

Investigation of Portland cement composites containing high amounts of different kinds of fly ashes

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Abstract. Utilization of fluidized fly ash in cement composite is problematic, e.g. because of its changeable chemical composition and increased water demand of the mixture. However, this kind of by-product shows some self-cementing properties, which may be beneficial for low-cement mixtures. The article compares the impact of various kinds of fly ashes, i.e. fluidized fly ash and conventional one, and their mixtures on hydration of fly ash–cement compositions in relation to properties of final material. The amount of fly ash in the binder was 50 wt%. Calorimetry, thermal analysis (TG/DTG) and infrared spectroscopy were used. Compressive strength and water absorption of hardened composites were also registered. It was found that both fly ashes exhibit delay effect in fly ash–cement pastes which causes extension of initial setting time and lower heat released compared to the reference without fly ash. At later hydration days, fluidized fly ash develops higher pozzolanic activity than conventional one. Compositions with fluidized fly ash show better compressive strength compared to those containing conventional one. Mixing of different materials of high and low activity (fluidized and conventional fly ash in this case) seems to be a good way for creation of new cement replacement material.

Keywords: fly ash, HVFA concrete, cementitious supplementary materials, pozzolanic activity, hydration.

Introduction

After addition of water into cement, hydration processes start to take place resulting in release of heat which amount and intensity are different for various kinds of cement, e.g. Portland cement and calcium aluminate cement (Pacewska, Wilińska, & Bukowska, 2009). Exothermic cement hydration are of special importance in the case of massive concrete constructions. In such case, temperature inside the element can rise considerably, while the outer layers are cooled more rapidly. Temperature gradient occurs which can cause thermal stresses. As a result, cracks may appear in the whole volume of hardened material, and concrete compressive strength and durability may be reduced (Zreiki, Bouchelaghem, & Chaouche, 2010; Jason & Masson, 2014; Batog, Golda, & Giergiczy, 2016; Kuriakose, Rao, & Dodagoudar, 2016; Jaskulski, Glinicki, Ranachowski, & Kubissa, 2019). Taking this into account, developing new binders that release less heat during hardening than cement became necessary.

One of the ways to lower the temperature inside hydrating concrete is reduction of the amount of Portland clinker in the composite, e.g. by the use of commercially available cements CEM II – CEM V type or conventional fly ash Class F as partial cement replacement (additive type II for concrete) (Knor, Glinicki, Holnicki-Szulc, Ossowski, & Ranachowski, 2013; Lee, Khil, & Yun, 2014; Batog et al., 2016; Tahersima, Ley, & Tikalsky, 2017). Concrete containing high amount (about 50 wt.% or higher) of fly ash in place of cement can also be considered for this purpose. Such composites are desirable not only for the reason of effective reduction of heat emission in massive constructions but also because of contribution to environmental protection. Proper use of fly ash in the concrete technology is part of pro-ecological actions of the sustainable development strategy connected with: reduction in CO₂ emission, energy saving, disposal of industrial by-products, limiting the storage area of by-products of coal combustion.

Using high amount of Class F fly ash (non-hydraulic non-clinker material) as partial cement substitute in the concrete, results in elongation of initial and final setting times, slower development of compressive strength and its lower value (especially in early periods) compared to cement concrete without fly ash (Hannesson, Kuder, Shogren, & Lehman, 2012; Huang, Lin, Chang, & Chen, 2013; Ramezani-pour, Bayat, Bagheri, & Moeini, 2016). In the case of massive concrete structures, limiting the exothermicity of the chemical reactions of hydration is a priority. Extended setting time may even be advantageous, ensuring proper consistency and workability for a sufficiently long time. Rate of strength increase is of secondary matter (Batog et al., 2016). However, in the case of large amount of fly ash and low content of cement, it may be difficult or even impossible to provide a suitable concrete strength class.

It happens, because cement is substituted by material which cannot harden itself but it needs $\text{Ca}(\text{OH})_2$ to reveal pozzolanic activity. Reaction between active components of fly ash and $\text{Ca}(\text{OH})_2$ goes slowly at ambient temperature (Kurdowski, 2010; Lothenbach, Scrivener, & Hooton, 2011). Moreover, in the case of mixture of cement and low-calcium fly ash, without additional components, $\text{Ca}(\text{OH})_2$ is provided only by hydration of cement. As a consequence, in the case of high cement replacement, compressive strength of hardened material can be low even after a long time (Sun, Shen, Tan, & Tanner, 2018). To counteract these inconveniences, reduction of water/cement ratio and using superplasticizers or different activation processes (chemical, mechanical) can be used (Jackiewicz-Rek, 2010; Garcia-Lodeiro, Donatello, Fernández-Jiménez, & Palomo, 2016; Wilińska & Pacewska, 2018), depending on cement replacement ratio and properties of cement substitute. Using supplementary cementitious material exhibiting self-cementing properties (instead of conventional fly ash) in concrete should also be considered. Such features and pozzolanic activity are shown by fly ash from fluidized combustion of coal.

Fluidized combustion of coal is more of a ecologically friendly technology compared to conventional pulverised combustion. However, fly ash which is formed in such combustion installation (fluidized fly ash) has significantly different properties compared to conventional Class F fly ash. Fluidized fly ash is composed of irregular porous grains (contrary to spherical vitreous grains of conventional fly ash). It contains higher amount of calcium compounds including CaSO_4 (Pacewska, Blonkowski, & Wilińska, 2008; Li, Chen, Huang, Ma, & Wu, 2012; Sheng, Li, & Zhai, 2012; Xia, Yan, & Hu, 2013; Škvára et al., 2016; Zhang, Choi, Sagawa, & Hama, 2017; Wilińska & Pacewska, 2019). Properties of this kind of fly ash do not meet PN-EN 450-1 (Polski Komitet Normalizacyjny, 2012) standard requirements for fly ash to be used in concrete. Its utilization in cementitious composites poses some difficulties, such as deterioration of the workability of the mixture, possible highly exothermic hydration (depending on the amount of free CaO), highly alkaline pH of the water extract, possibility of excessive expansion of formed products, especially dangerous when it occurs after the material has hardened (Li et al., 2012; Škvára et al., 2016). Exothermic fly ash hydration can cause that effective reduction of heat emission in massive concrete blocks may be impossible. Moreover, changeable chemical composition of fluidized ashes is also problematic.

In spite of the above mentioned difficulties, fluidized fly ash has potential as a material exhibiting self-cementing properties (Pacewska et al., 2008; Li et al., 2012; Sheng et al., 2012; Xia et al., 2013; Škvára et al., 2016; Zhang et al., 2017). Thus, it can be considered as cement replacement in low-cement concretes to improve some of their properties which are worsen in the case of using conventional Class F fly ash. Heat release and excessive expansion of such compositions should be under special consideration.

There are attempts to use fluidized fly ash in cement composite in typical amount – not exceeding 30% of binder mass (Pacewska, Blonkowski, & Wilińska, 2006; Pacewska, Wilińska, & Nowacka, 2011; Shen, Qian, & Zhang, 2013; Gazdič, Fridrichová, Kulisek, & Vehovská, 2017). Some studies show that fluidized fly ash can also be considered as component used in higher amount in cement-fly ash binder (sometimes also with introduction of additional chemicals) (Xia et al., 2013; Chen, Gao, Yan, & Liu, 2017; Horszczaruk & Brzozowski, 2018). Recently, this kind of fly ash is also proposed as component of non-clinker binder made of mixture of different industrial by-products (Dung, Chang, & Chen, 2014; Zhang et al., 2017; Kledyński, Machowska, Pacewska, & Wilińska, 2017; Hlaváček, Šulc, Šmilauer, Rößler, & Snop, 2018; Machowska, Kledyński, Wilińska, & Pacewska, 2019).

In the paper, utilization of fluidized fly ash (alone or in mixture with conventional one) in high volume fly ash concrete (50 wt.% of cement substitution) and without additional activating components was proposed. In this way, self-cementing and pozzolanic properties of fluidized fly ash are disclosed and their influence on properties of cement material can be observed. Features of binding materials strictly depend on chemical and physical processes taking place in the hydrating system. The aim of this work is to compare the impact of various kinds of fly ashes and their mixture on hydration of fly ash–cement compositions in relation to properties of final material.

Materials and methods

Materials and sample preparation

Fly ash from fluidized combustion of hard coal (PF), fly ash from conventional combustion of the same kind of coal (PK) as well as commercially available Portland cements CEM I 32.5R and CEM I 42.5R were used to prepare the composites. Average chemical compositions (wt. %) of fly ashes were as follows:

- for PF: 55% SiO_2 , 16% Al_2O_3 , 5% Fe_2O_3 , 10% CaO, 5% SO_3 , 2.5% $\text{Na}_2\text{O} + \text{K}_2\text{O}$, 2% MgO,
- for PK: 50% SiO_2 , 20% Al_2O_3 , 7% Fe_2O_3 , 5% CaO, 1% SO_3 , 3.5 % $\text{Na}_2\text{O} + \text{K}_2\text{O}$, 3% MgO.

The main crystalline components of fly ashes are: quartz and mullite in the case of PK, quartz, anhydrite and calcite in the case of PF. PK almost does not contain moisture, while PF shows small amount (about 1.5%) of adsorbed water. pH value of water extracts are alkaline (above 11) for both fly ashes. Other properties of PF and PK can be found in Wilińska and Pacewska (2019).

Cement-fly ash pastes were carried out using 50 wt.% of PF (or PK) and 50 wt.% of cement. In the case of binder containing mix of fly ashes, 25 wt.% of PF, 25 wt.% of PK and 50 wt.% of cement were used. Dry components were firstly mixed, then distilled water was added in an amount ensuring water to binder ratio equal 0.6 and

then all constituents were mixed. Reference sample was prepared without fly ash (cement + water, w/c = 0.6). Cement-fly ash pastes used for measurements of heat release after addition of water were hydrated in calorimeter. Specimens for thermogravimetry (TG/DTG) and infrared spectroscopy (IR) investigations were hydrated in small sealed bags at room temperature. At the appointed time, the specimens were removed from the bags and hydration was stopped by the use of acetone.

Cement-fly ash concrete series were made according to procedure described in Kubissa, Wilińska, and Pałuba (2013). Composition of binder and amount of water used to prepare concrete were the same as in the case of cement-fly ash pastes (50% of cement replacement, water/binder = 0.6).

Cement-fly ash mortars containing 25 wt% of PK, PF or their mixture were prepared to estimate pozzolanic activity of fly ashes and their mixture. Standard sand, Portland cements CEM I 32.5R and 42.5R as well as tap water (water/binder = 0.5) were used. The specimens were prepared according to PN-EN 1015-2 (Polski Komitet Normalizacyjny, 2002) standard. Pozzolanic activity index was calculated according to PN-EN 450-1 (Polski Komitet Normalizacyjny, 2012) standard. The mortars were water cured till 28th and 90th day of hydration.

Additionally, cement-fly ash mortars containing 50% of PF, PK or PF + PK as cement replacement were made. Portland cement CEM I 32.5R, tap water and river sand were used. Water to binder ratio was 0.6 for specimens containing PK and the mix of the two kinds of fly ashes. In the case of sample containing 50% of PF, higher amount of water was used (water/binder = 0.77) to improve workability of the mixture without additional introduction of chemical admixtures.

Methods

Calorimetric measurements were carried out by means of differential BMR calorimeter constructed at the Institute of Physical Chemistry of Polish Academy of Sciences. External temperature was 25 °C. Specimens (10 g of binder and 6 g of water) were hydrated in the calorimeter till 48 h. The measurements were started immediately after addition of water into binder. The results were calculated using computer software (Poznański, 2012).

Thermal analysis (TG/DTG) was conducted using SDT 2960 Thermoanalyser (TAInstruments). The conditions of the measurements were as follows: heating rate 10 °C/min, mass of sample: 9–13 mg, nitrogen atmosphere.

To collect IR spectra, FTIR spectrophotometer Genesis II, produced by Mattson (4000–400 cm⁻¹, sample preparation – pelletizing with KBr) was used.

Consistency of fresh mixtures was estimated according to the PN-EN 196-1:2016-07 (Polski Komitet Normalizacyjny, 2016) standard. The test of compressive strength and water absorption coefficient were carried out according to PN-EN 196-1:2016-07 and PN-EN 1015-18 (Polski Komitet Normalizacyjny, 2003) standards respectively.

Results and discussion

Pozzolanic activity index

Figure 1 shows pozzolanic activity indexes calculated basing on compressive strength of cement mortars containing 25% of fly ash. The measurements were carried out for Portland cement CEM I 32.5R because this kind of cement was used in the case of 50% fly ash-cement composites, and for CEM I 42.5R as such cement is required in the PN-EN 450-1 standard.

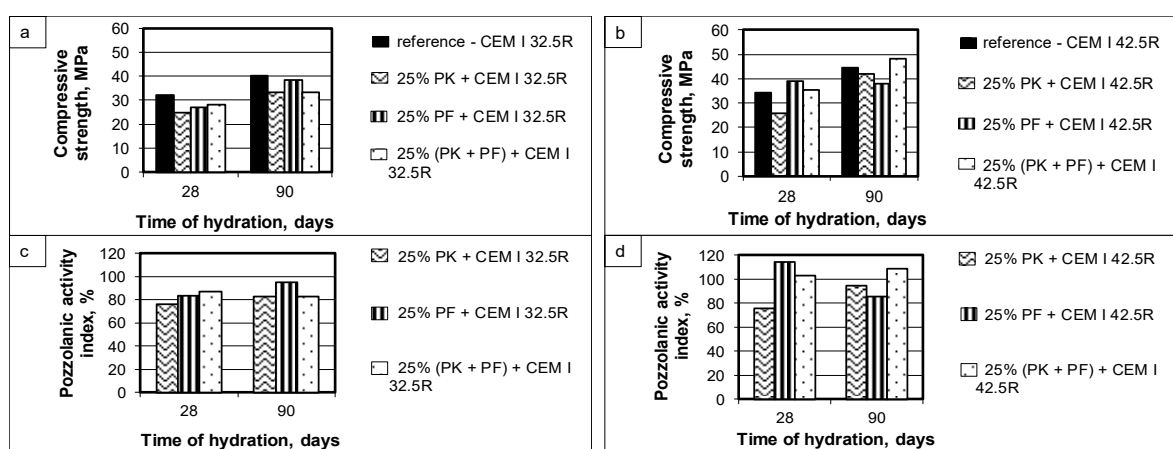


Figure 1. Compressive strength of cement-fly ash mortar (a, b) and pozzolanic activity index (c, d)

It is visible, especially for mortar containing PF, that in presence of higher class cement, fly ash can develop its activity quicker. This is the result of more intense hydration of CEM I 42.5R cement compared to CEM I 32.5R, and, as a consequence, higher hydration heat and formation of $\text{Ca}(\text{OH})_2$ in greater amount (Pacewska & Wilińska, 2013). Such conditions are favourable to develop pozzolanic activity of fly ash. As a result CEM I 42.5R cement mortars containing PF show 28-day compressive strength exceeding the value registered for reference. Slightly lower compressive strength was registered for mix containing PF + PK. Results obtained for CEM I 42.5R mortars after 90 days of hardening show that PK significantly develops its activity reaching compressive strength close to the reference (90-day pozzolanic activity index amounts to 95%). 25% PF-CEM I 42.5R cement mortar does not raise its compressive strength after 28th day of curing. It may indicate that PF develops its activity mainly during the first 28 days and does not contribute to the increase of strength in the later period. However formation of delayed ettringite and its negative influence on compressive strength cannot be excluded. The highest 90-day compressive strength was registered for sample containing mixture PK + PF. It indicates synergic effect of both kinds of fly ash.

In the case of mortars with CEM I 32.5R Portland cement, fly ashes develop their activity more moderately compared to specimens with higher class cement. Compressive strength of cement-fly ash mortars do not exceed the result for reference. Nevertheless, pozzolanic activity index achieved satisfactory values – about 80% and even 95% (after 90 days) for sample containing 25% of PF.

Research of cement-fly ash paste

Figure 2 presents the amount of heat released after different stages of hydration, starting from 1st h and ending at 48th h. As cement hydration process is exothermic, heat release is observed just after addition of water into cement-fly ash binder. This is an effect of grains wetting, dissolving of some components of the binders and finally precipitation of solid products. The amount of heat released is lower for pastes containing ashes compared to the reference sample throughout the test period. It indicates that clinker minerals and their reaction with water are mainly responsible for exothermic process. However, in the first hours after adding water, the amount of heat evolved by cement-fly ash pastes is higher than resulting from percentage replacement of cement. The heat registered for blended cement pastes amounts to above 60% of the reference value and even above 80% in the case of paste containing 50% of PF (till 4th h). It indicates nucleation and acceleration action of fly ash grains toward cement. In the case of pastes containing PF, porous structure of its grains, hydration of free CaO as well as initiation of hydration of active components of PF also contribute to this heat release.

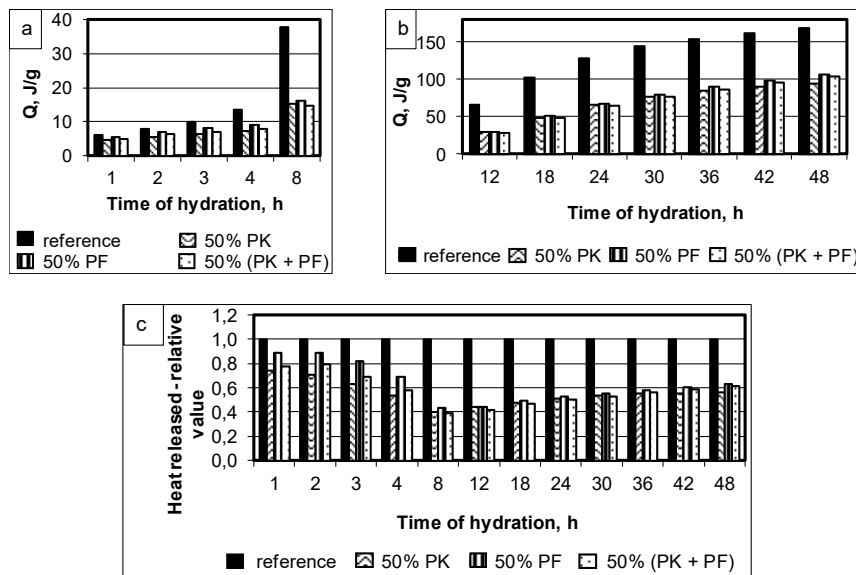


Figure 2. Total heat released after different time of hydration (a, b) and relative value of the heat evolved (c)

Sample with 50% of PF exhibits the highest heat released (compared to paste with 50% of PK and 50% of PF + PK) throughout the test period. It is especially visible in the early hours of hydration. In general, for all the pastes, the total heat released increases as the time of hydration is longer. However, intensity of heat release is higher in the case of reference paste compared to the samples containing fly ashes. It is especially visible in Figure 2c presenting relative values of the heat evolved calculated in relation to the results for reference paste. The relative values of heat released for cement-fly ash pastes decrease compared to specimen without fly ash up to 8th h of hydration (delay effect). It shows that hydration processes in the cement-fly ash blends go slowly and it results in elongation of initial setting time. After 8th h the intensity of heat release begins to gradually increase as a result of further cement hydration as well as development of fly ash activity

For all the samples the total heat released after 48 h is significantly lower than for the reference cement paste (the heat for fly ash-cement binders is about 60% of the value registered for specimen without fly ash). It shows that hydration of cement-fly ash pastes is of lower exothermicity than hydration of Portland cement. Thus, cement-fly ash binders containing 50% of fly ash have low hydration heat and, for this reason, they can be considered to use for massive constructions. This is also met for samples containing PF. However, fluidized fly ash can show different chemical composition (e.g. fly ash used in Nguyen, Chang, Shih, Chen, and Nguyen (2015) and Škvára et al. (2016)) including high amount of CaO and sulfate. Highly exothermic hydration of free CaO can result in increase of temperature of fly ash-cement mix. Thus, in the case of different fluidized fly ashes, their composition and thermal effect of hydration should be evaluated, as it determine the possibility to use this kind of material in high amount in binding mixture. In the case of too high exothermicity of hydration of PF-containing binder, modification of its composition by mixture with conventional fly ash can be considered. Estimation of the amount of hydration heat by continuous calorimetric measurements is a useful technique, especially for comparative studies, to select compositions of preferred level of total heat released. The next step of investigation should be registration of the hydration heat according to PN-EN 196-9:2010 (Polski Komitet Normalizacyjny, 2010) standard requirements and classification of the new binders.

TG/DTG curves (Figure 3) show three main mass losses typical for cement pastes: up to temperature about 420 °C – dehydration of hydrates type of C-S-H, C-A-S-H, ettringite etc. (abbreviations used in cement chemistry: C – CaO, S – SiO₂, A – Al₂O₃, H – H₂O), from 420 to 480 °C – decomposition of Ca(OH)₂, above 550 °C – decomposition of carbonates and reduction of Fe₂O₃ and CaSO₄ with carbon (Payá, Monzó, Borrachero, Perris, & Amahjour, 1998; van der Merwe, Strydom, & Potgieter, 1999). In general, similar shapes of the curves, in considered day of hydration, indicate similar qualitative compositions of samples but different quantitative compositions. TG/DTG curves registered at temperature range up to 150 °C on the 1st day of hydration for paste containing 50% of PF and, in lower degree, for paste 50% (PK + PF), indicate presence of gypsum (additional effect on DTG which is not observed for 50% PK and for the reference). It is a result of introduction of CaSO₄ coming from PF. This effect disappears over time confirming that gypsum undergoes chemical reactions. Simultaneously, increase of the mass loss at about 100 °C corresponding to the presence of C-S-H and ettringite-type phases takes place.

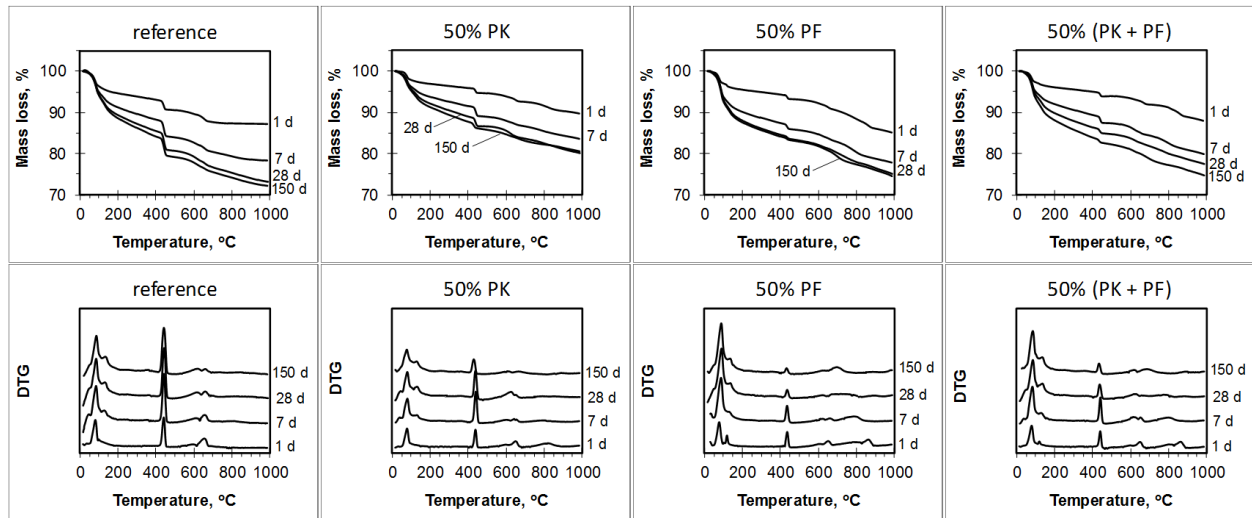


Figure 3. TG and DTG curves for cement-fly ash pastes after different days of hydration

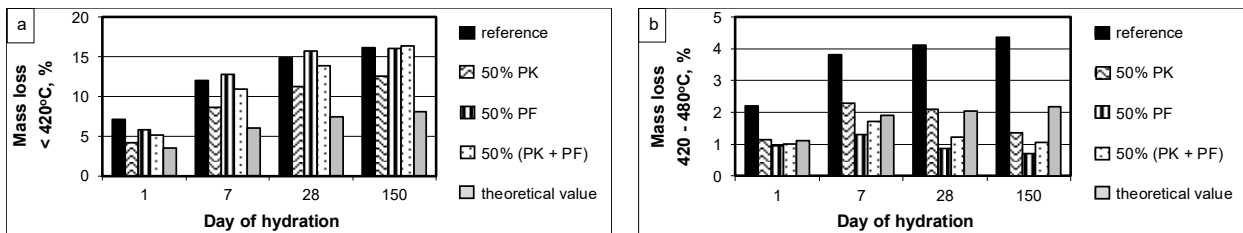


Figure 4. Mass losses at temperature range: up to 420 °C – evaporation of water bound in hydrates (a) and 420–480 °C – release of water during decomposition of Ca(OH)₂ (b)

In general, the mass loss related to dehydration of hydrates increases over time for all pastes while the mass loss corresponding to decomposition of $\text{Ca}(\text{OH})_2$ increases only for the reference (Figure 4). Paste containing 50% of PK exhibits the lowest amounts of water bound in hydrates (Figure 4a), however higher than theoretical values calculated as percentage reduction of the result for the reference (assuming that the additive is inactive and does not influence hydration of cement). Specimens containing PF quickly bind water and, on 7th day of hydration, 50% PF paste reaches values exceeding the result of the reference. Probably, formation of ettringite contributes to this. Figure 4b presents mass losses related to decomposition of $\text{Ca}(\text{OH})_2$ (a value proportional to the amount of $\text{Ca}(\text{OH})_2$ in the sample). It is evident that at early hydration days this mass loss for fly ash-containing pastes is close to theoretical value and can even exceed it (for 50% PK). This is a result of initially low pozzolanic activity of all fly ashes and acceleration of cement hydration by their fine grains (nucleation action). Sample containing 50% of PF shows the lowest amount of $\text{Ca}(\text{OH})_2$ starting from 7th day. It confirms that this kind of fly ash binds $\text{Ca}(\text{OH})_2$ faster and C-S-H, C-A-S-H and calcium sulfoaluminates are formed. After 28 days of hydration, 50% PF-containing paste shows small increase of bound water and also small reduction of $\text{Ca}(\text{OH})_2$. It may indicate that PF in high volume fly ash paste develops its activity mainly during the first month after addition of water. After this period, hydration processes go in moderate way. Probably, ettringite is mainly formed in pores of the structure in the time when the composite is not fully hardened and, for this reason, its formation does not worsen later strength. This conclusion needs to be confirmed in further detailed research. However, it was shown previously (Kubissa et al., 2013) that cement-50% PF concrete can achieve 90-day compressive strength almost 50% greater in relation to 28-day results. Mixture of PK + PF develops its activity slower than PF but faster than PK. After 150 days of hydration, thermal analysis results for 50% (PK + PF) are similar to those for 50% PF.

Relationship observed above related to the shapes of TG/DTG curves for pastes containing different fly ashes as well as mass losses were also confirmed in investigation of cement paste separated from cement concrete after 28th day of hardening in water (Figure 5). Linear relationship between the amount of bound water and 28-day compressive strength (according to data presented in (Kubissa et al., 2013) was shown (Figure 5b). The mass loss resulting from presence of $\text{Ca}(\text{OH})_2$ in the samples is the lowest for 50% PF composition. For 50% (PK + PF) it shows an intermediate value between the result registered for 50% PF and this one for 50% PK, similarly as bound water and compressive strength values.

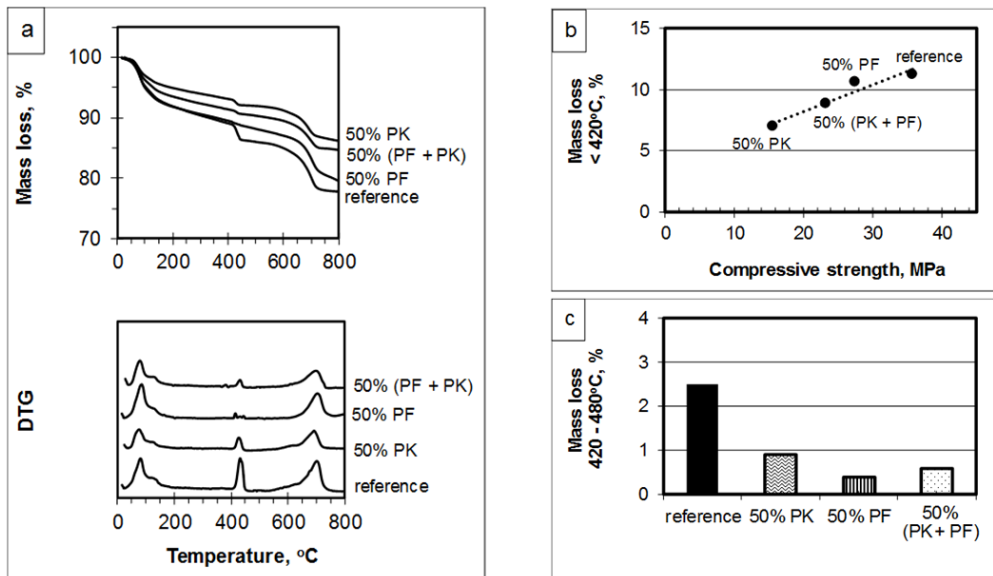


Figure 5. TG and DTG curves for cement paste separated from 28-days old concrete (a), relationship between mass loss up to 420 °C (evaporation of water bound in hydrates) and compressive strength for the concretes (b) and mass loss at 420–480 °C (c)

IR spectra (Figure 6) collected for cement-fly ash pastes after 150 days of hydration confirm presence of water (broad band at 3300–3700 cm^{-1} and middle intensity band at about 1650 cm^{-1}), carbonates (the band at 1350–1600 cm^{-1}), C-S-H phase (the intense band with the extreme at about 960 cm^{-1}). The clear presence of $\text{Ca}(\text{OH})_2$ (sharp band at 3640 cm^{-1}) is visible only for the reference paste. The higher amount of sulfates in 50% PF sample is indicated by the band at about 1090 cm^{-1} .

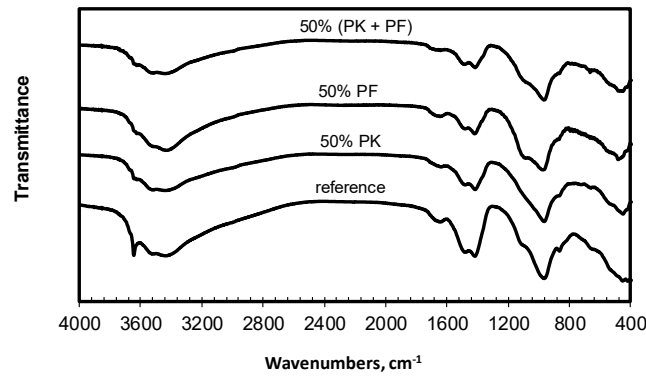


Figure 6. IR spectra for fly ash-cement pastes after 150 days of hydration

Research of cement-fly ash mortar

Investigation of cement mortar containing 50% of fly ash shows that such high amount of cement substitute causes very low early compressive strength (on 2nd day of curing, Figure 7). It confirms poor activity of fly ashes at early days and its development between 2nd and 28th day. Comparing with the 2-days results, compressive strength registered on 28th day was higher four, above seven and above five times for samples containing PK, PF and PK + PF, respectively. Further development of compressive strength and its higher values registered on 90th day shows reactivity of cement-fly ash systems. Composition containing 50% PF shows 90-day compressive strength close to value obtained for 50% PK, while composition containing PK + PF has the highest compressive strength both after 28th and 90th day of hardening. For comparison, previous investigation shows 90-days compressive strength of cement-50% PF concrete above 40 MPa and it was higher than results for 50% PK and 50% of mix PK + PF, close to result for Portland CEM II cement concrete (Kubissa et al., 2013). Because in the case of cement-50% PF mortar, water to binder ratio was higher than for other compositions, it can be concluded that increase of amount of water improves workability of the mixture but, similarly as in the case of typical cement concrete, it results in higher porosity of hardened composite. It is confirmed by higher water absorptivity and water absorption coefficient (Figure 7b) for specimen containing PF. Thus, mixing of highly porous PF and PK of spherical grains is better solution for composites containing high amount of fly ash. It improves workability of the mixture and provides improvement in compressive strength and sealing the structure.

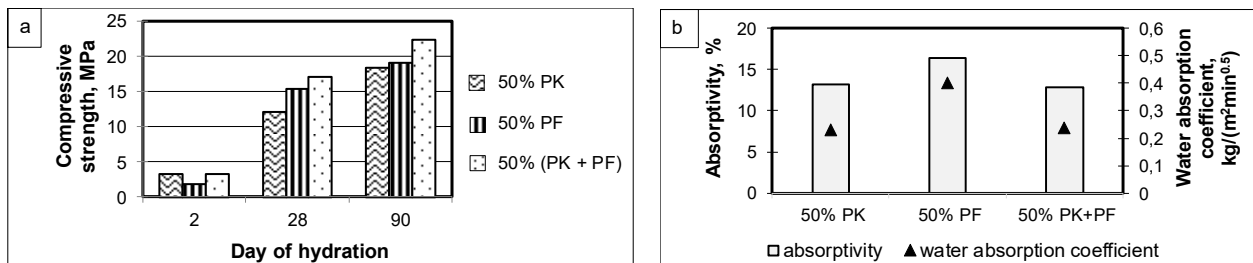


Figure 7. Compressive strength of cement-fly ash mortars after different curing time (a) and water absorption parameters after 60th day (b)

Conclusions

Fly ash from fluidized combustion of hard coal shows a little self-cementing properties and can be considered as component of high volume fly ash concrete. In this work, using 50% of this kind of fly ash (or its mixture with conventional fly ash) as cement substitute was proposed. Several conclusions can be drawn basing on results of calorimetric, TG/DTG, IR as well as compressive strength and water absorption investigations.

1. It was confirmed that fluidized fly ash exhibits higher pozzolanic activity than conventional one. This was evident in higher compressive strength of cement mortar containing 25% of fly ash cement substitution as well as faster and greater reduction of $\text{Ca}(\text{OH})_2$ in 50% fly ash-cement paste. The amount of water bound in hydrates was also higher. The class of Portland cement used influences the rate of development of compressive strength of cement mortar containing fluidized fly ash.
2. Replacement of 50% of cement by fluidized fly ash results in decrease of total heat released during 48h of hydration compared to reference cement paste without cement substitution. This reduction amounts to about 10–20% during the first 3 hours and about 40% after 48 hours. After 48 h, the amount of cumulative heat re-

leased in the case of cement paste with fluidized fly ash is only of about 13% higher compared to the result of sample containing the same amount of conventional fly ash. Thus, such compositions containing fluidized fly ash can be considered as low-heat release binder to be used in massive concrete structures. Standard requirements for such binders and development of heat release in big mass composite should be confirmed in future research.

3. By means of thermal analysis and IR spectroscopy several components of hardened 50% fluidized fly ash-cement paste were identified. There are: gypsum (at the early hydration days), sulfoaluminates type of ettringite, C-S-H and C-A-S-H phases, $\text{Ca}(\text{OH})_2$, carbonates. Their content changes depending on the time of hydration.
4. Higher reactivity of fluidized fly ash (compared to conventional one) and content of calcium and sulfate compounds cause higher compressive strength of cement mortar and concrete (50% of cement substitution) compared to composite containing the same amount of conventional fly ash as cement replacement. It is visible after longer hydration period.
5. Fly ash chemical composition as well as workability of 50% fly ash-cement binder can be modified using mixture of fluidized and conventional fly ash. Such mixture develops its activity more moderately than binder containing 50% of fluidized fly ash but faster than the one with 50% of conventional fly ash. In later periods of hydration, mix of these two fly ashes and cement reaches the amount of bound water similar to the reference sample and the amount of $\text{Ca}(\text{OH})_2$ is significantly reduced. Composites containing mix of fly ashes can achieve compressive strength even higher than those registered for sample containing fluidized fly ash.
6. This paper shows that fluidized fly ash (used in the research) or its mixture with conventional fly ash can be considered as binder components in cement mortar or concrete. However, fluidized fly ashes coming from different sources can differ significantly in their chemical compositions, including various amounts of CaSO_4 and free CaO. In the case of high content of such components, heat released by hydrating mixture can be higher. Moreover creation of delayed expansive phases should be excluded. For this reason, it is necessary to experimentally determine range of changes in physicochemical properties of fluidized ash to make its use in high volume fly ash concrete possible.

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