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WATERPROOFING OF PORTLAND CEMENT MORTARS WITH A SPECIALLY DESIGNED POLYACRYLIC LATEX.

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ABSTRACT

Polymer modified portland cement mortars, with polymer/cement ratios up to 0,20 (w/w) have been studied, in respect to their mechanical and waterproofing characteristics. The polymer here developed, characterised by low water absorption, improves the workability, the flexural strength and the resistance to penetration of water and salt solutions of the modified mortars. These effects become remarkable over a certain amount of polymer (p/c ratios> 0,05). The air entrainement due to the polymer has a negative influence on the compressive strength but increases the freeze-thaw resistance. A comparison with the traditional superplasticizers and waterproofing admixtures, which impart hydrophobic properties to hardened mortars and concretes is also presented.

Introduction

The polymer-cement systems are typical examples which show improved applicative and engineering properties when compared to those of portland cement concrete alone. A well designed polymer modification can bring in several technical benefits such as increased tensile and flexural strength and enhanced impermeability. Adhesion to different substrates, resistance to mechanical stress and chemical attack are also improved (1,2). Due to the combination of the advantages of the hard, brittle hydrated cement with those of the flexible and elastic resin, polymer-modified cements/concretes are far better suited for certain types of applications than other currently available building materials. Economically speaking, the excellent durability characteristics of latex-modified systems can compensate the higher initial price by reducing maintenance costs and increasing the service life.

The aim of this work is to illustrate some applicative results concerning the improvement of the impermeability characteristics by modification of portland cement mortars with a specially designed acrylic latex, whose film is characterised by low water absorption. A comparison with the traditional mortar waterproofing systems as well as with some market latices used in that field, is also presented.

Experimental

Preparation of polymer latex

The acrylic latex was obtained by a semi-batch emulsion polymerization of a mixture of apolar monomers (butyl acrylate and stearyl methacrylate), in presence of a reduced amount of surfactants (ca. 1% on total monomers) and a persulfate type initiator. The compatibility with the inorganic phase was reached by means of small amounts of functional monomers (methacrylic acid, acrylamide). TABLE 1 shows some properties of the developed dispersion (L1) and those of two commercial products taken in comparison: an acrylic dispersion (L2) and a styrene-butadiene latex (L3).

TABLE 1

Physico-Chemical Characteristics of Latices

	L1	L2	L3
Solid content (%)	50	30	40
pH	6,5	9,5	8,5
Brookfield viscosity - 20rpm, 23°C (mPa.s)	150	25	45
Minimum film forming temperature (°C)	7	14	12
Glass transition temperature - DSC (°C)	0	15	9
Water absorpt. of polym. film - DIN 53495 (wt %)	3	26	14

Preparation of cementitious mortars

The mortars were prepared with 425 portland cement (Italcementi) and "Torre del Lago" normal sand, in a Hobart type mixer, according to the Italian Standards (3). The sand to cement ratio (s/c) was 3; the polymer to cement ratio (p/c) was varied between p/c = 0 and p/c = 0,2; the water level was adjusted to achieve a constant flow of 150 mm ± 10%. In a second series of experiments, water was kept constant to remove the effect of the water/cement ratio on the results. A suitable amount of a defoamer was added to the latex before mortar preparation, in order to obtain wet densities of 2,20 ± 0,05 kg/dm^3.

A melamine base superplasticizer, Liquiment MPK, from Chemie Linz GmbH, as water reducing agent and a market waterproofing admixture belonging to the family of fatty acid salts, MIXAL 100, from Lanchital SpA, were considered for comparative tests. The former was added in the proportion required to obtain the desired flow, the latter was dosed according to the producer indication.

Mortar characterization

Fresh mortars were tested in terms of initial flow (slump test according to UNI 7044) and wet density (by measuring the mass required to fill a 400 ml cup). 4x4x16 specimens were prepared for the mechanical characterization and for the determination of water absorption and salt solutions penetration.

The standard curing procedure (28 days water immersion) was chosed for reference unmodified mortars, for plasticized mortars and for mortars modified with hydrofuges; a 28 days dry curing procedure (23°C and 50% R.H.) was preferred for polymer modified mortars.

The 28 days hardened mortars were measured for compressive and flexural strength. Water absorption and salt solution penetration were carried out in accordance with UNI 7699 and UNI 7928 respectively.

Results and Discussion

Fresh mortar properties

As already reported (4,5), one of the main effects caused by the addition of a polymer dispersion in a cementitious system (mortar or concrete) is a clear improvement of the workability. The plasticizing effect, generally proportional to the amount of the added latex, depends on the monomer composition and on the type/concentration of surfactants and/or protective colloids present in the latex. The polymer dispersion here developed, although containing low amounts of surfactant, has excellent compatibility with the inorganic phase and water reducing properties, thanks to its specific structure and functionality. For polymer/cement ratios over 0,1 a reduction of about 35÷40% in the water request is observed; classical superplasticizers are able to reduce the water level by 20÷30%. FIG. 1 shows the w/c ratio required to obtain polymer modified mortars with similar initial flow, as a function of the p/c ratio.

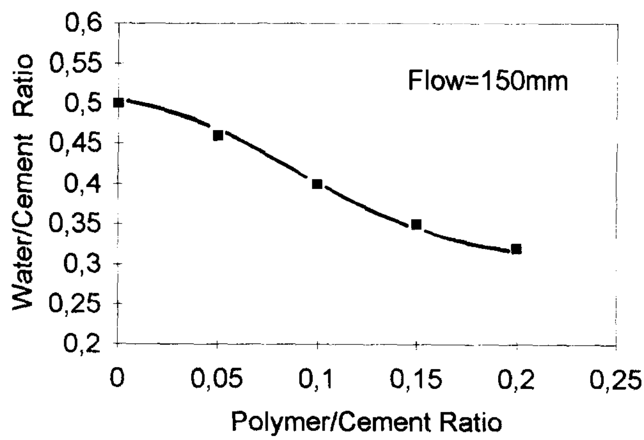

FIG. 1
Water/Cement ratio vs. Polymer/Cement ratio, at constant flow (F = 150 mm ± 10%)

A secondary effect associated to the addition of polymer dispersions in mortar or concrete mixtures is the reduction of the wet density. Because of the surfactant used in the manufacture of the latex, excessive amounts of air can be entrained during mixing operations. The phenomenon is usually controlled by the addition of a suitable amount of a defoamer and, like in our case, by an appropriate choice of the type and dosage of the surfactant system.

Mechanical properties

The mechanical characteristics (especially the flexural strength) of polymer modified mortars/concretes are correlated to the polymer composition (glass transition temperature, presence of functional groups interacting with the inorganic matrix) and to the addition level, as reported in (1,6,7). The water reducing properties and the air entrainment ability of polymer latices have also a certain influence on mechanical characteristics, especially on compressive strength.

The results of mechanical characterization after 28 days of curing together with some determinations carried out on fresh mortars are summarised in TABLE 2. As reported elsewhere (2), the effect of latex addition on compressive strength is not always positive: comparing the results obtained at constant flow and density, mortars modified with latex L1 show compressive strengths very close to the reference mortars; the comparison at constant w/c ratio reveals a reduction of compressive strength (-5÷10%) in all cases.

The advantage brought by the water reduction properties of the polymeric latex is compromised, for low addition levels (p/c<0,1), because of density reduction due to air entrainment. For polymer levels higher than 15÷20%, the decrease in strength is associated to the greater presence of the soft polymeric material into the stiff cementitious matrix.

TABLE 2

Fresh Mortars Properties and Mechanical Characteristics after 28 Days of Curing.

Sample	W/C	P/C	Flow (mm)	Wet Density (kg/dm^3)	Compressive Strength (MPa)	Flexural Strength (MPa)
Ref.	0,55	0,00	165	2,29	40,0	7,5
Ref. (1%MPK)	0,50	0,00	160	2,28	48,0	8,0
Ref. (1,5%MPK)	0,45	0,00	140	2,33	52,5	9,0
MIXAL 100	0,55	0,00	165	2,22	40,0	7,5
L1	0,55	0,05	215	2,15	35,0	8,5
L1	0,48	0,05	165	2,20	41,0	10,0
L1	0,40	0,10	163	2,27	49,0	11,5
L1	0,35	0,15	150	2,22	46,0	14,0
L1	0,30	0,20	145	2,20	42,5	15,0
L2	0,45	0,10	160	2,29	42,5	12,0
L3	0,45	0,10	160	2,27	42,0	11,5

The effect of latex addition on flexural strength is advantageous even over the superplasticized systems, contradicting the theory according to the increase in strength for polymer modified concretes is only due to the water reduction. The observed increases are proportional to the polymer addition levels.

The mechanical characteristics obtained with market latices (L2 and L3) are in the same order of magnitude of those presented by product L1, while the addition of the waterproofing admixture (Mixal 100) does not influence the mechanical strengths.

The presence of a certain amount of air micro bubbles, corresponding to a decrease of 3÷5% in wet density, has a beneficial effect on freeze-thaw stability. The reference mortar, after 300 freeze-thaw cycles (according to UNI 7087) shows a decrease in compressive strength of about 20%, while a mortar modified with latex L1 (p/c = 0,1), submitted to the same treatment, reveals a decrease of only 5%.

Waterproofing properties

Water absorption is generally correlated to the water/cement ratio. Mortars prepared with high w/c ratios give raise to highly porous materials. FIG. 2 illustrates the results of water absorptions of polymer modified mortars (dry curing) after 7 days immersion as a function of p/c ratio. The results obtained at constant water/cement ratio (w/c=0,55) point out the waterproofing ability of the polymer itself, without considering the beneficial effect due to its water reducing properties. The series produced at constant flow gives better results because of the lower w/c ratios involved.

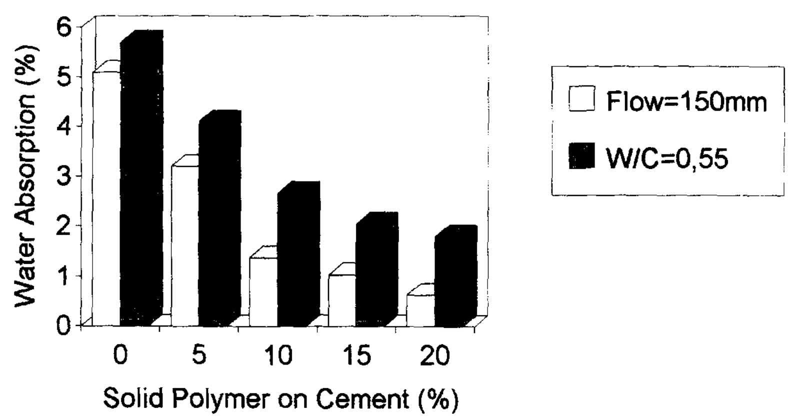

FIG. 2
Water absorption after 7 days immersion vs. Polymer/Cement ratio.

As a consequence of the water evaporation the polymer builds an elastic film through the cementitious matrix, covering the internal cavities with an hydrophobic layer and reducing the formation of micro cracks during the curing process. This effect becomes more remarkable over a certain amount of polymer (p/c>0,05), under this level the polymer has not the ability to form a continuous film and acts as a filler. Moreover the low water/cement ratios permitted by the use of such latex result in higher density mortars much more impervious to penetration by water and salt solutions.

A comparison between the developed latex, the two commercial latices and the market waterproofing admixture is shown in FIG. 3. Latex L1 gives better results than Mixal 100 and latices L2 and L3. The reference superplasticized mortars show water absorption values lower than 3%. A relationship between the water absorption of polymer film (See TABLE 1) and the water absorption of the corresponding polymer-modified mortars can be established from the obtained results. Furthermore, the presence of polymeric latices in amount higher than 10% on cement produces a surface repelling effect, useful against the penetration of rain water or condensed humidity.

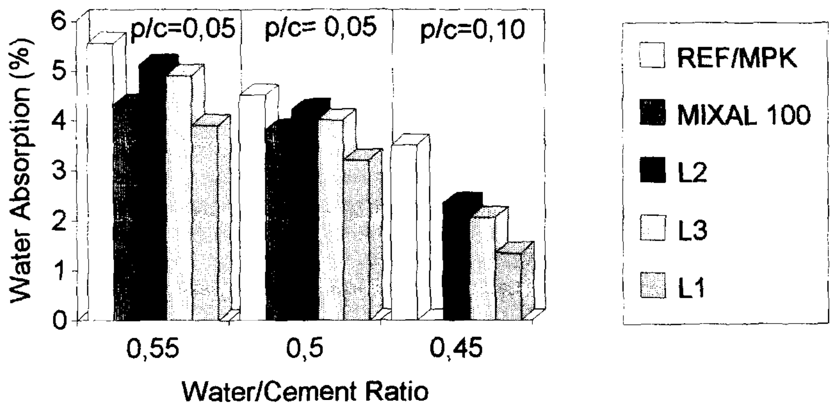

FIG. 3
Water absorption vs. Water/Cement ratio. Comparison with traditional mortars.

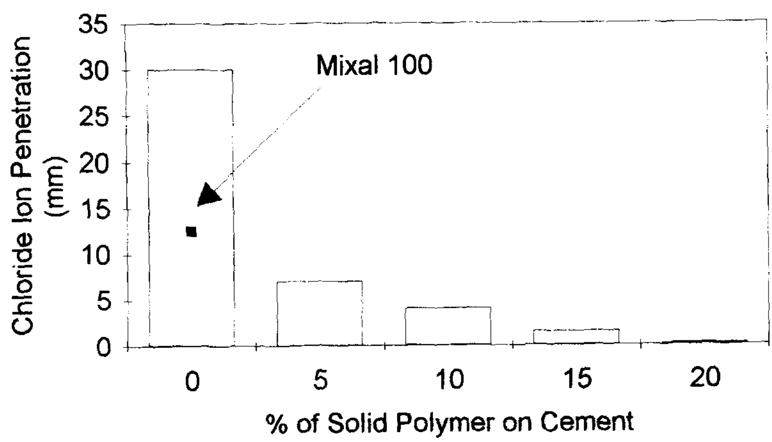

FIG. 4
Chloride ion penetration after 7 days treatment vs. % of solid polymer.

The penetration depth values obtained on dryed polymer modified mortar briquettes after 7 days of treatment with a $CaCl_2$ 0,1N solution are lower than that of unmodified mortars, and tend to markedly decrease with raising p/c ratio. The results concerning the constant flow series are reported in FIG. 4. The chloride ion penetration depths of polymer-modified mortars follow almost the same trend as that of their water absorptions.

Conclusions

1. A polymeric latex with low water absorption of the film and plasticizing properties at the same time is developed.
2. The addition of the new latex to cementitious mortars allows a remarkable reduction in the water/cement ratio, comparable to that showed by other latices present on the market. Some reduction in wet density is also observed.
3. The polymer modified mortars obtained show a clear improvement in flexural strength, independently from the water reducing ability of the polymer itself; compressive strength remains in the same range of the reference mortar. A certain increase in freeze-thaw stability is also observed.
4. There is a correlation between the water absorption of the polymer film and the waterproofness of the corresponding polymer modified mortars. The waterproofing properties are enhanced when the plasticizing effect of the latex is fully applied. The chloride penetration depths are in good agreement with the corresponding water absorptions.
5. The comparison with the traditional mortars can suggest applicative conditions in which the use of polymeric latices, like that here developed, is advantageous over the state of the art solutions.

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