Influence of temperature and moisture on the shelf-life of cement admixed with redispersible polymer powder

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HIGHLIGHTS

- Neat cement and cement containing RDP were aged at 40 °C/90% RH.
- As latex RDPs, EVA and carboxylated SB were used.
- RDPs improve shelf-life of cement via partial film formation.
- Mortars containing RDP retain their mechanical properties better than plain mortar.

GRAPHICAL ABSTRACT
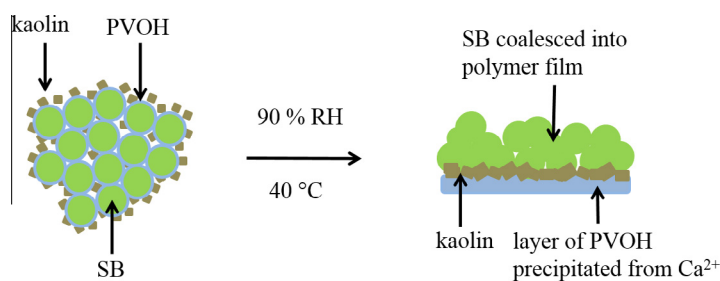
Mechanism of partial film formation
in cement / RDP blend exposed to high humidity

ARTICLE INFO

ABSTRACT

The shelf-life of cement blended with redispersible polymer powder (RDP) used in drymix mortars was studied after exposure to an atmosphere of elevated temperature (40 ± 1 °C) and moisture ($90 \pm 3\%$ RH) simulated in a climate chamber. As RDP samples, ethylene–vinylacetate and carboxylated styrene–butadiene were used. The behaviour of the cement/RDP blends was studied with respect to film formation of the RDPs and the mechanical properties of the resulting mortars. It was found that the presence of RDP decelerates the prehydration of cement in humid environment and thus improves its shelf-life. At the same time, cement triggers a partial premature film formation from RDP powder during aging. Furthermore, mortars containing aged cement/RDP blends retained their mechanical properties much better than mortars casted from cement which had been aged individually. Apparently, RDP can protect cement from rapid aging.

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1. Introduction

Cement presents the most commonly used binder material in the world, with an annual consumption of 4.2 billion tons in 2014 [1]. Its low cost, easy application and high compressive strength are the main reasons for its universal acceptance.

A mortar is a composite material which includes a binder phase and sand. Hydrated cement, a product resulting from the chemical reaction between cement and water, coats the sand and forms a rock-like solid matrix. During the hydration reaction the cement hardens and gains strength.

For decades researchers have been working to improve the microstructure of hydrated cement in an attempt to optimize its

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workability, strength and durability, for example *via* the incorporation of polymers into the mixture. Nowadays, several types of polymers used as chemical admixtures are available for the construction industry.

Among those additives are film forming latex polymers such as ethylene–vinyl acetate–versatic acid and styrene–butadiene copolymers. Numerous studies have been published about these materials [2–5]. When cement mortar is modified with latex, some of its undesired properties such as brittleness and low flexural strength are then improved. Additionally, the cohesion during the fresh state and the adhesion strength in the hardened state are enhanced [6–10]. These effects are owed to the formation of latex films in the cement paste [11–14]. The polymer films result from coalescence of individual latex polymer particles after dehydration of the mixture [15–18].

Mortars modified with redispersible latex polymer powder (RDP) are available as drymix blend and applied, for example, as tile adhesives and tile grouts, as adhesive mortar for external thermal insulation systems and as water-proofing membranes. RDPs are usually obtained by spray-drying the liquid latex dispersion containing a colloidal stabilizer and an anti-caking agent. The influence of these spray-drying aids on the properties of the mortar has to be taken into account when using RDPs [19].

It has been reported in previous literature that, in order to form a film in a cementitious matrix, the latex has to undergo particle coalescence which occurs in four main stages [11,18]. Initially, the latex is present as an aqueous dispersion (stage I), then forms a dense particle packing (stage II) until the latex particles start to deform and arrange in hexagonal shape in order to minimize their interfacial tension (stage III). Finally, the polymers diffuse across primary latex particle boundaries and the particles coalesce into coherent polymer films. (stage IV). Relative to this process, it has been observed that the spray-drying aids present in RDPs affect the film formation. For example, polyvinyl alcohol (PVOH) used as colloidal stabilizer in a carboxylated SB latex was found to reduce the negative charge of the SB particles by coating some of the free carboxylate groups that might react with calcium ions present in the cement pore solution. This way, the electrostatic repulsion between latex particles is reduced and the transition from stage II to stage III is accelerated [19]. A similar effect was observed for kaolin which is added as an anticaking agent to RDPs [20].

The main difference between a liquid latex dispersion and a RDP is that in the latter, at first the spray-drying aids which are attached to the surface of the polymer powder particles need to dissolve or disperse and separate from the surface to allow coalescence and film formation [20]. Limited shelf-life is a problem well-known to the drymix mortar industry [21]. In this context, shelf-life means the time period over which a drymix mortar blend remains usable and is fit for the intended application. During storage, the cement contained in the drymix mortar can age and the RDPs may form a film prior to application. Cement aging is the consequence of a reaction between anhydrous cement, water vapor and CO_2 present in air that leads to partial hydration of the surface of the cement grains. It has deleterious effects on some engineering properties such as compressive strength, workability and setting time of the cement paste. For example, *Whittaker* et al. [22] studied the effect of aging on the engineering properties of a CEM I Portland cement sample exposed to relative humidities (RH) of 60% and 85% respectively over periods of 7 and 28 days. They demonstrated that aging results in the formation of a barrier of hydrates with few nm thickness covering the surface of the cement grains. Its thickness depends on the values of RH, temperature and exposure time. This was confirmed by *Dubina* et al. [23] who studied the aging of pure clinker phases and found that only the surface of the clinker particles was hydrated, as was confirmed later by X-ray photoelectron spectroscopy (XPS) [24]. Other studies focussed on

the prehydration behaviour of OPC and oil well cement *Dubina* and *Plank* [25–29].

Dubina and *Plank* [30] have also investigated the long-term stability of drymix mortars during storage. They found that the water sorption of each phase started at different RHs. CaO and C_3A were found to present the most reactive in respect to water sorption. For example, CaO starts to sorb water at 14% RH only and binds it chemically while orthorhombic C_3A sorbs water both chemically and physically beginning at 55% RH. For the calcium silicate phases, water sorption starts at 74% RH and the amount of water absorbed is very minor.

Meier and *Plank* [31] found that exposing anhydrous cement to humid environment greatly impacts its hydration behaviour. After aging a Portland cement sample for 1 day only, the heat flow from the hydration measured *via* isothermal calorimetry was decreased severely. Moreover, when the cement was aged for more than 3 days, the main hydration peak characteristic for C-S-H formation had disappeared entirely. Instead, a new peak at early hydration time (0–3 h) attributed to delayed ettringite formation had occurred. These authors also studied the performance of PCE superplasticizers and retarders in aged cement that was previously exposed to humidity. They found that the dispersing performance of the PCEs decreased with prolonged aging time of the cement and that the effectiveness of the retarders was different when applied to aged cement. These examples demonstrate that moist air can have a significant impact on the behaviour of cement and on the performance of some admixtures.

None of those previous researches have studied the influence of aging on RDPs commonly used in drymix mortars. These polymers might also age or undergo premature film formation before the mortar is applied. When this happens, the advantages attributed to them such as e.g. higher flexural and adhesive strength might be lost.

The aim of this research was to understand potential processes and reactions occurring during moisture exposure of a drymix mortar modified with RDP. It was sought to elucidate the processes relating to the latex powder (e.g. film formation, cement/RDP interaction) on a molecular scale and to connect those with the macroscopic properties of the drymix mortar. Another goal was to find out whether the shelf-life of the drymix mortar is linked to the chemistry of the RDP (EVA versus SB polymers) present in the blend and how the spray-drying aids contained in the RDPs may influence the process.

2. Materials and methods

2.1. Materials

The cement used in this study was an ordinary Portland cement CEM I 52.5N from HeidelbergCement, Geseke plant, Germany which is commonly used as base cement in many drymix mortar formulations. Its phase composition as determined

Table 1
Phase composition of the CEM I 52.5N sample as determined by Q-XRD using *Rietveld* refinement.

Phase	wt%
C_3S, m	54.1
C_2S, m	26.6
C_3A, c	3.3
C_3A, o	4.3
C_4AF, o	2.5
Free lime (*Franke*)	0.1
Periclase (MgO)	0.0
Anhydrite	2.6
$CaSO_4$ hemihydrate[*]	1.2
$CaSO_4$ dihydrate[*]	0.02
Calcite	3.6
Quartz	1.2
Arcanite	0.5

[*] Determined *via* thermogravimetry.

by quantitative X-ray diffraction (Bruker AXS D8 Advance, Karlsruhe, Germany) using *Rietveld* refinement (software Topas 4.0) is shown in Table 1. Average particle size (d_{50} value) of the cement sample measured *via* laser granulometry (Cilas 1064, Cilas Company, Marseille, France) was found at 11.8 μm. Specific density of the cement was 3.2 g/cm^3 as obtained by Helium pycnometry (Ultrapycnometer 1000, Quantachrome Instruments, Boynton Beach, USA) and its *Blaine* value was 3.54 cm^2/g.

Ethylene–vinylacetate (EVA) and carboxylated styrene–butadiene (SB) redispersible polymer powders were provided by Dow Olefinverbund GmbH, Schkopau/Germany. Their chemical structures are shown in Fig. 1. The redispersible powders were produced by spray-drying of the EVA or SB mother liquor latexes with the addition of kaolin as an anticaking agent (~12 wt%) and polyvinyl alcohol (PVOH) as a protective colloid (~10 wt%) [20]. The properties of the latex powders are presented in Table 2.

As kaolin, a commercial sample, KaMin HG 90 from KaMin LLC, Macon, Georgia, USA, was used.

An antifoaming agent (Agitan® P800 from Münzing Chemie GmbH, Abstatt, Germany) was used to reduce the air that both latexes entrain into the mixture.

2.2. Procedures

2.2.1. Aging of cement

Anhydrous cement was aged in a climate chamber at 40 ± 1 °C and 90 ± 3% relative humidity (RH) for 1, 3 and 7 days. For exposure, the material was spread out on a Plexiglas® plate in a 1 mm thick layer. During the aging, the cement powder agglomerated into sheets as a result of moisture uptake. The sheets were broken by shaking them manually in a PE bottle until a powder was achieved.

2.2.2. Aging of cement/RDP blends

The RDPs were blended at 4% by weight of cement (bwoc) into the anhydrous cement, homogenised and aged in the climate chamber for 1, 3 and 7 days. The fresh and aged samples were looked at in cement paste or mortar. After aging, cement generally exhibits a higher water demand to achieve the same workability as before aging [32]. For this reason, in all mixes, a water to cement ratio (w/c) of 0.6 was chosen because it ensures reasonable workability also for the aged slurry mix.

Cement pastes were prepared by placing the appropriate amount of the fresh or aged cement sample (neat or blended with RDP) in a 10 mL tubular glass ampoule or in a test tube where it was mixed with DI water at a w/c ratio of 0.6. The glass ampoules were sealed with a metal lid and the test tubes with a plastic wrap and shaken for 2 min on a vortex mixer to homogenize the paste.

For determination of compressive and flexural strengths, mortar specimens were prepared from fresh, non-aged or aged cement/RDP blends containing 4 wt% EVA or SB powder. The mortars (w/c ratio = 0.6) contained norm sand according to EN 196-1 [33] at a ratio of 3:1 (s/c = 3). The mortar specimens were prepared following EN 196-1 standard [33] and were cured for 28 days at 22 ± 2 °C and 50 ± 3% RH.

For the investigation on the impact of spray-drying aids, the respective amounts of PVOH or kaolin contained in the EVA or SB powders were taken into account.

Furthermore, the neat EVA and SB powders were also studied by exposing them for 1, 3 and 7 days to 40 ± 1 °C and 90 ± 3% RH in the climate chamber.

2.3. Analytical methods

2.3.1. Heat flow calorimetry

The hydration of fresh and aged cement in the presence and absence of the RDPs was tracked *via* heat flow calorimetry using a TAM Air isothermal heat conduction calorimeter (Thermometric, Järfälla, Sweden).

In a 10 mL tubular glass ampoule 4 g of the fresh or aged cement sample (neat or blended with RDP) were mixed with DI water at a w/c ratio of 0.6. The glass ampoules were sealed with a metal lid, shaken for 2 min on a vortex mixer to homogenize the paste and transferred into the instrument. Heat flow curves were recorded over 90 h at 20 °C.

Table 2
Properties of the redispersible latex powder samples.

Component or property	EVA powder	SB powder
Colloidal stabilizer	PVOH	PVOH
Anti-caking agent	Kaolin	Kaolin
Primary particle size [nm]	300–1250	150–600
Particle size distribution	Polydisperse	Polydisperse
Anionic charge density [C/g]		
In water @ pH 7.0	1.0	27.3
In water @ pH 12.5	12.8	32.0
T_g [°C]	20.0	6.0
MFFT [°C]	3.0	5.0

2.3.2. X-ray diffraction and SEM imaging

The fresh and aged non–hydrated samples were studied by means of X-ray diffraction. XRD scans were taken at room temperature from all samples on a D8 Advance instrument (Bruker AXS, Karlsruhe/Germany).

Scanning electron microscopic (SEM) images were captured using a FEI XL 30 FEG microscope equipped with a large field detector under low vacuum conditions (1 mbar H_2O pressure, corresponding to ~4% RH at room temperature). Morphology of the samples was studied on uncoated samples before and after exposure to humid air in the climate chamber.

2.3.3. Particle size and turbidity measurements

Redispersibility of the RDPs after aging was assessed by comparing the particle size of the polymer before and after aging using dynamic light scattering (DLS) technique (Zetasizer Nano ZS, Malvern Instruments, Worcestershire, UK) and photometric turbidity measurement. Turbidity was determined *via* light absorbance measurement of a 0.005 wt% aqueous dispersion of the aged latex powder at a wavelength of 550 nm on a spectral photometer (Spectroflex 6100 WTW, Weilheim, Germany).

2.3.4. Mechanical properties

Mortar prisms were prepared from fresh or aged cement samples (with or without RDP). The compressive and flexural strengths were determined according to EN 196-1 [33].

3. Results and discussion

3.1. Aging of the neat cement

The prehydration of cement occurring under humid climate conditions is greatly fostered by capillary condensation of water vapor in the interstitial spaces between the micrometer sized cement particles, as has been shown before by Dubina et al. [34]. Here, the moisture uptake on the anhydrous cement sample in the climate chamber was monitored *via* XRD analysis (Fig. 2).

When the cement was aged for 1, 3 and 7 days, then reflections signifying calcite appeared which grew in intensity with the time of exposure. Occurrence of the polymorph calcite was attributed to the relatively high humidity under which free lime and/or calcium hydroxide (Portlandite) have been shown in an earlier work to react with atmospheric CO_2 to calcite [34]. Normally, Portlandite formation signifies the reaction of the calcium silicates (C_3S, C_2S). As is evident in Fig. 2, with prolonged aging time the reflection
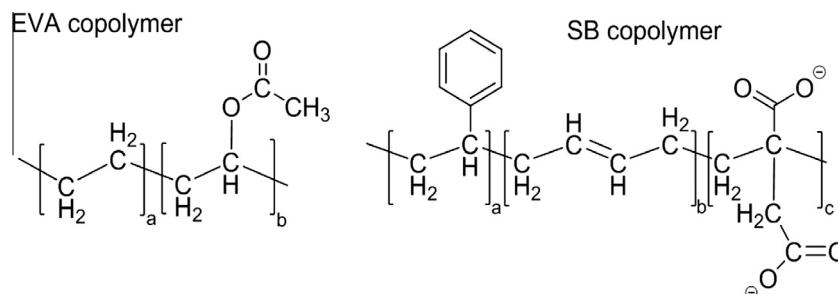

Fig. 1. Chemical structures of ethylene–vinylacetate and of carboxylated styrene–butadiene latex copolymers.
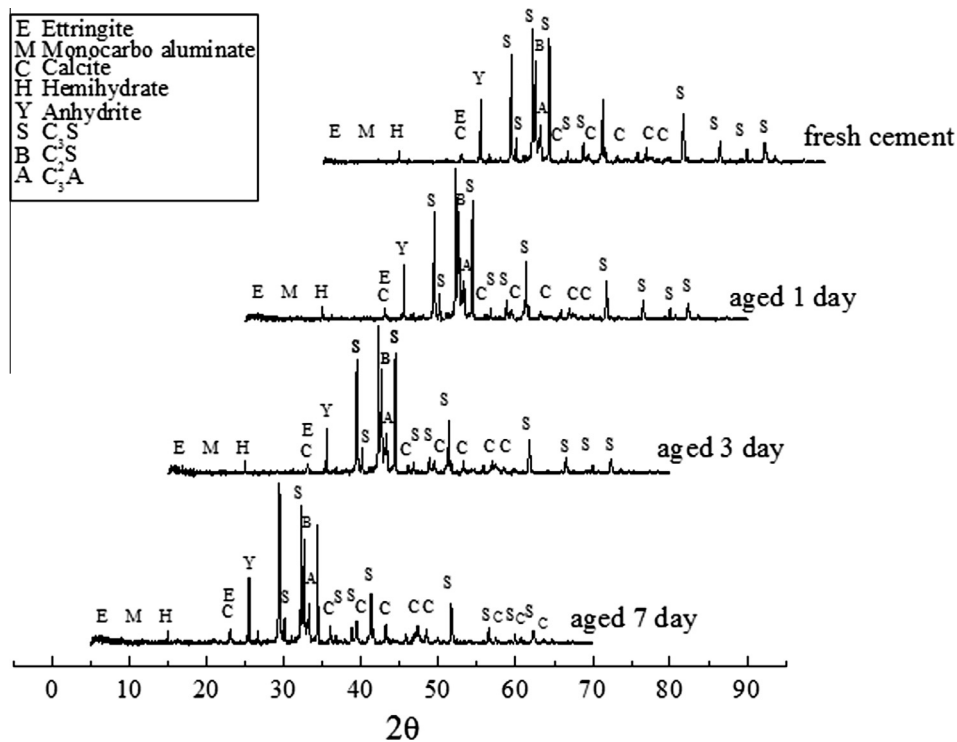
Fig. 2. XRD patterns of the fresh and aged cement sample shown in the range of 5–70° 2θ.

characteristic for C_3S decreases, thus confirming the release of Portlandite. Preparation artefacts were excluded by repeating the XRD measurements for each sample three times whereby always a comparable decrease in signal intensity for C_3S was observed.

Also, minor reflections assigned to ettringite and monocarbo aluminate can be observed.

As was presented before, individual clinker phases react differently in the presence of humidity, with free lime being the most reactive one, followed by C_3A [23]. This explains why calcite was formed as a dominant hydration product, as is presented in Fig. 2.

3.2. Aging of the neat RDPs

The powders prepared from liquid ethylene–vinylacetate and carboxylated styrene–butadiene latexes were aged for 1 and 7 days in the climate chamber. Like cement before, the powders were spread out in a 1 mm thick layer on a Plexiglas® plate and subjected to air possessing 90 ± 3% RH at 40 ± 1 °C.

After 1 day of storage of the latex powders in the climate chamber, the EVA sample had remained completely unchanged and powdery whereas the SB polymer had compacted into sheets, as can be seen in Fig. 3.

To determine any changes in particle size which had occurred during aging, 0.01 wt% aqueous dispersions were prepared from the EVA and SB RDPs before and after aging. The powders were dispersed in DI water and sonicated in an ultrasonic bath for 1 min. Their particle size distribution was measured *via* dynamic light scattering (Fig. 4). Surprisingly, and contrary to the impression given by Fig. 3, no substantial difference was found for the size distribution of the fresh and aged SB latex. This result was further confirmed by turbidity measurement of 0.005 wt% aqueous dispersions of both EVA and SB powders following the procedure of [20]. Apparently, under the influence of heat and moisture the SB powder only compacts during the aging while no particle coalescence takes place. Such compaction is owed to the stickiness of PVOH.
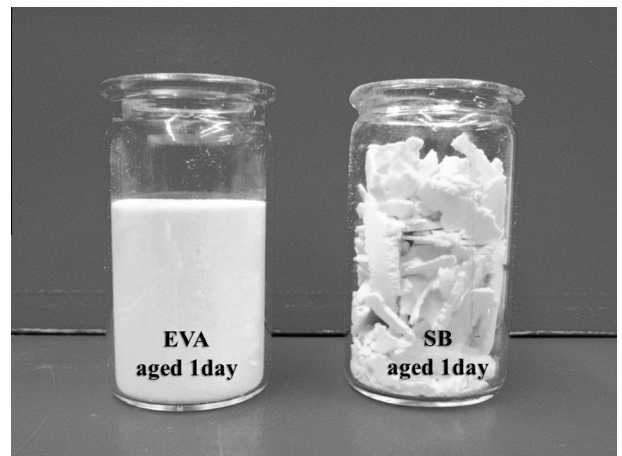

Fig. 3. Optical images of EVA and SB powder samples aged for 1 day at 40 °C/90% RH.

The result suggests that for such harsh storage conditions, the dosage of the anticaking agent, in this case kaolin, in the SB powder is insufficient.

From the results it can be assumed that PVOH which was added as a protective colloid and covers the surface of the SB particles, sorbs water and forms a polymer film there which prevents the SB particles from coalescing. Such films do not occur for the EVA powder because there, the kaolin covers the surface of the latex particles more uniformly, as has been shown in previous work [36] and thus hinders the access of water to the EVA particles. This is, however, not the case for the SB powder, as there is less kaolin present on its surface. In this case, water can get in contact with PVOH and partially dissolve it, thus leading to stickiness and caking of the SB powder.
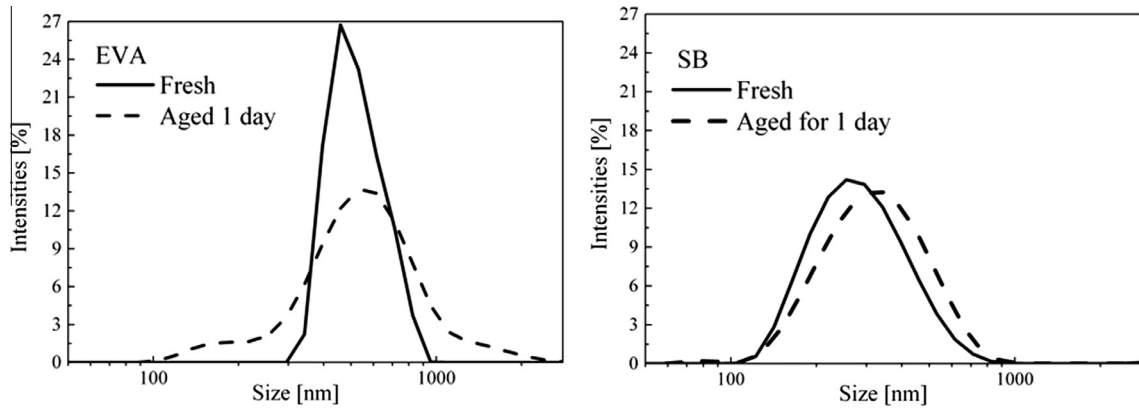
Fig. 4. Particle size distributions of 0.01 wt% aqueous dispersions prepared from EVA (left) and SB (right) RDPs fresh and after 1 day of aging, measured *via* dynamic light scattering.
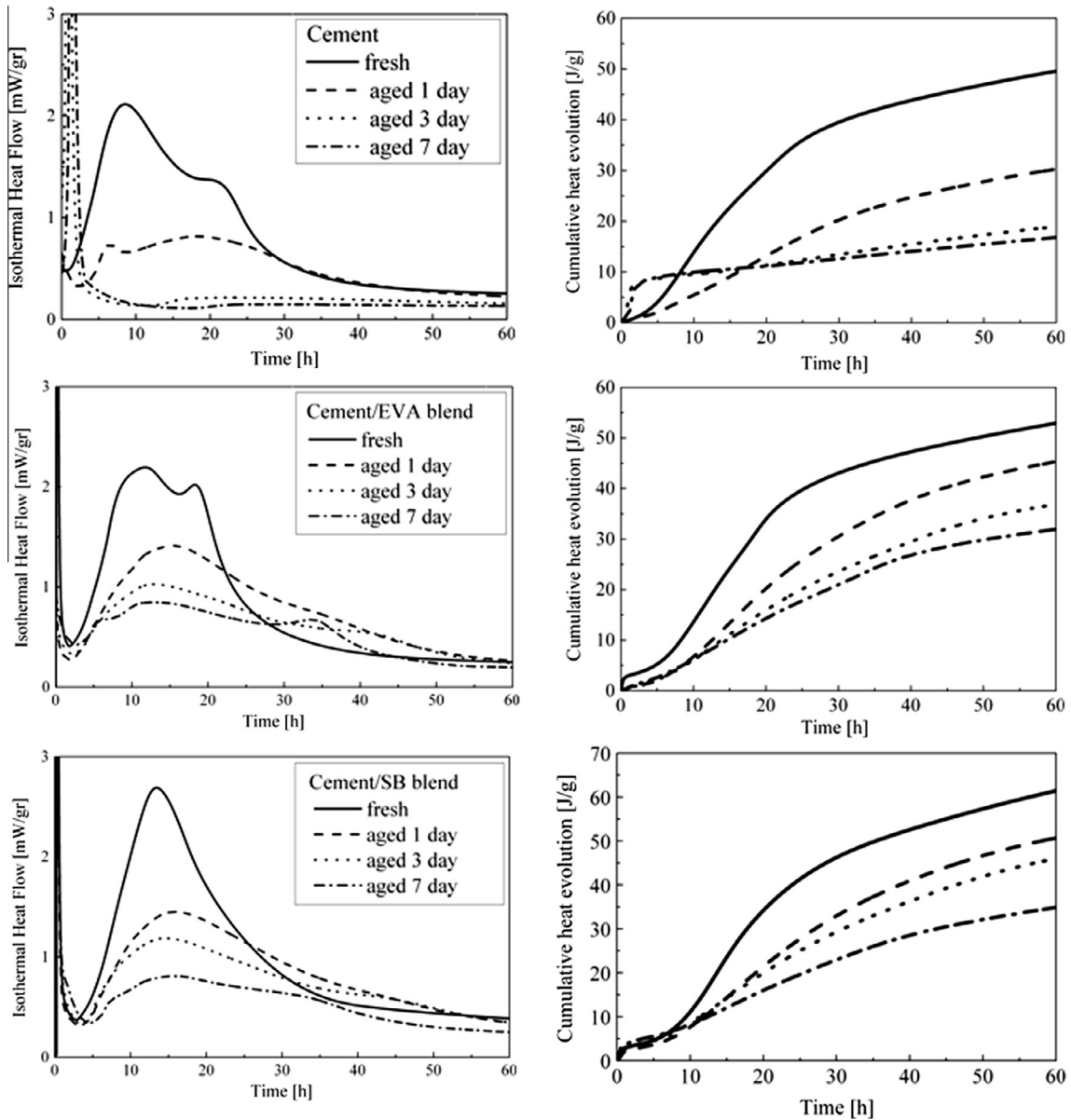

Fig. 5. Time-dependent and cumulative heat release during hydration of cement (top), cement blended with 4 wt% EVA (middle) or SB powder (bottom), aged over different time periods.
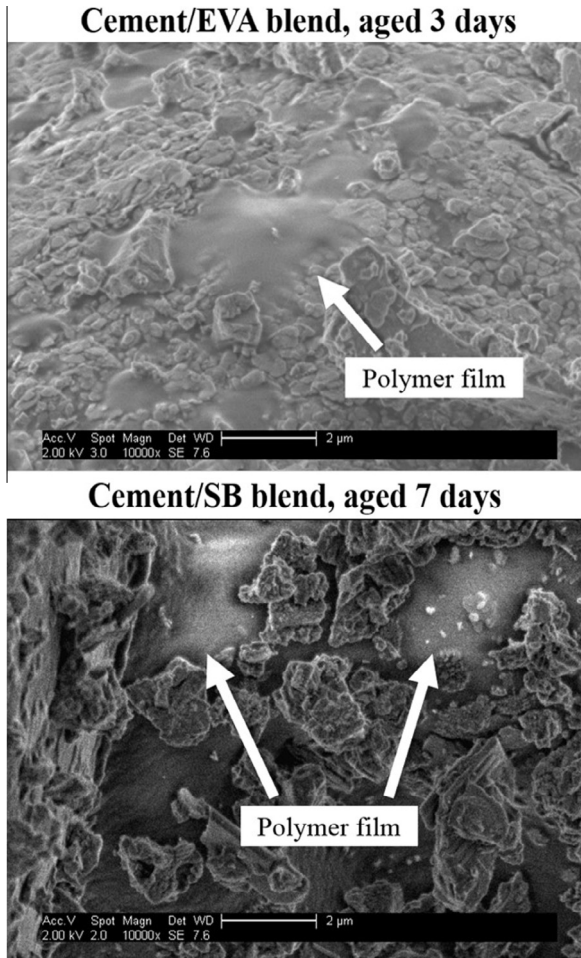
Cement/EVA blend, aged 3 days

Cement/SB blend, aged 7 days

Fig. 6. SEM images of cement/EVA blend aged for 3 days (top) and cement/SB blend aged for 7 days (bottom) at 90% RH and 40 °C.

3.3. Aging of cement/RDP blends

Isothermal calorimetry revealed that exposing anhydrous cement blended with EVA or SB powder to moist air greatly impacts its hydration reaction. The main hydration peak signifying C-S-H formation weakens significantly with aging time, indicating strong retardation. This effect manifests itself in a heat release over a longer period of time (Fig. 5). Even the new peak found at very early hydration time for aged cement which signifies delayed ettringite formation as reported by *Meier* and *Plank* [31] is no longer detectable when the cement is aged with RDPs.

Apparently, the presence of RDPs alters the hydration reaction of the aged cement. The cumulative heat release shows that

cement aged for 1 day releases about 40% less heat, while for cement/RDP blends such decrease in heat release can be observed only after 7 days of aging.

The results allow to conclude that some sort of interaction between the anhydrous cement and the latex powders may occur in the climate chamber. Unfortunately, in the XRD patterns of the fresh and aged samples no differences could be detected which is owed to the formation of a very thin layer only (~few nm) of hydrates on the surface of the cement particles.

Results from SEM imaging also suggest that during aging, some of the RDP particles may already have coalesced into polymer films. For example, for the EVA powder films are visible already after 3 and 7 days of aging (Fig. 6, top). Whereas when the SB powder was aged with cement, then films were detected after 7 days of aging only (Fig. 6, bottom). Apparently, when cement is aged together with RDPs, then premature film formation can occur resulting in less RDP particles being available for the coalescence later in the mortar

3.3.1. Premature coalescence of RDP during aging

To assess the quantity of latex particles which have been lost by premature film formation during aging, cement pastes were prepared from the fresh and aged cement/RDP blends using a high water to cement ratio (w/c = 2) to check the amount of latex present in the paste's bleeding water. The rationale behind this experiment was that when the RDP had coalesced into films, then the turbidity of the bleeding water would be reduced compared to that of a non-aged cement/RDP blend.

As can be seen in Fig. 7, the fresh, non-aged cement/EVA blend produces plenty of polymer particles in the supernatant. However, when mixing the 1 day aged cement/EVA blend with water, the aqueous supernatant is nearly transparent, signifying that the EVA particles are no longer dispersed. Either they have flocculated or they may even have converted into polymer films. The same observation was made for the blend of cement/SB.

Interestingly, the EVA and SB powders form films in the climate chamber only when stored together with cement. When aged SB and EVA powders were mixed with fresh cement, however, both were able to redisperse well in water, although not as complete as fresh RDP in fresh cement (Fig. 7).

The temperature in the climate chamber (40 °C) is considerably higher than the minimum film forming temperatures for the EVA (3 °C) and the SB polymer (5 °C). Furthermore, the significant amount of water absorbed by the anhydrous cement can dissolve the PVOH, thus enabling the latex particles to interact with each other and coalesce into films. This could explain why premature particle coalescence occurs in the presence of cement, but not when the pure RDPs are exposed to humidity.

In order to further understand the film formation which had occurred when the cement/RDP blends were aged in the climate chamber, the polymer powders were aged with different minerals
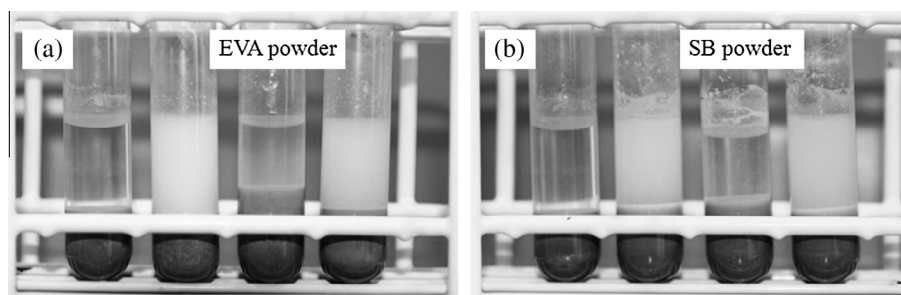

Fig. 7. Visual analysis of the presence of latex polymers in the supernatant of, from left to right, (a) fresh cement paste, fresh cement/EVA blend, cement/EVA blend aged 1 day and fresh cement mixed with 1 day aged EVA; and (b) same test as in (a) but with SB instead of EVA powder.

to better elucidate the role of the hygroscopicity of cement, its release of minerals upon contact with water and its high pH in the presence of humidity.

It has been presented before that neat RDP powders do not form films in the climate chamber. To confirm whether such film formation depends on water physically bound to a hygroscopic substrate, cement was replaced with kaolin. This mineral was blended with 4 wt% of RDP and 4 wt% of anhydrous $CaCl_2$ or CaO. The mixtures were aged for 7 days in the climate chamber and analysed *via* SEM.

In the presence of hygroscopic $CaCl_2$, no film formation was detected. Unchanged powder particles were found next to large

kaolin agglomerates, as is evidenced for the kaolin + SB samples in Fig. 8. However, when the RDPs were aged together with kaolin and CaO, a phase that is similarly hygroscopic than $CaCl_2$, but additionally provides a high pH to the liquid phase, then both polymers, EVA as well as SB, coalesced into films. There, large polymer films can be observed on the kaolin particles.

PVOH is a colloidal stabilizer which coats the latex particles. For the latex powders to form a film it is necessary to dissolve the PVOH layer and expose the particle surface directly to water so that the latex particles can coalesce. When latex powder is subjected to high temperature and high humidity, then PVOH will
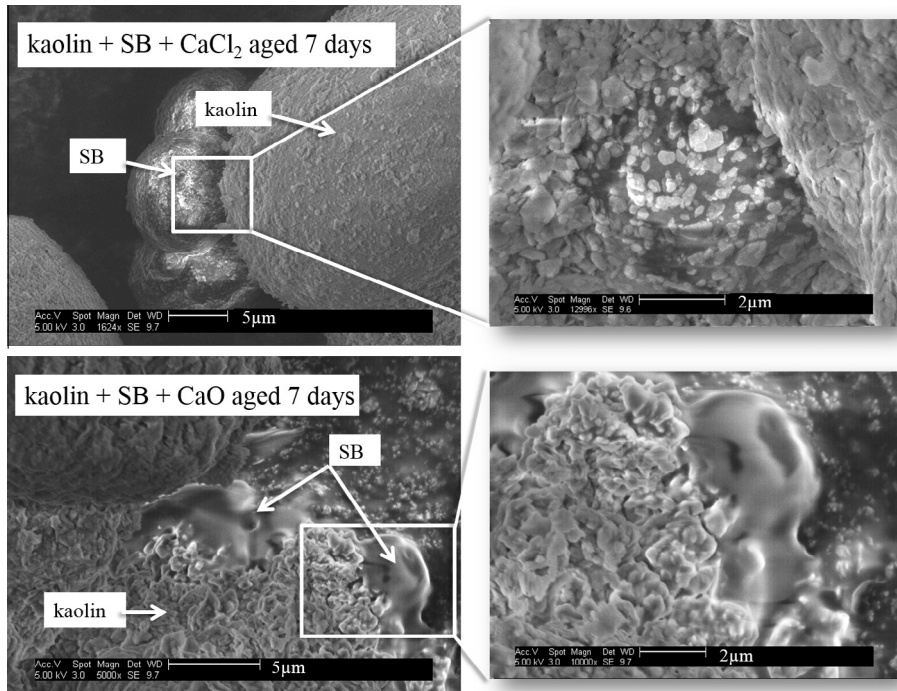

Fig. 8. SEM images of kaolin aged with SB and $CaCl_2$ and kaolin aged with SB and CaO; aging conditions: 40 °C/90% RH/7 days exposure.
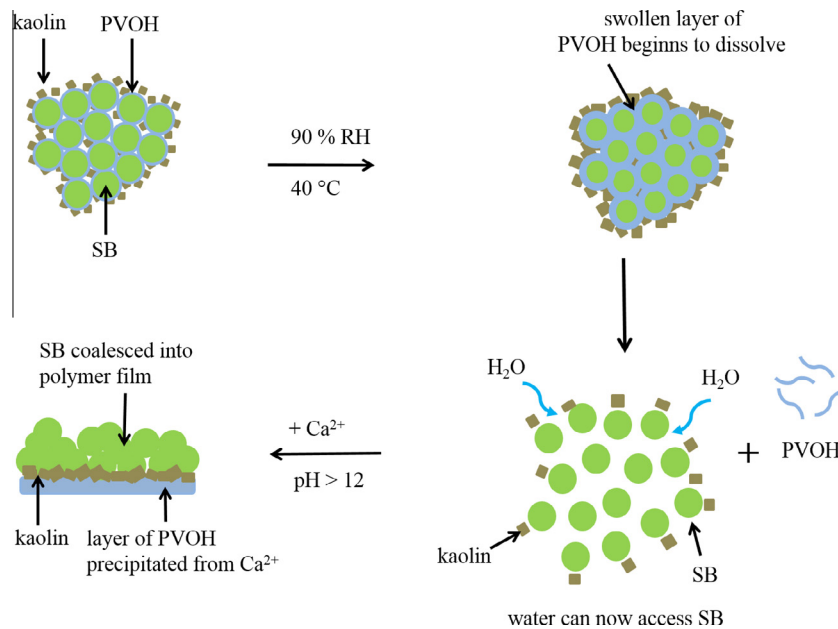

Fig. 9. Model explaining the process occurring during aging of an RDP in the presence of cement leading to film formation.
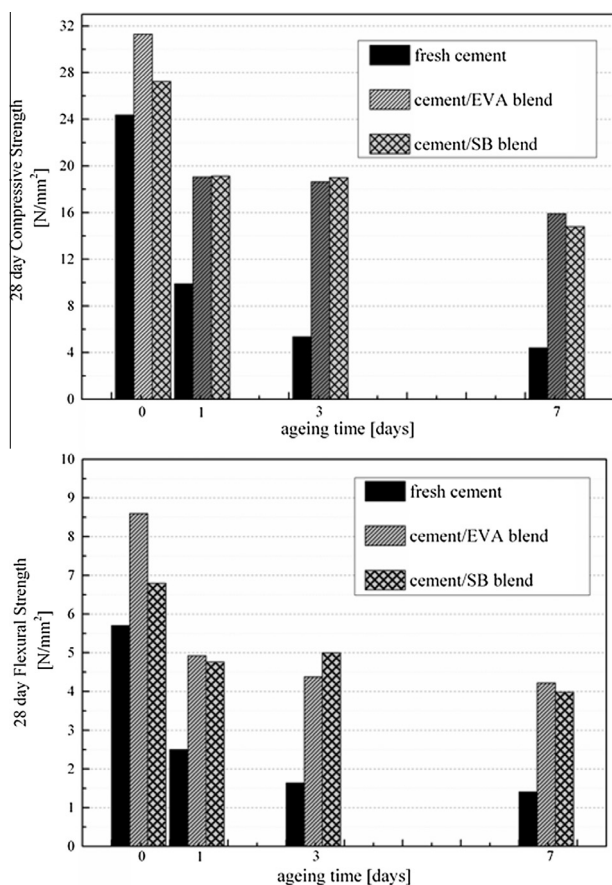
Fig. 10. Compressive (top) and flexural (bottom) strengths of mortars prepared from cement/RDP blends fresh and aged for 1, 3 and 7 days, measured according to EN 196-1.

absorb water, but cannot dissolve, thus it keeps the latex particles separated from each other and they are unable to coalesce into a film. Earlier work, however, has revealed that at pH = 12.5 PVOH will precipitate in the presence of calcium ions (Ca^{2+}) due to interaction of Ca^{2+} with deprotonated hydroxyl groups while at pH = 7, no such precipitation does occur [19]. This explains why film formation was found only when the polymer powders were mixed with CaO, but no such observation was made when aged with $CaCl_2$.

From these results it can be established that in such humid environment EVA latex particles coalesce faster into films than the SB latex studied here. Furthermore, RDPs form a film only in the presence of cement because the latter not only attracts water, but, at the same time provides Ca^{2+} ions and a high pH to the liquid phase as a result of capillary condensation of water between the powder particles [19,35]. These factors must all be present to allow film formation. A schematic representation of what happens during aging of an RDP with cement is displayed in the scheme of Fig. 9.

3.4. Mechanical properties of RDP-modified mortar

Mortar specimens were prepared as mentioned in Section 2.2.2. For the non-modified cement, the loss of compressive strength after aging was massive. After 1 day of aging only, 60% of the initial strength of the mortar prepared from fresh cement had disappeared (Fig. 10). After 7 days of aging, less than 20% of the initial strength was remaining. For the RDP-modified mortars, the loss of strength was much less pronounced. After 1 day of aging, both the SB- and the EVA-modified mortars had lost 30% and 40% of

their initial strength, respectively. For the 7 days aged samples, more than 50% of their initial strength had been retained.

As expected, the flexural strengths of the polymer-modified mortars are consistently higher than those of the non-modified ones (Fig. 10). Again, aging affects the latex-modified mortars much less than the non-modified samples.

4. Conclusions

The shelf-life of blends from cement and EVA or SB latex powders as used in the drymix mortar industry is affected when subjected to a humid atmosphere. This instability can be attributed to partial prehydration of the surface of anhydrous cement and the film formation of the RDPs.

In humid environment the PVOH layer present on the surface of the RDP particles will dissolve allowing EVA and SB polymer powders to coalesce into a film which partially protects the cement from aging. For that reason, cements blended with EVA or SB polymer powders age less than neat cement when stored for the same period of time in the climate chamber.

As a result, the compressive and flexural strengths of the mortars casted with cement aged for 1 day only dropped by more than 60% compared to those of the mortar prepared from fresh cement. Whereas, even after 7 days of aging, the strengths of RDP-modified containing mixed with an aged cement/RDP blends still were more than 50% of the strength of the non-aged blend. Apparently, an RDP blended cement resists exposure to humid air considerably better than neat cement.

It becomes evident that in moist atmosphere, an interaction between the RDP and cement occurs. On the one hand, the presence of cement triggers partial film formation by the RDP; while on the other hand, such films protect cement from rapid aging in humid environment, thus improving its shelf-life. Still, any exposure of dry mixes to moisture should be avoided as much as possible, because such aging will always lead to decreased strengths.

In future research it would be interesting to study how the premature film formation from the RDP observed during the aging affects the adhesive strength of mortars. The latter represents one of the most important properties of RDP-modified mortars.

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