ZBORNIK RADOVA
CONFERENCE PROCEEDINGS

MATRIB 2010

Vela Luka

Otok / island Korčula, Hrvatska / Croatia

23-25. lipnja / June 2010.

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PLINOSERVIS Kuzman

IZDAVAČ / PUBLISHER: Hrvatsko društvo za materijale i tribologiju

Croatian Society for Materials and Tribology

c/o FSB, Ivana Lučića 5, 10000 Zagreb

tel.: +385 1 61 68 400; fax: +385 1 61 57 126

e-mail: hdmt@fsb.hr, http://www.fsb.hr/hdmt

UREDNICI / EDITORS: Zdravko Schauperl, Mateja Šnajdar

CIP zapis dostupan u računalnom katalogu Nacionalne i sveučilišne knjižnice u Zagrebu pod brojem 741208.

ISBN 978-953-7040-18-5

NAKLADA / ISSUE: 120

MECHANICAL PROPERTIES OF SBR LATEX MODIFIED MORTAR

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Abstract

Among the various latex modified mortars application, repair mortar is one of them. The purpose of this research is to investigate the mechanical properties of repair mortar modified with polymeric latex. The influence of Styrene-Butadiene-Rubber (SBR) latex (solid content 47 %) on commercial calcium aluminate cement's (CAC) properties was observed. Mortar specimens with constant W/C ratio (0.4) and with different latex content (0 - 20 %) were prepared. Workability and air content entrapment in the mortar fresh state were investigated. In the hardened mortar state compressive and flexural strength, open porosity, density, and dynamic modulus at different curing age (1, 7 days and transformed specimens) were investigated. The test results showed that inclusion of SBR latex increased the workability and air entrapment of fresh state mortar and reduction in dynamic modulus and open porosity of hardened state mortar. Specimens with higher latex percentage at curing age of 7 days showed increment in bending strength, due to coagulation process of polymer.

Keywords: calcium aluminate cement, SBR latex, latex modified mortar, mechanical properties.

Introduction

Cement based materials usage is widely. Therefore, properties of those materials need to be improved. One way of cement-based materials properties improvement is a polymer inclusion. Polymer which is used in properties modification can be a polymer latex, redispersible polymer powder, water-soluble polymer or liquid polymer. Among the different presentations of polymer admixtures, polymer latex is in most widespread use. The inclusion of polymer latex improve workability of fresh state, due to the "ball bearing" action of polymer particles, the entrained air and the dispersing effect of surfactants.[1, 2] Therefore, an important W/C reduction can be achieved, which effects on porosity and strength of hardened state mortar.

The improvement of bending strength while keeping its compressive strength, ductility, bonding strength to concrete substrate, low permeability of hardened latex modified mortars (LMM) is achieved as well.[1, 3, 4]

Calcium aluminate cement (CAC) is very versatile special cement advantageously used in numerous specific applications[5]. Due to their fast hardening with high early strengths even at low temperatures CAC is advantageously used for repair work of highways and airport's runways.

Those LMMs properties allow floor and bridge overlays, repair mortars, bonding ceramic tile agents and precast elements joining material usage.[6, 7] Polymer latex modification of cement mortar is governed by both cement hydration and polymer film formation processes in their binder phase. A co-matrix is formed by both processes.[1, 8]

Two different ways of adding polymers to cement materials are possible[9]: keeping constant the water-to-cement ratio (W/C); and fitting the consistency of the composite, by adjusting the W/C or the inclusion of plasticizers (polymer latex).

This paper summarizes the results of an experimental test program on LMM with constant W/C and different latex content in the fresh and hardened states.

Materials

Cement used in the research was Calcium aluminate "ISTRA 40" (Istra Cement d.d.). Styrene-Butadiene-Rubber (SBR) (LGM d.o.o. Zagreb) in latex form with a solid content of 47%, nonionic surfactant and antifoaming agent in the commercial composition; and quartz sand with size of 0.5-1.0 mm are used.

Specimen preparation

The sand-to-cement ratio (S/C) and water-to-cement ratio (W/C) of mortar were 3 and 0.4, respectively. Latex-cement ratios (P/C) were 0%, 5%, 10%, 15%, and 20%. The amount of water of the latex was taken into account in the W/C. In mixing method, water and latex were mixed together, then cement was added and everything was mixed in a standard laboratory mixer for 30 sec at speed of 140 rpm. Later, sand was added into mix and whole was mixed for 30 sec at speed of 140 rpm and at 285 rpm for another 30 sec. After that, mixing was stopped for 60 sec, and then continued for 60 sec at speed of 285 rpm.

The fluidity of the fresh mix was tested using flow table. The amount of entrapped air in fresh mortar was reduced by vibrating the prismatic mould. 40 x 40 x 160 mm prisms were cast and cured for 1 day at the temperature of 22°C and 90% of relative humidity. Then, the specimens were demoulded and cured in different conditions, which are summarized in Table 1.

Table 1. Curing age of specimens

Series	*Curing age in the mould*	*Curing age out of the mould*
I	24 h, T = 22°C, 90 %RH	20 h, ϑ = 23°C, 35 %RH
II	24 h, T = 22°C, 90 %RH	6d, ϑ = 23°C, 35%RH
III	24 h, T = 22°C, 90 %RH	6d: T = 23°C, 35%RH.+ 24h: 70°C+19d: T = 23°C, 35%RH

Experimental methods

Consistency of fresh state SBR LMM was measured using the flow table test according to EN 1015-3. The content of entrapped air was measured by a pressure method according to EN 1015-7. Latex percentages of 0%, 5%, 10%, 15% and 20%, regarding to cement weight, were used.

In hardened state, bending and compression test of LMM were done according to EN 1015-11. The bending tests were performed with 40 x 40 x 160 mm specimens and compression test were carried out on two pieces of original 160 mm prisms for each mix.

Open porosity of transformed specimens was determined by measuring the weights of dry, saturated and submerged samples (broken halves of specimens) for each composition, and was calculated according to the following equation:

$$P_{open} = \frac{W_{sat} - W_{dry}}{W_{sat} - W_{sub}} \cdot 100, [\%] \tag{1}$$

where W_{dry} is the dry weight, W_{sat} is the saturated weight (specimen submerged in water for 24 h) and W_{sub} is the submerged weight (saturated specimen submerged in water and measured its weight with a hydrostatic scale).

Dynamic ultrasonic modulus (E, GPa) for each composition was computed using the following equations:

$$E = \frac{v^2 \rho}{K}, [GPa] \tag{2}$$

$$K = \frac{(1-\nu)}{(1+\nu)(1-2\nu)} \tag{3}$$

where ρ (g/cm^3) is the density, v (km/s) the velocity of ultrasonic pulse propagation through the specimen (160 mm long) and ν is Poisson's coefficient taken to be $\nu = 0{,}2$ for all dosages of latex[9]. The velocity of ultrasonic pulse propagation through the specimen was measured by TICO Proceq Testing Instruments with time resolution of 0.1 μs, voltage impulse of 1 kV, pulse repetition of 3 s^{-1} and frequency of 54 kHz.

Results and discussion

The consistency gained with constant W/C and different latex percentage is shown in Fig. 1. The increase of latex percentage in LMM shows increase of workability, due to the plasticizer effect of the latex. The content of entrapped air increases with the lower percentage of polymer addition reaching maximal values at 15 and 20 % of latex addition (Fig. 2). By introducing the latex at the beginning of mixing procedure and the utilization of high speed mixing (see paragraph on specimen preparation) allowed high entrapment of air.

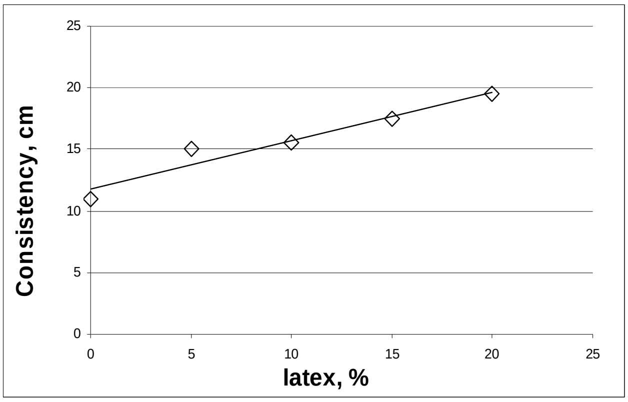

Fig. 1. Consistency of LMM with different latex percentage

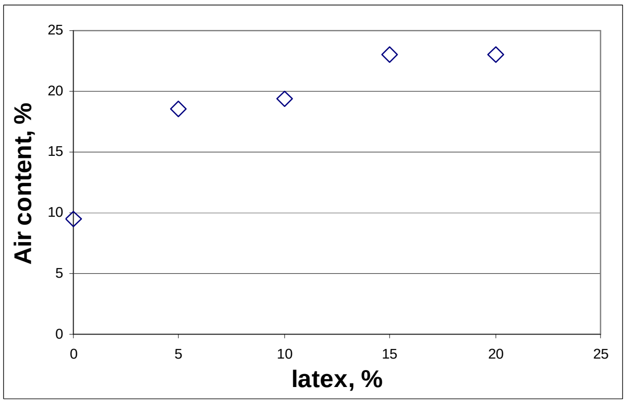

Fig. 2. Air content of fresh state LMM with different latex percentage

Table 2. Results of LMM at different curing ages

Latex,%	*I*	*II*	*III*
	Ultrasonic velocity, km/s	Ultrasonic velocity, km/s	Ultrasonic velocity, km/s
0	4,14	3,56	4,05
5	3,87	3,77	3,70
10	3,51	3,57	3,51
15	3,34	3,39	3,27
20	3,32	3,42	3,21

Flexural and compressive strength at 1, 7 days and 28 days with transformation are shown in Figs. 3 and 4. The addition of latex reduces bending strength. Specimens at 7 days show increase at higher percentage of latex, due to latex coagulation process. Specimens at 1 day show a reduction, due to time deficiency for latex coagulation process. The inclusion of SBR latex in cement mortar produces a decrease of compressive strength, due to lower mechanical capacity of latex with regard to cement mortar, for a constant W/C ratio and due to higher entrapped air content (Fig. 2). Transformed specimens show the lowest compressive strength at every latex percentage, due to porosity which is formed by transformation process. Compressive strength of dried specimens (Fig. 5) decreases with latex inclusion, due to polymer properties. Compressive strength values of dried specimens are lower than non-dried ones, due to transformation process of metastable hydration products at higher temperatures.

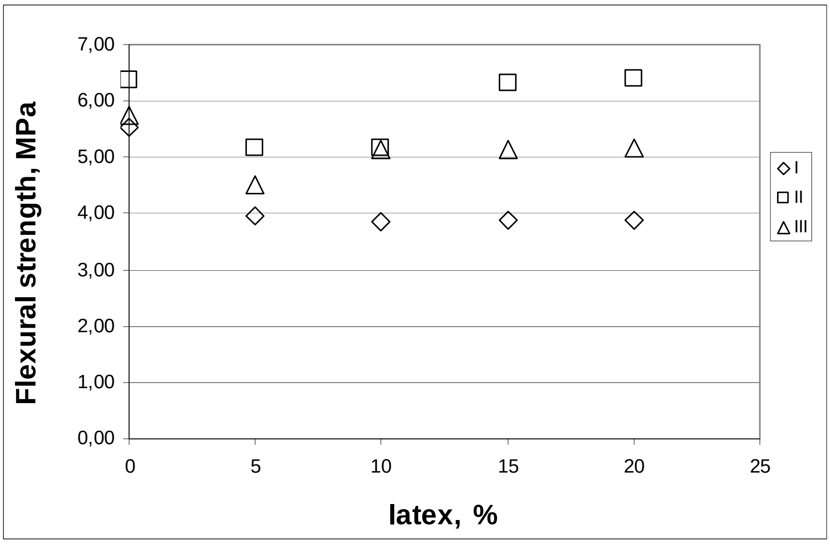

Fig. 3. Bending strength of LMM with different latex percentage at different curing ages

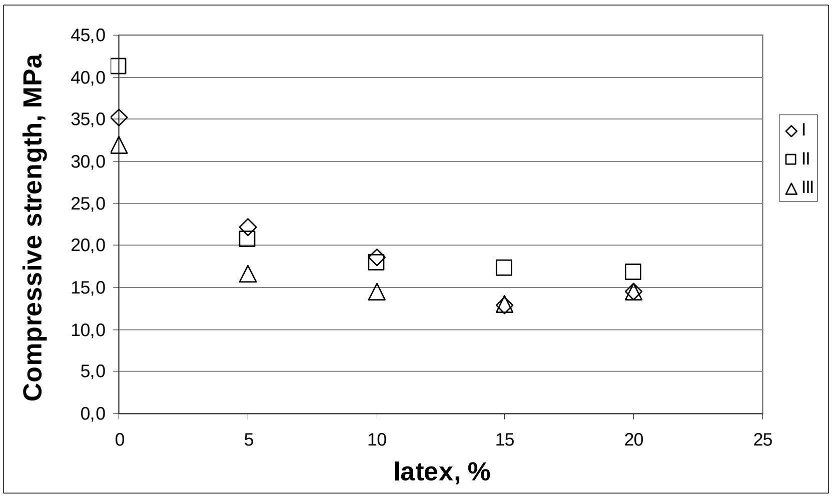

Fig. 4. Compressive strength of LMM with different latex percentage at different curing ages

Dried transformed specimens show higher compressive strength values regarding other two dried series and transformed specimens, due to higher hydration and polymer coagulation dosage, and earlier transformation process in wet conditions.

Open porosity of transformed specimens decreases while latex percentage increases (Fig. 6).

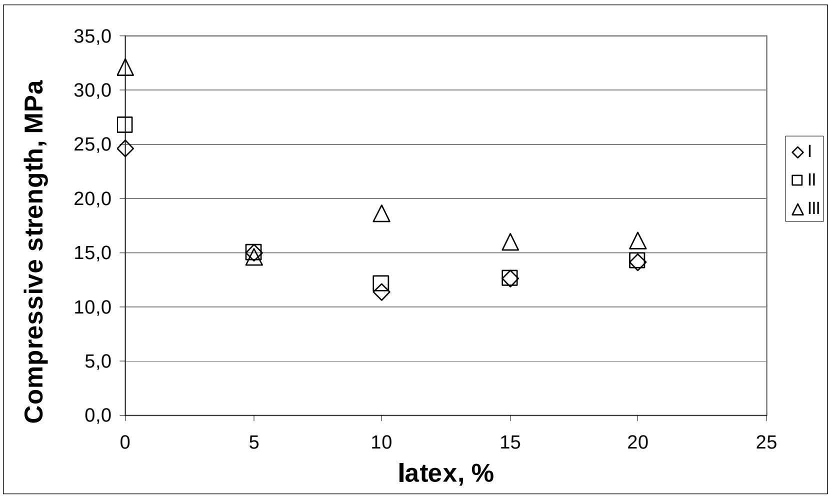

Fig. 5. Compressive strength of dried LMM with different latex percentage at different curing ages

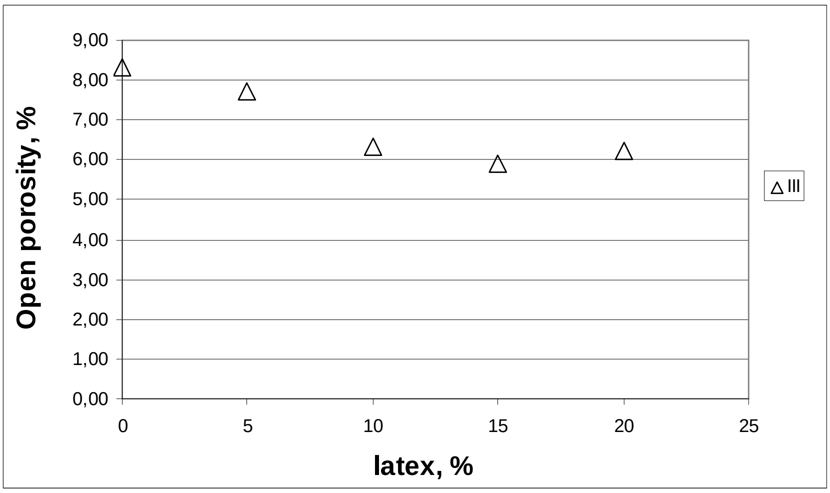

Fig. 6 Open porosity of transformed LMM with different latex percentage

Fig. 7 illustrates density of specimens at 1 day, transformed specimens and calculated density. The increase of latex percentage produces decrease of density, due to polymer structure. Experimental densities are in good agreement with the calculated ones.

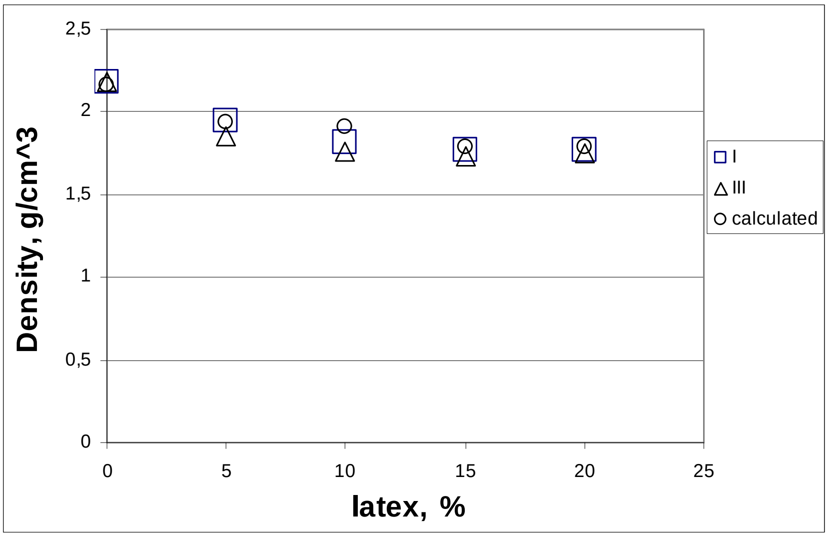

Fig. 7. Density of LMM with different latex percentage at different curing ages and calculated density

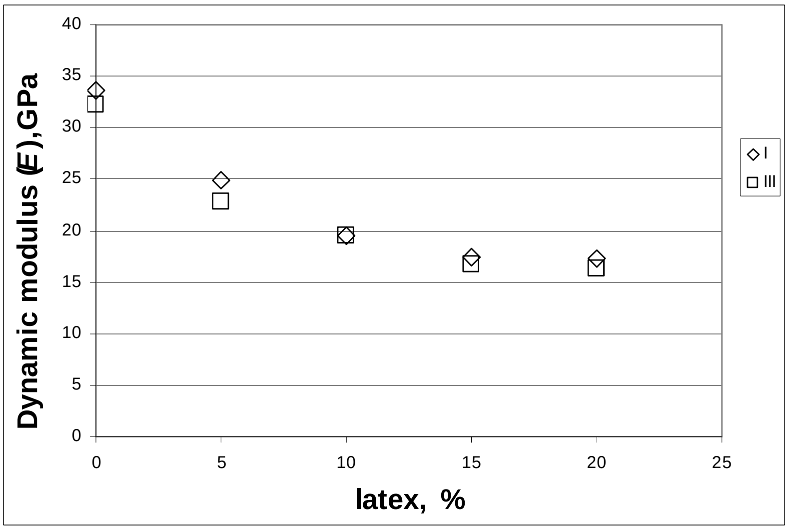

Fig. 8. Dynamic modulus of LMM with different latex percentage at different curing ages

LMM stiffness decreases with latex increase, as shown in Fig. 8, due to lower polymer stiffness regarding mortar stiffness.

Conclusion

The inclusion of SBR latex increases workability of fresh state mortar, which provides mortar preparation with lower water-to-cement (W/C) ratio. Lower content of free water would reduce hardened state mortar porosity and lead to mortar strength improvement. Advanced mechanical properties of latex modified mortar can be obtained by longer treatment in dry conditions, which means higher degree of polymer coagulation process.

By introducing the latex at the beginning of mixing procedure and the utilization of high speed mixing allowed high entrapment of air. The latex addition increases the content of air entrapment. The higher air entrapment is expected to enhance other properties of material such as the lower permeability due to more closed porosity and the higher resistance to frost.

To create a material with the best properties for a desired specific application an optimization of mechanical and durability properties is required.

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