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THE TEMPERATURE INFLUENCE ON THE PROPERTIES OF THE FINE – GRAINED SUSPENSION USED IN UNDERGROUND WORKINGS

WPŁYW TEMPERATURY NA WŁAŚCIWOŚCI PŁYNNYCH ZAWIESIN DROBNOZIARNISTYCH STOSOWANYCH W WYROBISKACH PODZIEMNYCH

Underground hard coal exploitation is often done under conditions of spontaneous fire hazard. The primary way to combat this threat is advanced, active or passive fire prevention. An important activity is the isolation of gobs using aqueous suspensions of fly ash as well as mineral binders. Therefore, the fine-grained suspension are often used in conditions of elevated temperature.

The paper presents results of research on the effect of temperature (up to 80°C) on the properties of suspensions in a liquid state, including their rheological parameters and setting time. Suspensions prepared using the ashes from the hard coal combustion in fluidized bed boilers, and with the addition of Portland cement CEM I 42.5.

During the research it was noted that the increased temperature significantly affect the acceleration of solidification processes of suspensions. In the case of rheological properties, the effect of temperature is ambiguous, among others, due to the phenomenon of sedimentation. However, in most cases, particularly for suspensions of higher solids content a marked increase in shear stress and viscosity of the suspensions with increasing temperature were observed .

Keywords: fly ash, suspension, underground fire hazard, rheology

Eksploatacja węgla kamiennego w Polsce, odbywa się często w warunkach zagrożenia pożarami endogenicznymi, których źródła należy upatrywać w naturalnych skłonnościach niektórych węgli do samozapalenia. Obecnie podstawowym sposobem walki z tym zagrożeniem jest zaawansowana, czynna lub bierna profilaktyka pożarowa. Ważnym jej kierunkiem jest izolacja zrobów w celu uniemożliwienia lub ograniczenia wymiany gazowej pomiędzy gruzowiskiem zawałowym a przestrzenią roboczą uzyskiwana za pomocą zawiesin materiałów drobnoziarnistych – najczęściej zawiesin popiołowo-wodnych oraz spoiw mineralnych.

Zawiesiny i spoiwa są niejednokrotnie stosowane w warunkach podwyższonej temperatury wynikającej zarówno z rozpoczęcia procesów samozagrzewania węgla jak i z samej temperatury górotworu.

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Podwyższanie temperatury zawiesin i spoiw może mieć miejsce już na etapie transportu rurociągiem (w fazie płynnej), ale przede wszystkim podczas podawania do zrobów, gdzie temperatura jest niemal zawsze wyższa niż w części roboczej ścian.

W artykule przedstawiono wyniki badań, których celem było określenie w jaki sposób podwyższona temperatura w zakresie do ok. 80°C, wpływa na właściwości zawiesin w stanie płynnym oraz na czas ich wiązania. Do przygotowywania zawiesin wykorzystywano popioły lotne pochodzące ze spalania węgla kamiennego w kotłach fluidalnych a także cement portlandzki CEM I 42,5. Sporządzanie zawiesin oraz badania prowadzono w oparciu o normę PN-G-11011:1998 „Materiały do podsadzki zestalanej i doszczelniania zrobów. Wymagania i badania." Badanie czasu wiązania zawiesin prowadzono zgodnie z wymogami normy PN-EN 196-3+A1:2009 „Metody badania cementu – Część 3: Oznaczanie czasów wiązania i stałości objętości". Próbki zawiesin umieszczano w komorach klimatycznych, w których panowała zadana temperatura (40, 60 i 80°C) oraz wilgotność (100%). Pomiaru czasu wiązania dokonywano w odstępach czasowych od 30' do 6 h.

Badania wpływu temperatury na właściwości reologiczne zawiesin realizowano na stanowisku laboratoryjnym składającym się z reometru RN 4.1 firmy Rheotest (Rys. 1.) wyposażonym w układ grzewczy. Badania prowadzono w dwóch schematach pomiarowych: oznaczonych jako „test standardowy" oraz „test długi". W pierwszym, pomiaru dokonywano podczas zmiany prędkości obrotowej rotora od 0 do 1000 obr/min oraz od 1000 obr/min do 0, co odpowiadało szybkości ścinania w zakresie 0÷435 [1/s]. Każdy etap trwał 60s. W ten sposób uzyskiwano możliwość wykreślenia krzywych płynięcia przy prędkości rosnącej oraz malejącej, co dobrze oddaje cechy tego typu mieszanin transportowanych grawitacyjnie, rurociągami. W schemacie drugim podstawowym celem było określenie wpływu czynnika czasu na właściwości reologiczne zawiesin, w nawiązaniu do etapu transportu zawiesin rurociągami oraz wypływu i penetracji zrobów. W tym celu prowadzono pomiary naprężeń stycznych podczas ruchu obrotowego ze stałą prędkością obrotową 500 obr/min (prędkość ścinania ok. 220 [1/s]), przez okres 10 minut, a następnie z prędkością 100 obr/min (ok. 44 [1/s]) przez 5 minut.

Składy sporządzonych zawiesin oraz podstawowe ich właściwości (gęstość, rozlewność oraz ilość wody nadosadowej) zestawiono w tabeli 1 oraz na rysunkach 2÷3. Sporządzone zawiesiny charakteryzowały się gęstością w zakresie od 1,288 do 1,458 g/cm^3, w zależności od zawartości popiołu w zawiesinie oraz dodatku cementu. Jednym z podstawowych badań kontrolnych konsystencji zawiesin jest określenie ich rozlewności. Zwiększenie ilości popiołu wpływało na zmniejszanie się rozlewności zawiesin, a zastępowanie części popiołu cementem powodowało sytuację odwrotną, wynikającą z różnic w wodożądności tych składników. Z tego powodu wraz ze zwiększaniem się gęstości zawiesin ze wzrostem ilości cementu (o takim samych stosunku części stałych do wody – s/w), ich rozlewność zwiększała się. Np. zawartość cementu w ilości 20% w zawiesinach spowodował wzrost rozlewności w stosunku do zawiesin bez cementu od 35 mm do 90 mm.

Ilość wody nadosadowej zawiesin ulegała zmniejszeniu wraz ze wzrostem udziału popiołu w stosunku do wody. Natomiast obecność cementu powodowała jej. Sezonowanie zawiesinie w temperaturach w zakresie od 40 do 80°C wpływało na ograniczenie ilości wody nadosadowej.

Czas wiązania dla zawiesin o takim samym udziale części stałych do wody wyraźnie zmieniał się w zależności do temperatury, w której sezonowano próbki (Rys. 4÷7). We wszystkich przypadkach wraz ze wzrostem temperatury następowało przyspieszenie początku jak i skrócenie czasu wiązania zawiesin. Zawartość cementu jeszcze bardziej potęgowała to zjawisko ¾ czas wiązania zawiesin w temperaturze 60 czy 80°C skracał się nawet poniżej 10 godzin od sporządzenia zawiesiny.

Wyniki badań właściwości reologicznych omówiono na przykładzie zawiesin sporządzonych na bazie popiołów fluidalnych bez dodatku cementu. Wyniki badań „testów standardowych" przedstawiono na rysunkach 8÷13, w postaci krzywych płynięcia i krzywych lepkości, a dla pomiarów czasowych – w postaci krzywych obrazujących zmianę naprężeń stycznych w czasie, na rysunkach 14÷18.

Podczas ogrzewania zawiesin, szczególnie do temperatury ok. 40°C, a także w krótkim okresie czasu, obserwowano zmniejszanie się naprężeń stycznych, co w przypadku transportu hydraulicznego rurociągami przekładać się może na obniżenie oporów przepływu. W wyższych temperaturach sytuacja była bardziej zróżnicowana i zależna zarówno od pierwotnej konsystencji zawiesin jak i od rodzaju popiołu. Dla ogrzewanych do temperatury 60°C zawiesin o niskiej zawartości części stałych, oraz przy niższych prędkościach obrotowych, obserwowano stopniowe zwiększanie wartości naprężeń stycznych wraz z upływem czasu pomiaru. Rozpatrując uzyskane wyniki w kontekście zastosowania w praktyce, można przyjąć, że niewielkie podniesienie temperatury zawiesin podczas ich transportu nie powinno znacząco wpływać na parametry przepływu rurociągami. Jednak w przypadku transportu zawiesin o dobrych właściwościach wiążących, na długich trasach przez wyrobiska o wyższej temperaturze skał może dochodzić

do przyspieszania procesów hydratacji oraz osadzania się zawiesin na ściankach rurociągów. Zawiesiny deponowane w zrobach, w których panuje wysoka temperatura w krótkim czasie ulegną zestaleniu ograniczając m.in. możliwość przepływu powietrza oraz innych gazów. Jednocześnie jednak lokowanie zawiesin w zrobach, w których panuje wyraźnie wyższa temperatura, np. w przypadku zaawansowanych procesów samozagrzewania, może przyczyniać się do zmniejszania zdolności penetracji gruzowiska oraz powodować szybsze zatykanie wylotu rurociągu.

Słowa kluczowe: popiół lotny, zagrożenie pożarowe, reologia

1. Introduction

The underground coal exploitation in Poland is often connected with the hazard of endogenous fire, which appear due to natural properties of some kinds of coal to self ignition. The deeper the excavation is carried out the bigger the number of longwalls where this process can occur. The fire hazard is constantly present in Polish coal mines (Trenczek, 2008), and the places where it is really intense are the gob (caving) of longwall system. The basic tool to fight with this phenomenon is advanced, passive or active fire prevention. The important thing is to insulate the workings to prevent or limit the gas exchange between gob and the working space, what is also important in the case of methane danger. The ash-water suspension and mineral binders are in Polish coal mines an important means in fire prevention. They allow for external (binders) and internal (suspension) insulation of gob. The main aim of the suspension use is to fill and seal the rubble caving.. The suspensions properties and problems with their application for caving insulation have been widely described in many publications and the monographic works (Dong et al., 2013; Dziurzyński & Pomykała 2006; Frączek 2010; Krause et al., 2009; Lisowski 1997; Mazurkiewicz et al., 1997; Mysłek 2001; Plewa & Sobota 2002; Piotrowski & Łukowicz 2007; Piotrowski et al., 2009, Pomykała 2005; Strumiński 1996). The continual researches, analysis and simulations are conducted for concerning their effectiveness, location and the application process itself (Dziurzyński et al., 2014; Piotrowski 2011). Mineral binders, as well as ash-water suspension as means on fire prevention are mainly used to isolation of caving from the currently excavated places. The effectiveness such actions is proved by many examples (Jarczyk & Kania 2001; Madaj et al., 2012; Zimończyk et al., 2006).

Fine-grained suspension is often used in the presence of increased temperature occurring mainly in abandoned caving but also in current excavations. The increase in suspension temperature may appear during the pipeline transportation and after its placing in the gob. In the first case the main source of the heat can be rock mass or the chemical processes within the suspension, especially when the ash used in it contains products of flue gas desulphurization. The practice in this field reveals that in case of some ashes in the result of long mixing their water suspensions, what may be treated as pipeline flow simulation, even temperatures above 45°C can be obtained (Pomykała, 2006).

The temperature raise in the suspension in liquid phase occurs most often during its application to the caving. The local temperature there is usually higher than in the longwall working space. It may result from the temperature of the rock mass or because the process of the coal self heating has just started. In the first case the temperature may be over 50°C, in the latter may reach significantly higher rates.

The properties of ash-water suspension and mineral binders used in coal mines are of significant difference. It is due to the properties of the materials used, mainly flying ashes obtained from different types of installations. It influences the properties of the suspension and binders made from them. This refers also to fire prevention, as the consistency of the suspension affects the ability to caving penetration, the content of supernatant water, water demand, setting time. One of the factors, which may influence the fine-grain suspension properties, is temperature.

The aim of the researches was to determine the influence of raised temperatures (to 80°C) on the properties of the suspension in the liquid phase and on its setting time.

2. Materials and the research methods

To prepare the tested suspension there have been used flying ashes obtained from the coal combustion in fluidal bed boilers ('fluidal ashes') in two different installations (ashes PK and PJ), and the Portland cement CEM I 42,5. The preparations of suspension and the tests have been conducted according to the Polish standard PN-G-11011:1998 "Materials for hydraulic solidified backfilling and sealing of caving. The requirements and tests." The tests on the suspension setting time have been conducted according to the standard PN-EN 196-3:2009 – Methods of cement testing – Part 3: The determination of setting time and volume stability.

For the testing purposes there have been prepared fine-grained suspension, differ in composition and content of the solid parts. The suspensions have been prepared observing the limits of fluidity 150 to 300 mm. It forced the use of different suspensions recipes (different shares of solids) for each ashes. If the cement has been used it always replaced the referring amount of ash. Having been mixed, the suspension samples were placed in container, with the determined temperature (40, 60, and 80°C) and humidity (100%). The measurements were taken every 30 minutes up to 6h depending on the properties of suspension and the temperature of seasoning.

The tests on the influence of the temperature on the rheological properties of suspensions were conducted at the laboratory stand consisting of viscometer (reomether) RN 4.1 by Rheotest (Fig. 1) containing the system allowing to set the temperature during the tests. The unit consists

Fig. 1. Viscometer Rheotest RN4.1 with the equipment

of annular cylinder filled with water connected with circulation system – water bath, heat exchanger and circulation pomp.

For the tests there were used the cylinder having the diameter of 40 mm and the rotor – diameter 28 mm. Such a set allows to obtain the shear rate 435[1/s] at the rotation speed 1000 rot/min.

The researches were conducted within two measurement schemes: "standard test – ST" and "long test – LT". During the first one the measurement was taken during the changes of rotation speed from 0 to 1000 rot/min (c.a. 435[1/s]) and from 1000 rot/min to 0. Each stage lasted for 60 sec. This let draw the flow curves at the increasing and decreasing speed what well reflects the properties of these types mixtures transported by gravity, in pipelines (Stryczek et al., 2009. Stryczek & Wiśniowski, 2001; Pomykała et al., 2012). The second method aimed to determine the influence of the other factor – time. To set this there were conducted measurements while the rotation movement with the constant speed. To make the test closer to reality the speed was 500rot/min what refers to shear rate c.a. 220 [1/s] lasting for 10 minutes, and later the movement with the speed 100 rot/min (44 [1/s]) lasting for 5 minutes. This scheme was thought to be related to suspension transportation in the pipelines as well as outflow and caving penetration.

3. The course of the measurement:

The "standard test" was conducted as the first one for each of the suspensions at the temperature of 25°C. Next, the suspension in the measuring vessel was changed to eliminate the "memory effect". Than it was placed in the heating cylinder, then two standard tests with the suspension heating were conducted (the results are shown in the charts marked as two values of temperature – initial and the final one). After the each test the temperature was controlled. In the next step the suspension was replaced by a new one and the "long test" started (10 minutes at the speed of 500 rot/min and 5 minutes at the speed of 100 rot/min. This stage was followed by two standard tests (marked as S1) in target temperature. Their aim was to determine the changes the properties of the suspension which had been heated for a few minutes.

The suspension markings used in the charts contains the following information:

- the type of ash (PK or PJ),
- the ratio of solids to water w/s (e.g. 067:1 abbreviated 0.67)
- the content of cement (mass participation in solids originated from replacing the given mass of ash),
- the seasoning temperatures were marked on the charts for rheological properties. If not marked in the other way, the single value marks the measurement taken in the given temperature; two values (e.g. 25-40°C) mean the measurement rheological properties during the suspension heating.

4. The basic properties of suspension

For the research purposes there have been prepared suspensions with the ash PK, of three proportion of solids to water – 0.67:1, 0.77:1 and 0.90: 1 (marked as PK0.67; PK0.77; PK0.9), and also ash PJ for which s/w = 1.0 and 1.11. Content of cement was various from 0 to 20% (example marking: _c20% means 20% cement content of suspension solids). The basic properties of suspensions are showed in table 1 and figures 2 and 3.

TABLE 1

Basic properties of suspension

Suspension symbol	The ratio of solids to water s/w	The proportion of cement in solids [%]	Suspension density [g/cm³]	Fluidity [mm]	The amount of supernatant water [%], at temperature:			
					25°C	40°C	60°C	80°C
PK_0,9_c0%	0,90	0	1,407	155	5,00	6,25	3,75	1,25
PK_0,9_c10%	0,90	10	1,415	170	6,25	6,50	5,00	2,50
PK_0,9_c20%	0,90	20	1,417	190	7,50	7,50	6,25	3,75
PK_0,77_c0%	0,77	0	1,350	200	6,25	5,25	5,25	2,50
PK_0,77_c10%	0,77	10	1,355	220	6,25	6,25	5,55	4,25
PK_0,77_c20%	0,77	20	1,358	250	10,00	8,75	8,00	4,75
PK_0,67_c0%	0,67	0	1,288	230	11,25	11,25	9,75	6,25
PK_0,67_c10%	0,67	10	1,290	280	12,50	12,50	11,25	7,25
PK_0,67_c20%	0,67	20	1,308	320	15,00	13,75	13,25	7,50
PJ_1,11_c0%	1,11	0	1,458	180	8,75	10,00	6,25	5,00
PJ_1,11_c10%	1,11	10	1,446	225	10,00	10,00	7,50	5,25
PJ_1,11_c20%	1,11	20	1,447	240	15,00	15,00	11,25	5,50
PJ_1,0_c0%	1,00	0	1,381	230	13,75	11,25	7,50	6,75
PJ_1,0_c10%	1,00	10	1,413	250	15,00	15,00	8,75	6,75
PJ_1,0_c20%	1,00	20	1,418	270	20,00	17,50	11,25	7,50

The discussed suspensions were made of density from 1.288 to 1.458 g/cm^3. This is connected with the content of ash in relation to water in the suspension and the presence of cement. The differences were noticed in the case of suspension fluidity testing. The increase in the amount of ash PK in the suspension caused the decrease in the flow from 230 mm to 155 mm. Replacing of the part of ash for cement caused the reverse situation resulting from the water demand of solids in suspension. Despite the increase of suspension density according to the increase of the amount of cement on suspension showing the same s/w, their fluidity increased as well. For example, the 20% content of cement in suspensions resulted in the increase of flow in relation to no-cement suspensions by: 35 mm (for PK 0.9); 50 mm (for PK 0.77 and 90 mm (for PK 0.67).

The amount of supernatant water went down according to the increase of ash share in relation to water. However, the presence of cement in the suspension caused the increase in the amount of supernatant water. The biggest amount of supernatant water was observed in the suspension PJ_1,0_c20% at the temperature 25°C what showed the significant exceeding of the PN-G-11011:1998 standard. Seasoning temperature in the range 40°C÷80°C caused the limitation in the amount of supernatant water. This was connected with the speed of water bonding processes within the suspension components, depending on seasoning conditions (Neville, 2000).

5. Suspension and binder setting time in the condition of elevated temperature

The results of the researches on the setting time of suspension samples seasoned in temperatures 40, 60 and 80°C are shown in the figures 4÷6.

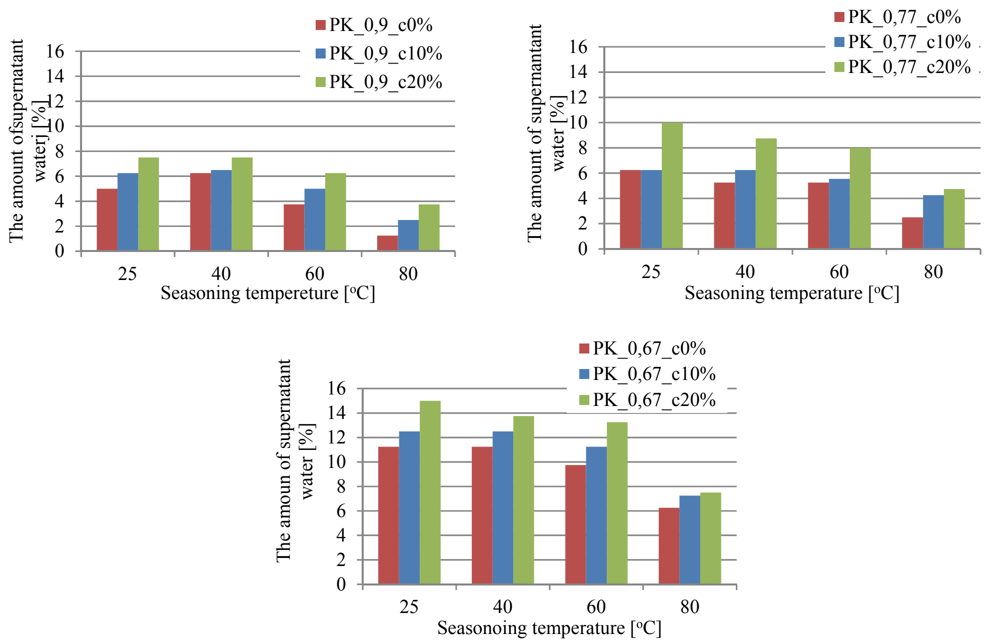


Fig. 2. The amount of supernatant water of suspension of s/w respectively 0.9; 0.77; 0.67, made on the basis of flying ash from fluidal boiler (PK) and Portland cement in the amount of 0%, 10% and 20% of solids

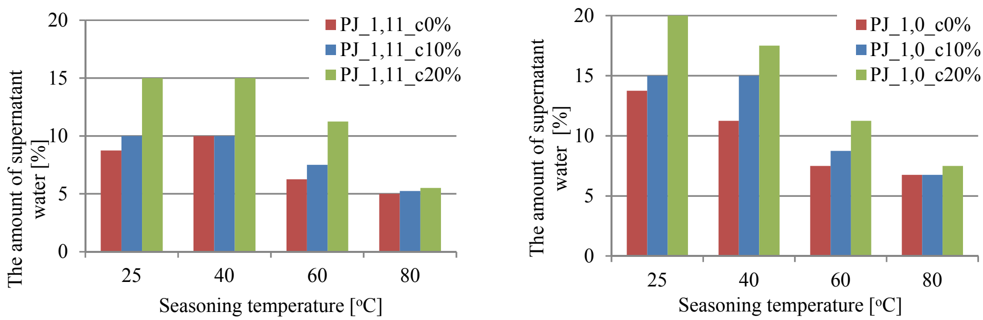
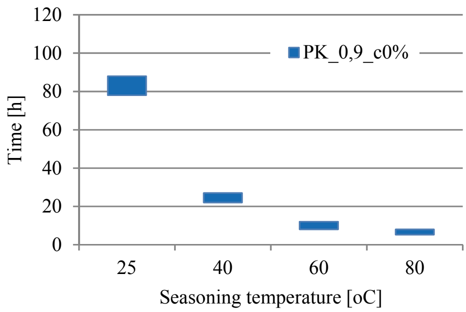
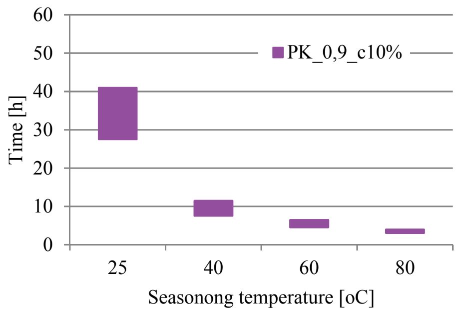


Fig. 3. The amount of supernatant water of suspension of s/w respectively 1.0 and 1.11, made on the basis of flying ash from fluidal boiler (PJ) and Portland cement in the amount of 0%, 10%and 20% of solids

The setting time for the suspension of the same s/w changed significantly according to the seasoning temperature. In all cases, along with the temperature increase the setting started faster and the setting time was shortened. The presence of cement in the suspension even make this phenomenon more intense, causing that the setting time at temperatures 60°C or 80°C lasted less than 10 hours. This time shortening is connected with the faster occurrence of hydration products, what was described also in other publications (Fattuhi, 1997; Kurdowski, 1991; Lothenbach et al., 2007; Wenhua et al., 2012).





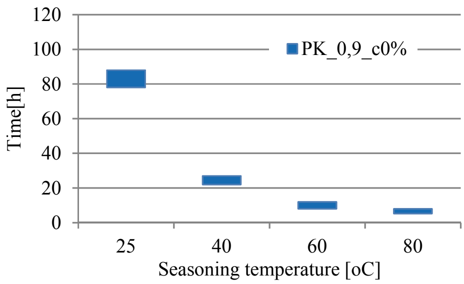


Fig. 4. The setting time of suspension of s/w = 0.9 :1 based on fluidal flying ash PK and Portland cement in amount of 0, 10 and 20% of solids

6. The rheological properties

The results on rheological properties researches have been described with the example of suspension made with fluidal bed ash PK and PJ without cement. The results of "standard tests" are shown as flow and viscosity curves, and for the timing measurements as the curves showing the changes of shear stresses in time. For the test purposes there were prepared suspensions of same relations ash to water like previously (PK0.67, PK0.77, PK0.9 and PJ1.1, PJ1.0). The figure 7 shows the flow curves of (marked S1) for the suspensions at the temperature 25°C.

The flow curve for the suspension PK0.9 seems to be of a great interest. The consistency of this suspension differs greatly from the others, looks rather like paste. With the increase of the rotation speed, the flow curve shows the changeable slope largely similar to plastic liquid. During the second phase of the test, when the rotor reduces its speed, the curve is more uniform and characteristic for rheological Bingham model. Such differences indicate on significant thixotropic of the suspension. The other suspensions show similar flow curves in the comparable rate. The next step was made to compare the flow curves of suspension which were heated during the test to standard curves at the temperature of 25°C. While heating two tests were made immediately so the initial temperature in test starts from 25°C this means that the suspension was poured into the vessel just before the test. In other cases the second test is described (initial temperature of second test is the same as final temp. of the first one). The results are shown in figures 8÷12.

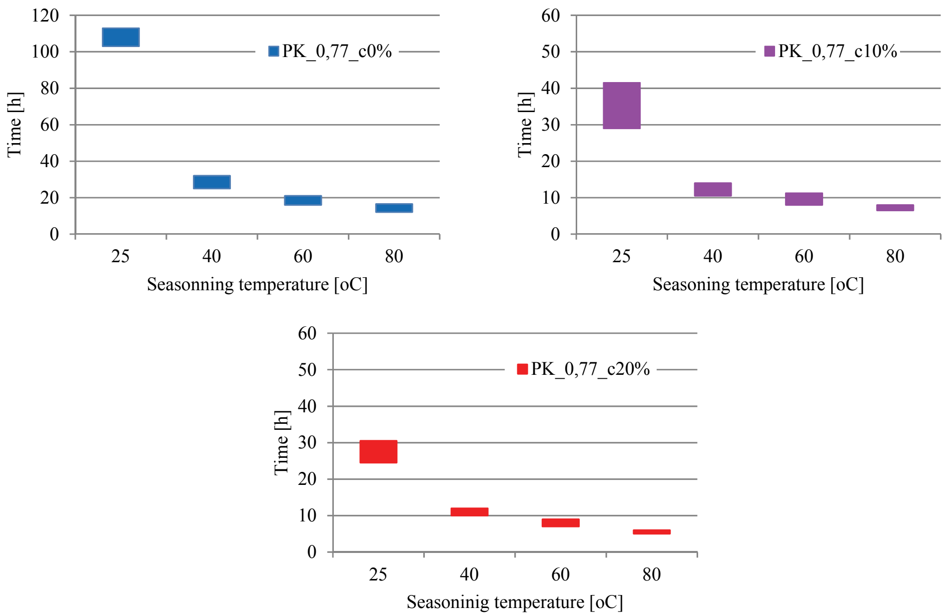


Fig. 3. The setting time of suspension of s/w = 0.77:1 based on PK ash and Portland cement in amount of 0, 10 and 20% of solids

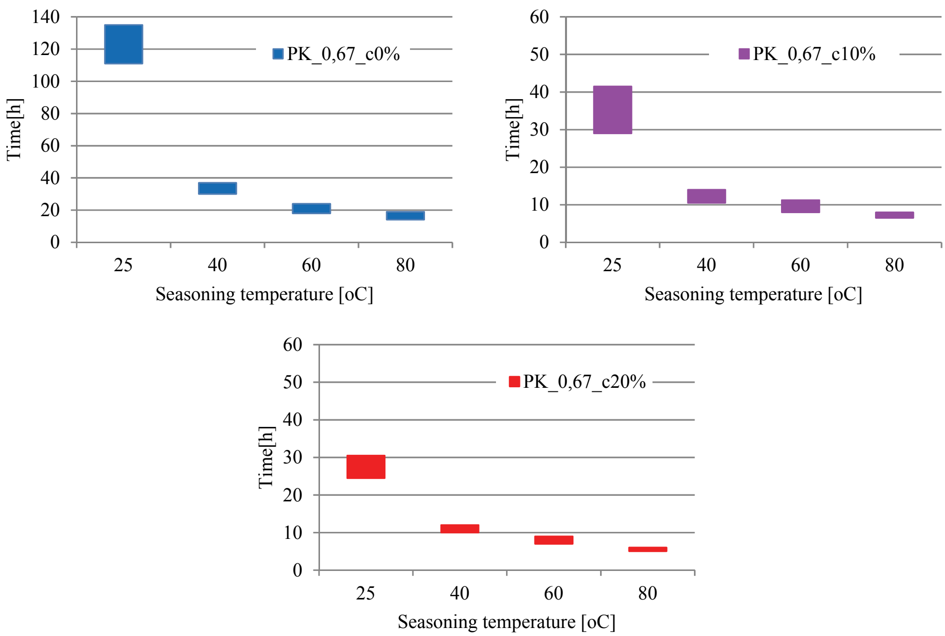


Fig. 4. The setting time of suspension of s/w =0.67:1 based on PK ash and Portland cement in amount of 0, 10 and 20% of solids

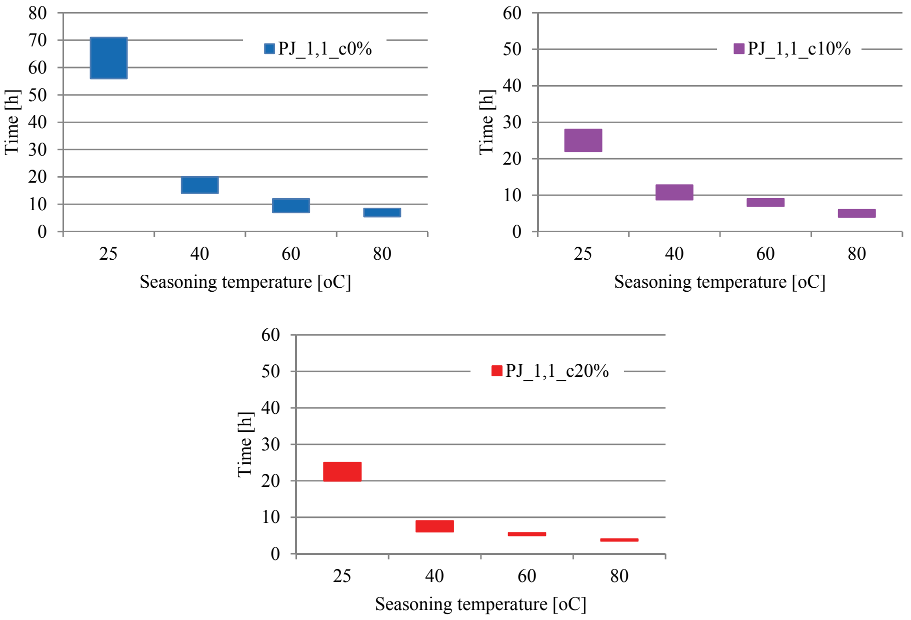


Fig. 5. The setting time of suspension of s/w = 1.1:1 based on PJ ash and Portland cement in amount of 0, 10 and 20% of solids

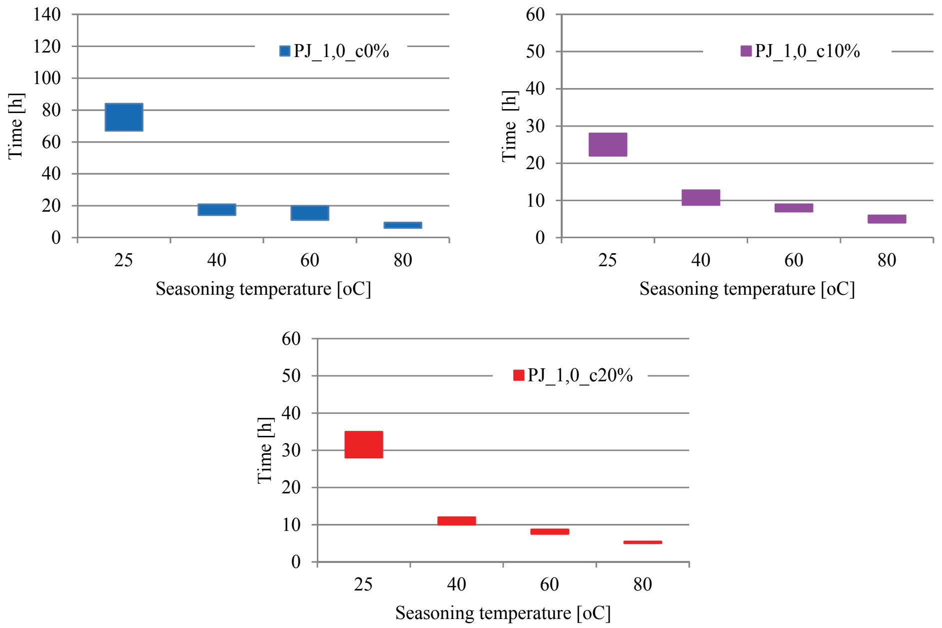


Fig. 6. The setting time of suspension of s/w =1.1:1 based on PJ ash and Portland cement in amount of 0, 10 and 20% of solids

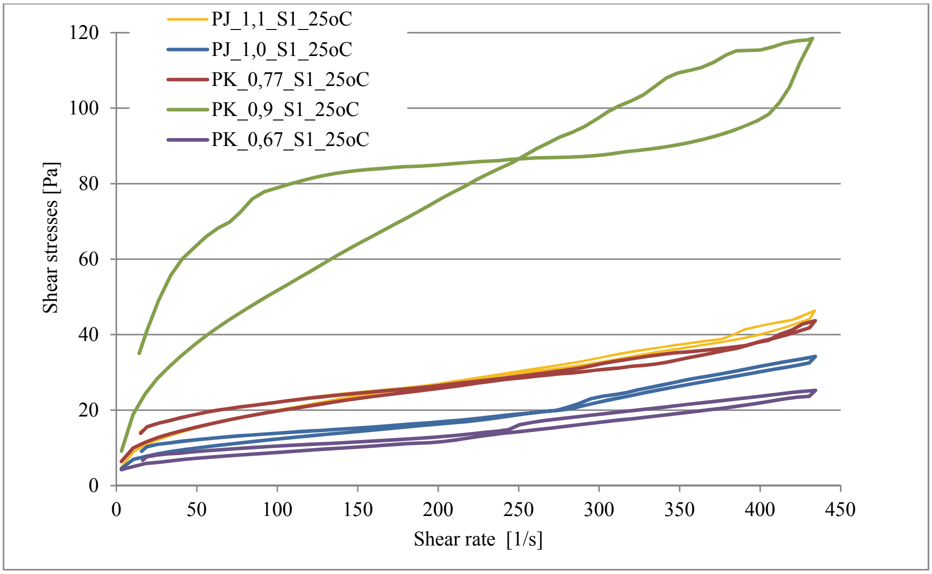


Fig. 7. Flow curves for the tested suspensions

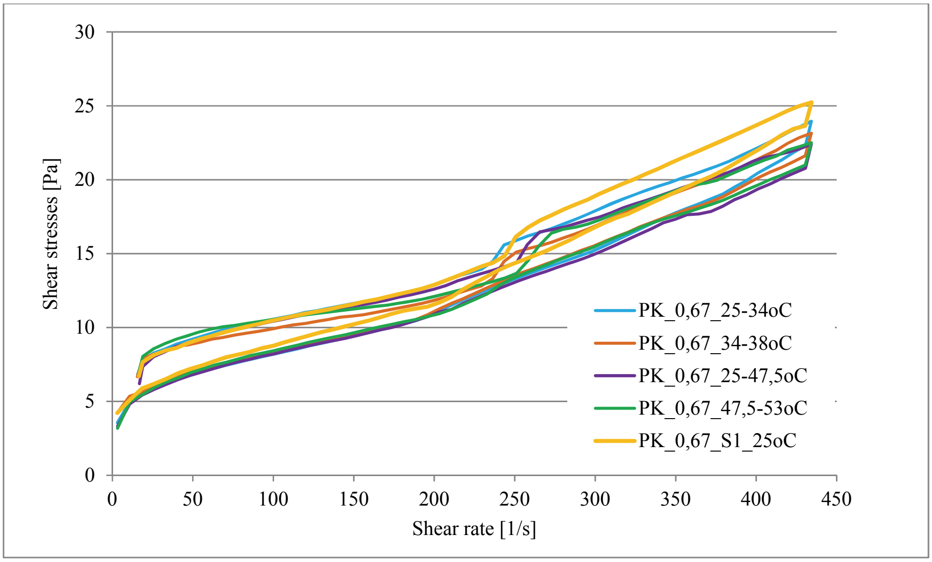


Fig. 8. The flow curves obtained during heating the suspension PK0.67 in comparison with standard (PK_0.67_S1)

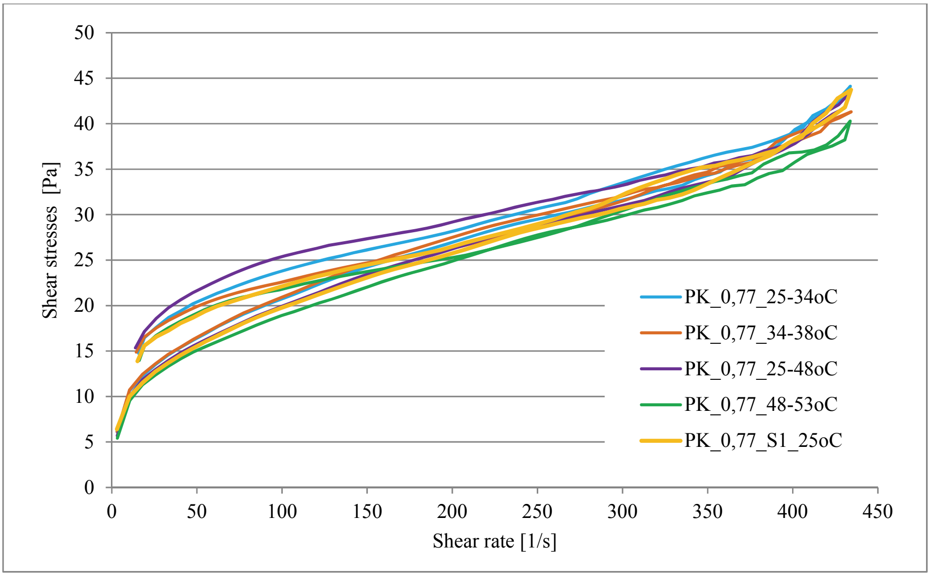


Fig. 9. The flow curves obtained during heating the suspension PK0.77 in comparison with standard (PK_0.77_S1)

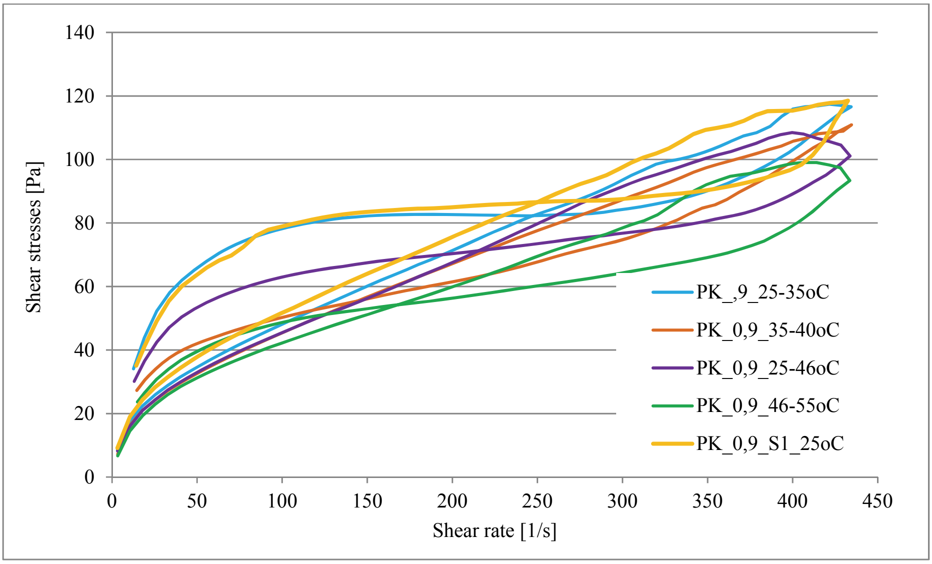


Fig. 10. The flow curves obtained during heating the suspension PK0.9 in comparison with standard (PK_0.9_S1)

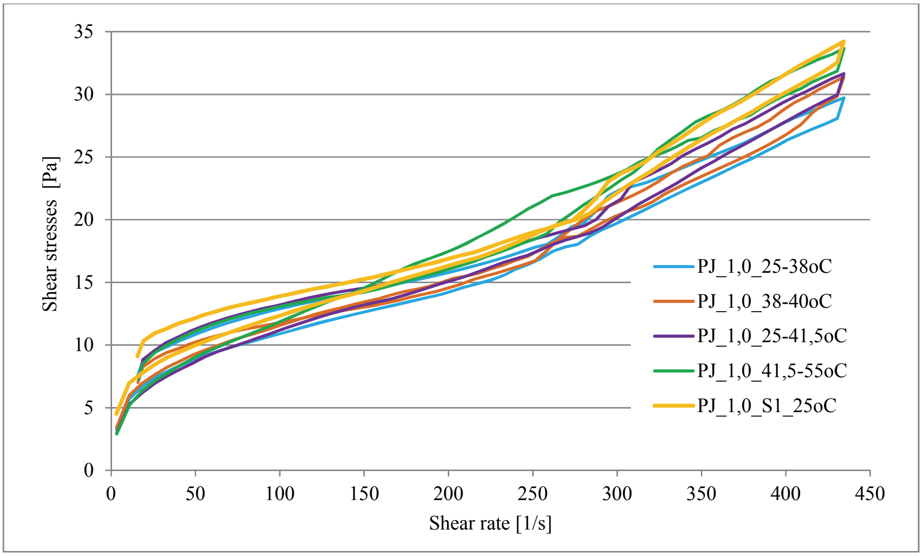


Fig. 11. The flow curves obtained during heating the suspension PJ1.0 in comparison with standard (PJ_1.0_S1)

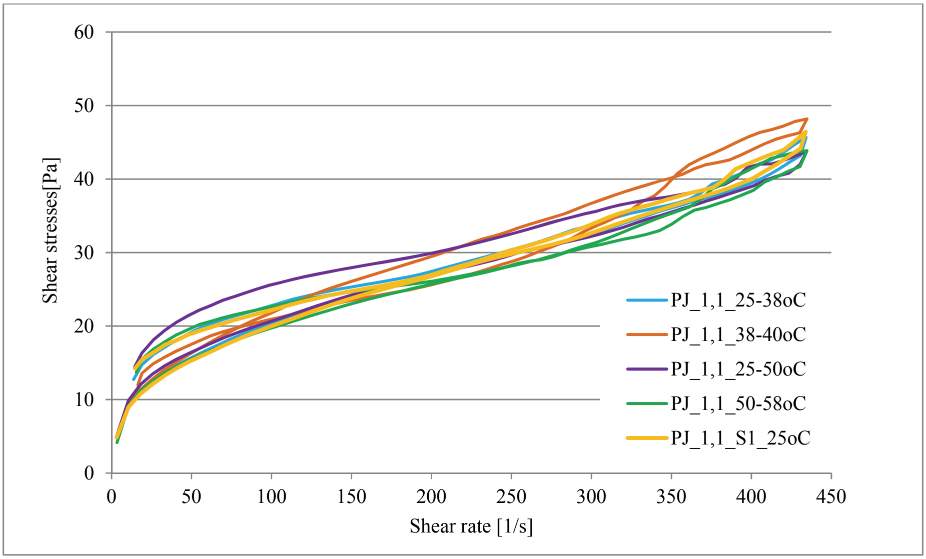


Fig. 12. The flow curves obtained during heating the suspension PJ1.1 in comparison with standard (PJ_1.1_S1)

In all cases, lower values of shear stresses were obtained during the first stage of heating in comparison with the standard flow curve, whereas during the second stage of heating shear stresses were getting higher – in some cases beyond the limits described by the standard curves.

During the next step the values of shear stresses during the 'long test' (10 minutes at the speed of 500 rot/min and 5 minutes at the speed of 100 rot/min.) were defined. The results are shown in figures 13÷17.

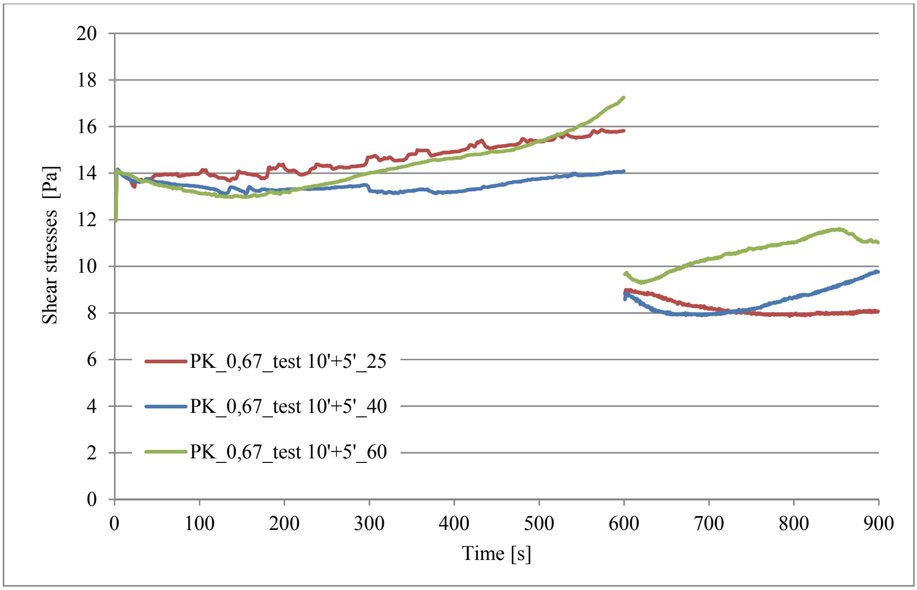


Fig. 13. The measurement of shear stresses during the "long test" on suspension PK_0.67

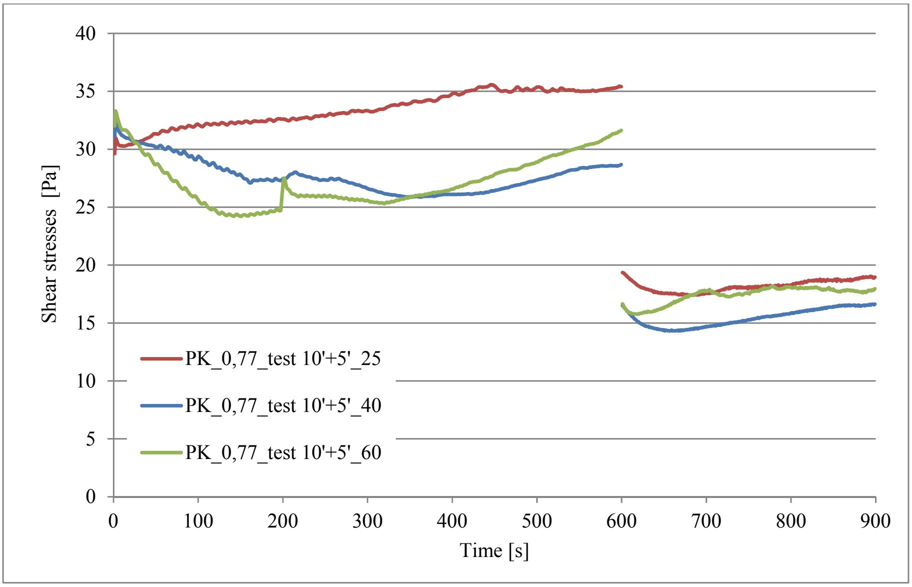


Fig. 14. The measurement of shear stresses during the "long test" on suspension PK_0.77

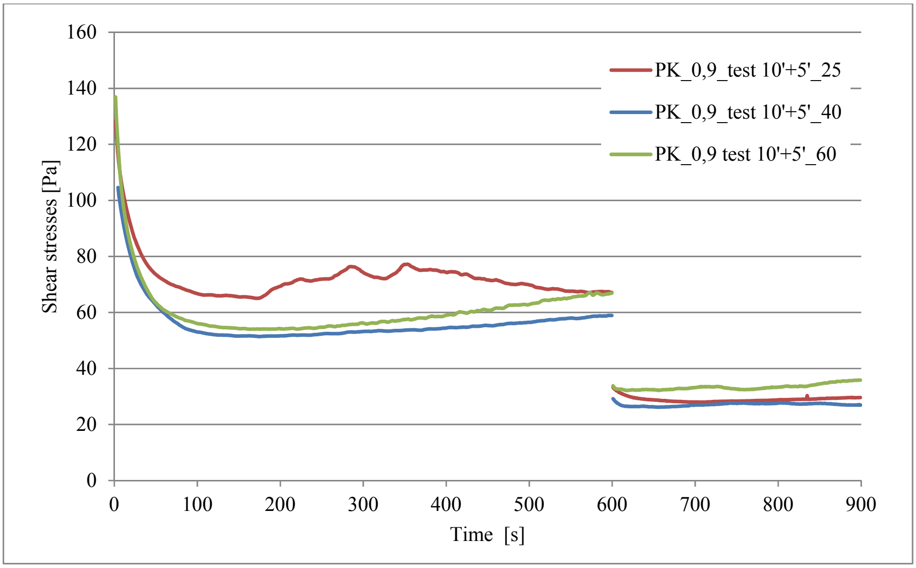


Fig. 15. The measurement of shear stresses during the “long test” on suspension PK_0.9

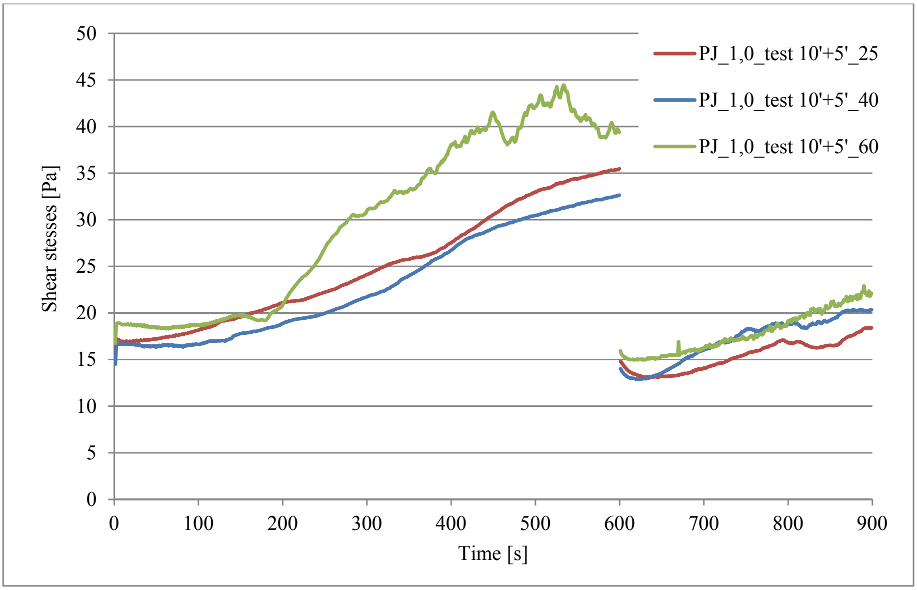


Fig. 16. The measurement of shear stresses during the “long test” on suspension PJ_1.0

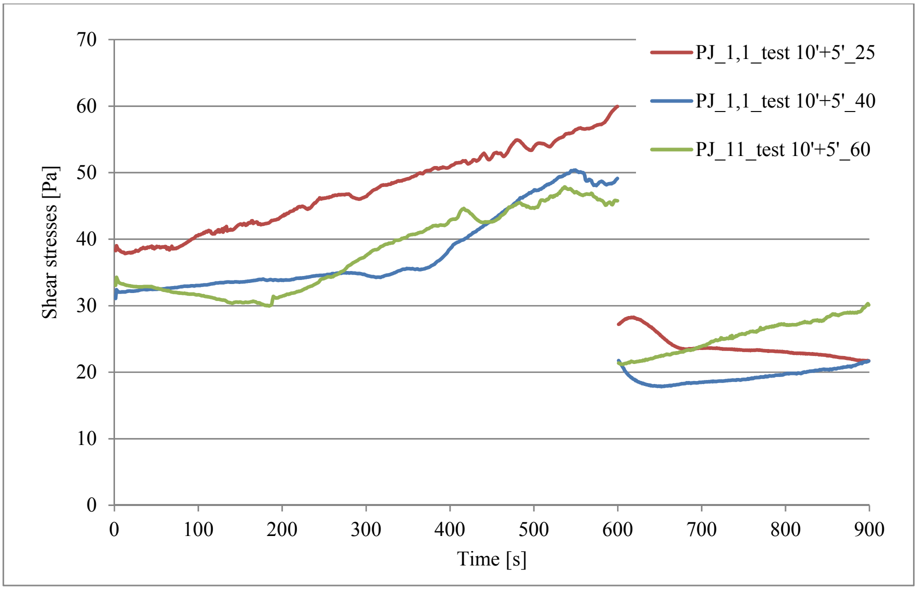


Fig. 17. The measurement of shear stresses during the "long test" on suspension PJ_1.1

The results of 'long tests' reveal great differences among the suspensions characteristics depending on the kind of ash used and the share of solids. For the suspensions PK0.77, PK0.9 and PJ1.1 the values of shear stresses are smaller than the ones obtained at the temperature of 25°C. An example of this is a temporary shear stress decrease in the first minutes of the PK0.77 test. However, along with time and due to the raised temperature the gradual increase in shear stresses can be observed (also for suspensions with smaller solid content: PK0.67 and PJ1.0). The growth rate of shear stress at 60°C is much higher than at lower temperatures. Moreover, points out different shape of curves for the suspension PK0,9, as was the case for the flow curves.

7. Conclusions

The main objective of the researches was to determine the influence of temperature on the properties of liquid and solidifying suspensions and mineral binders applied to the insulation of underground workings and gob.

The conducted researches proved that the raised temperature causes the acceleration of suspension solidifying processes. This refers not only to the binders or suspensions with share of cement but also to suspensions based only on fly ash. Similar trend was observed also for supernatant water.

The influence of temperature on the rheological properties is not so obvious and the differentiated courses of the curves or the sedimentation, especially among the suspension with the bigger content of solids, make the result interpretation more complicated. During the suspension heating within the short time, the decrease of the shear stresses was noticed. This may reduce the flow resistance during the hydraulic transportation. In other cases the situation was more differentiated on dependent both on initial consistence of suspensions and the type of ash. But generally, for the suspensions heated to the temperature of 60°C the value of shear stresses was growing steadily with time.

Analyzing the obtained results for the practical purposes it can be assumed that a slight raise of suspension temperature should not affect the parameters of the pipeline transportation. However, it should be taken under consideration that the transportation through the excavations of the higher temperature of rocks may cause some problems, especially in the case of suspensions of good binding properties (contained desulphurization products). On these occasions the hydration processes can be fastened and the suspension can embed on the inner surface of the pipeline.

The suspensions applied for gob insulation at elevated temperature may solidified faster, limiting this way the opportunity of air and other gases flow. However, the high temperature of the rock (eg. as a result of a late start preventive operation and/or advanced self-heating processes) may adversely affect the ability of caving penetration by the suspensions, leading to rapid clogging of the outlet pipe, thereby reducing the effectiveness of these actions.

The results of the researches shown in the article have been developed within the realization of the research project of the Ministry of Science and Education no N N524 338240 "The temperature influence on the properties of suspensions and binders used in fire prevention in the coal mines" and statutory research no 11.11.100.482.

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