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Polymer modified factory-made dry mortars as modern building materials

Summary — Nowadays modified formulated dry-mix mortars have become inseparable part of the modern building technologies and practice. Currently development in the construction materials industry concerns the use of additives and polymeric binders in order to improve technical properties of mortars, mainly cement-based ones. It is not possible to meet today's technical demands for modern cementitious adhesives and grouts for tiles without using redispersible emulsion powders and cellulose ethers as additives. This paper gives an introduction into the application of redispersible emulsion powders and cellulose ethers in ceramic tiles adhesives and grouts as well as requirements and test methods for ceramic tiles adhesives and grouts specified in Poland. In the paper requirements for ceramic tiles adhesives and grouts specified in the Polish National Standards PN-EN 12004 and PN-EN 13888 have been presented.

Key words: dry-mix mortars, tile adhesives, pointing mortars, modification, redispersible powder resins, cellulose ethers, properties, Standards.

GENERAL INFORMATION AND RECENT PROGRESS IN DRY-MIX MORTARS FIELD

Nowadays modified formulated dry-mix mortars have become inseparable part of modern building technologies and practice. In formulated products, hydraulicly active minerals such as cements, limes and sulphates are mixed with fillers, synthetic resins and admixtures in order to achieve well defined macroscopic properties typical for specific applications such as fast setting, rapid hardening, high early strengths, shrinkage compensation, *etc.*

The most important components of a modern mortar are:

— mineral binders (Portland cements, high-alumina cements, special purposes cements, hydrated lime, calcium sulphates — anhydrite and α- or β-gypsum),

— polymer binders (redispersible emulsion powders),

— fillers (silica sands, silica flours, dolomite fillers, calcium carbonate light and special fillers),

— additives (thickeners, setting and hardening accelerators and retarders, plasticizers, water reducers and fluidifiers, air entraining agents, foaming agents, antifoaming agents, hydrophobic agents, wetting agents and pigments).

All these raw materials interact chemically and physically. The strongest interaction — because it is on purpose — takes place between the admixtures and the active materials or between the active minerals themselves. There are practically no chemical interactions between mineral binders and fillers and between polymer binders and fillers as well.

Basic knowledge of chemical reactions, physical phenomena as well as the structures of hardened materials formed in the process of cement hydratation and hydrolysis, constitutes one of the principle conditions for the optimum use of cement. With respect to cement, the term "hydration" is a simplification. Processes that occur in a mixture of cement with water are much more complex and they comprise reactions of hydratation and hydrolysis, dissolution processes of clinker components in the liquid phase as well as chemical reactions between particular cement components taking place in the course of the setting process [1].

In Poland, the last decade of the twentieth century was a period of rapid development of dry-mix mortars market [2]. During the last decade in Poland new dry-mix mortar plants of capacity more than two million tonnes have been established. The use of prepacked dry-mix mortars not only significantly increases the production performance and the productivity on construction sites but also let avoid on-site mixing errors, thus war-

rants a high degree of application safety and reliability. Prepacked dry-mix mortars ensure always exactly the same ratio of consistently high quality binders, aggregates and additives mixed, thus ensure always high quality of the mortar.

Currently development in the construction materials industry concerns the use of additives and polymeric binders in order to improve technical properties of mortars, mainly cement-based ones. With the development of science and technology, the use of different mortar additives has grown substantially last four decades [3]. Thanks to research and development studies, carried out in numerous research centers, our understanding of mortar structure and microstructure is much more comprehensive today, giving us a better opportunity to control the properties of the construction materials.

TYPES OF REDISPERSIBLE EMULSION POWDERS AS MORTAR MODIFIERS

Among different mortar modifiers, a special role is played by a group of redispersible emulsion powders. Widespread use of synthetic polymers in the construction materials industry began in the 1950's. The first redispersible homopolymer of vinyl acetate was obtained in 1957, while first redispersible copolymer was developed two years later. The first redispersible emulsion powder, based on vinyl acetate/ethylene copolymer, was produced in 1970 [3]. The introduction of redispersible synthetic resins enabled modification of cement mortars with the use of one-component systems.

Redispersible emulsion powders are made by spray drying special dispersions. When these powders are redispersed in water, they form a dispersion showing the same particle size distribution as that of the original product. Redispersible emulsion powders are thermoplastic resins with glass transition temperature below 30 °C. Minimum film forming temperature of emulsion powders used to enhance cement quality should be below 20 °C. Today redispersible emulsion powder range comprises many homopolymer, copolymer and terpolymer grades for a variety applications in the building industry. Regarding their chemical structure they can be of different types:

— vinyl acetate homopolymers,
— vinyl acetate/ethylene copolymers,
— vinyl acetate/acrylic copolymers,
— vinyl acetate/vinyl ester of versatic acid copolymers (VeoVa),
— styrene/butadiene copolymers,
— acrylate homopolymers,
— styrene/acrylic copolymers.

For modification of cement mortars mostly vinyl acetate/ethylene and vinyl acetate/VeoVa copolymers are used.

The effect of redispersible emulsion powders on the properties of cement mortars has been a subject of intensive studies for many years [3—9]. Today the research and development departments of redispersible emulsion powder producers are busy trying to introduce new generations of powder resins and to modify the properties of those which are already commercially available.

Now redispersible emulsion powders are being used to modify a technical performance of ceramic tile adhesives, grouts, adhesives for thermal insulation systems, plasters, trowelling compounds, concrete repair mortars, screeds and self leveling compounds, sealing slurries and wallpaper adhesives. It is not possible to meet today's technical demands for modern building materials without using of redispersible emulsion powders.

The next part of this paper gives an introduction into the application of redispersible emulsion powders and cellulose ethers in ceramic tiles adhesives and grouts (both these products belong to dry mortars group) as well as requirements and test methods for ceramic tiles adhesives and grouts specified in Poland.

STANDARDIZATION OF TILE ADHESIVES AND GROUTS

In all European Community countries and in some other countries in Europe the European Standard EN 12004 *"Adhesives for tiles — Definitions and specifications"* (as the Polish National Standard since 2002) and the European Standard EN 13888 *"Grouts for tiles — Definitions and specifications"* (as the Polish National Standard since beginning of 2003) regulate the requirements and classification of tile adhesives and grouts, respectively. Both PN-EN 12004 for adhesives and PN-EN 13888 for grouts for tiles regulate the initial type testing, production control frequency as well as classification and designation. Standard PN-EN 12004/A1 regulates CE marking and labelling of adhesives for tiles. Adhesives for intended use specified as "internal and external floorings and internal and external wall and ceiling finishes", according to PN-EN 12004/A1, shall follow the system of attestation of conformity number 3 (Construction Products Directive 89/106/EEC Annex, III.2.(*ii*), second possibility).

Other European Standards [10—22], which also have already had the status of the Polish National Standards, describe the test methods to be used to determine the characteristics of ceramic tile adhesives and grouts.

Currently in Poland, according to PN-EN 12004, cementitious tile adhesives are categorized in two groups:

— standard adhesives (C1),
— adhesives for special requirements (C2).

There are also two groups of cementitious grouts, according to PN-EN 13888:

— standard grouts (CG1),
— cementitious grouts with improved characteristic (CG2).

Some of the requirements of PN-EN 12004 Standard concerning the ceramic tile adhesives are summarized in

Table 1. Those concerning the grouts for tiles, described in PN-EN 13888 Standard, are given in Table 2.

Table 1. Selected specifications for cementitious tile adhesives (C1 — standard adhesives and C2 — adhesives for special requirements) according to PN-EN 12004 Standard

Properties	Requirement of class		Test method
	C1 N/mm^2	C2 N/mm^2	
Initial tensile adhesion strength	≥0.5	≥1.0	8.2 of PN-EN 1348
Tensile adhesion strength after water immersion	≥0.5	≥1.0	8.3 of PN-EN 1348
Tensile adhesion strength after heating ageing	≥0.5	≥1.0	8.4 of PN-EN 1348
Tensile adhesion strength after freeze-thaw cycles	≥0.5	≥1.0	8.5 of PN-EN 1348
Open time: tensile adhesion strength	≥0.5 (after ≥20 min)	≥1.0 (after ≥30 min)	PN-EN 1346

Table 2. Specifications for cementitious grouts for tiles (CG1 — standard grouts and CG2 — grouts with improved characteristic) according to PN-EN 13888 Standard

Properties	Requirement (value, unit)	Test method
Class CG1		
Abrasion resistance	≤2000, mm^3	PN-EN 12808-2
Flexural strength after dry storage	≥3.5, N/mm^2	PN-EN 12808-3
Flexural strength after freeze-thaw cycles	≥3.5, N/mm^2	PN-EN 12808-3
Compressive strength after dry storage	≥15.0, N/mm^2	PN-EN 12808-3
Compressive strength after freeze-thaw cycles	≥15.0, N/mm^2	PN-EN 12808-3
Shrinkage	≤2, mm/m	PN-EN 12808-4
Water absorption after 30 min	≤5, g	PN-EN 12808-5
Water absorption after 240 min	≤10, g	PN-EN 12808-5
Class CG2		
Abrasion resistance	≤1000, mm^3 (high)	PN-EN 12808-2
Water absorption after 30 min	≤2, g (reduce)	PN-EN 12808-5
Water absorption after 240 min	≤5, g (reduce)	PN-EN 12808-5

ROLE OF CELLULOSE ETHERS AS ADDITIVES TO TILE ADHESIVES AND GROUTS

As it was already mentioned in this paper, nowadays the manufactures of tile adhesives and grouts have a broad range of different additives to choose from. The most important of them, beside mentioned before redispersible emulsion powders, are cellulose ethers.

Cellulose ethers are used in tile adhesives and grouts in order to give them sufficient water retentivity. It is necessary to ensure that the mixing water is available to the tile adhesive or grout. This is a prerequisite for strong bonding. High water retentivity also ensures prolonged wetting capability of the adhesive once it is combed onto the substrate. An additional function of cellulose ether is to enhance the tile adhesive's non-slumpy property.

The improvement of mineral binders (mostly cement) with redispersible emulsion powders shows the effect of enhancing of a whole range of properties as follows:

— 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.

EFFECT OF REDISPERSIBLE EMULSION POWDERS ON THE PROPERTIES OF DRY MORTARS

Redispersible emulsion powders significantly improve the quality of tile adhesives and grouts. In the case of thin coatings, where the surface is big in comparison with the volume, very often there is not enough water available for complete hydration of a cement and the dry mortar is therefore not strong enough [7]. By adding polymeric binder, in the form of redispersible emulsion powder, to the cement based mortar a new system is created. In this system cement needs water to develop its full strength, while polymer binder forms a film by giving up water. Formulators of ceramic tile adhesives, by using different grades of redispersible powders, can influence some properties of the final product, mostly the open time (*i.e.* skin formation, what does not warrant yet adequate tensile adhesion strength), tensile adhesion strength after heat conditioning (high temperature cause both the tile adhesive and substrate drying up excessively) and deformability (normal stress due to the works for which adhesives are assembled or installed can be properly accommodated).

Unfortunately, for the characteristics of wetting capability (measured in accordance with [14]) and transverse deformation (measured in accordance with [16]) there are no limit values for tile adhesives and grouts, but it is left to the producer to declare the values to provide further information. Taking into account that tile adhesives should resist the degrading actions of climate and the

normal stress, due to the works for which they are intended, assembled or installed, the knowledge about transverse deformation of cementitious adhesives and grouts is crucial for choosing the appropriate product, considering all the possible risks. Till now only adhesives producers in Germany have reached agreement that for cementitious adhesives called "flexible" the value of transverse deformation, measured in accordance with [16], should not be lower than 2.5 mm [23].

Taking into account that, for satisfactory service, it is necessary to select and install ceramic tiles and adhesives and grouts for tiles competently and to keep appropriate initial treatment, protection and maintenance of them, the final draft of Technical Report prCEN/TR 13548, *"General rules for the design and installation of ceramic tiling"* was prepared by Technical Committee CEN/TC 67 and published in June 2003. The purpose of this document is to promote good design and installation standards for ceramic tiling across the Europe.

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