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## Research on the possibility of using sludges from washing dolomite and limestone aggregates in the building ceramics technology

### Introduction

Poland is a country with considerable and diversified industrial rock resources (Radwanek-Bak and Nieć 2015) and the important role of meeting the needs of society. Their resources should be therefore rationally used. It requires in particular safeguarding access to deposits areas. The way to indicate the valuable deposits to protect them seems to be their valuation, using uniform criteria. The authors present a simple method of mineral deposits value ranking. It consists of deposits ranking value in four, separate domains: quality and size (resources). This is a country rich in limestone and dolomite deposits. Limestone deposits are mainly exploited for use in the lime and cement manufacturing industry and crushed stones production. Dolomite deposits are mainly exploited for use in production of crushed stones and refractory materials. The crushed stones are divided into a construction stones and road aggregates (Kozioł and Ciepliński 2012). Limestone mining for crushed stones production amounted to 11.494 Mt in 2016, while dolomite mining for the same sector amounted to 2.598 Mt (PIG-PIB 2017).

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After mining and crushing, aggregates are washed in order to remove clayey pollutants (Naziemiec 2010). The washing of aggregates leads to the production of waste sludge containing clay minerals and fine-grained limestone or dolomite. The authors estimated that one washing plant in Poland can generate up to 600,000 tons of sludge per year. Typical aggregate washing plants produce at between 5 and 80 tons of waste sludge per hour. This quantity depends on the plant size and the materials being processed. In general, 10–15% of the raw stone will become waste sludge (Chang et al. 2010). To date, the problem of the utilization of waste from washing aggregates has not been solved (Naziemiec 2015). They are used only for the reclamation of post-mining areas.

The possibility of applying sludge from washing limestone aggregate as an additive to sludge generated during the washing process of quartz sand in masonry technology was tested by Sokolář (Sokolář et al. 2014). Differences and similarities between sludge coming from carbonate and silicate stones are presented in the work (Careddu and Dino 2016). Sivrikaya studied the possibility of using stone waste obtained from processing plants in the stabilization of clayey soil (Sivrikaya et al. 2014). Sludge from a gravel pit and sewage sludge from a wastewater treatment plant were used for production of lightweight aggregate (Chang et al. 2010; González-Corrochano et al. 2016 2012) as well as stone cutting sludge (Moreno-Maroto et al. 2017).

There are several works about utilization stone slurry or dust generated from marble and limestone processing activities or fine grained calcite in the ceramic industry (Almeida et al. 2007; Betancourt and Martirena 2011; Bilgin et al. 2012; Cultrone et al. 2005; Eliche-Quesada et al. 2012; Fernando et al. 2006; Saboya et al. 2007; Vodova et al. 2014). Research on the possibility of the application of sludge from washing limestone aggregate as an additive to ceramic masses is presented in (Kłosek-Wawrzyn 2016; Sveda 2000). The influence of dolomite on the brick body was determined in (Kłosek-Wawrzyn and Bugaj 2016). New phases in ceramics with dolomite were studied at (Sedmale et al. 2006). Dolomite quarry waste as sand replacement in sand brick was considered at work (Nur Fitriah et al. 2016).

However, pure calcite or dolomite is commonly used in ceramics. It is used as a source of CaO and MgO oxides during the production of ceramic glazes and for the production of faience, sanitary ware, special ceramics and ceramic tiles (Kłosek-Wawrzyn 2016; Kłosek-Wawrzyn et al. 2014; Moreno-Maroto et al. 2017; Morse 1948).

This minerals can be a natural admixture of clays used in the production of building ceramics, but they are not widely used in this industry (Kłosek-Wawrzyn 2016; Morse 1948). Carbonates may constitute as much as 15% of the mass parts of clay intended for the production of roof tiles and 10% of mass clays intended for the production of bricks (Ramachandran et al. 2002).

Carbonates, mostly coarse calcite (called marl) with a particle size larger than 0.5 mm present in building ceramic masses is a harmful admixture. Coarse grains of carbonates usually turn to CaO during firing clay materials. Their contact with moisture is associated with a 2.5-fold increase in volume, which could cause the destruction of clay masonry units. The presence of coarse MgO grains in the fired materials is disadvantageous for similar

reasons as the presence of coarse CaO grains. MgO reacts with water slower than CaO (Małolepszy et al. 2013). Fine grained carbonate minerals mainly calcite present in clays are not a harmful constituent (Kłosek-Wawrzyn et al. 2017).

The addition of dolomite, in comparison to the addition of calcite to ceramic masses, results in the formation of more liquid phase during sintering (Schmidt-Reinholz and Schmidt 1997). Sintering with the liquid phase is accompanied by the crystallization of calcium aluminosilicates (Cultrone et al. 2005; Schmidt-Reinholz and Schmidt 1997).

The characterization of sludge from washing the aggregates and the determination of the possibilities of their recovery and reuse are consistent with the European Commission's Thematic Strategy on the Prevention and Recycling of Waste (EC raw material strategies). This paper presents laboratory research on the properties of two types of sludge: from washing dolomite and limestone aggregates. In this paper preliminary research on the possibility of use of washing aggregates sludge in ceramics technology was made.

## 1. Materials and methods

### 1.1. Materials

Two samples of washing aggregates sludge were examined: dolomite sludge – DS and limestone sludge – LS. Samples were taken from dolomite and limestone mines and stone processing plants located in Central-Eastern Poland. The mines exploit deposits of Devonian deposits. Dolomite washing was carried out in log washer, vibrating screens, hydrocyclone and filter press. Limestone washing was carried out in the log washer, vibrating screens, dewatering bucket wheel and filter press.

The delivered raw materials had a high level of water content (Table 1). DS had more favorable properties compared with LS: it had a smaller water content and was characterized by its smaller fluctuations.

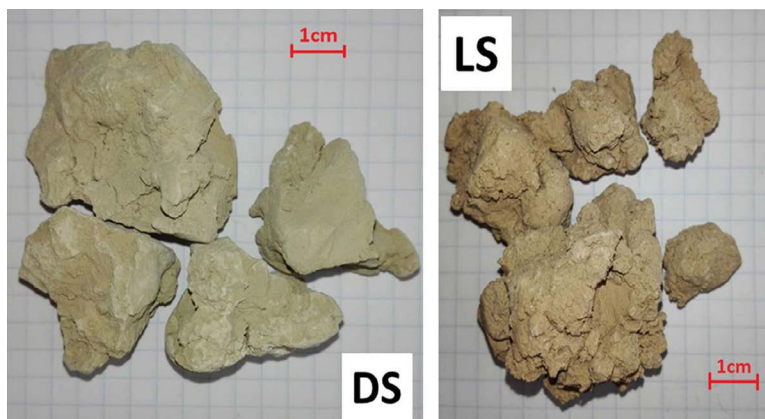
Table 1. Water content of sludge

Tabela 1. Zawartość wody w szlamach

Sludge	Average water content AWC [%]	The smallest received value of AWC [%]	The highest received value of AWC [%]
DS	21.7 ± 1.2	19.2	23.9
LS	29.3 ± 2.1	23.9	42.4

DS – dolomite sludge, LS – limestone sludge.

Sludges were dried in the laboratory dryer at  $105 \pm 5^\circ\text{C}$  to a constant weight and prepared for analysis according to the methodology. Photographs of dried sludges are presented on Phot. 1.



Phot. 1. Photographs of dried sludges  
DS – dolomite sludge, LS – limestone sludge

Fot. 1. Fotografie wysuszonych szlamów: DS – szlam z płukania kruszywa dolomitowego, LS – szlam z płukania kruszywa wapiennego

## 1.2. Methods

Characteristics of waste properties from dolomite and limestone aggregates washing included the following tests:

- ◆ Semiquantitative chemical analysis was tested by using the wavelength fluorescence spectroscopy method (WDXRF); PANalytical WDXRF Axios mAX sequence spectrometer with a goniometer with wave dispersion on analysis crystals and a 4 kW Rh lamp was used.
- ◆ Mineralogical composition was investigated by the XRD method, Seifert FPM XRD 7 analyzer (measuring range  $2\theta = 5\text{--}60^\circ$ , detector – scintillation counter, Cu anode, anode current – 29 mA, lamp voltage – 35 kV, counting time – 3 s, counter movement –  $0,05^\circ$ ) was used.
- ◆ Grain size distribution of raw materials was carried out by sieve and areometric method.
- ◆ Simultaneous Thermal Analysis (STA) measurements of sludge (dried and milled to a grain size below  $60\ \mu\text{m}$ ) were carried out with Netzsch Jupiter 449F3 analyzer at temperature range  $20\text{--}1000^\circ\text{C}$  (heating rate  $10^\circ\text{C}/\text{min}$ , atmosphere: ‘synthetic air’, dynamic flow  $40\ \text{ml}/\text{min}$ ). At the same time Evolved Gas Analysis (EGA) was carried out by using mass spectrometer QMS 403 Aëolos.

- ◆ Thermal behavior of masses and precisely linear changes during heating were made with a DIL802 dilatometer from BÄHR-Thermoanalyse GmbH (heating rate 10°C/min, holding time in maximum temperature 10 min, cooling –20°C/min).
- ◆ Characteristic temperatures were determined in heating microscope Hesse Instruments with automatic registration of sample volume changes in the entire measuring range based on measurements of the area of the sample outline.

A few pieces of dried sludge were fired and subjected to steam exposure in order to verify their stability. After summarizing the research, it was possible to set out the directions of waste utilization.

## 2. Results and discussion

### 1.2. Physicochemical analysis

Semiquantitative chemical analysis are shown in Table 2. Dolomite sludge – DS has three times more content of  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  than limestone sludge – LS. Is due to higher clay mineral content. Also, the higher content of  $\text{K}_2\text{O}$  in DS is due to higher content of clay mineral (mainly illite). DS is characterized by more than twice  $\text{Fe}_2\text{O}_3$  content. After firing at 1000°C it has reddish color (Phot. 2).



Phot. 2. Lumps of washing aggregates sludges  
a – after firing, b – after 4 hours of steam subjection; DS – fired lumps of dolomite sludge,  
LS – fired lumps of limestone sludge – LS

Fot. 2. Bryłki szlamów z płukania kruszyw: a – po wypaleniu, b – po 4-godzinnym kontakcie z parą wodną;  
DS – szlam z płukania kruszywa dolomitowego, LS – szlam z płukania kruszywa wapiennego

Limestone sludge has twice as much as dolomite sludge CaO content, which is due to carbonates (mainly calcite) content. DS has 7 times more MgO, which is due to dolomite content. High carbonate content in limestone sludge was confirmed by XRD measurement results (Fig. 1) and STA (Fig. 4), EGA (Fig. 5). These results and the small clayey mineral content (Fig. 1, Table 2) suggest that it cannot be used as the main raw material in building ceramic masses, but only as an additive.

Table 2. Semiquantitative chemical analysis (XRF) of sludges

Tabela 2. Analiza półilościowa (XRF) szlamów

Oxide	DS	LS
SiO <sub>2</sub>	30.6	10.9
Al <sub>2</sub> O <sub>3</sub>	11.1	4.7
Fe <sub>2</sub> O <sub>3</sub>	4.2	1.6
TiO <sub>2</sub>	0.7	0.5
CaO	22.6	44.3
MgO	3.1	0.5
K <sub>2</sub> O	2.5	0.6
Na <sub>2</sub> O	0.1	0.1
SO <sub>3</sub>	0.7	0.1
LOI	24.0	36.1
Sum	99.6	99.4

DS – dolomite sludge, LS – limestone sludge.

Fig. 1 presents the mineralogical composition of sludges. It confirms a higher content of illite in dolomite sludge – DS and higher content of calcite in limestone sludge – LS. The results are consistent with the statements based on the chemical composition analysis. Limestone sludge has a small amount of kaolinite, the presence of which was not recorded in dolomite sludge. Dolomite sludge contains small amounts of goethite – FeO(OH), the presence of which was not found in the limestone sludge sample tested using the XRD method, but the results of thermal analysis suggest its presence (Fig. 4–5). Goethite presence is reflected in high Fe<sub>2</sub>O<sub>3</sub> content (Table 2). Limestone sludge has a higher amount of quartz, which can increase sintering temperatures and decrease plasticity.

The grain size distribution of raw materials is presented in Table 3. Dolomite sludge is clearly more fine-grained. Grains with a size above 0.5 mm present in limestone sludge are potentially hazardous. After firing, they can cause chipping due to presence of coarse active

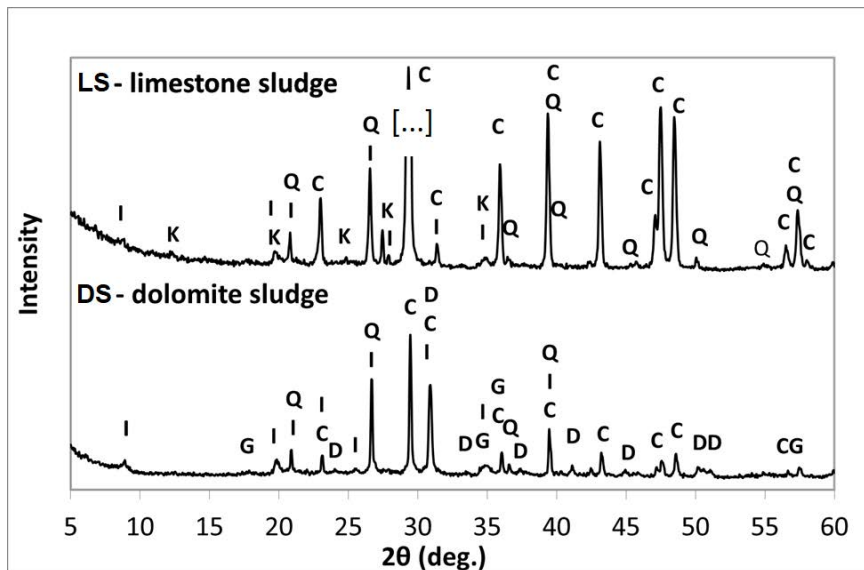


Fig. 1. XRD curves of dolomite sludge – DS and limestone sludge – LS; C – calcite, D – dolomite, G – goethite, I – illite, K – kaolinite, Q – quartz

Rys. 1. Dyfraktogramy szlamu z płukania kruszywa dolomitowego – DS i szlamu z płukania kruszywa wapiennego – LS

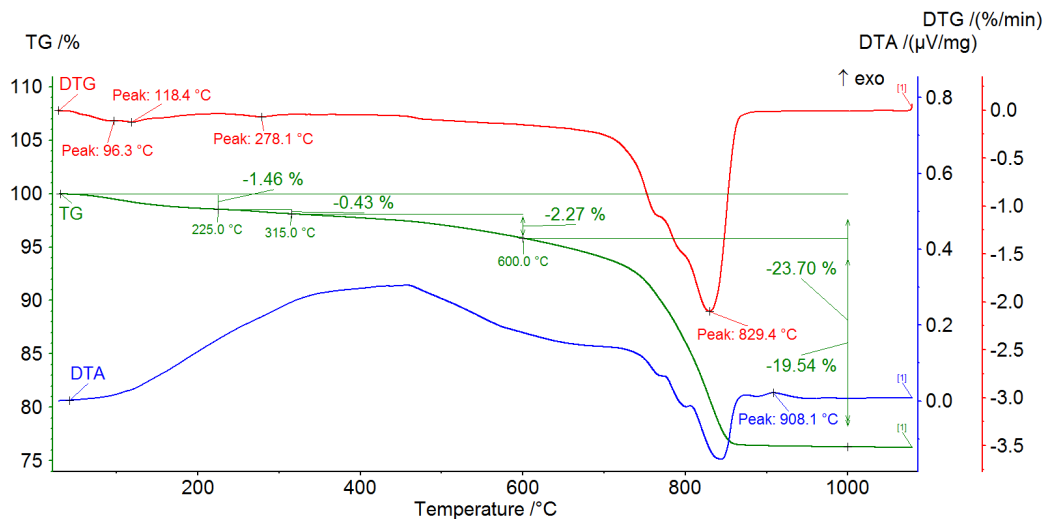


Fig. 2. DTA/TG/DTG curves of dolomite sludge – D

Rys. 2. Krzywe STA szlamu z płukania kruszywa dolomitowego – DS

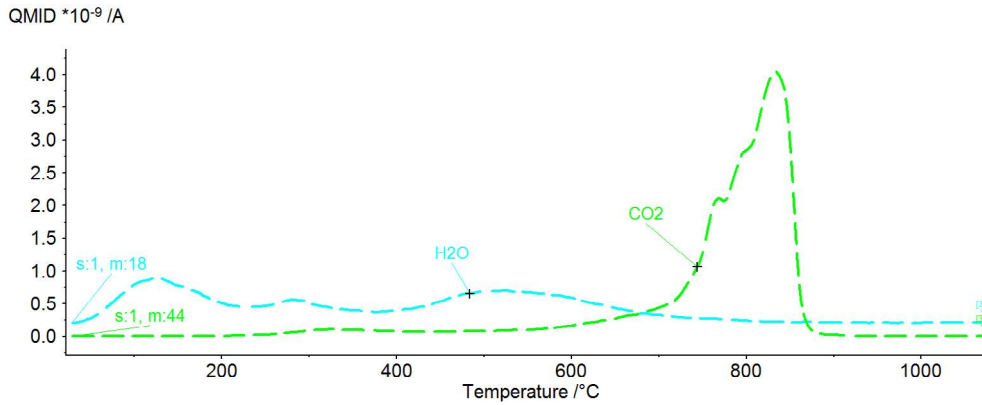


Fig. 3. EGA curves of dolomite sludge – DS

Rys. 3. Krzywe EGA szlamu z płukania kruszywa dolomitowego – DS

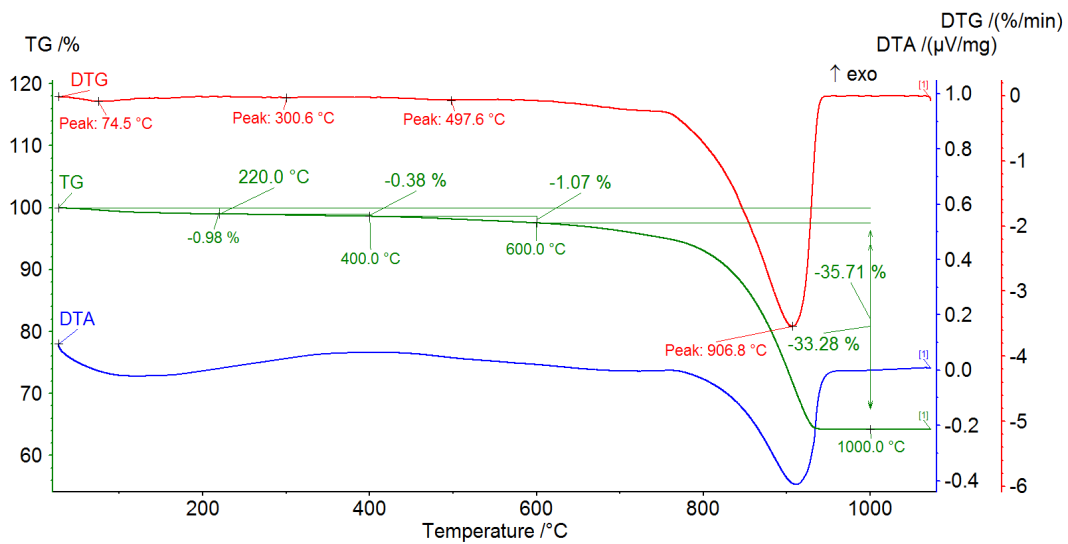


Fig. 4. DTA/TG/DTG curves of limestone sludge – LS

Rys. 4. Krzywe STA szlamu z płukania kruszywa wapiennego – LS



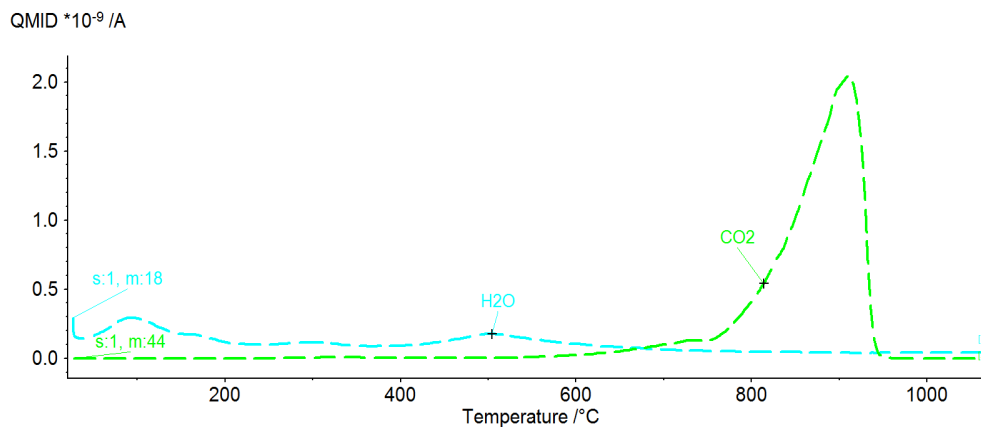


Fig. 5. EGA curves of limestone sludge – LS

Rys. 5. Krzywe EGA szlamu z płukania kruszywa wapiennego – LS

Table 3. Grain size distribution of raw materials

Tabela 3. Uziarnienie szlamów

Fraction	Percentage share of faction [% mas]	
	DS	LS
[mm]	Sieve analysis	
2.0–4.0	–	1.01
1.0–2.0	–	3.23
0.5–1.0	0.03	4.02
0.25–0.5	0.07	3.36
0.125–0.25	0.31	6.76
0.63–0.125	1.50	9.03
<0.063	98.09	72.63
[µm]	Areometric analysis	
>20	12.1	37.9
2–20	36.7	39.1
<2	52.2	23.0

DS – dolomite sludge, LS – limestone sludge.

CaO grains. They can react with humidity, increasing their volume and destroying the fired material. The amount of grains with a diameter above 0.5 mm in LS is 8.26%, which disqualifies the possibility of use the sludge in an unchanged form. Before use limestone sludge in building ceramics industry, grinding is necessary.

The areometric analysis revealed that dolomite sludge has a high content of clayey substance, which can affect the increased kinetics of sintering. The areometric analysis confirmed greater coarseness of limestone sludge.

## 2.2. Thermal analysis

Figure 3 and 5 present Simultaneous Thermal Analysis STA respectively for dolomite – DS and limestone sludge – LS. The weight loss in the temperature range 600–1000°C is due to carbonate (calcite and dolomite) thermal decomposition. It is higher for limestone sludge – LS which indicates a greater amount of carbonates present in the raw material.

The EGA curves of DS and LS samples are shown in Figure 4 and 6. The results are presented in the form of ionic current curves in the function of the temperature for CO<sub>2</sub> (m/z = 44) and H<sub>2</sub>O (m/z = 18). The EGA curves of both samples show that water is released in three steps between 20 and 200°C, 200 and 400°C, 400 and 600°C in a very small quantity. The first release of water is due to the dehydration of clay minerals. Weight loss up 200°C is higher for dolomite sludge, due to the high content of clay minerals (mainly illite). This is compatible with the XRD analysis and confirmed in the results of the semiquantitative

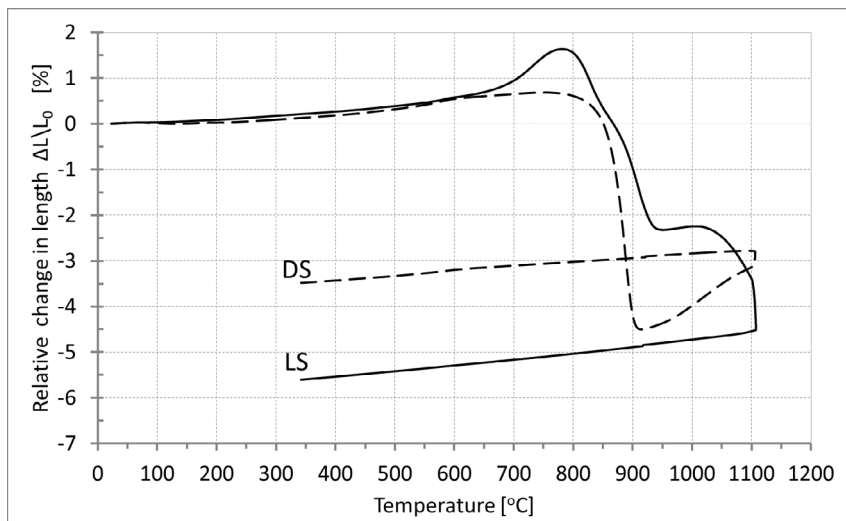


Fig. 6. Dilatometric curves of dolomite sludge – DS and limestone sludge – LS

Rys. 6. Krzywe dylatometryczne szlamu z płukania kruszywa dolomitowego – D i szlamu z płukania kruszywa wapiennego – LS

chemical analysis – the high content of  $K_2O$  (Table 2) and the grain size distribution of raw materials – a higher quantity of fractions below  $2\ \mu\text{m}$  (Table 3). The second release of water is due to the dehydration of goethite. According to (Zhang et al. 2010), the release of water from goethite structures occurs in the temperature range between  $265\text{--}372^\circ\text{C}$ . The presence of goethite was not confirmed in the calcite sludge sample (Fig. 1). An increase of the ion current for  $H_2O$  connected with a slight increase of the ion current for  $CO_2$  in the dolomite sludge sample is caused by the firing of organic matter (Fig. 3). The third release of water is due to the dehydroxylation of clay minerals. This effect on the ion current curve has a sharper course in the case of calcite sludge (Fig. 5). This is due to the presence of kaolinite. In dolomite sludge illite dominates and the effect of its dehydroxylation is gentler (Fig. 3). The value of the ion current strongly depends on the mass of the sample, therefore it is not compared. The carbon dioxide release occurs between  $600^\circ\text{C}$  and  $900^\circ\text{C}$  in three stages for DS (Fig. 3) and between  $600^\circ\text{C}$  and  $980^\circ\text{C}$  in one stage for LS (Fig. 5). The first effect is due to dolomite and calcite decomposition to  $MgO$  and  $CaO$  and the second effect is due to calcite decomposition to  $CaO$ .

Dilatometric curves of dolomite sludge – DS and limestone sludge – LS are presented in Fig. 6. The relative change in length at the end of the measurement is higher for LS and it is equal to  $-5.6\%$  (for DS it is equal to  $-3.5\%$ ). The following effects are marked on the dilatometric curves:

- ◆ High temperature expansion associated with the increase in interatomic distances, typical of most of the solids. For the DS sample this effect is visible up to  $775^\circ\text{C}$  (with a  $+0.7\%$  relative change in length) and for LS up to  $790^\circ\text{C}$  (with a  $+1.6\%$  relative change in length).
- ◆ Strong shrinkage associated with decarbonation and solid state sintering. For the DS sample this effect is visible from  $775^\circ\text{C}$  to  $915^\circ\text{C}$  (with  $-3.8\%$  relative change in length) and for LS up to  $790^\circ\text{C}$  to  $945^\circ\text{C}$  (with  $-0.7\%$  relative change in length). The higher effect for DS results from finer grain size of DS and a greater amount of fractions below  $2\ \mu\text{m}$  (Table 3). Despite the high content of calcite in LS (Table 2, Fig. 1 and Figs. 5–6) a relative change in length is significantly smaller than in the DS sample due to sintering dominance over decarbonation.
- ◆ Reaction in solid state and reaction sintering. For the DS sample this effect is visible from  $915^\circ\text{C}$  to the end of the measurement (relative change in length is  $+1.7\%$ ). For LS sample this effect is visible from  $945^\circ\text{C}$  to  $1015^\circ\text{C}$  (the relative change in length is  $+0.1\%$ ). A higher relative change in length for DS is proof of the high kinetic  $CaO$  (and  $MgO$ ) reaction with clay minerals. This also results from finer grain size of DS and greater amount of fractions below  $2\ \mu\text{m}$  (Table 3).
- ◆ Sintering with small amount of liquid phase. This effect is visible only for the LS sample, from  $1015^\circ\text{C}$  to the end of heating (relative change in length is  $-2.3\%$ ).
- ◆ Osostatic sintering with  $-1.03\%$  and  $+0.34\%$  relative change in length respectively for limestone and dolomite sludge.
- ◆ Cooling to  $400^\circ\text{C}$  with no clear effects on cooling curves.

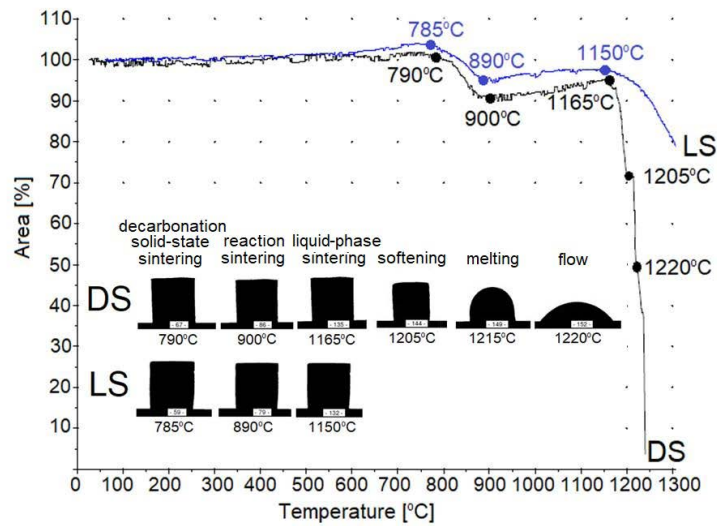


Fig. 7. Heating microscopy results of dolomite sludge – DS and limestone sludge – LS

Rys. 7. Wyniki mikroskopii wysokotemperaturowej: szlam z płukania kruszywa dolomitowego – DS, szlam z płukania kruszywa wapiennego – LS

Table 4. Characteristic temperatures from heating microscopy results of raw materials: DS – dolomite sludge and LS – limestone sludge

Tabela 4. Temperatury charakterystyczne określone metodą mikroskopii wysokotemperaturowej: DS – szlam z płukania kruszywa dolomitowego, LS – szlam z płukania kruszywa wapiennego

Characteristic temperature	DS		LS	
	temperature [°C]	area of sample outline [%]	temperature [°C]	area of sample outline [%]
Beginning of decarbonation and solid state sintering	790	101	785	104
End of decarbonation/start of reaction in solid state and reaction sintering	900	92	890	95
Start of sintering with small amount liquid phase	1 165	96	1 150	98
Softening temperature	1 205	72	nd	nd
Sphere temperature	1 215	71	nd	nd
Flow temperature	1 220	56	nd	nd

nd – not determined.

Dilatometric curves indicates a greater ability to react between clay minerals and oxides from decarbonated carbonates (CaO and MgO).

For further consideration of sintering, the heating microscopy results should be analyzed (Table 4 and Fig. 7). The temperatures of the beginning of decarbonation and solid state sintering, the end of decarbonation and the start of reaction in the solid state and reaction sintering and also the temperatures of the start of sintering with small amount liquid phase differ insignificantly between sludges. The differences are not as significant as differences in the softening temperature. The softening temperature for limestone sludge was not determined – it can be over 1300°C. The softening temperature for dolomite sludge is 1205°C and the flow temperature is 1220°C. A smaller temperature of the forming liquid phase for DS is due to the high quantity of glass-forming oxides such as: SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> (Table 2) and the high content of small grains (Table 3) probably containing fluxing agent such as: CaO, MgO, Fe<sub>2</sub>O<sub>3</sub>, K<sub>2</sub>O.

Characteristic temperatures from heating microscopy results suggest that both raw materials can be used in building ceramic technology. However, limestone sludge cannot be used without processing due to its coarseness (Table 3).

### 2.3. Firing test

To verify the applicability of raw materials without processing for the building ceramic industry, lumps of washing aggregates sludge were collected, dried and fired at 1000°C for 2 hours. After firing, the samples were subjected to steam. After 15 minutes of steam subjection, the fired lumps of limestone sludge crumbled into small grains, which confirms the previous assumptions based on sieve analysis (Table 3). It confirmed that limestone sludge must be ground before its application in building ceramic technology and suggests that it can be used as an additive not as the main raw material in building ceramic masses. Fired lumps of dolomite sludge after 4 hours of steam subjection (Phot. 2) were unchanged after firing. This positive result suggests possibility of its application in building ceramic technology.

In order to verify the obtained results, it is necessary to carry out research on the possibility of using dolomite and limestone sludge for specific ceramic products with the study of their material properties.

## Conclusions

In this paper preliminary research on the possibility of using washing aggregates sludges in the building ceramics technology was conducted. Selected properties of dolomite sludge and limestone sludge such as: water content, particle size distribution (by using sieve and areometric method), chemical composition (by using XRF method), mineral composition

(by using XRD method), thermal properties (by using thermal methods: STA/EGA, dilatometry, heating microscopy) and the stability of fired materials during steam exposure were determined.

For tested samples of materials it was found that:

- ◆ Dolomite sludge contains more clay minerals and less carbonates than limestone sludge.
- ◆ Dolomite sludge is more finely grained than limestone sludge.
- ◆ Limestone sludge has large fluctuations in water content and has a high content of potentially hazardous calcite grains compared to dolomite sludge.
- ◆ During heating up to 1300°C of both dried sludges, decarbonation and sintering take place. Dolomite sludge softens, melts and flows below 1300°C. Such behavior was not observed for limestone sludge.
- ◆ After firing sludges at 1000°C, material made of limestone sludge is not resistant to steam.

The obtained results suggest the possible application of sludges in building ceramic technology. However, research on a larger number of samples is required. Analyzing the presented results it can be assumed that:

- ◆ Dolomite sludge can be used in ceramic technology without processing as single component of ceramic masses, although it is necessary to carry out research on the properties of fired materials and comparison to requirements for properties of specific ceramic products for this purpose;
- ◆ Limestone sludge has to be ground before its application in ceramic technology and results suggest that it cannot be used as the main raw material in ceramic masses, but only as an additive.

To verify the obtained results, carrying out technological research on the properties of fired materials from sludges is necessary. Comparison with the requirements for properties of specific ceramic materials is essential. Due to the high variability of sludge properties, which is caused by the diversity of rinsing processes and the changeability of dolomite and limestone deposits, in order to obtain reliable results, tests should be performed on a larger number of samples.

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**RESEARCH ON THE POSSIBILITY OF USING SLUDGES FROM WASHING DOLOMITE  
AND LIMESTONE AGGREGATES IN THE BUILDING CERAMICS TECHNOLOGY**

**Key words**

thermal analysis, washing aggregate sludge, limestone sludge, dolomite sludge, building ceramics

**Abstract**

Washing is very popular technological operation removing clay particles from aggregates. The amount of mineral washing sludges increases. Besides filling the excavations, there is no common method of their utilization. The usage of sludges from washing aggregates in building ceramics might be environmentally friendly way to utilize them.

This paper presents laboratory research on two type of sludges: from dolomite and limestone aggregates washing. Selected properties of sludges such as water content, particle size distribution (sieve and areometric method), chemical composition (XRF), mineral composition (XRD), thermal properties (STA/EGA, dilatometry, heating microscopy) and stability of fired materials during steam exposure were determined.

It was found that dolomite sludge contains more clay minerals and less carbonates, it is more finely grained than limestone sludge. Limestone sludge has large fluctuations in water content and has high content of potentially hazardous calcite grains. During heating up to 1300°C of both dried sludges decarbonation and sintering take place. Dolomite sludge softens, melts and flows below 1300°C. After firing sludges at 1000°C material made of limestone sludge is not resistant to steam.

The obtained result suggests that dolomite sludge can be used in building ceramics technology without processing as main component of ceramic mass. Limestone sludge have to be ground before its application in building ceramic materials. Results suggest that it can not be used as the main raw material in ceramic masses, but only as an additive.

**BADANIA MOŻLIWOŚCI ZASTOSOWANIA SZLAMÓW Z PŁUKANIA KRUSZYW  
DOLOMITOWYCH I WAPIENNYCH W CERAMICE BUDOWLANEJ**

**Słowa kluczowe**

szlam z płukania kruszywa, szlam wapienny, szlam dolomitowy,  
analiza termiczna, ceramika budowlana

**Streszczenie**

Płukanie jest operacją technologiczną pozwalającą na usunięcie z kruszyw minerałów ilastych. Z roku na rok ilość szlamów powstających podczas płukania kruszyw wzrasta. Poza rekultywacją obszarów kopalni, nie ma powszechnej metody utylizacji tych odpadów. Możliwość użycia szlamów z płukania kruszyw wapiennych w ceramice budowlanej może być przyjazną środowisku metodą ich wykorzystania.

W artykule przedstawiono wybrane badania laboratoryjne dwóch szlamów z płukania kruszywa: dolomitowego i wapiennego. Odpady scharakteryzowano pod względem zawartości wody, składu granulometrycznego (analiza sitowa i areometryczna), chemicznego (XRF) i mineralnego (XRD), właściwości termicznych (STA/EGA, dylatometria, mikroskopia wysokotemperaturowa) oraz trwałości spieków w obecności pary wodnej.

Stwierdzono, że odpad z płukania kruszywa dolomitowego zawiera więcej minerałów ilastych i mniej węglanów oraz jest bardziej drobnoziarnisty niż odpad z płukania wapienia. Odpad z płukania kruszywa wapiennego charakteryzują duże wahania zawartości wody i duża zawartość potencjalnie niebezpiecznych ziaren kalcytu. Podczas ogrzewania wysuszonych próbek szlamów do 1300°C zachodzi dekarbonatyzacja i spiekanie. Odpad z płukania kruszywa dolomitowego mięknie, topi się i płynie przed osiągnięciem temperatury 1300°C. Po wypaleniu szlamów w 1000°C spiek ze szlamu wapiennego nie jest odporny na działanie pary wodnej. Odpad z płukania kruszywa dolomitowego może być wykorzystany w ceramice budowlanej bez jego przetwarzania jako podstawowy składnik mas ceramicznych.

Odpad z płukania kruszywa wapiennego nie nadaje się do zastosowania w ceramice budowlanej bez jego poprzedniego zmielenia. Jego właściwości sugerują możliwość zastosowania go jedynie jako dodatek do mas ceramicznych, nie jako ich główny składnik.