft polymer and the brittle, rigid cement matrix ideally complement one another. Since the polymer still has an adhesive effect when dry, thin-layer modified mortars will adhere to the substrate even if the water evaporates quickly or soaks into the substrate, and the mineral cement component of the binder cannot hydrate sufficiently. Under wet conditions (such as in water immersion test B), on the other hand, the cement is capable of hydrating further and is responsible for most of the adhesive strength. However, the tensile adhesion strength values are not necessarily higher than for dry ageing. This property is highly dependent on the substrate. The small amount of polymer has little effect here. After redrying, on the other hand, the values are again as high as (or even higher than) those for dry ageing, since the mineral bonding is supplemented by organic bonding.

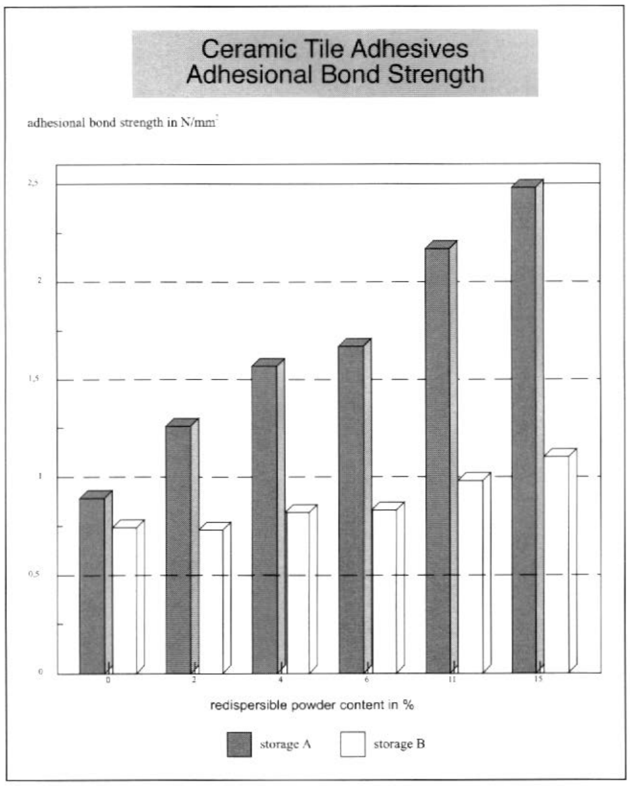

Figure 5.

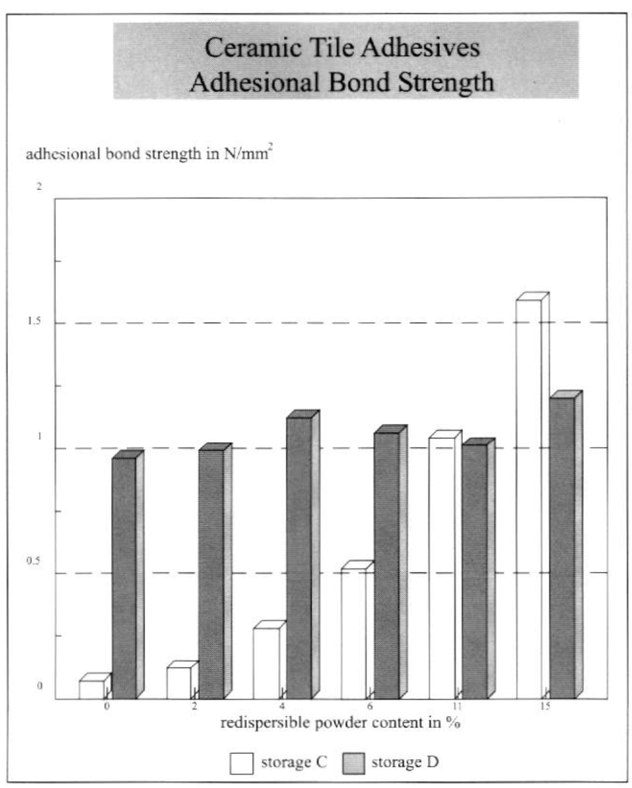

Figure 6.

This combined effect of the mineral and organic binders is also demonstrated by the immersion test under alternating freeze-thaw conditions D (Fig.6), in which extensive hydration of the cement is again observed. It is even more pronounced in the test for heat ageing C at 70°C. The adhesion of unmodified mortar is very poor in this case, since, in addition to being inadequately hydrated because the required water has been removed, there are also thermal stresses (different coefficients of expansion) and increased shrinkage of the substrate. Drastic though these conditions may be, they nevertheless occur in practice particularly with dark-coloured tiles in outdoor applications, which are heated by the sun in summer. In such cases modification with redispersible powders is the only way to ensure good adhesion. This improved adhesion under such climatic conditions is partly the result of the improved plasticity (ie, reduced brittleness) of the adhesive, which ensures that the thermal stresses (mainly shear stresses) can be more easily dissipated.

The improved plasticity can be demonstrated by, for example, the CEN test, in which all the 3 mm-thick mortar stripes show deflection values which increase as a function of the proportion of polymer. Fig. 7 shows corresponding test results.

According to the European draft standard, the stripes were aged for 14 days at 100 % relative humidity, followed by 14 days in a standard climate.

Figure 7 demonstrates that the flexibility of a tile adhesive is improved by increasing modification with a (flexible) polymer (increasing deformation at break). Furtheron a redispersible powder improves the strength values of the mortars, too (increasing bending force).

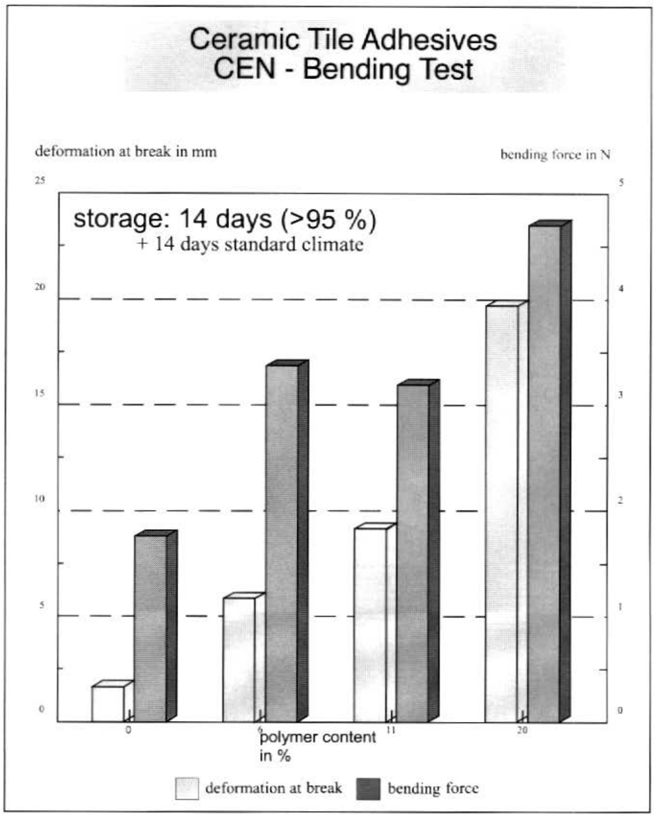

Figure 7.

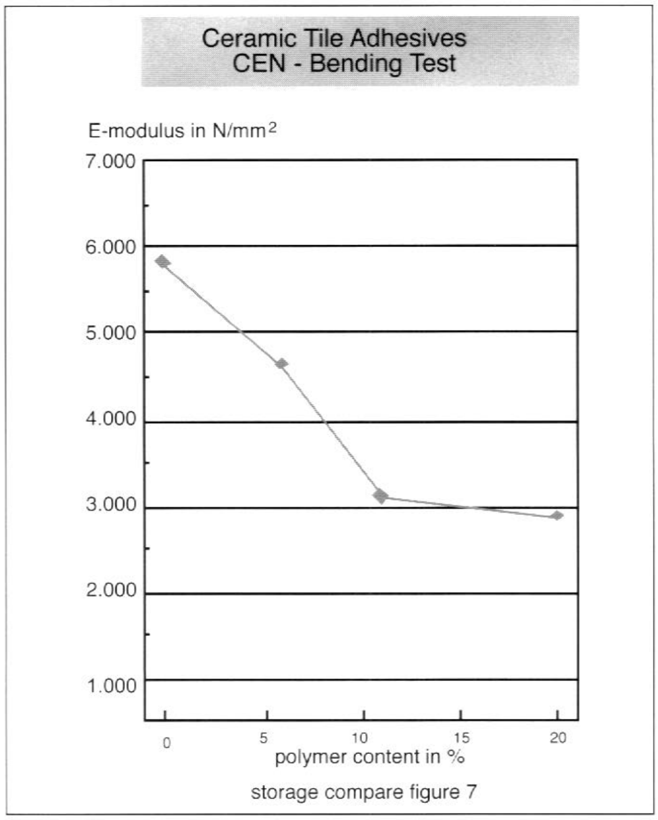

Figure 8.

The plasticity of a system is measured by the modulus of elasticity. We determined this from the CEN strip bending test by measuring the initial gradient of the stress/strain curves. We plotted the modulus of elasticity values as a function of the polymer content (Fig. 8). As expected, we again found that the modulus of elasticity decreased with increasing modifier content.

SUMMARY

The quality of mineral tile adhesives can be improved significantly by the addition of modern redispersible powders.

Redispersible powders improve the application characteristics and, together with the thin-bed method, allow increased yields and easier and faster working methods.

Redispersible powders increase the adhesion and plasticity of adhesive mortars. These are extremely important advantages, for example, when working on difficult substrates (like e.g. gypsum bo ards, wood substrates, smooth concrete walls or old tiles) with quality tiles having low water absorption, with large tiles or under extreme climatic conditions.

Redispersible powders further improve the workability and rheology of tile adhesives (either their non-slump properties on the wall or their self-levelling property when applied to floors depending on the type of powder used), and improve their water-retention.

But redispersible powders also provide other advantages. They reduce storage and transport costs and minimize environmental pollution from plastics packaging. They can be used in ready-mixed mortars that do not need to be protected against frost and have a long storage life without preservatives.

This powders are environmentally friendly binders. They contain no solvents, no preservatives, and are reliable and simple to handle.

The use of such ready-mixed mortars can also improve the consistency of the product - virtually eliminating mixing errors on site. These additional advantages have ensured the rapid spread of powder technology, and the increased use of single-component construction materials.