

Hydration study of mechanically activated mixtures of Portland cement and fly ash

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(Received 19 May, revised 19 September 2006)

Abstract: Fly ash (FA) can be used in cement mixtures with certain limitations. The problem of the mentioned mixtures lies in the insufficient activity of the particles of FA in the reactions which are important for the establishment of the mechanical characteristics of cement. This is particularly true for the hydration reactions. As a result of this, cement pastes formed by mixing ash and clinker have worse characteristics compared to those of pure Portland cement (PC), especially in the early period of setting. As is well known, FA can be a good solution for the neutralization of the negative effects generated due to the creation of free $\text{Ca}(\text{OH})_2$ during the hydration of PC, provided that the problems with the low activity of FA are overcome. For the experiments in this study, a mixture of Portland cement and fly ash was used, the content of ash in the mixture being 30 % and 50 %. Mechanical activation was performed in a vibrating ring mill. The goal of this study was to demonstrate, through experimental results, that during the mechanical activation of a PC and FA mixture, the components in the mixture which mostly affect the direction, rate and range of hydration reactions occurring in the mixture had been activated. The values of the compressive strength of the activated and non-activated mixtures and the changes of their specific surface area proved that during the grinding process, the mixture PC+FA had been mechanically activated. The highest increase of compressive strength was achieved in the early period of setting, which indicates an improvement in the early hydration of the mixture. XRD, DTA and TG analyses showed that the alite (C_3S) and belite (C_2S) from the PC and a part of the fly ash were activated.

Keywords: fly ash, mechanical activation, activity, cement.

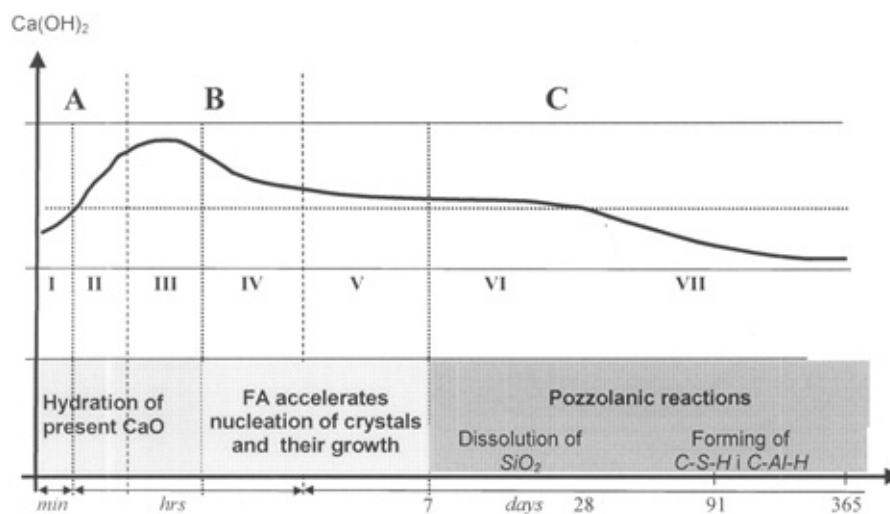
INTRODUCTION

The identification of a universal model for the hydration of Portland cement and fly ash mixtures requires the study of the mechanisms of the hydration of Portland cement and fly ash, as well as their interaction during the process.

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Hydration of PC consists of a series of simultaneous chemical reactions related to the hydration of the individual materials constituting PC. Very often, for the purpose of presenting a model for the process of Portland cement hydration, the reaction of alite (C_3S) and water is used, *i.e.*, alite hydration.¹

On the basis of the simplified model of alite hydration² and the principles of the progress of pozzolanic³ reactions, the process of PC+FA hydration is presented in Fig. 1 as a multiphase process, where an: early, medium and late period of



Early period

- I* preinduction- hydration of portland cement and creation of C-S-H, C-AI-H, and $Ca(OH)_2$ products
II Induction- stagnancy period

Medium period

- III* acceleration phase
IV nucleation phase

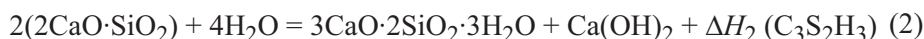
Late period

- V* crystal growth
VI dissolution of amorphous SiO_2
VII pozzolanic reactions

Fig. 1. Physical model of the hydration of PC+FA mixture.

hydration can be differentiated. A parameter of the progress of the hydration reaction of a PC and FA mixture is the change of the concentration of $Ca(OH)_2$. In the earliest period, after several minutes, the first hydration of alite and belite (C_2S) from Portland cement with the release of hydration heat occurs:²

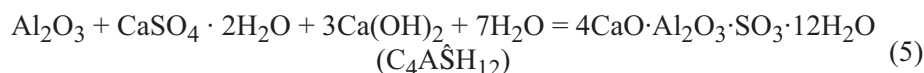
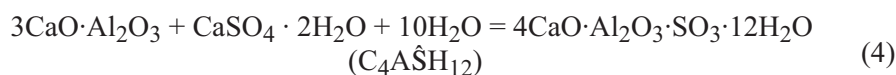
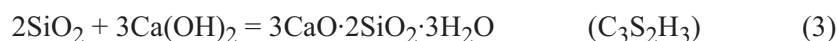




As a product of the cement hydration reaction $\text{Ca}(\text{OH})_2$ is formed. The higher presence (concentration) of $\text{Ca}(\text{OH})_2$ in cement paste causes an instability of concrete exposed to the action of soft water and acidic solutions, as well as to the action of high temperatures. After the early period of setting, there is a stagnation period, during which the emission of hydration heat is relatively low. The physical changes in the cement paste during this period can be seen in its gradual hardening. After the period of stagnacy, in the medium phase, the reaction accelerates and a new hydration of the cement occurs. The maximum is reached 9–10 h after the beginning of the reaction. Due to the increase of the OH^- ion concentration, as a result of the generation of $\text{Ca}(\text{OH})_2$, the environment becomes progressively alkaline. Fly ash which is negligibly activated in this early period, acts as an inert material which accelerates the setting of the cement paste by acting as a nucleus for the sedimentation of C–S–H, C–Al–H and $\text{Ca}(\text{OH})_2$, which appear after cement hydration.^{3,4}

In the nucleation phase, the final formation of the structure of the cement paste occurs.

In the late period, the cement paste hardens, while the pH value increases in the pores of the cement paste, which affects the dissolution of the molecules of amorphous SiO_2 .⁵ $\text{Ca}(\text{OH})_2$, created by the hydrolysis of alite and belite, behaves as an activator of the latent hydraulic properties of fly ash and reacts, in so-called pozzolanic reactions, with the active part of the fly ash (SiO_2 , Al_2O_3). In this way, the negative influence on the quality of cement can be reduced or entirely neutralized:



As the pozzolanic reactions progress, the fly ash particles lose their spherical form and become increasingly coated by a layer of the product, and after a period of 6 months they can no longer be identified.⁶ During the hydration of cement with added FA, the same hydration products appear as during the hydration of Portland cement.

There are data⁷ supporting the fact that many cements with added fly ash have better mechanical properties than PC itself. The increased resistance to corrosion of cements with added FA is accounted for by the lower content of $\text{Ca}(\text{OH})_2$ in the cement paste, and thus in the concrete. For the same reasons, Portland cement with added FA behaves better when exposed to high temperatures.⁸

During the hydration of PC and FA mixtures, certain problem arise:

* In the stagnacy phase and in the late hydration period, there is the deceleration of the hydration of alite.⁹

* Insufficient early hydration activity of belite.¹⁰

* Insufficient hydration activity of fly ash. Pozzolanic reactions are, in comparison to the hydration reaction of Portland cement, much slower and they occur to an observable extent only after one or two weeks.¹¹

There has been a series of attempts to increase the hydration activity of the individual components of cement and fly ash, from the temperature^{11–13} and synthesis method,¹⁴ to addition of certain activators.¹⁵ Only a small number of papers deal with the influence of grinding on the hydration activity of the components of cement, and there are even less papers on fly ash.⁹ For this reason, this paper demonstrates how and to what extent mechanical activation of PC+ FA mixtures affects the hydration properties of the PC + FA mixtures and their mechanical properties.

EXPERIMENTAL

For the tests of the action of mechanical activation on mixtures of Portland cement and fly ash, gypsum from the Gruža (Serbia) bed, fly ash from Thermal Power Plant Kragujevac (Serbia) and Portland cement cliniker which is a standard product of the Cement factory of Novi Popovac (Serbia) were chosen. Portland cement was produced by milling the Portland cement clinker and gypsum to a particle 95 % < 100 µm. Mixture samples with 30% and 50% of fly ash in the mixture with Portland cement were named PC30FA and PC50FA, respectively. Their chemical composition and the pozzolanic activity of fly ash are presented in Table I.

TABLE I. Chemical composition of the employed raw materials

Compounds	Portland cement	Fly ash Kragujevac
SiO ₂	22.54	40.40
Al ₂ O ₃	6.11	16.50
(Fe ₂ O ₃) _u	2.26	5.69
CaO	65.27	27.70
MgO	2.93	1.93
Na ₂ O	0.32	1.17
K ₂ O	0.38	1.84
SO ₃	=	2.65
Pozzolanic activity		9.5

Mechanical activation of PC and the cement mixture (PC30FA i PC50FA) was performed in a vibrating ring elements mill (type MN 954/3). The activated components and mixtures were designated with the letter A: APC, APC30FA, APC50FA. The optimal time of activation was determined by monitoring the change of the specific surface in the course of grinding of PC, FA and the cement mixtures in the period from 0 to 60 min. A time of 10 minutes was chosen.¹⁶ From the non-activated and mechanically activated cement mixtures, standard prisms for compressive and bending strength tests were made after 2, 7 and 28 d of setting time, then for water consumption and binding time according to the standard testing methods (EN 197-2). Table II presents the characteristics of the activated and non-activated samples.

The samples analyzed on a Philips X-ray diffractometer, model PW-1710, with a curved graphite monochromator and a scintillation counter. The thermal changes of the samples were determined by differential thermal analysis (DTA) and thermogravimetry (TG) using a Netsch STA 409EP instrument. The samples were thermally treated in the temperature range from 20 to 1000 °C.

RESULTS AND DISCUSSION

As was previously stated, the problems during the hydration process of mixtures of PC and FA are related to the deceleration of alite hydration, the insufficient belite activity in the early hardening period and the slow rates of pozzolanic reactions. The reason for the deceleration of the hydration reaction of alite in the stagnacy phase and the late period of hydration is the generation of a layer of hydration products on the surface of the particles, which does not permit further interior absorption.⁹ Research related to the activity of belite showed that the hydration activity of belite in the first 28 d is very low, almost negligible.¹⁰ The cause of the low activity of fly ash lies in two factors: (1) the surface layer of the glassy phase of the fly ash particles is dense and chemically stable. This layer protects the interior part which is spongy, porous, amorphous and, therefore, with high activity, (2) internal Si–Al glass chains are firm. The chains should be disintegrated in order to allow activity.

TABLE II. Characteristic of the activated and non-activated cement mixtures

Characteristics	APC/PC	APC30FA/PC30FA	APC50FA/PC50FA
Compressive strength/MPa			
2 d	24.2/6.3=3.84	16.3/2.8=5.82	20.9/1.9=11.0
7 d	36.5/15.9=2.30	36.6/7.6=4.82	34.7/6.3=5.51
28 d	44.6/24.2=1.84	52.6/15.7=3.35	51.3/14.7=3.44
Setting time/h			
Start	0.2/4.00	0.2/7.20	0.4/4.45
End	1.0/5.15	1.0/9.30	2.16/8.35
Water consumption/%	30.0/27.00	31.6/36.00	32.0/37.00
Specific surface area, By BLEIN/cm ² g ⁻¹	4635/2427	7535/2978	7852/2780

The increase in the hydration rate of the cement mixture (PC+FA) mechanical activation can be summed up through the following effects:

* Acceleration of alite hydration;

* An increase in the early belite hydration. The research of Zhong *et al.*¹⁰ showed that the hydration rate of belite rapidly increases after mechanical activation. This refers particularly to the early hardening period. The research also demonstrated that particle size reduction lasting longer than optimal leads particle enlargement and a reduction in the free surface energy. This confirms that the free surface energy is one of the main factors of the increase of belite hydration. The increased early hydration of belite results in an increase of the pH value due to the creation of a larger number of moles of Ca(OH)₂.

* An increase in the fly ash activity. The increased concentration of $(\text{OH})^-$ ions due to the increased amount of hydration of alite and belite results in the destruction of the outer layer which prevents an early onset of the pozzolanic reactions.¹⁰ The Si–Al chains inside the particles of FA are broken and a large number of active groups participating in the pozzolanic reactions is formed. (Equations (3–6)) which is presented in Fig. 2.

The structure of the cement paste setting can be connected with the number of links between the cement particles. (Fig. 3a).⁹

As has already been stated, in the nucleation period, C–S–H, C–Al–H and $\text{Ca}(\text{OH})_2$ are grouped around the fly ash particles, which act as crystallization centers (Fig. 3b).⁹

As for the activated material, due to the increase of the free surface energy, an increased number of links between the activated Portland cement (APC) particles. The activated particles of fly ash (AFA), through the formed active groups, facilitate the establishment of a high number of links with the Portland cement particles (Fig. 3c).⁹ Such a structure results in an increase of the mechanical characteristics of the mixture.

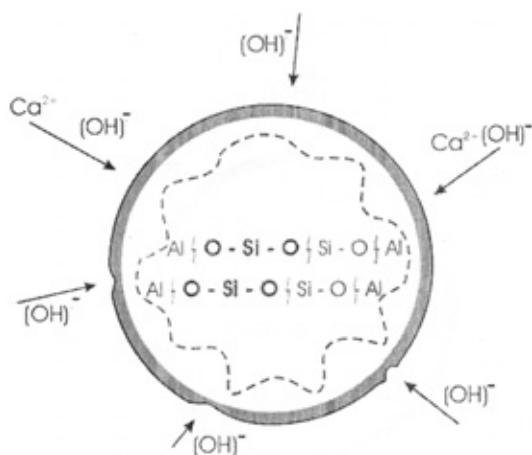


Fig. 2. Mechanism of the activation of fly ash particles.

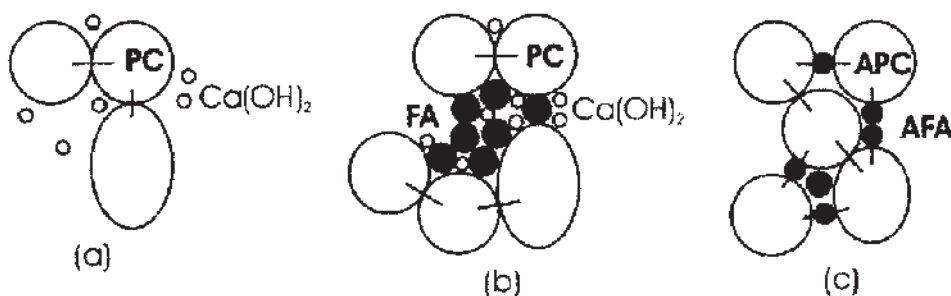


Fig. 3. Mechanism of the hydration of non-activated and activated mixtures of PC+FA.

On the basis of the experimental results presented in Table II, it may be observed that the compressive strength of the cement mixtures decreases with increasing fly ash content. The compressive strength of the non-activated mixtures

was always lower than the compressive strength of the pure Portland cement regardless of the mixture composition.

Since fly ash has a lower reactivity than Portland cement, its presence in the mixture negatively affects the early compressive strength.

To confirm the action of mechanical activation on the hydration capacity of the mixture of PC and FA, the compressive strength of the activated and non-activated mixtures with 30 % and 50 % of fly ash content were observed, as well as the compressive strength of the activate and non-activated Portland cement. In Fig. 4 it can be seen that mechanical activation of PC, PC30FA and PC50FA, resulted in an improvement of the hydration process because the compressive strength in all three cases was significantly (up to 11 times in the earliest period).

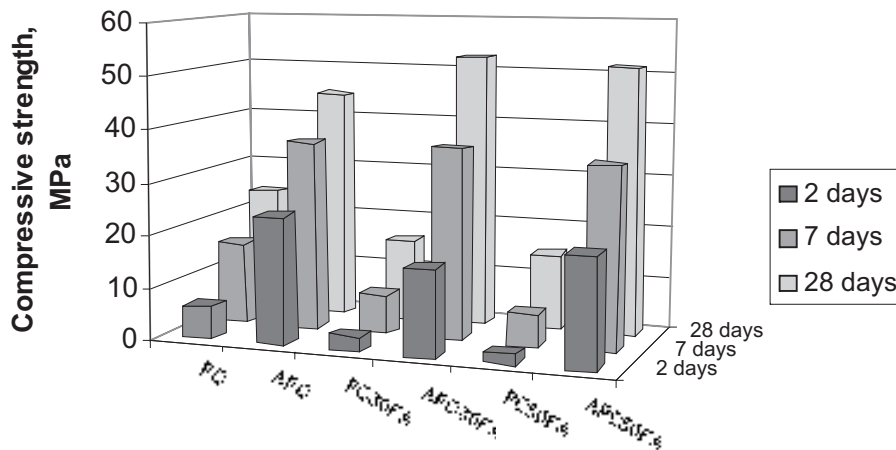


Fig. 4. Compressive strength of the activated and non-activated samples.

Mechanical activation leads to an increase of the specific surface area (Table II) *i.e.*, to an increase of the active surface which can participate in the hydration reactions during the binding and hardening processes. However, apart from the increase of the specific surface area during mechanical activation, a structural change in the surface occurs. These changes lead to an increase of the free surface energy, *i.e.*, to increases in the reactivity of the fly ash and clinker particles in the hydration reactions and consequently in the pozzolanic reactions. The kinetics of these reactions can be significantly changed after mechanical activation in the sense of their acceleration, which further results in significant increases in the compressive strength achieved after 7 and 28 d of setting.

Comparing the compressive strength of the activated and non-activated Portland cement it may be observed that mechanical activation affects an improvement in the compressive strength characteristics, by several times (Table II). In the earliest period of setting, this ratio is almost 4 ($24.2/6.3 = 3.84$), and with passage of the setting time it drops to $36.5/15.9 = 2.3$, that is, $44.6/24.2 = 1.84$. It is obvious that this increase was not caused only by the increase of the specific surface

area. The increase in the PC activity was caused either due to an acceleration of alite hydration, or to an increase in the early belite hydration, or both. With the cement mixtures, the influence of mechanical activation was even higher (APC30FA, with a setting time: $16.3/2.8=5.82$; $36.6/7.6=4.82$; $52.6/15.7=3.35$; APC50FA: $20.9/1.9=11.00$; $34.7/6.3=5.51$; $51.3/14.7=3.49$), which indicates a significant increase of the fly ash activity. It is indicative that the increase is the highest in the earliest period of setting, for the mixture with the highest content of FA (50 % of FA). The pozzolanic reactions were accelerated.

The thesis of the increased activity of the cement mixtures after mechanical activation was confirmed by the increased rate of binding of the cement mixtures, *i.e.*, a decrease of the start and termination time of the setting of the cement mixtures (Table II).

Comparing the start and termination setting time of the activated and non-activated mixtures and activated and non-activated Portland cement, it can be observed that the shortening of the starting and termination time of setting is the most prominent with the mixtures with 30 % of FA.

XRD, DTA and TGA study of hydration

XRD Analysis. A relative indicator of changes at the level of the crystal lattice of the minerals of PC and cement mixtures can be the change in the intensity of the diffraction maxima. Diffractograms of the non-activated and activated samples of Portland cement as well as of the cement mixtures with different mass contents of fly ash (30 % and 50 %), are presented in Figs. 5, 6 and 7.

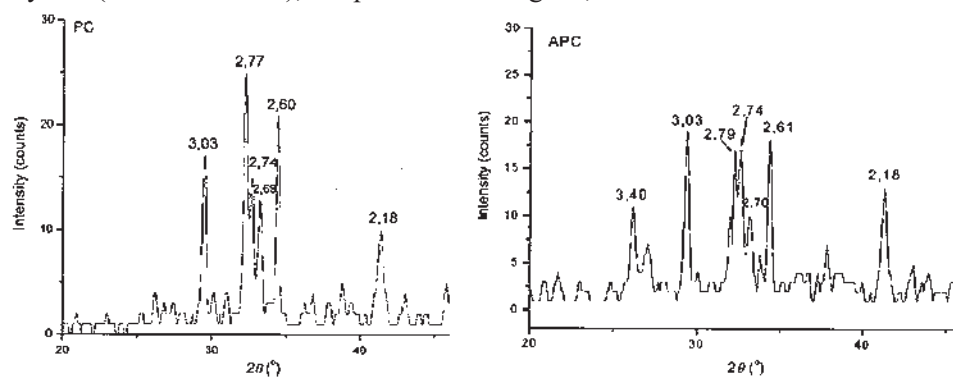


Fig. 5. X-Ray diffractograms of (a) PC and (b) APC samples powders.

From 5a and 5b, it can be observed that the maximum of alite was reduced, (2.6 Å) in the diffractogram of activated Portland cement. The diffraction maximum of belite did not decrease (2.74 Å). In the cement mixtures where the content of ash was 30 % (Fig. 6), both alite and belite were activated (A 2.60 Å, B 2.74 Å). In this mixture, a peak originating from quartz was identified (3.36 Å). As this peak was not present in the diffractogram of APC the quartz must have originate from

the fly ash. A decrease of this diffraction maximum is evident, which indicates that the mechanical activation of fly ash could be related to the breakage of Si–O–Si chains.

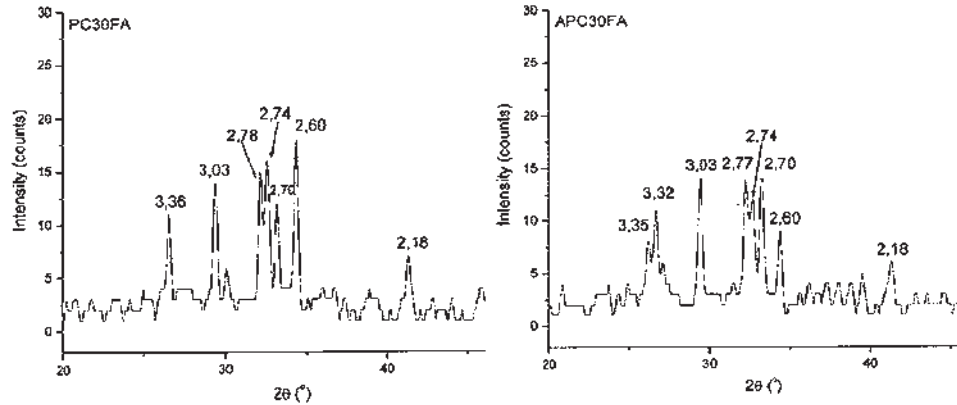


Fig. 6. X-Ray diffractograms of (a) PC30FA and (b) APC30FA samples powders.

In the diffractogram of the mixture with the high content of fly ash (PC50FA), the highest peaks corresponded to quartz (3.36 Å and 4.28 Å). (Figs. 7a and 7b). After mechanical activation, the diffraction maximum was reduced, which indicates the increased reactivity of the fly ash.

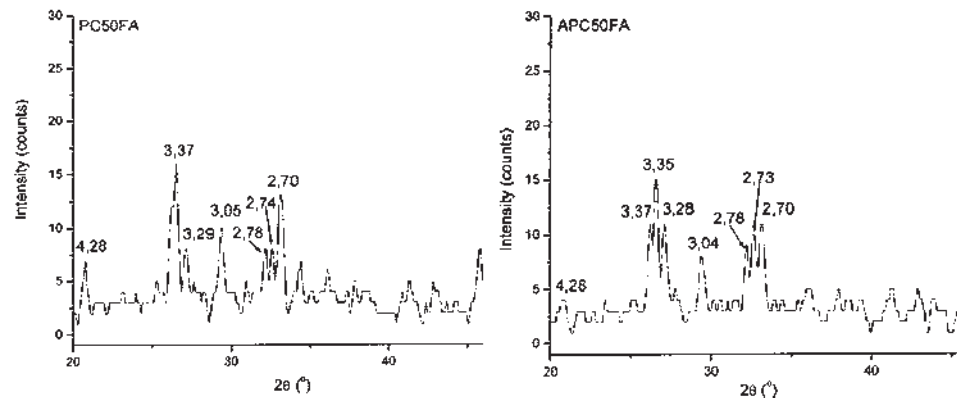


Fig. 7. X-Ray diffractograms of (a) PC50FA and (b) APC50FA samples powders.

The intensities of the diffraction maxima for the observed mineral phases in the treated Portland cement and the cement mixtures before and after mechanical activation, are presented in Table III.

Comparing the values of the diffraction maxima of the basic phases given by $I_0 - I_A / I_0$, it can be concluded that mechanical activation, induced changes at the level of the microstructure of the observed phases in Portland cement and the cement mixtures. Namely, the intensity of diffraction maxima in the majority of cases decreased, most likely at the expense of the width of the diffraction profiles. From the previous statements, it can be concluded that due to mechanical activation of

the treated samples, the accumulation of defects of certain phases was increased, which resulted in an increase of their total reactivity.

TABLE III. Intensities of the diffraction maxima of the basic phases in PC and PC+FA before and after mechanical activation (MA)

<i>d</i> value/Å		PC, APC			PC30FA, APC30FA			PC50FA, APC50FA		
		Intensity			Intensity			Intensity		
		Before MA	After MA	$\frac{I_0 - I_A}{I_0}$	Before MA	After MA	$\frac{I_0 - I_A}{I_0}$	Before MA	After MA	$\frac{I_0 - I_A}{I_0}$
		I_0	I_A	%	I_0	I_A	%	I_0	I_A	%
2.60	C ₃ S	52	36	31	40	20	50	75	49	35
2.74	C ₂ S				16	12	25	95	86	9.5
3.05	C ₃ A							116	93	20
3.36	Quartz			25	18	28	16	11	31	31
4.28							76	48	37	37

DTA Analysis. On the basis of DTA and TG analyses, changes in the properties of the cement mixtures which occurred due to their mechanical activation can be interpreted, and which cannot be perceived from X-ray analysis. The increase of the reactivity of the activated mixtures can be proved by the decreasing melting temperature of certain minerals and the temperatures of characteristic reactions. The energy received during mechanical activation leads to changes in the crystal structure, which causes a reduction of the reaction enthalpy and, therefore, to a reduction of the decomposition temperature.

The DTA curves of PC and the cement mixtures with a mass content of fly ash of 30 % and 50 %, before and after mechanical activation are presented in Figs. 8a and 8b, respectively. Comparing the DTA of the samples before and after mechanical activation, several differences can be seen. At the temperature of *ca.* 140 °C there is an endothermic effect related to the loss of water from the gypsum. In Fig. 8b, it can be seen that the temperature of water loss from gypsum from the mechanically activated sample of PC50FA had decreased from 141 to 126 °C, which indicates an increased reactivity of the sample. No changes were observed for PC and PC30FA.

The endothermic effect at 750 °C relates to the decarbonization of CaCO₃ which is present in gypsum and ash. The decrease of decomposition temperature from 769 °C for PC30FA to 708 °C for APC30FA as well as the decrease from 765 °C for PC50FA to 710 °C for APC50LP indicates that cement mixtures had increased reactivity due to mechanical activation, hence the CaCO₃ decomposition process took place at lower temperatures. The exothermic peak which relates to the combustion of the organic components in the ash moved in the activated mixture APC30FA from 464 °C to 469 °C, and in APC50FA to 459 from 465 °C in the non-activated mixture.

On the basis of the results of the DTA analysis of the cement mixtures, it can be said that the properties of the gypsum and fly ash were changed by mechanical activation.

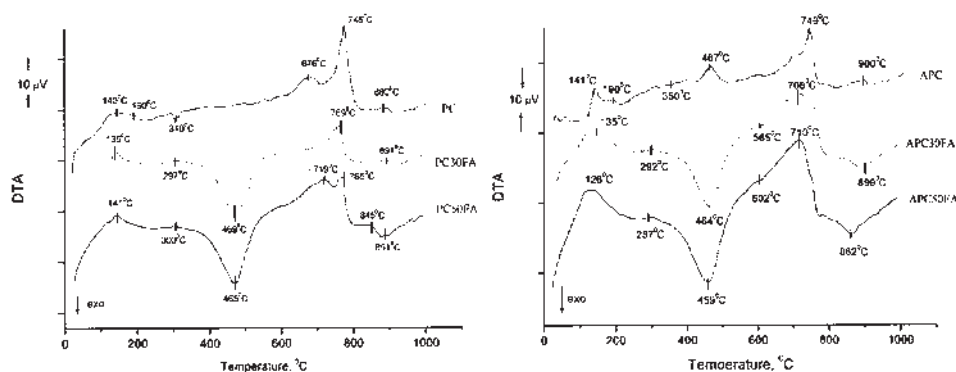


Fig. 8. DTA Analysis of samples of PC and cement mixtures of PC with 30% and 50% content of fly ash before (a) and after (b) mechanical activation.

TG Analysis results. The results of TG analysis of the tested samples are presented in Table IV. The loss of mass in the 0–100 °C interval relates to loss of humidity from the sample. The loss of mass in the 110–220 °C interval refers to loss of water from gypsum. It can be seen from Table IV that there is an increased loss of mass from APC50FA from 1.47 to 3.66 % in the temperature range 110–220 °C. In the 220–550 °C interval there is an increased loss of mass for mixture with 30 % FA from 0.65 % for non-activated mixtures to 2.51 % for activated mixtures, and for PC50FA from 2.86 % for non-activated mixtures to 3.50 % for activated ones, which mainly refers to loss of mass due to the combustion of organic compounds in the ash. An increased loss of mass was observed in the 550–800 °C interval, which refers to decarbonisation of CaCO_3 from the ash. In the case of the PC30FA mixture, the value increased from 2.95 to 8.97 %, and of PC50FA from 9.18 % to 11.26 %. Comparing the difference in the loss of mass for the whole temperature interval from 0 to 1000 °C before and after mechanical activation of the samples ($\text{APC} \times \text{FA} - \text{PC} \times \text{FA}$), it can be seen that the effect decreased with increasing mass content of ash in the mixture (Table IV). This can indicate that the mechanical activation had a greater impact on the cement part of the mixture in relation to the fly ash.

TABLE IV. Mass loss of cement mixture PC+FA, %

	0–110 °C	110–220 °C	220–380 °C	380–550 °C	550–800 °C	800–1000 °C	0–1000 °C	$\text{APC} \times \text{FA} - \text{PC} \times \text{FA}$
PC30FA	0.57	1.06	0.16	0.49	2.95	+0.25	4.98	
PC50FA	1.15	1.47	0.98	1.88	9.18	+0.08	14.58	
APC30FA	1.31	1.86	0.98	1.53	8.97	0.0	14.65	9.67
APC50FA	1.42	3.06	0.98	2.52	11.26	0.0	19.24	4.66

From the TG analysis it can be seen that mass loss in the cement mixtures increased after the mechanical activation, which indicates increased reactivity.

The increased reactivity of the cement mixture which was determined by DTA

and TG analyses influence the course of the hydration and concrete setting processes. Namely, apart from the basic hydration reactions which occur in this case, there are also secondary reactions, pozzolanic reactions, with the participation of the fly ash. Since it was established that fly ash was also activated, the pozzolanic reactions will proceed more efficiently, leading to improved final qualities of the cement pastes, which is confirmed by the result of the testing of the mechanical characteristics of the pastes.

CONCLUSIONS

During the process of mechanical activation of PC and FA mixtures, alite, belite and quartz in the cement mixtures were activated. These components in the tested samples mostly affected the direction, rate and range of the hydration reaction process.

* The mechanical activation of Portland cement and mixtures of Portland cement with fly ash significantly influenced the increase of strength of all the tested samples. In the earliest period of setting, the strength increase of PC was almost 4 (3.84), while it is even higher with the mixtures. Hence, for APC30FA, it was 5.82 and for APC50FA it was 11. Together with the setting time, the increase of the compressive strength resulting from the mechanical activation decreased, which indicates that the increase in the activity was affected by the acceleration of the alite hydration and the increase of early hydration of belite. That the pozzolanic reactions were also accelerated is indicated by the higher increase of strength for mixtures with higher contents of ash. Also, the starting and termination times of concrete binding were reduced. Namely, for APC, the start of binding was reduced from 4 to 0.2 h and the end from 5.15 to 1 h. With the mixtures, these reductions were even more pronounced.

* XRD Analysis confirmed that due to the mechanical activation, changes at the structural level of the samples of PC+FA occurred, primarily of alite and belite from the Portland element, and quartz from the fly ash. Hence, for example for PC with 50 % of fly ash, the intensity of the diffraction maximum for alite was reduced by 35 % for belite by 9.5 % and for quartz by 37 %.

* In the DTA analysis of activated and non-activated samples of PC and mixtures of PC+FA, changes of certain peaks were noticed. For example, for the mixture of PC with 50 % of fly ash, the peak at 765 °C, which refers to the decarbonization of CaCO₃ appeared at 710 °C which can indicate an increase of the reactivity of the fly ash and the gypsum from the Portland cement.

* TG Analysis of the activated and non-activated samples of PC and PC+FA confirmed the increase of the total mass loss of the activated samples, which indicates the increased reactivity of those mixtures which had been mechanically activated.

The mechanical activation of PC+FA mixtures is an effective way of increasing their hydration characteristics and increasing the early compressive strength.

The increased reactivity of the cement mixtures after mechanical activation, which was confirmed by XRD, DTA and TG analyses, affects the course of the hydration and setting processes of cement pastes. Namely, apart from the basic reactions of alite and belite which are accelerated, the pozzolanic reactions are also accelerated and become more efficient. Thus, the increased reactivity of the active portion of fly ash enables the application of high concentrations of fly ash in cement mixtures (up to 50 %).

Acknowledgements: This paper is the result of the project No. 6706 which was financed by the Ministry of Science and Environment of the Republic of Serbia in 2005–2007.

ИЗВОД

МЕХАНИЗАМ ХИДРАТАЦИЈЕ МЕХАНИЧКИ АКТИВИРАНИХ СМЕША
ПОРТЛАНД ЦЕМЕНТА И ЛЕТЕЋЕГ ПЕПЕЛА

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Летећи пепео се може користити у цементним смешама уз одређена ограничења. Проблем наведених смеша огледа се у недовољној активности честица LP у реакцијама које су значајне за успостављање механичких карактеристика цемента. То се посебно односи на реакције хидратације. Услед тога, цементне пасте настале мешањем пепела и Портланд цемента имају лошије карактеристике у односу на чист PC, поготову у ранијем периоду очвршћивања. За експерименте у овом раду употребљена је смеша порланд цемента (PC) и летећег пепела (LP) са учешћем пепела од 30 % и 50 %. Механичка активација изведена је вибро-млину са прстеновима. Циљ овог рада је да се експерименталним резултатима покаже да је током процеса механичке активације смеше PC и LP дошло до активације оних компонената унутар смеше које у највећој мери утичу на правац, брзину и обим одвијања реакција хидратације смеше. Експериментални резултати испитивања чврстоће на притисак активираних и неактивираних смеша и промене њихових специфичних површина показали су да је током млевења дошло до механичке активације смеше PC+LP. Из резултат се види да је највећи пораст чврстоће на притисак постигнут у раном периоду очвршћивања, што говори о побољшаној хидратацији смеше. Резултати XRD, DTA и TG анализе показали су да је дошло до активације алита и белита из PC и дела летећег пепела.

(Примљено 19. маја, ревидирано 19. септембра 2006)

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