Study of The Properties of the Ash-Water Suspension of the Incinerated Sewage Sludge Ash (Issa)

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Summary

The article presents the results of a study on the possibility of the use of ash in suspension technologies applied in underground minEng. Suspensions are prepared with two types of ashes derived from different installations combusting municipal sewage sludge in fluidized bed boilers. Properties of suspension as well as ways of its use was determined in accordance with Polish Norm PN-G-11011:1998. The resulting suspensions did not meet the requirements concerning application in backfilling, and depending on their composition they may be used for insulation and caulking of gob.

Keywords: suspension technologies, fly ashes, municipal sewage combustion

Introduction

In recent years, the market of byproducts from fossil fuels combustion goes through a lot of changes. This applies in particular to the type of burned fuels in power plants and combined heat and power plants as well as the ways of management of arising fly ashes and slags. Until recently, one of the largest recipients of fly ashes were hard coal mines, which use them in order to prepare ash-water mixtures applied in backfills and/or in caulking of gob [1]. Nowadays the mines more often, despite the needs and possibilities of the fly ashes management, have problems with their derivEng. This is the result of the application of ash in increasing quantities in construction sites, road and cement industries [2-5]. Because ash-water suspensions are used in many mining technologies, mines are seeking for other wastes which may substitute "traditional" ashes derived from hard coal.

Completely new ashes from installation of thermal conversion of municipal sewage sludge are obtained in Poland from several years. As from January 1st 2013 sewage sludge storing is prohibited, it seems that the thermal method will be widely used in terms of disposal sewage sludge. This will increase the amount of ashes (ISSA) and the need to seek for new opportunities for their development [6-8]. One of the kind of waste derived in this type of installations is fly ash caught from a stream of exhaust gases (waste having code 19 01 14). Conducted tests of physical-chemical properties of this waste obtained in two different installations allowed to conclude, that this waste comforts the requirements for filling materials in terms of backfilling and caulking in terms of norm PN-G-11011:1998 [9]. It primarily meets the needs concerning the environmental issues related to leaching the chemical pollutants (e.g. heavy metals, chlorides, sulfates) as well as radioactivity [10]. In that case the next step was to carry out the tests aiming the determination of properties of ash-water suspensions for their use in backfills and caulkEng. The results of tests are presented in this article.

Subject of tests and methodology

The objective of the test were ash-water suspensions prepared from fly ashes (having code 19 01 14) which are derived in installations for thermal treatment of municipal sewage. Ashes (marked as K-1 and G-2) came from two different installations combusting municipal sewage in fluidized bed boilers. For each ash different suspensions with variety in ash to water ratio were prepared (a/w). Additionally, in chosen suspensions of similar consistency (suspension from ashes K1 and G2 had a/w = 0.9 and a/w = 1.3, respectively) part of ash was substituted with Portland cement CEM I 42.5 R.

Study of the properties of suspension were carried out in accordance to the norm PN-G-11011:1998 "Materials for backfilling and caulking of gob. Requirements and tests". Following properties were tested:

- suspension density,
- fluidity,
- rheological properties,
- amount of post sedimentation water,
- setting time,
- resistance on uniaxial compression and slakeability of suspensions seasoned for 28 days.

Results

Results related to tests of density, slakeability, amount of post sedimentation water and setting time for particular suspensions prepared from ash K-1 and G-2 are presented in Tab.1. and Fig.1. and Fig.2. In addition Tab.2. shows results of studies on properties of suspensions [6] having different a/w ratio, which were derived from ash from combustion of hard coal in pulverized-fuel boiler (ash marked as WP) and fluidized bed boiler (ash marked as WF).

During research the weight ratio of ash to water was selected in the way that slakeability ranged between 180 and 330 mm (suspensions of such slakeability are used in mines and the norm defines minimum value as 180 mm). Therefore, in the course of the research the suspensions from K-1 ash had a/w ratio from 0.5 to 0.9. The amount of G-2 ash needed in order to prepare suspensions of proper slakeability was much higher, and it was equal from 0.8 to 1.3 parts for one part of the water. It may be noticed, that at the same weight ratio of ash to water (a/w = 0.8 and a/w = 0.9), in dependence of type of ash (K-1 of G-2), the suspensions of different properties were obtained. Generally, prepared suspensions were characterized with densities from 1.19 to 1.5 Mg/m^3 which, except one case, comforts the requirements of the norm that allows minimal density of suspension equal 1.2Mg/m^3. It has been observed, that slakeability of the suspensions decreased with the growth of concentration of the ash in the suspension, and it equaled from 335 to 160 mm. The amount of post sediment water (unbounded water in suspension) ranged from 43 to 8%. None of the prepared suspensions have met the requirements of the standard for backfilling (the amount of post sediment water is maximum 7), while the demands for caulking (max. 15%) was comforted by three suspensions (ash K-1, a/q = 0.9; ash G-2, a/w = 1.2 – 1.3). Setting time of suspension was 24h, but depending on the amount and type of ash in suspension the binding started to occur after different times. The resistance on uniaxial compression of bounded suspensions and seasoned for 28 days in dry air conditions ranged from 0.01 to 0.03 MPa. All samples after placing in water for 24h were soakEng.

Insignificant uniaxial tension strength as well as 100% soaking disqualified possibility of application these suspensions for backfillEng. The only opportunity of their use in hard coal mines is backfilling and isolation of gob.

The results obtained in the study in comparison

Tab. 1 Properties of ash-water suspensions prepared from the ash K-1 and G-2

Tab. 1 Właściwości zawiesin popiołowo-wodnych sporządzonych z popiołu K-1 i G-2

Rodzaj popiołu	Stosunek wagowy popiołu do wody p/w	Gęstość pozorna [Mg/m^3]	Rozlewność [mm]	Ilość wody nadosadowej [%]	Czas wiązania [godz.]		Wytrzymałość na jednoosiowe ściskanie [MPa]	Rozmakalność [%]
					Początek	Koniec		
K-1	0,5	1,19	335	43,0	312	336	0,01 – 0,03	100
	0,6	1,25	270	28,8	312	336		
	0,7	1,27	235	21,3	240	264		
	0,8	1,34	180	15,1	168	192		
	0,9	1,37	165	10,5	144	168		
G-2	0,8	1,32	310	28,0	360	384		
	0,9	1,37	270	22,4	280	304		
	1,0	1,42	245	21,6	164	188		
	1,1	1,43	210	15,5	164	188		
	1,2	1,45	185	9,3	120	144		
	1,3	1,50	160	8,0	96	120		
WF	0,7	1,28	305	16,9	96	144	0,30	82
	1,0	1,36	170	3,1	36	84	0,37	80
WP	1,5	1,39	300	4,8	120	144	0,10	100
	2,5	1,51	235	3,6	48	96	0,15	100

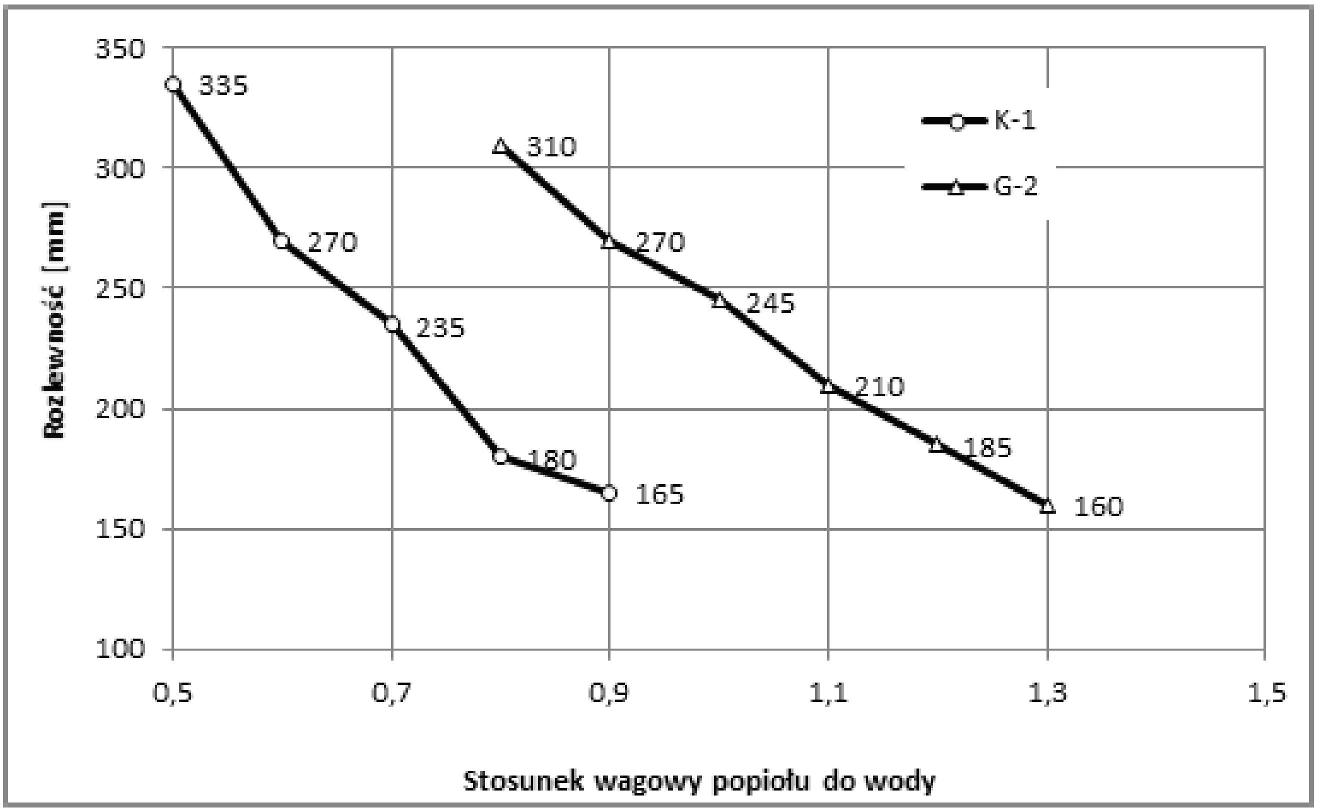

Fig. 1 Spreading of ash slurries prepared from K-1 and G-2

Rys. 1 Rozlewność zawiesin sporządzonych z popiołów K-1 i G-2

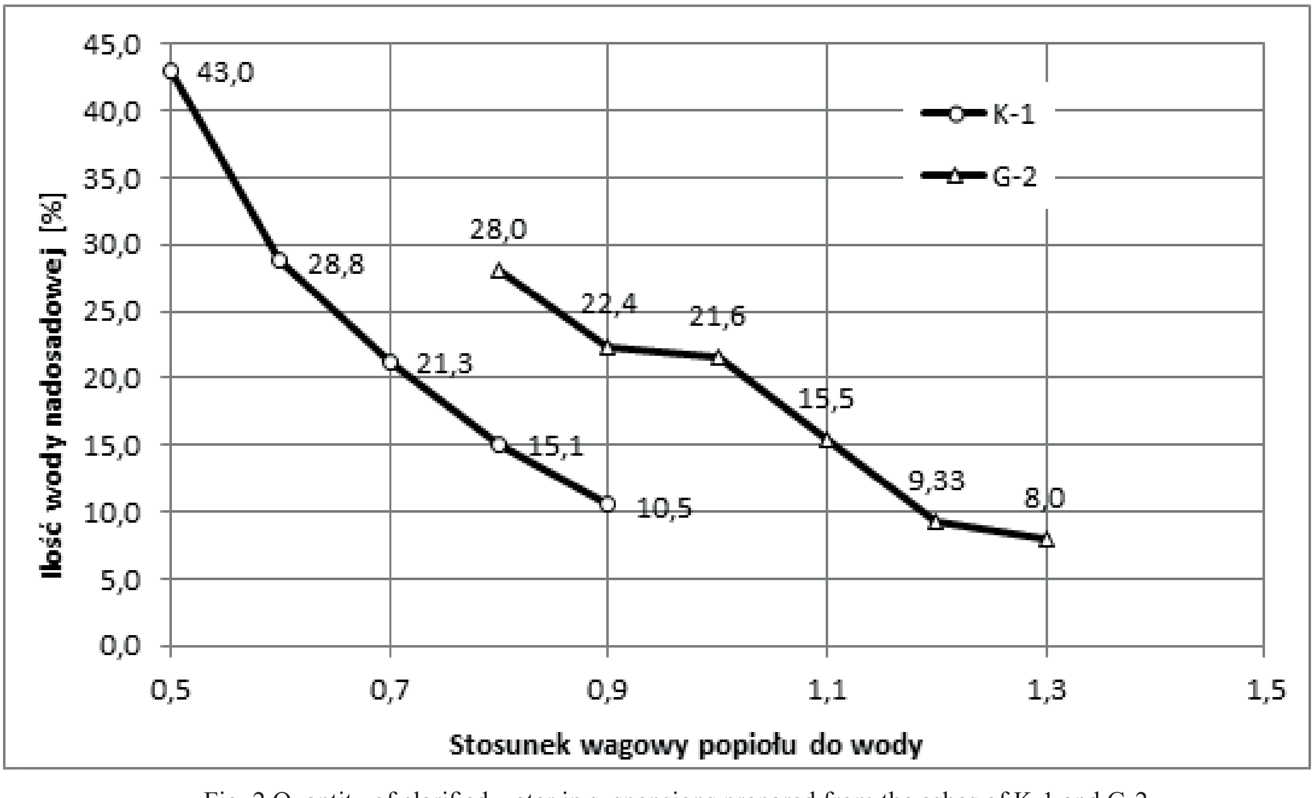

Fig. 2 Quantity of clarified water in suspensions prepared from the ashes of K-1 and G-2

Rys. 2 Ilość wody nadosadowej z zawiesin sporządzonych z popiołów K-1 i G-2 to the properties of suspensions used in mining and prepared from the ashes from coal combustion indicate, that there are possibilities of forming suspension of similar consistency. However, clear differences are visible in setting time (particularly in case of suspensions of high a/w ratio) and uniaxial tension resistance of solidified suspensions after 28 days of seasonEng.

In order to improve the properties of suspensions prepared from the ISSA the K-1 ash composition of a/w = 0.9 ratio was substituted with Portland cement CEM I 42.5R using percentage of weight of 5, 10, 20 and 40%. The results of research on properties of suspensions with cement addition is depicted in Tab.2 and in the figures 3 and 4. For comparison terms the data related to suspension without cement and same a/w ratio is presented. Substitution the part of ash with cement in the suspension composition has significantly changed the properties. Along with higher participation of cement, the slakeability and amount of post sedimentation water was increasing, which in case of both examined suspensions (K-1 with 20 and 40% cement participation in solid phase) exceeded 15%. That amount of post sediment water causes, that these suspensions do not meet the conditions of standard PN-G-11011 and cannot be used in caulking of gob. Cement addition significantly accelerated initiation of the suspension setting process. Shortening of the time of termination of setting process has been also observed. The uniaxial tension resistance of solidified suspensions has substantially increased after improving cement concentration up to minimum 20% in the mixture with ash – Tab.3.

Rheological properties of suspensions

Application of suspensions in the technology of backfilling requires the determination of their density [Mg/m³] as well as rheological properties like: viscosity η_z (depending on liquid: structural, apparent, dynamic) [Pa·s] and liquid limit τz [Pa]. Study on rheological properties was made using rotation viscometer. The results are basing on Bingham rheological model. This model was developed for liquid perfectly plastic and viscous. The rheological equation of this model is as follows:

$$\tau = \tau_g + \eta_p \cdot \gamma \text{ [Pa]}$$

where:
τ – tangential stress [Pa],
τ_g – liquid limit [Pa],
η_p - plastic viscosity [Pa · s],
γ – shearing speed [s^{-1}].

The results of the tests of rheological properties are presented in form of flow curves based on Bingham model. In Fig.5. and Fig.6. flow curves of examined suspensions are presented. Fig.7. depicts the impact of the addition of cement on flow curves behavior of suspensions K-1 having a/w = 0.9.

With both the ashes it is possible to prepare suspensions of a similar consistency, although the content (ash/water ratio) of each of them will be different. For the preparation of suspensions of a similar consistency it is required to decrease K-1 ash share than G-2 ashes (Fig.5. and Fig.6.).

Plastic viscosity of suspension prepared from both types of ashes K-1 and G-2 depends primarily on solids content. However, the flow curves characteristics is different. In case of suspensions of K-1 ash, with increasing solids content (a/w ratio) the plastic vis-

Tab. 2 Properties of ash-water suspensions prepared from the ash K-1 and cement

Tab. 2 Właściwości zawiesin popiołowo-wodnych sporządzonych z popiołu K-1 oraz z cementem

Rodzaj popiołu	Zawartość składników stałych w zawiesinie [% wag.]:		Stosunek wagowy części stałych do wody s/w	Gęstość pozorna [Mg/m³]	Rozlewność [mm]	Ilość wody nadosadowej [%]	Czas wiązania [godz.]	
	Popiół	Cement					Początek	Koniec
K-1	100	0	0,9	1,37	165	10,5	144	168
K-1	95	5		1,38	180	11,1	96	120
K-1	90	10		1,38	190	13,4	42	66
K-1	80	20		1,40	225	17,6	33	50
K-1	60	40		1,45	285	27,8	25	40

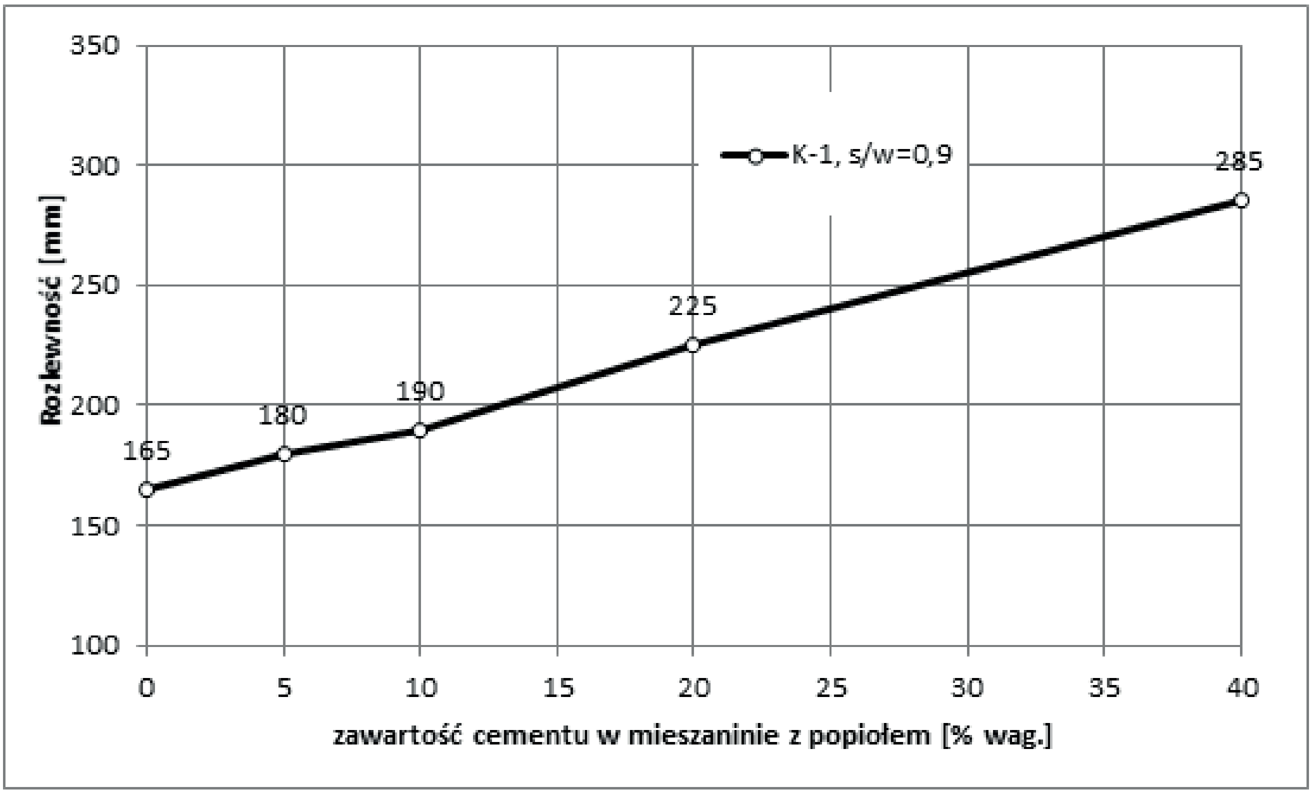

Fig. 3 Spreading of suspensions made from ash K-1 and cement

Rys. 3 Rozlewność zawiesin sporządzonych z popiołu K-1 oraz cementu

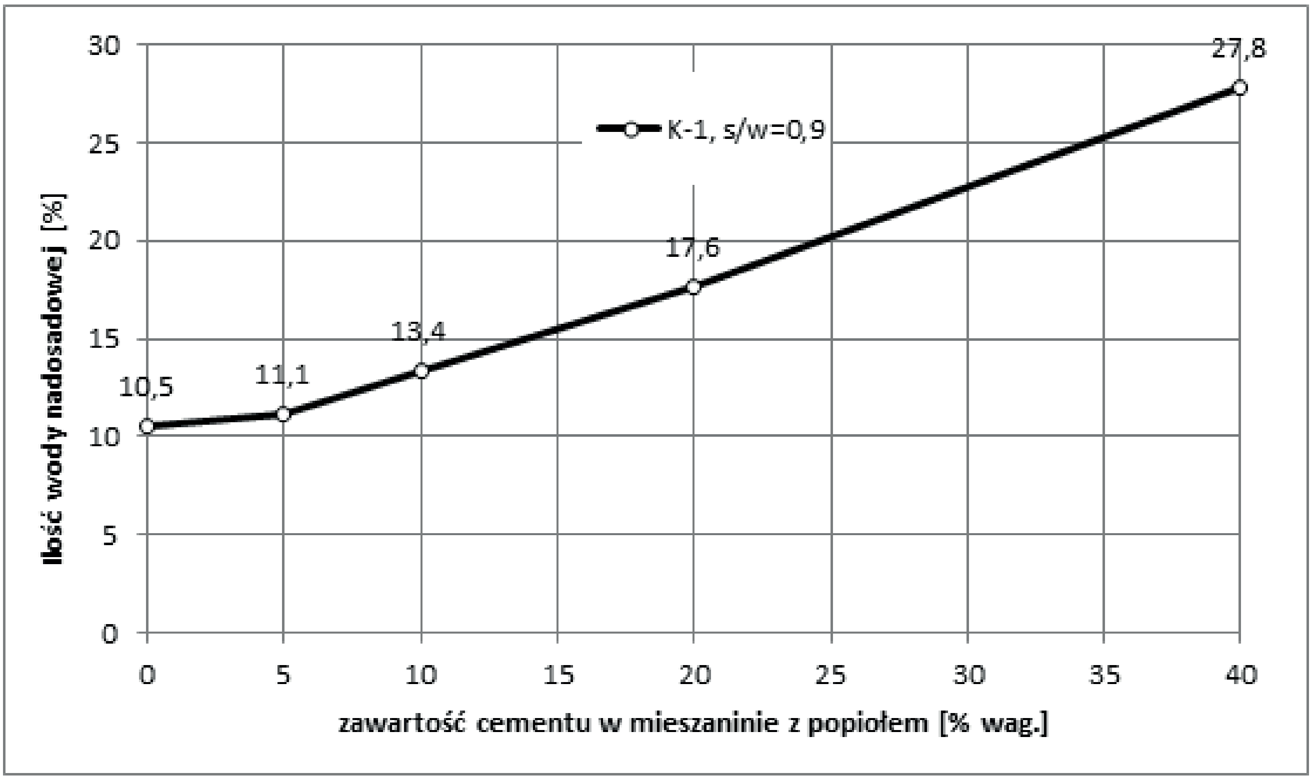

Fig. 4 Quantity of clarified water of slurry from the ash K-1 and the cement

Rys. 4 Ilość wody nadosadowej z zawiesin sporządzonych z popiołu K-1 oraz cementu

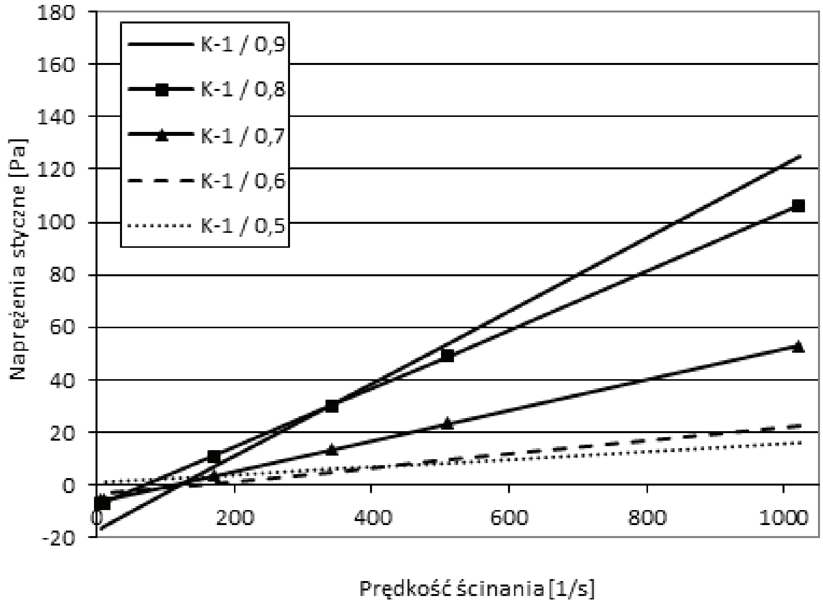

Fig. 5 The flow curves by the Bingham model, suspensions made from ash K-1 without the addition of cement

Rys. 5 Krzywe płynięcia wg modelu Binghama, zawiesin sporządzonych z popiołu K-1 bez dodatku cementu

Tab. 3 Properties of solidified ash and water-ash suspensions prepared from the ash K-1 and G-2 and the cement after 28 days of aging

Tab. 3 Właściwości zestalonych zawiesin popiołowo-wodnych sporządzonych z popiołu K-1 i G-2 oraz z cementem po 28 dniach sezonowania

Rodzaj popiołu	Zawartość składników stałych w zawiesinie [% wag.]:		Stosunek wagowy części stałych do wody s/w	Wytrzymałość na jednoosiowe ściskanie [MPa]	Rozmakalność [%]
	Popiół	Cement			
K-1	100	0	0,9	0,03	100
K-1	95	5		0,02	100
K-1	90	10		0,02	100
K-1	80	20		0,13	100
K-1	60	40		0,60	83

cosity increases while liquid limit decreases (negative values presented in Fig.5 comes arise only from the linear model fitting). Other obtained results refer to suspensions from G-2 ash, for which plastic viscosity and liquid limit increase along with a/w ratio increase.

Differences in rheological properties were observed for suspensions of the same solids content, but differing in the cement contribution. Studies in this field were made for suspensions prepared basing on K-1 ash (Fig.7). The share of cement up to 10% only slightly has changed the flow curves characteristics. Clear differences have been reported for suspensions having 20% and 40% of cement contribution. In these cases the lower values have been measured for the biggest shear stress velocities, and thus a much smaller plastic viscosity of such suspensions has been obtained.

Summary

Conducted studies were related to the properties

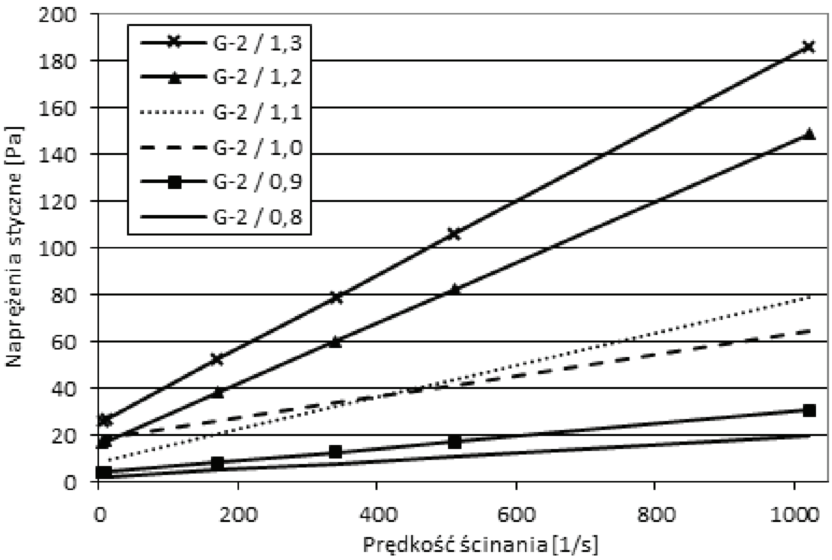

Fig. 6 The flow curves by the Bingham model, suspensions prepared from the ashes G-2 without the addition of cement

Rys. 6 Krzywe płynięcia wg modelu Binghama, zawiesin sporządzonych z popiołu G-2 bez dodatku cementu

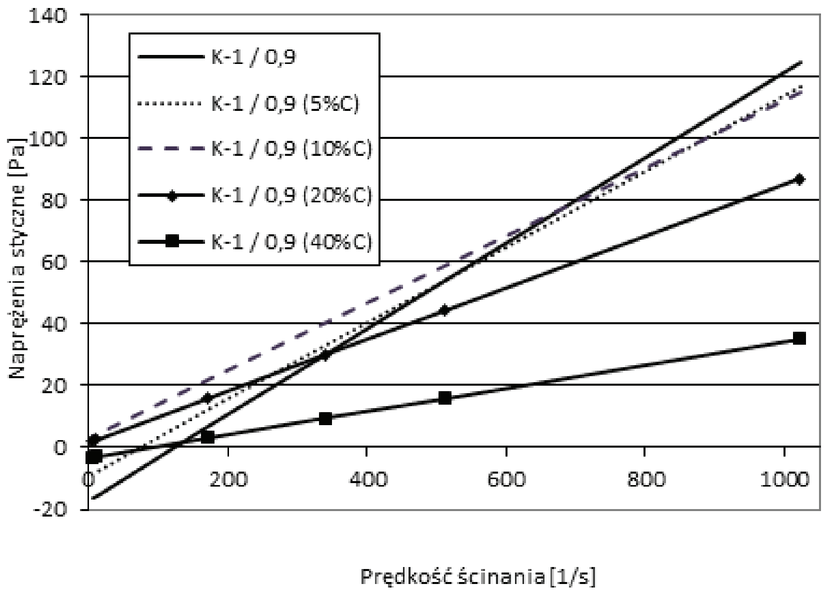

Fig. 7. The flow curves by the Bingham model, suspensions prepared from the ash K-1, solids to water ratio 0.9:1, different content of cement

Rys. 7 Krzywe płynięcia wg modelu Binghama, zawiesin sporządzonych z popiołu K-1 o stosunku części stałych do wody wynoszącym 0,9:1, o różnej zawartości cementu

of suspensions prepared from ashes derived from incineration of municipal sewage sludge (having code 19 01 14) for their use in suspension technologies used in the hard coal minEng. Ashes came from two different installation in which municipal sewage sludge is burned in fluidized bed boilers. The origin of the ash had a significant impact on the properties of the suspensions. Studies have shown that these suspensions cannot be used alone as a backfilling due to not meeting the requirements of norm PN-G-11011 regarding the amount of post sedimentation water, uniaxial tension resistance and slakeability in water. Replacing part of ash with cement increased slakeability and amount of post sedimentation water. On the other hand, it greatly accelerated binding and, for suspension of 20% and higher cement content, it improved mechanical properties.

Depending on the composition of the suspensions there is the possibility of using this type of ashes in mining technologies related to caulking and isolation of gob. Due to the requirements of the standard [9], techniques of obtaining the ashes must consider the origin of ash, type of technology in which ash is going to be used and the amount of binding agents added.

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Summary

W artykule przedstawiono wyniki badań nad możliwością wykorzystania popiołów lotnych w technologiach zawiesinowych stosowanych w górnictwie podziemnym. Zawiesiny sporządzono z dwóch popiołów pochodzących z różnych instalacji, spalających komunalne osady ściekowe w kotłach fluidalnych. Właściwości zawiesin jak i kierunek ich zastosowania określono zgodnie z Polską Normą PN-G-11011:1998. Sporządzone zawiesiny nie spełniały wymagań dotyczących zastosowania w podsadzce zestalanej, natomiast w zależności od ich składu mogą być stosowane do izolacji i doszczelniania zrobów zawałowych.

Słowa kluczowe: technologie zawiesinowe, popioły lotne, spalanie komunalnych osadów ściekowych