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Bonding of Concrete with Recycled Concrete Aggregate with Epoxy and Epoxy-Dispersion Adhesives

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Abstract

Contact gluing is undoubtedly one of the modern ways of bonding materials. The presented article examines the possibility of applying water-soluble epoxy dispersion adhesives to concrete surfaces of building constructions. The applicability of water-soluble epoxy dispersion adhesives is verified by adhesion tests where the degree of adhesion of the adhesive to recycled concrete surfaces is being compared to the degree of adhesion of standard epoxy and silicate adhesives. The obtained results confirm comparable adhesive and cohesive properties of tested dispersion and common epoxy adhesive from resin E520. The values of adhesion of the tested dispersion were also clearly higher than values obtained for reference silicate adhesive. This makes water-soluble epoxy dispersion adhesives eligible and competitive in the field of contact gluing of building materials.

Key Words: Epoxy dispersion adhesives; synthetic adhesives; gluing of concrete; adhesion;

Introduction

Nowadays, recycled concrete is increasingly used in construction practice. It can easily replace less to medium quality concretes made of natural aggregates. In addition, it is an ecological variant, as it is made with a secondary raw material in the form of recycled concrete aggregate. However, recycled concrete structures usually need to be further equipped, i.e. there are parts of variant construction materials that must be connected to the other parts of the structure. Gluing is undoubtedly one of the possible connection variants.

The emergence of modern adhesives based on synthetic resins is associated with the end of World War II. It can be said that the development of new types of synthetic adhesives in the last half century has been moving forward by leaps and bounds. Current synthetic resins are offered by manufacturers in two forms - classic (insoluble in water – e.g. CHS Epoxy 1200) and dispersive (with and without additional solvents - eco-friendly compositions). In general, construction adhesives can be divided into two categories: 1) solution and dispersion adhesives (solidified by evaporation or absorption of water or an organic solvent) and 2) reactive adhesives (solidified by a chemical reaction caused by external influences, e.g. elevated temperature or the addition of a hardener). Hot melt adhesives are often used in piping and insulation systems. These adhesives must first be melted, then they are solidified at normal temperatures and they are bonding the desired surfaces.

The principle of evaluating the applicability and suitability of modern epoxy dispersions [1-4] for bonding building materials consists in comparing the adhesive properties of the dispersions, applied to variously modified concrete adherents, and the adhesive properties of conventional silicate and epoxy adhesives. The degree of adhesion can be objectively determined according to the standard CSN EN 1015-12 as the maximum tensile stress induced by a load acting perpendicular to the surface of the applied adhesive and expressed as adhesion in N/mm2 [5].

Experimental study

Description of tested materials and principle of test procedures

During the research, the adhesive and cohesive properties [6-8] of a modern water-soluble dispersion two component adhesive for building applications (marked L1; in text I) were tested (see Table 1). The adhesive is manufactured by SYNPO Pardubice, as Composition of the component A of adhesive L1 is: 73% dispersion CHS EPOXY 160 V 55; 20% Calcimat KO-1/30; 0.5% Bentone LT; 0.2% Bayferrox 316. Component B of adhesive L1 contains 6.5% of hardener Telalite 1040.

Table1: Overview of adhesives and penetrations and their purpose in the adhesion test

Marking of adhesive and penetration in the text - type	Production designation of adhesive and penetration	Production designation of the hardener	Mixing Ratio Adhesive: Hardener /: (water)	Purpose in the adhesion test
I	Adhesive L1 –adhesive for construction applications component A	Adhesive L1 component B	100:07	testeddispersion adhesive
II	Flexkleber elastic adhesive	-	5 : 1,4	reference silicate adhesive
III	Adhesive E520 component A – resin	Telalit 2007	02:01	reference adhesive
IV	Penetration C HS Epoxy 160V55 – epoxy dispersion	Telalit 1040	100:09:00	surface penetration system
V	Adhesivefor gluing targets component A	Adhesivefor gluing targets compo-nent B	02:01	adhesivefor determining the adhesion to the substrate

The tests were performed on a concrete base made of recycled concrete. To verify the necessity of surface treatment of the adhered before the actual gluing, some concrete surfaces were sanded, some additionally penetrated with a water-soluble epoxy dispersion type IV (CHS Epoxy 160V55 + hardener Telalite 1040 - see Table 1). Concrete with recycled concrete aggregate is at least twice as absorbent as concrete with mined dense aggregate, therefore the applied layer of epoxy dispersion may prematurely lose its ability to disperse water with negative consequences of cracking and insufficient fusion of the dispersed adhesive (Figure 4 – aerated concrete). The degree of adhesion of the hardened aqueous dispersion to the substrate was determined by a pull-off adhesion test (it is a determination of adhesion fu in N/mm2according to [4]) and was compared with the adhesion of classic elastic silicate adhesive Flexkleber from Knauf company and the adhesion of epoxy adhesive E520 to the corresponding substrate.

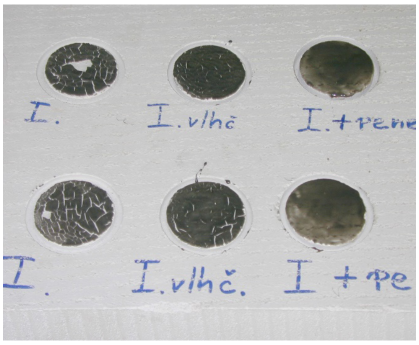

Figure 4: Cracked surface of L1 on aerated concrete

The assessment of the adhesive properties of adhesives was performed on the basis of the determination of adhesion according to the standard CSN EN 1015-12 “Methods of test for mortar for masonry –Part 12: Determination of adhesive strength of hardened rendering and plastering mortars on substrates”. The adhesion of the adhesive to the substrate fuin N/mm2was determined as the maximum tensile stress induced by a load perpendicular to the surface of the adhesive applied to the substrate. Such a load was exerted by means of a pull off target with a diameter of 50 mm, glued with a special fast-setting type V adhesive to the tested circular surface of the adhesive (see Figure 1). The required adhesion was expressed as the ratio of the derived load and the tested area. The mechanical method of pulling off a steel target Ø 50 mm by the Swiss device DYNA Z 15 from the company PROCEQ is shown in Figure 2.

Figure 1: Gluing of the pull-off target to the substrate

Figure 2: Pulling-off the target with DYNA Z 15

Adhesion test procedure

The technology of penetration, application of tested adhesives and gluing of pull-off targets on concrete adherents can be divided into the following subgroups:

a) Application of the tested dispersion adhesive type I to the penetrated surface of the concrete adherent. The circular area limited by the borehole is penetrated once with type IV penetration. After 24 hours of drying, a thin layer of type I adhesive is applied with a spatula, this layer is left to dry and harden for about 1 month (see Figure 3). Then a pull-off target is glued to this thin layer of the tested adhesive with the type V adhesive (see Figure 1). After 24 hours the adhesion test is performed (in practise Figure 2 and Figure 5).

Figure 3: Adhesive L1 applied on the concrete surface

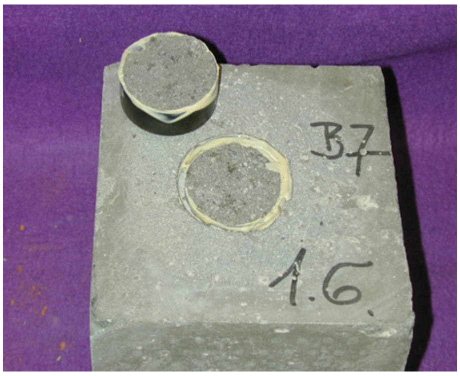

Figure 5: Pull-in-off the penetrated concrete adherent during the adhesion test of type **II** and **III** adhesives

b) Application of the tested dispersion adhesive type I to the raw (unpenetrated) surface of the adherent (concrete). The stage of penetration and subsequent 24-hour drying is omitted, otherwise the procedure is the same as a).

c) Application of a reference silicate type II adhesive on the raw (non-impregnated) surface of the concrete adherent. An approximately 1 mm thick layer of type II adhesive is applied to the circular area limited by the borehole, this layer dries and hardens for approx. 1 month. Then there is a pull-off target glued on the type II silicate adhesive layer by the adhesive type V. After 24 hours the adhesion test is performed (illustratively for ceramics Figure 6).

Figure 6: Loss of cohesion of silicate adhesive type **II**

Result

The results of the tested dispersion adhesive (type I) and reference silicate and epoxy adhesive (type II and III) are shown in Figure 7. Test of modern dispersion adhesive were always performed on six separately drilled samples of a given type of adherent, tests of reference adhesives on at least three separate samples of a given adherent.

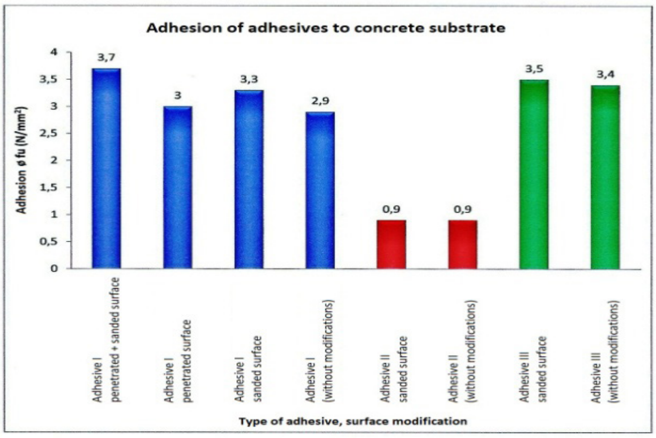

Figure 7: Results of adhesion of type **I**, type **II**, and type **III** adhesives to a variant-modified concrete adherent

Discussion

Concerning the adhesion properties of the tested water-soluble epoxy dispersion adhesive type I, the greatest attention was paid to adhesion itself. Tensile failure appeared during the adhesion test of the type I adhesive (adhesive L1) to all modified variants of the concrete adherents. This means that the adhesion is always greater than the achieved test result. The importance of penetration of concrete adherents by type IV mix before the actual application of type I dispersion adhesive cannot be clearly demonstrated (adhesion to the penetrated substrate is higher than the measured adhesion fu for type I adhesive). However, the effectiveness of this penetration can be assumed for porous adhesives (bricks, gas silicates) where there is a risk of rapid drying and subsequent cracking of the dispersion adhesive. Tensile failure in the layer of adhesive appeared also during the adhesion test of the reference silicate adhesive type II. (Flexkleber) to all concrete adherents. This means the self-cohesion of the adhesive mass collapsed. The adhesion is always greater than the achieved test result. In terms of adhesion, second reference epoxy adhesive type III epoxy adhesive behaves similarly to the tested type I dispersion adhesive.

Conclusion

Epoxy dispersions are gaining ground in construction practice due to a) good adhesion to wet substrates, b) the possibility of using wet fillers, c) low toxicity and non-flammability d) negligible dilution costs and overall savings of up to 20 % in production compared to epoxy resins. In addition, the research and results of performed adhesion tests according to the standard CSN EN 1015-12 show that for raw, as well as modified types of concrete surfaces, the resulting adhesion to the substrate and internal cohesion of dispersion adhesive L1 is higher than for silicate adhesive FLEXKLEBER and is comparable to epoxy resin E520. This makes water-soluble epoxy dispersion adhesives eligible in the field of contact gluing of building materials. The presented research confirms the competitiveness of modern water-soluble epoxy dispersion adhesives while leaving room for a more detailed examination of the most optimal composition.

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