INFLUENCE OF HEMC AND EVA POLYMERS ON SOME PROPERTIES OF DRY-SET MORTARS

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ABSTRACT

Adhesive dry-set mortars used for ceramic tile instalation are generally modified with vinylic and cellulosic polymers to improve some properties. In order to evaluate the influence of such polymers, mortars were mixed with different polymer/cement ratios (EVA and HEMC). Water retention and consistency of fresh mortar, and compressive and splitting tensile strengths and Young's modulus of hardened mortars were measured. Results showed that small quantities of both polymers can sharply change those properties.

1. INTRODUCTION

Dry-set mortars have been widely used for ceramic tile installation all over the world. They consist basically in polymer modified mortars with the following approximated composition: 24% of portland cement, 73% of aggregates (very fine sand and eventually fine ground limestone) and up to 3% of polymers (vinylic or cellulosic resins). According to WAGNER (1973) [1], polymer modified mortars are used since the 60s in Europe and USA for ceramic tile installation, and methyl-cellulose was the most employed polymer due to its great water retention capacity. The use of some others water soluble polymers, like hydroxy-ethyl-cellulose and polyvinyl alcohol, had begun on 70s. Nowadays, some Brazilian dry-set mortars are modified with hydroxy-ethyl-methyl-cellulose (HEMC) and vinyl acetate/ethylene copolymer (VAE or EVA).

According to OHAMA (1984) [2], polymer modified mortars have a monolithic co-matrix where both the polymeric and the hydrated cement matrixes are homogenized. Their properties depend upon this co-matrix, which is characterized by a net structure where the hydrated cement phase and the polymeric phase are interpenetrated, joining

[1] WAGNER, H.B. *Polymer modification of portland cement systems.* Chemical Technology, feb.1973, p.105-108.

the aggregates in a single mass. Small quantities of polymers added to dry-set mortars improve their viscosity and water retention capacity. The polymer particles, together with the air bubbles entrained during mixture process, promote the slip between particles of cement and aggregates, improving the mortar workability. These effects are stronger for higher polymer contents, and the bond strength to porous materials is higher due to the formation of a polymeric film on the interface between them (SAKAI e SUGITA, 1995).[3]

Due to its high superficial activity, the polymer is responsible for higher plasticity and air entraining, and extended setting time. Depending on the polymer type, mechanical strength of polymer modified mortars can increase or decrease if compared with conventional ones. According to OHAMA (1984) [2], polymer latex (including vinylic ones) are responsible for tensile and flexion strengths improvement, while water soluble polymers (including the cellulosic ones) cause generic strength decrease.

With regard to mortars composition, RAMAKRISHNAN (1992) [4] says that the influence of polymer/cement ratio on mortar properties is more pronounced than water/cement ratio due to the interaction between hydrated cement and polymers and to its effect at the interface between cement paste and aggregates. Obviously, other factors such as grain size distribution of the aggregates, cement/dry materials ratio and mixture and curing conditions also influence mortars properties.

Fourteen different mortars were studied in order to evaluate the influence of polymer/cement ratio. The effects of polymer content and type on the mortars properties (hardened and fresh states) were studied. Retention water capacity, consistency, splitting tensile and compressive strengths and Young's modulus were determined. Bond strength to ceramic tiles was also determined.

2. MATERIALS

The following materials were employed in the mixtures: Brazilian Type I-S portland cement (with up to 5% ground limestone), washed quartzose sand and fine ground dolomitic limestone. Tables 1 to 4 show the complete materials characterization. Two kinds of polymers were employed: hydroxy-ethyil-methyl-cellulose (HEMC) and vinyl acetate/ethylene copolymer (EVA). Both polymers were added in dry powder form to the mortars during mixing (before water addition).

A rotational low speed mixer was used. First, dry materials were mixed (cement, sand, ground limestone and polymers) during 60 seconds. They were then added to the water and mixed for 120 seconds more. The subsequet steps followed the recommendations contained in European standard CEN TC67/WG3 N.62 [5] ("Ceramic tile adhesives - Determination of open time").

The materials proportion was 1:2.8:0.2 in weight (cement:sand:ground limestone). The water/dry materials ratio was kept constant (0.18), and so was the water/cement ratio (0.72). Table 5 shows the polymers contents for the tested mortars.

[2] OHAMA, Y. *Polymer-Modified Mortars and Concretes.* In: RAMACHANDRAN, V.S. (Ed.) Concrete Admixtures Handbook. New Jersey: Noyes Publications, 1984. Cap.7, p.337-429.

[3] SAKAI, E.; SUGITA, J. *Composite mechanism of polymer modified cement.* Cement and Concrete Research, vol.25, 1995, p.127-135.

[4] RAMAKRISHNAN, V. *Properties and applications of latex-modified concretes.* In: MALHOTRA, V.M. (Ed.) Advances in Concrete Technology. Ottawa: Energy, Mines and Resources Canada, 1992, p.807-858

[5] COMITE EUROPEEN DE NORMALISATION. *Ceramic Tile Adhesives - determination of open time.* CEN/TC 67, april 1993.

Physical characterization	Specific mass (g/cm^3)			3.12
	Specific area (m^2/kg)			333
	Fineness (residue in # 75 µm sieve) (%)			1.06
	Setting time	Inicial (min)		181
		Final (min)		258
	Hot expansibility (min)			0.25
	Compressive strength		3 days (MPa)	28.4
			7 days (MPa)	34.3
			28 days (MPa)	41.6
Chemical characterization (%)	Ingnition loss			3.44
	Insoluble residue			0.56
	Al_2O_3			4.28
	SiO_2			19.59
	Fe_2O_3			2.60
	CaO			62.12
	MgO			4.31
	SO_3			2.42
	Free lime			2.03
	Na_2O eq.			0.71

Table 1. *Physical and chemical characterization of portland cement*

Maximum characteristic size (mm)			0.60
Fineness modulus			2.20
Specific mass (Picnometer) (kg/dm^3)			2.61
Grain size distribution	**Sieve # (mm)**	**retained %**	**Retained accum.%**
	1.2	0.08	0.08
	0.6	2.25	2.33
	0.3	28.84	31.17
	0.15	55.69	86.86
	Bottom	13.14	100.00

Table 2. *Washed sand characterization.*

CaO	29.70
MgO	21.14
SiO_2	3.24
Al_2O_3	0.03
Fe_2O_3	0.08
TiO_2	0.08

Table 3. *Chemical analysis of ground sandstone (X-rays fluorescence - %)*

Grain diameter (µm)	Volume (accum.%)
2.000	96.83
5.000	90.08
10.00	81.77
25.00	53.12
45.00	23.72
62.00	12.75
75.00	7.91
100.0	2.84
125.0	0.609
150.0	0.035

Table 4. *Grain size distribution of ground limestone (laser diffraction)*

	RM*	M1	M2	M3	M4	M5	M6	M7	M8	M9
HEMC	-	0.1	0.2	0.5	1.0	2.0	0.5	0.5	0.5	0.5
EVA	-	-	-	-	-	-	1.0	2.0	4.0	7.0

	M10	M11	M12	M13
HEMC	-	-	-	-
EVA	1.0	2.0	4.0	7.0

* reference mortar

Table 5. *Polymers contents in mortars (% on the weight of cement)*

The EVA effect was studied taking mortar with 0.5% HEMC (M3) as reference. Mortars M10 to M13 (without HEMC) were also molded with the purpose of evaluate the influence of EVA on fresh state mortars.

For bond strength tests, a type gres ceramic tile with average water absorption of 3.67 % (according to ISO 10545-3/1995) [6] was used.

3. EXPERIMENTAL PROCEDURE

3.1 FRESH MORTAR PROPERTIES

Water retention capacity and consistency were determined. The method MR-4 (1982) recommended by RILEM [7] was followed for water retention capacity test. This test basically consists on the contact between the mortar and a blotting paper during a standard time. The mortar is weighted before and after the contact. For mortars consistency determination, the method described by ASTM C 230/1998 (flow table test)[8] was adopted.

All tests were performed at approximately constant temperature and relative humidity, 23°C and 70% respectively.

3.2 HARDENED MORTAR PROPERTIES

For Young's modulus and splitting tensile and compressive strengths determination, cylindrical specimens 50 mm diameter and 100 high were molded and stored in laboratory ambient up to the test day (age of 28 days).

The test methods recommended by ASTM C 780/1991 [8] for compressive and splitting tensile strengths were adopted. Young's modulus of the mortars was determined following the procedure described by Brazilian standard NBR 8522/83 [9]. Deformations were measured by strain-gages attached to two opposite sides of each specimen, connected to a data-logger, which registered the applied charge and deformation data each 1.5 seconds. The Young's modulus results were obtained from the average between both strain-gages.

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[5] COMITE EUROPEEN DE NORMALISATION. *Ceramic Tile Adhesives - determination of open time.* CEN/TC 67, april 1993.

[6] INTERNATIONAL STANDARDIZATION ORGANIZATION. *Determination of water absorption, apparent porosity, apparent relative density and bulk density.* ISO 10545 - part 3, 1995.

[7] RILEM. *Water-retention capacity of mortars (MR-4, 1982).* RILEM. *Technical Recommendations for the testing and use of Construction Materials.* London: E & FN SPON, 1994.

[8] AMERICAN SOCIETY FOR TESTING AND MATERIALS. *Standard specification for flow table for use in tests of hydraulic cement: C 230-98.* In: Annual Book of ASTM Standards. Philadelphia, Pa, 1998.*Standard test method for pre-construction and construction evaluation of mortars for plain and reinforced unit masonry: C 780-91.* In: Annual Book of ASTM Standards. Philadelphia, Pa, 1991.

[9] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *Argamassa para assentamento de paredes e revestimento de paredes e tetos - Determinação do teor de água para obtenção do índice de consistência-padrão.* Rio de Janeiro: NBR 13276, 1995. *Concreto - Determinação do módulo de deformação estática e diagrama tensã-deformação.* Rio de Janeiro: NBR 8522, 1983.

3.3 BOND STRENGTH

The test method recommended by CEN/TC 67 (1993) [5] was adopted for bond strength determination. According to this standard, ceramic tiles must be fixed over a standardized concrete slab. After fixing process, the slabs were stored in a laboratory environment up to the age of 28 days, when the tensile test was performed. The load was applied at a rate of 0,25 KN/s, as specified by the European standard.

4. RESULTS AND DISCUSSION

4.1 FRESH MORTAR PROPERTIES

The test results proved the influence of cellulosic polymer content (HEMC) on the mortar water retention capacity. With higher HEMC content, the water loss of the mortar decreases in contact with porous materials, i.e., the water retention capacity is higher. The maximum water retention capacity (~100 %) was obtained when 0.5% HEMC was present.

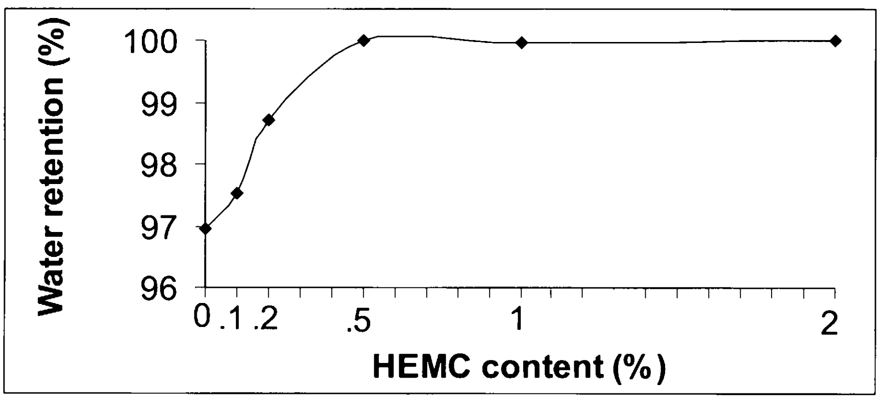


Figure 1. Water retention capacity (%) x HEMC content (% on the weight of cement)

Either the addition of EVA to mortars with 0.5% HEMC mortars did not alter their water retention capacities, as shown in Figure 2, or the test method adopted had no sensibility to show this difference. For mortars without HEMC, EVA copolymer had no great influence on the mortar water loss; however, a range of disperse results was detected (0 to 2% EVA).

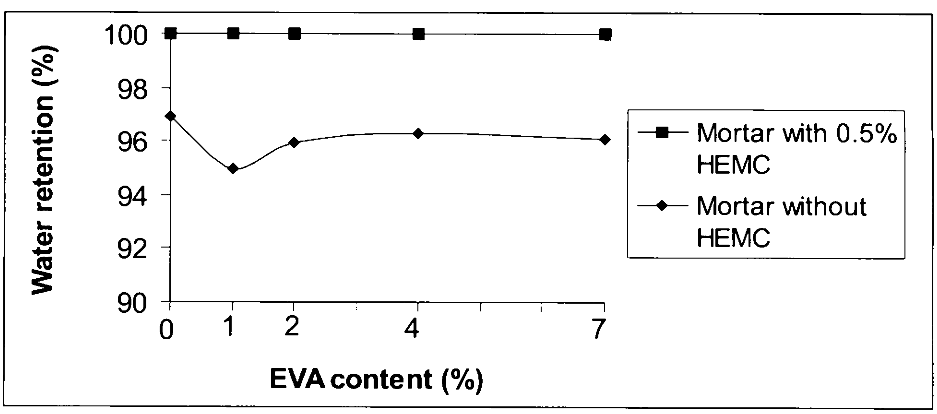


Figure 2. Water retention capacity of the mortars (%) x EVA content (% on the weight of cement)

Figure 3 shows the effect of HEMC on the consistency of dry-set mortars. Increasing the HEMC content, more plastics the mortars become due to an increase of aqueous phase viscosity (OHAMA, 1984) [2], and the results of flow table test are lower. For the used water/cement ratio (0.72), the standard consistency index (255±10 mm, prescribed by Brazilian standard NBR 13276/95) [9] corresponds to an HEMC content between 0.33 and 0.44 (values obtained by linear interpolation).

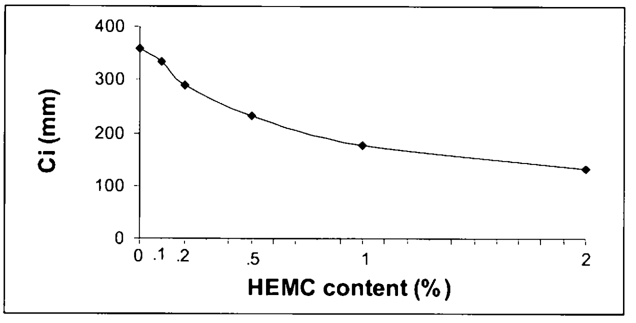
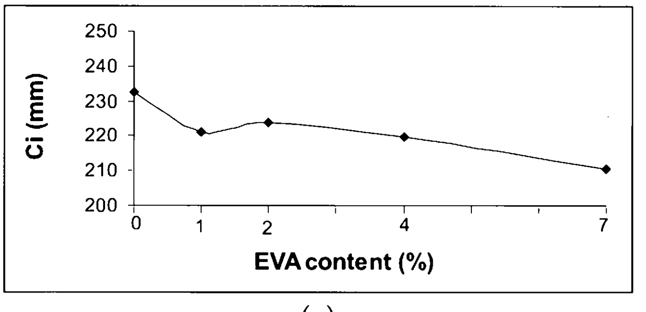
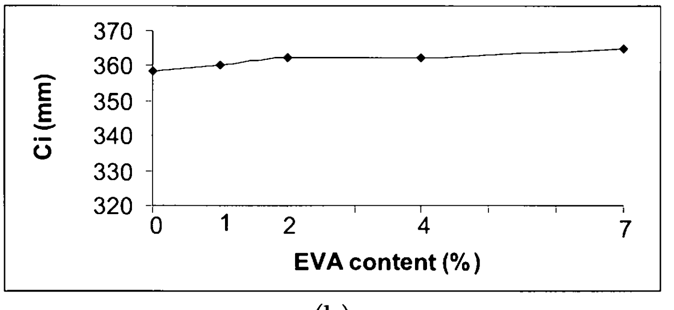


Figure 3. Consistency index (Ci) of the mortars as a function of the HEMC/cement ratio (in weight)

EVA contents had no significant effect on the mortars consistency if compared to HEMC effects (Figure 4). However, it could be noted in mortars with HEMC that increasing the EVA content the mortars became more consistent (lower Ci). On the other hand, vinylic polymer modified mortars showed greater spreading over flow table, suggesting some interaction between polymers on presence of water or cement paste. The distinct behavior showed by modified mortars with 0.5% HEMC and up to 2% EVA also suggests some kind of interaction.



(a)



(b)

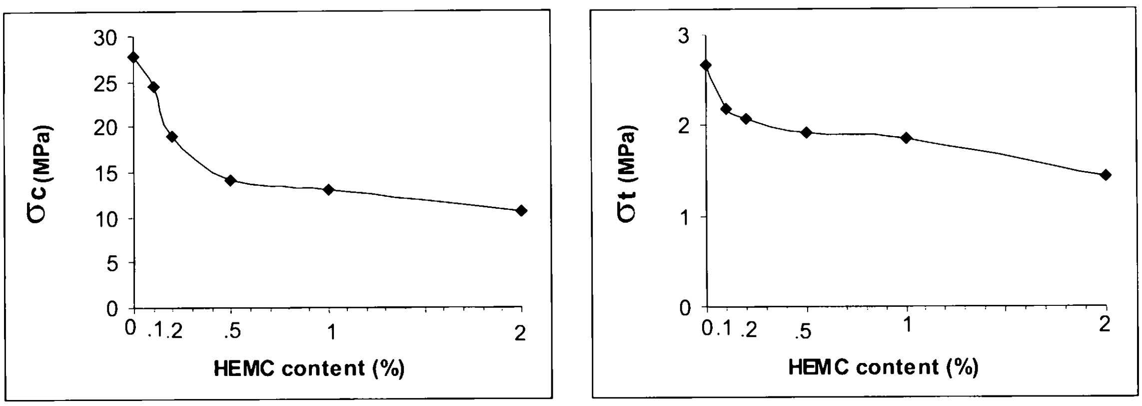
Figure 4. Consistency index (Ci) variation as a function of the EVA/cement ratio (in weight) in mortars with 0.5% HEMC (a) and in mortars without HEMC (b)

[2] OHAMA, Y. *Polymer-Modified Mortars and Concretes.* In: RAMACHANDRAN, V.S. (Ed.) Concrete Admixtures Handbook. New Jersey: Noyes Publications, 1984. Cap.7, p.337-429.

[9] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *Argamassa para assentamento de paredes e revestimento de paredes e tetos - Determinação do teor de água para obtenção do índice de consistência-padrão.* Rio de Janeiro: NBR 13276, 1995. *Concreto - Determinação do módulo de deformação estática e diagrama tensã-deformação.* Rio de Janeiro: NBR 8522, 1983.

4.2 HARDENED MORTAR PROPERTIES

Compressive tests results showed significant strength decrease in mortars with increasing HEMC/cement ratio up to 0.5%. Higher HEMC contents caused less effect (Figure 5). Probably, the mechanical strength decreases due to air entrained in the mortars by the polymers. However, it can be seen that the ratio between splitting tensile and compressive strengths increases up to the addition of approximately 0.5% HEMC (Figure 6).



(a) (b)

Figure 5. Compressive strength σc (a) and splitting tensile strength σt (b) as a function of HEMC/cement ratio (in weight)

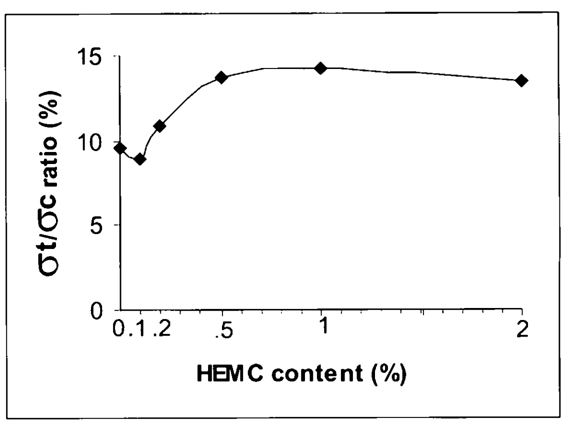


Figure 6. σt/σc ratio as a function of HEMC content

For mortars containing also EVA, it could be noted a tendency of increasing tensile strength for EVA contents higher than 2% (Figure 7b). This may be due to the high tensile strength of the polymer and to its bridge effect over microcracks, preventing their propagation (OHAMA, 1984) [2]. Besides, the polymer is responsible for a better adhesion between cement and aggregates and for a change in the transition zone, turning hard the growth of microcracks (SAKAI and SUGITA, 1995) [3]. On the other hand, the effect is opposite for compressive strength (Figure 7a). Higher contents of EVA are responsible for lower strength values due to air entraining.

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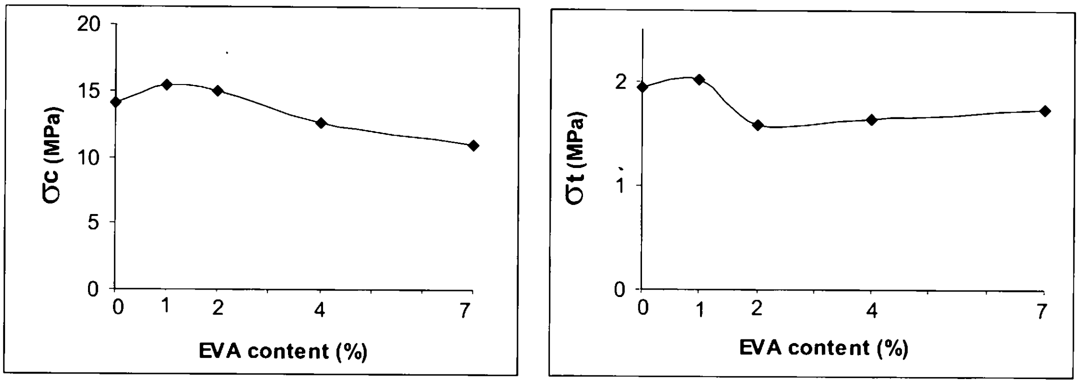
[2] OHAMA, Y. *Polymer-Modified Mortars and Concretes.* In: RAMACHANDRAN, V.S. (Ed.) Concrete Admixtures Handbook. New Jersey: Noyes Publications, 1984. Cap.7, p.337-429.

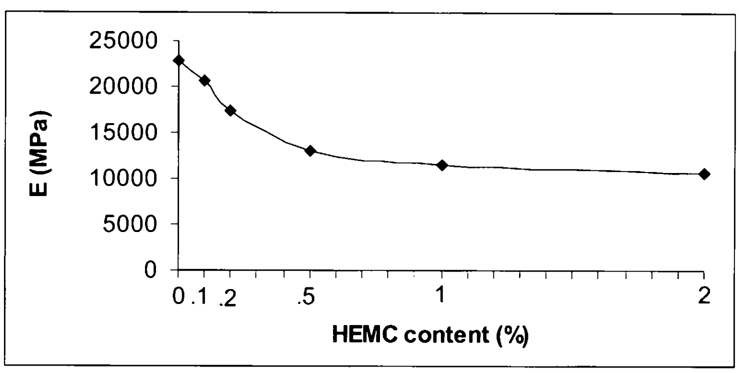
[3] SAKAI, E.; SUGITA, J. *Composite mechanism of polymer modified cement.* Cement and Concrete Research, vol.25, 1995, p.127-135.



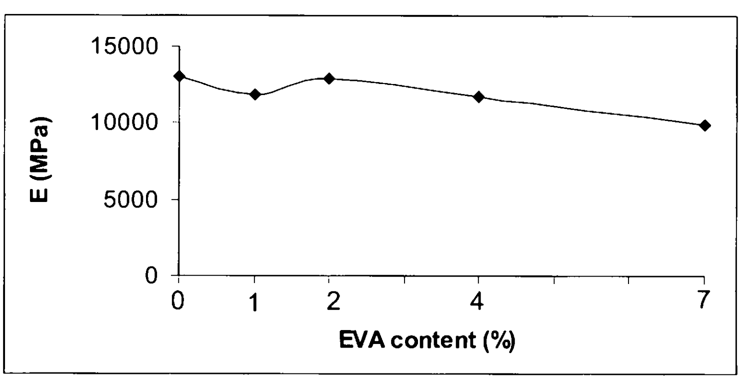
(a) (b)

Figure 7. Compressive σc (a) and splitting tensile strengths σt (b) as a function of EVA/cement ratio (in weight) for mortars with 0.5% HEMC

Figure 8 shows Young's modulus results, obtained from the average of two specimens. It can be noted a sharp modulus reduction for mortars with higher HEMC contents (the reduction is sharply up to 0.5% HEMC). The same effect occurs with addition of EVA, although not so pronounced. The low elasticity modulus of the polymers (0.001 to 10 x 10^3 MPa, according to OHAMA, 1984) [2], and their interaction form with hydrated structure of the mortar might be responsible for greater elasticity of polymer modified mortars.



(a)



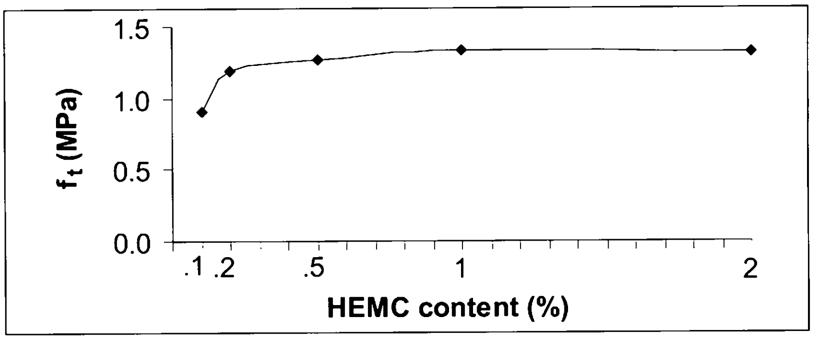
(b)

Figure 8. Young's modulus (E) of the mortars as a function of HEMC/cement ratio (a) and as a function of EVA/cement ratio in mortars with 0.5% HEMC (b)

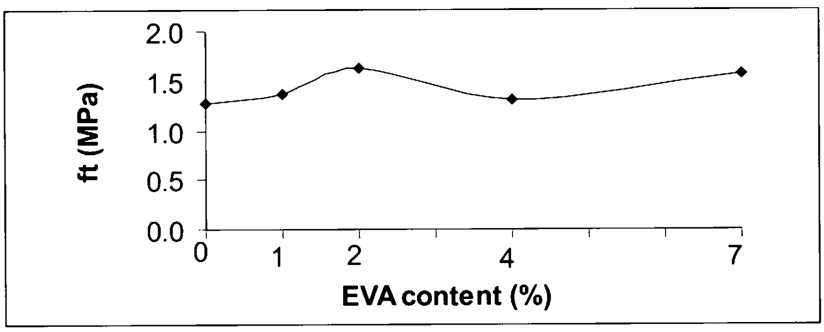
[2] OHAMA, Y. *Polymer-Modified Mortars and Concretes.* In: RAMACHANDRAN, V.S. (Ed.) Concrete Admixtures Handbook. New Jersey: Noyes Publications, 1984. Cap.7, p.337-429.

4.3 BOND STRENGTH

Figure 9 shows the tensile bond strength results in function of HEMC and EVA contents. From its analysis, it can be observed that there is an increase of bond strength for higher amounts of HEMC in the mortar up to 0.5%. For mortars also modified with EVA, this tendency is not clearly observed (Figure 9b).



(a)



(b)

Figure 9. Bond strength ft as a function of HEMC/cement ratio (a) and as a function of EVA/cement ratio for mortar with 0.5% HEMC (b).

According to AFRIDI et al. (1995) [10], the ethylene monomer content in the EVA copolymer may change the bond strength. Therefore, the behavior observed in Figure 9b might also be related to the content of ethylene in the EVA.

5. CONCLUSIONS

From the tests performed with dry-set mortars containing different contents of EVA and HEMC polymers, it was possible to conclude that:

- HEMC polymer sharply increases the water retention capacity of the mortars up to a content of 0.5% on the weight of cement. EVA effect is not significant in the tested content range (0 to 7%).

- HEMC caused a reduction respectively of 46 and 62% on splitting tensile and compressive strengths. On the other hand, there is an increase in $\sigma t/\sigma c$ ratio for HEMC contents up to 1%. EVA caused a reduction of compressive strength but an

[10] AFRIDI, M.U.K.; OHAMA, Y.; IQBAL, M.Z.; DEMURA, K. *Water retention and adhesion of powdered and aqueous polymer-modified mortars.* Cement and Concrete Composites, vol.17, 1995, p.113-118.

increase of splitting tensile strengths in mortars with more than 2% EVA due to the better adhesion between cement paste and aggregates, and due to the prevention of microcracks growth.

- The tensile bond strength increases with higher HEMC contents, but the results are approximately constants for contents higher than 0.5%. EVA seems to cause an increase in strength values, but the results show a great dispersion in the range studied (0 to 7%).

- Some kind of interaction seems to occur between HEMC and EVA polymers when they are present in the same aqueous solution. This conclusion may be drawn from the both the fresh and hardened mortar tests, where a fluctuation of test results was found without any other apparent cause. The evaluation of such an interaction will be performed in the near future.