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Possibilities of using ash from thermal treatment of municipal solid waste in hardening slurries

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Abstract: In recent years, there has been a marked increase in the amount of municipal waste generated in Poland. In 2020, 21.6% of all municipal waste was subjected to a thermal treatment process. Consequently, the amount of ashes generated is significant. Due to their properties, it is difficult to utilize this type of waste within concrete production technology. One of the waste utilization methods is to add it to hardening slurries used in, among others, cut-off walls. The article assesses the possibility of using ashes from municipal waste incineration as an additive to hardening slurries. It also discusses the technological properties of hardening slurries with the addition of the ashes in question. The experiment showed that it is possible to compose a hardening slurry based on tested ashes with technological properties suitable for use as a cut-off wall. Further research directions were proposed.

Introduction

A hardening slurry is a thixotropic (thixotropy is the slow recovery of structure of a shear-thinning dispersion as the applied stress is reduced (Mewis 1979)), mix (suspension) of water, binder (usually cement-based), and clay material (usually bentonite), as well as, depending on the intended use, other ingredients (e.g., blast furnace slag and fly ash). They exhibit thixotropic properties in the liquid state and have the ability to set through chemical bonding. They can be used for the construction of building structures in the ground substrate or when filling gaps and openings in the ground and execute trench cut-off walls (Rafalski 1995, Kledyński 2000, Kledyński and Rafalski 2009, Jefferis 2012, 2013).

Cut-off walls are commonly used in construction to protect excavations against the inflow of groundwater, in embankments, dam substrates and levees, as well as to seal landfills (prevention of contaminants penetrating into the soil and groundwater) (Jefferis 2008, Kledyński and Rafalski 2009, Talefirouz et al. 2016, Ruffing and Evans 2019).

Hardening slurry technology allows for the execution of cut-off walls using the single- or two-phase method. In the single-phase method, the excavation slurry used during the digging stage has a full composition that includes cement, allowing it to bond later. In contrast, the excavation slurry in the two-phase method is typically a bentonite-water mixture, with the binder added only after reaching full depth. Mixing of the binder can be done in the excavation, or the excavation slurry can be replaced with hardening slurry through displacement, allowing for the formation of an impermeable cut-off wall (Kledyński and Rafalski 2009).

Table 1 shows specific requirements in terms of the properties in liquid state of the hardening slurries used for cut-off walls in levees, as based on domestic experiments (Borys et al. 2006, Borys 2012). The technological properties of the hardening slurries are as follows:

- bulk density: determines the pressure supporting excavation walls and displacement potential in the two--phase method;
- viscosity: important in the stages of slurry production, pumping, and trench execution as it determines the susceptibility of the slurry to penetration into the ground and to displacement in the two-phase method;
- water bleed: measure of slurry stability and its segregation tendency;
- structural or gel strength of the slurry: closely related to its thixotropy, which refers to its ability to transform into a gel-like state while at rest. This gel exhibits a certain shear strength, which is known as the 'structural' strength and helps to prevent the sedimentation of the slurry components and excavated material.

Hardening slurries, like any building material (especially cement-based), carry an unavoidable carbon footprint. A 'carbon footprint' is difficult to define, as it requires a clear statement of underlying assumptions and, often, the methodological approach. There is currently no widely accepted and definitive definition of the term 'carbon footprint' in the context of environmental impact assessment (Wiedmann and Minx

2008). Conceptually, a carbon footprint should consider all emissions of a product both backward in time from the point of use to emission sources and forward in time to include the use and disposal stage of products (Peters 2010). The definition of a product's carbon footprint, according to the standard ISO/TS 14067:2013, is the sum of greenhouse gas emissions and removals throughout its lifecycle, expressed as carbon dioxide equivalents (CO2-eq). The CO2-eq is calculated using a characterization factor that measures the radiative forcing impact of a greenhouse gas relative to that of carbon dioxide over a specific period (typically 100 years). This calculation is based on a life cycle assessment, which evaluates the environmental impacts of a product system's inputs, outputs, and potential impacts. The standard uses a single impact category of climate change to evaluate the carbon footprint.

Quantification of the carbon footprint of a product is extremely difficult, especially when considering all stages of the product's life cycle (Fig. 1). There are various methodologies available in the literature for calculating carbon footprints, as described by (Chomkhamsri and Pelletier 2011). When it comes to building materials, it is widely accepted that replacing raw materials with anthropogenic materials, especially waste materials, can bring about significant benefits for both the climate and the principles of the Circular Economy (CE).

Hardening slurries are an excellent example of a building material in which this approach can be implemented. The slurries contain waste from various processes, such as ground granulated blast-furnace slag (Garvin and Hayles 1999, Opdyke and Evans 2005, Kledynski and Machowska 2013, Kledyński et al. 2021), fluidized and conventional ash from coal combustion (Falaciński and Kledyński 2007, Falaciński 2012, Kledyński et al. 2016, 2021), and ash from thermal treatment of municipal sewage sludge (Falacinski and Szarek 2016, Wojtkowska et al. 2016, Szarek 2019, 2020). It has been possible to develop hardening slurries with desired technological and performance properties using combustion by-products, without the need for a binder (Kledyński et al. 2021).

The experiment described in this paper aimed to test the feasibility of developing recipes for ash-based hardening slurries that would meet the technological requirements for hardening slurries intended for cut-off walls. The studies focus on the utilization of thermal treatment of municipal waste (TTMW) by-products in slurries – two types of TTMW ash,

Table 1. Selected properties of hardening slurries used in cut-off walls in levees
Source: own elaboration based on (Borys et al. 2006; Borys 2012)

Properties	Unit	Value
Bulk density: – diaphragm method (narrow-space excavation) – Deep Soil Mixing – DSM – vibration method (Jet Grouted Diaphragm Wall – JGDW)	[g/cm^3]	1.15÷1.40 1.30÷1.50 1.50÷1.60
Conventional viscosity (marsh funnel runoff time)	[s]	≤50
Daily water loss	%	≤4.0
Structural strength after 10 min	[Pa]	1.4÷10.0

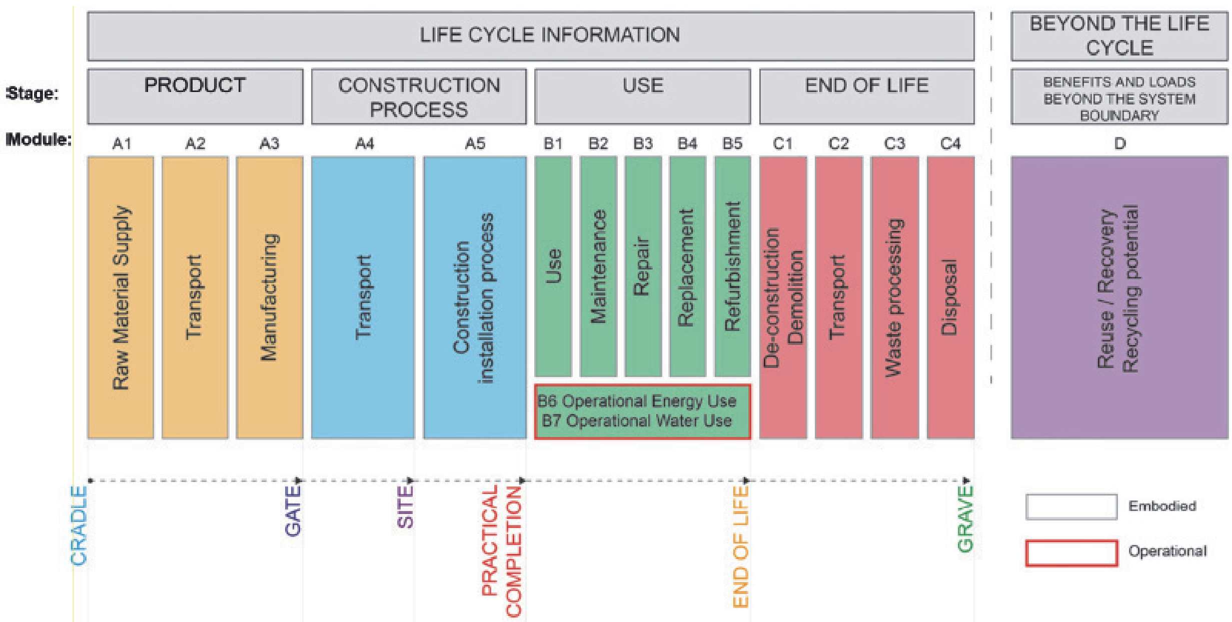


Fig. 1. Lifecycle stages and modules (Orr et al. 2020)

which are designated 19 01 07* and 19 01 13* (* sign indicates hazardous waste) in accordance with (Dz.U. 2020 poz. 10).

Municipal waste (MW) management is a challenge, even for highly developed countries, since there is a positive correlation between the economic growth of a country and the amount of generated waste (Wielgosiński 2016). As the collection system for municipal waste gradually tightens and the environmental awareness among citizens grows, the amount of municipal waste collected in Poland is expected to increase. According to Statistics Poland data (Domańska et al. 2020), there has been over a 114% increase in the amount of separately collected municipal waste in Poland between 2015 and 2021. The available literature and various studies show a clear upward trend in the amount of municipal waste generated over the last few years (Pawnuk et al. 2022). For example, municipal solid waste can be used as an artificial soil substrate (Alwaeli et al. 2022), however, it is much more commonly used as an energy source, among others, as an alternative fuel (RDF) for cement production (Uliasz--Bocheńczyk et al. 2021). Conversion technologies of the chemical energy of municipal waste to various forms of final energy use are considered important in the pursuit of a low--emission economy (Primus et al. 2021). TTMW generates by-products such as slags, bottom ash, and fly ash, which can be managed in a way that aligns with the Circular Economy concept and the waste handling hierarchy (as outlined in Journal of Laws from 2013, item. 21). Instead of being treated as waste (which is currently costly for TT plants), these by-products can be transformed into valuable products. For this purpose, it is necessary to identify the properties of generated waste and its applicability. Researchers have explored the use of municipal solid waste ash in a variety of applications, including building materials, particularly in cement and concrete technology as well as geotechnical applications, as reported in the literature. (Ferreira et al. 2003, Siddique 2010*a*, *b*, Lam et al. 2011, Kumar and Mittal 2019, Liang et al. 2020).

Materials and methods

Thermal treatment of municipal solid waste by-products

Studied ashes (Fig. 2) were generated due to MW incineration in a grate furnace. Flue gas treatment processes involved flue gas denitrification by primary methods and a secondary selective non-catalytic nitrogen oxide reduction (SNCR), as well as flue gas treatment using the semi-dry method with limewash slurry combined with the flux and ash method using activated carbon (aimed at reducing acidic contaminants, ash, heavy metals, dioxins and furans). Flue gas dedusting employing a fabric filter was also applied.

Ash labelled 19 01 07* (solid flue gas treatment waste (classified as A1 according to Dz.U. 2020 poz. 10) is an odorless, homogeneous light-grey material, with a very fine homogeneous grain fraction. It exhibits dusting properties and a tendency toward lumping.

Fly ash labeled as 19 01 13* and containing hazardous substances (classified as A2 according to Dz.U. 2020 poz. 10) exhibits a heterogeneous structure, as shown in Figure 2. Compared to the 19 01 07* ash, it has a coarser grain size and contains unburned residues from the combustion process.

Table 2 shows the chemical composition and selected physical properties of the tested ashes compared to the selected requirements of the standard (EN 450-1:2012). The oxide composition of the ashes was analyzed using wavelength dispersive x-ray fluorescent spectrometry (WD-XRF) on molten samples. References to the research methods applied when testing selected physical properties of ash can be found in Table 2.

The tested ashes do not meet the requirements of the EN 450-1 (EN 450-1:2012) standard, not only by definition but also due to physical and chemical properties (exceeded thresholds of the chemical composition, low activity and loss on ignition, high fineness and water demand). This prevents from using the material as an additive of II type for concrete. Despite the significant variation of fineness test results, the

Table 2. Selected properties of ashes compared to the selected requirements of the (EN 450-1:2012)
Source: own elaboration based on (EN 450-1:2012)

Properties	Ash		Chemical and physical requirements for fly ash according to EN 450-1
	A1	A2	
	Mass Share (%)		
Cl	5.213±1.043	0.376±0.075	≤ 0.10
SO_3	4.11±0.82	1.9±0.38	≤ 3.0
$SiO_2 + Al_2O_3 + Fe_2O_3$	8.16±1.64	27.26±5.45	≥ 70
Na_2O_{eq} (PN-EN 196-2:2013-11)	2.69±0.64	1,45±0,32	≤ 5.0
MgO	1.31±0.26	3.08±0.62	≤ 4.0
P_2O_5	0.430±0.086	1.423±0.285	≤ 5.0
Loss on ignition (EN 450-1:2012)	21.4±2.14	11.1±1.11	≤ 9.0
Fineness (PN EN 451-2:2017-06)	17.81±1.66	78.82±1.72	cat. N ≤ 40.0 cat. S ≤ 12.0
Activity index after 28 days of curing [%]	51	33	≥ 75
Water demand (EN 450-1:2012) (%)	108	107	≤ 95 (S category only)

authors observed no large differences in the workability of mortars with the added ash and no significant differences in water demand (elevated in both cases).

Figure 2 shows selected morphology images of the tested ash acquired using the SEM technique. Both tested ash types are characterized by varying morphology. The spherical grains observed in the A2 ash are not composed of aluminosilicate glass, which is typical for fly ash used in concrete, but are mainly composed of iron. On the other hand, the zone present in the A1 ash has an element composition that is characteristic of ash. This can be seen in Figure 2.

Hardening Slurries

The following materials were employed in developing hardening slurry recipes:

- tap water;
- sodium bentonite;
- portland cement CEM I 42.5 R;
- ash from the incineration of municipal waste deemed 19 01 07* – A1;
- ash from the incineration of municipal waste titled: 19 01 13* – A2.

The recipes of the designed hardening slurries are shown in Table 3.

The composition of the hardening slurries was determined in the laboratory based on the properties being tested, with the numbering of the slurries being assigned randomly.

Hardening Slurries Testing Methods

Liquid slurries were tested in terms of technological properties as follow:

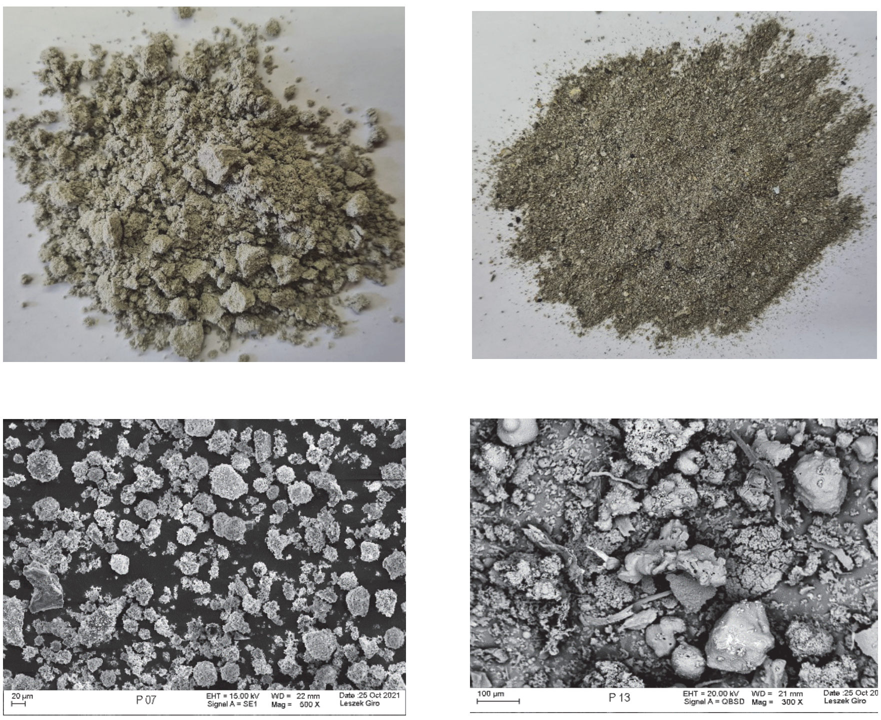
- Bulk density was determined using a Baroid arm scale (BN-90/1785-01:1990);
- Conventional viscosity was determined using a flow viscometer (Marsh funnel (Marsh 1931, Almahdawi et al. 2014)). The time (in seconds) for the outflow of a 1 dm^3 of liquid slurry was measured (in a 1.5 dm^3 slurry poured into a funnel);
- Daily water loss (water bleed) was determined as a percentage share of water volume spontaneously escaping from a 1.0 dm^3 slurry after a motionless day in a calibrated measuring cylinder (PN-85/G-02320:1985);
- Structural strength was determined using a shearometer after a 10 min motionless standstill of the slurry (BN-90/1785-01:1990).

Statistical analysis

Statistical analysis was performed using STATISTICA v13 software. Pearson's correlation tables between the independent variables (bentonite, cement and ash content) and the dependent variables (bulk density, conventional viscosity, daily water loss, structural strength after 10 min) have been presented. Based on the analysis of partial and semi-particle correlations, the redundancy of the variables and the correlation of the residuals with an assumed significance level of $\alpha = 0.05$, multiple regression models were constructed. If there was a significant collinearity among independent variables, linear regression models based on calculated statistics was used. Additionally, when the regression model was based on two independent variables, stratified plans, fitted by the Method of Least Squares were plotted. Pairwise deletion of missing data was applied.

Results and discussion

Technological properties of the tested hardening slurries are listed in Table 4.



A1 Ash (19 01 07*) A2 Ash (19 01 13*)

Fig. 2. Studied ashes

The following tables show the linear correlation matrix between the independent variables and the dependent variables (Table 5), regression analysis (Table 6) and matrix of partial and semi-particle correlations between independent variables and dependent variables (Table 7).

The table shows partial and semi-particle correlation values only when the regression model included the contribution of at least two explanatory variables.

Bulk density

Table 1 shows that the liquid slurry density of each recipe is sufficient to ensure the stability of the hollowed excavation, as indicated in Table 4.

Analysis of the result of the A1 ash (19 01 07*) reveals a significant Pearson linear correlation between the liquid volume density of the hardening slurry and the content of bentonite and cement in its composition. The linear correlation

Table 3. Recipes of designed hardening slurries per 1000 dm³ of water
Source: own elaboration

Recipe	Water [dm³]	Bentonite [kg]	Ash [kg]	Cement [kg]	Recipe	Water [dm³]	Bentonite [kg]	Ash [kg]	Cement [kg]
	W	B	A1	C		W	B	A2	C
A1R1	1000	30	100	400	A2R1	1000	30	100	400
A1R2	1000	30	125	375	A2R2	1000	30	125	375
A1R3	1000	30	150	350	A2R3	1000	30	150	350
A1R4	1000	30	175	325	A2R4	1000	30	175	325
A1R5	1000	30	200	300	A2R5	1000	30	200	300
A1R6	1000	30	225	275	A2R6	1000	30	225	275
A1R7	1000	30	250	250	A2R7	1000	30	250	250
A1R8	1000	30	275	225	A2R8	1000	30	275	225
A1R9	1000	30	300	200	A2R9	1000	30	300	200
A1R10	1000	30	325	175	A2R10	1000	30	325	175
A1R11	1000	30	350	150	A2R11	1000	30	350	150
A1R12	1000	25	175	400	A2R12	1000	25	200	400
A1R13	1000	20	200	400	A2R13	1000	25	225	400
A1R14	1000	25	225	375	A2R14	1000	25	250	375
A1R15	1000	20	225	350	A2R15	1000	25	275	350
A1R16	1000	20	250	325	A2R16	1000	20	300	325

Table 4. Technological properties of the tested hardening slurries
Source: own elaboration

Recipe	Bulk density [g/cm³]	Conventional viscosity [s]	Daily water loss (24h) [%]	Structural strength after 10 min. [Pa]	Recipe	Bulk density [g/cm³]	Conventional viscosity [s]	Structural strength after 10 min. [Pa]
A1R1	1.300	52	4.0	10.0	A2R1	1.300	62	5.8
A1R2	1.295	53	4.5	6.5	A2R2	1.320	58	8.5
A1R3	1.300	57	3.5	9.0	A2R3	1.305	56	9.0
A1R4	1.305	58	2.5	9.5	A2R4	1.305	45	4.8
A1R5	1.300	58	1.0	11.0	A2R5	1.305	52	6.5
A1R6	1.295	80	1.0	20.0	A2R6	1.305	49	5.3
A1R7	1.290	80	1.0	17.0	A2R7	1.300	53	9.0
A1R8	1.290	115	0.5	22.0	A2R8	1.305	57	12.5
A1R9	1.290	145	0.0	32.0	A2R9	1.300	53	8.0
A1R10	1.290	–	0.0	40.0	A2R10	1.310	56	11.0
A1R11	1.285	–	0.0	50.0	A2R11	1.350	220	28.0
A1R12	1.33	47	7	2.8	A2R12	1.34	57	8.5
A1R13	1.32	42	7	2.1	A2R13	1.35	58	12
A1R14	1.32	52	3	5.3	A2R14	1.315	42	5
A1R15	1.315	42	5	6.7	A2R15	1.36	49	8
A1R16	1.31	48	2	6	A2R16	1.345	44	6.5

coefficient between the two independent variables (bentonite and cement) is smaller, in absolute value, than the correlation coefficient between them and the dependent variable. Thus, the condition of non-linearity of the independent variables is satisfied, and a multiple regression model can be constructed (Stanisz 2007).

Given the values of the calculated statistics (standardized Beta regression coefficient and adjusted multiple regression coefficient of determination R-squared), a regression model based on two independent variables, cement and bentonite, was constructed, which explains about 87% of the variance of the variable under investigation (Table 6). Bentonite has the most decisive influence on the bulk density of the hardening slurry (responsible for about 26% of the variability of the variable), as confirmed by the arrangement of the isolines in the contour plot (Fig. 3).

The A2 ash (19 01 13*) data analysis reveals a noteworthy Pearson's linear correlation between the liquid bulk density

Table 5. Linear correlation matrix between the independent variables and the dependent variables
Source: own elaboration

A1 Ash							
Independent variables				Dependent variables			
	Bentonite	Cement	Ash	Bulk density	Conventional viscosity	Daily water loss	Structural strength after 10 min.
Bentonite	1.0000	-0.5290*	0.0554	-0.8467	0.5239	-0.6306	0.5414
Cement	-0.5290	1.0000	-0.8691	0.7809	-0.8804	0.8777	-0.9319
Ash	0.0554	-0.8691	1.0000	-0.4165	0.6485	-0.6729	0.7933
A2 Ash							
Independent variables				Dependent variables			
	Bentonite	Cement	Ash	Bulk density	Conventional viscosity	Daily water loss	Structural strength after 10 min.
Bentonite	1.0000	-0.4485	-0.2299	-0.6885	0.2172	–	0.1784
Cement	-0.4485	1.0000	-0.7321	0.2019	-0.4840	–	-0.5530
Ash	-0.2299	-0.7321	1.0000	0.3491	0.3839	–	0.5113

* – significant correlation coefficients are highlighted in red

Table 6. Regression analysis
Source: own elaboration

A1 Ash				
	Bulk density	Conventional viscosity	Daily water loss	Structural strength after 10 min.
Intercept	1.3070*	195.0854	-2.0482	58.3995
Bentonite	-0.0007	–	-0.0492	0.0849
Cement	0.0001	-0.3961	0.0214	-0.1509
Ash	–	–	–	–
Standard error of estimate	0,0051	14,771	1,1100	1,246
R-squared	0,9332	0,7750	0,8088	0,213
Adjusted R-squared	0,8709	0,7563	0,7793	–
A2 Ash				
	Bulk density	Conventional viscosity	Daily water loss	Structural strength after 10 min.
Intercept	1.4536*	–	–	20.4511
Bentonite	-0.0048	–	–	–
Cement	–	–	–	-0.0367
Ash	–	–	–	–
Standard error of estimate	0,01607	–	–	4,7633
R-squared	0,4740	–	–	0,3058
Adjusted R-squared	0,4365	–	–	0,2563

* – significant parameters of the regression equation are highlighted in red

of the hardening slurry and the bentonite content. A linear regression model was developed based on the bentonite proportion, which explains approximately 44% of the variability observed in the studied variable (see Table 6). This finding suggests that the bentonite content is a significant factor influencing the liquid bulk density of the hardening slurry.

Conventional viscosity

Hardening slurries based on A2 ash were characterized by higher conventional viscosity. Not every tested recipe meets the requirements (Table 1).

Analysis of the A1 ash (19 01 07*) data reveals a significant linear correlation between conventional viscosity and both cement and ash content. Due to the collinearity of the independent variables considered and the other statistics, a linear regression model of one explanatory variable (cement) was constructed, explaining approximately 76% of the variability of the variable under investigation. The experimental results do not coincide with the known dependence of the conventional viscosity on bentonite content and activity (Kledyński and Rafalski 2009, Szarek 2019).

The conventional viscosity for hardening slurries based on the A2 ash (19 01 13*) shows no significant linear correlation with any of the independent variables considered. Analysis of the statistics indicates that it is not possible to construct a meaningful regression model.

Daily water loss

Daily water loss (Table 4) in the tested hardening slurries (based on A1 ash) ranges from 0% to 7%. Almost every recipe meets the requirements (Table 1).

The results indicate a significant Pearson's linear correlation between daily water loss and all independent variables (hardening slurries based on the A1 ash). To account for the collinearity of the independent variables (cement and ash), a multiple regression model was constructed. The model also included an interaction term between cement and bentonite, although the parameter estimate for bentonite was not statistically significant. However, it was retained in the model because it had a positive effect on the adjusted R-squared. Overall, the multiple regression model explained approximately 78% of the variability in the dependent variable. The cement has the most significant influence on the daily water loss of the hardening slurries, explaining approximately 41% of the variability observed in the variable. The experimental results do not coincide with the known dependence of the daily water loss on bentonite content (Kledyński 1989, Szarek 2019).

Structural strength after 10 min.

When analyzing the results showing structural strength after 10 min (Table 4), it can be seen that 10 recipes recorded a value higher than 10.0 Pa (the limit value according to the criterion from Table 1). The other recipes satisfy the requirement set out in Table 1.

The results indicate a significant Pearson linear correlation between structural strength and all independent variables (hardening slurries based on the A1 Ash). To address the collinearity of the independent variables (cement and ash) and other statistical considerations, a multiple regression model was constructed, which included an interaction term between cement and bentonite. Despite the lack of statistical significance for the bentonite parameter estimate, it was retained in the model due to its positive effect on the adjusted R-squared. Overall, the multiple regression model explains approximately 85% of the variation observed in the variable under consideration. Cement has the most significant influence on the structural strength of the hardening slurries, explaining approximately 58% of the variability observed in the variable. This finding is supported by the arrangement of the isolines in the contour plot shown in Figure 4.

The results indicate a significant Pearson linear correlation between structural strength and cement and ash content (hardening slurries based on the A2 Ash). Due to the collinearity of the independent variables considered (cement and ash) and other statistics, a linear regression model was constructed, taking into account the effect of cement on the dependent variable explaining approximately 26% of the variation in the variable under investigation.

The A1R16 recipe meets all the requirements for the technological properties of hardening slurries used in cut-off walls in levees (Table 1).

Table 7. Partial and semi-particle correlations matrix between independent variables and dependent variables – hardening slurries based on A1 ash
Source: own elaboration

	Bulk density	Conventional viscosity	Daily water loss	Structural strength after 10 min.
Partial correlation				
Bentonite	-0.8180*	–	-0.4089	0.1572
Cement	0.7374	–	0.8261	-0.9047
A1 Ash	–	–	–	–
Semi-particle correlation				
Bentonite	-0.5110	–	-0.1960	0.0570
Cement	0.3923	–	0.6411	-0.7607
A1 Ash	–	–	–	–

* – significant correlation coefficients are highlighted in red
The table shows partial and semi-particle correlation values only when the regression model included the contribution of at least two explanatory variables.

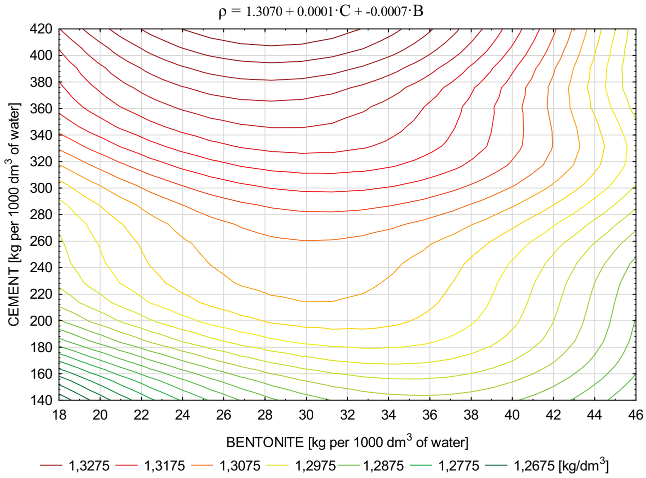


Fig. 3. Contour plot of the effect of the addition of bentonite and cement on the bulk density of the hardening slurry

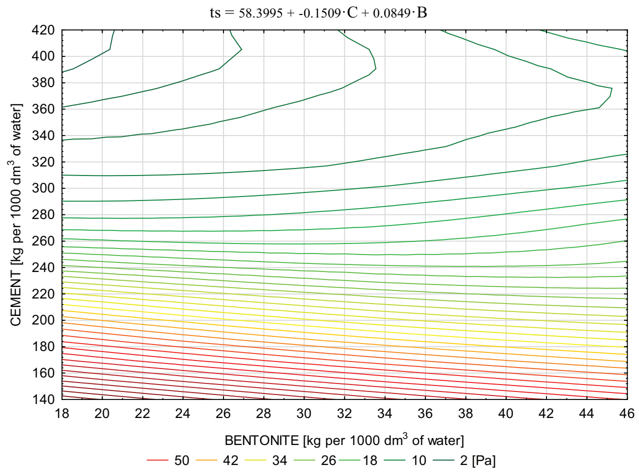


Fig. 4. Contour plot of the effect of the addition of bentonite and cement on the structural strength after 10 min. of the hardening slurry

Conclusions

The following conclusions can be drawn from the research carried out:

- it is possible to prepare a hardening slurry based on TTMW ash (19 01 07*) that exhibits desirable technological properties for use in cut-off walls in levees;
- cement had the most potent effect on the tested properties of liquid hardening slurries;
- the study did not confirm the dependence of technological properties of hardening slurries on bentonite, known from the literature on the subject;
- the study did not find any significant influence of the ashes on the technological properties of the hardening slurries;
- it is recommended to conduct further research with the participation of the statistical planning of the experiment, which will eliminate the collinearity of the independent variables.

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Możliwości wykorzystania popiołu z termicznego przekształcania odpadów komunalnych w zawiesinach twardniejących

Streszczenie: W ostatnich latach w Polsce nastąpił wyraźny wzrost ilości wytwarzanych odpadów komunalnych. W 2020 roku 21,6% wszystkich odpadów komunalnych zostało poddanych procesowi termicznego przekształcania. W związku z tym ilość wytwarzanych popiołów jest znaczna. Ze względu na ich właściwości trudno jest wykorzystać ten rodzaj odpadów w ramach technologii betonu. Jedną z metod wykorzystania odpadów jest dodawanie ich do zawiesin twardniejących stosowanych m.in. w przesłonach przeciwfiltracyjnych. W artykule oceniono możliwość wykorzystania popiołów ze spalania odpadów komunalnych jako dodatku do zawiesin twardniejących. Omówiono również właściwości technologiczne zawiesin twardniejących z dodatkiem badanych popiołów. Przeprowadzony eksperyment wykazał, że możliwe jest skomponowanie zawiesiny twardniejącej na bazie badanych popiołów o właściwościach technologicznych odpowiednich do zastosowania jako ściana odcinająca. Zaproponowano dalsze kierunki badań.