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EFFECT OF SEWAGE SLUDGE ADDITION ON POROSITY OF LIGHTWEIGHT EXPANDED CLAY AGGREGATE (LECA) AND LEVEL OF HEAVY METALS LEACHING FROM CERAMIC MATRIX

The results of using municipal sewage sludge as a component of porous ceramic sinters are described. Due to high porosity the ceramic sinters can be widely applied and we have focussed on ecological aspect of this application.

The results of the gaseous pollutant emission measurements carried out during industrial test are presented. Metal leaching from the end product was also tested. It was found that metals were fixed within the sinter structure. The ash matter from sludge was embodied into the solid phase.

1. INTRODUCTION

An inevitable by-product of a wastewater treatment plant is municipal sewage sludge. In EU countries, the amount of the sewage sludge produced has continuously increased [12] due to the implementation of the Directive no. 91/271/EEC [7], which requires the states to increase the number and efficiency of wastewater treatment plants. The utilization of sewage sludge is a global problem.

Sewage sludge contains 40–80% of organic matter (60% on average) [10]. Organic matter, phosphorus, potassium and microelements allow sewage use in agriculture but a high content of heavy metals [1], [19] limits its natural usage according to the Directive no. 86/278/EEC [5]. Organic pollutants (AOX, PAH) present in sewage sludge resulted in the application of strict criteria concerning their utilization [17]. The requirements of the Directive 99/31/EC [8], limiting the amount of wastes in storage yards, and the restrictions on natural utilizing of sewage sludge lead to the search for waste-free methods of its utilization. Previously published attempts to use sewage sludge in ceramics ended in failure.

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The research carried out by TAY and SHOW [20] proved that organic substances from sewage sludge introduced to the brick raw material mass resulted in the reduction of product's quality (deformation). LIEW with his team [15], [16] noticed the expansion of bricks as a result of the organic substance disintegration from the sludge during the process of burning out. BALGARANOVA and others [2] also found a negative influence of municipal sewage sludge addition on the usable properties of bricks.

According to JORDAN [13], sewage sludge added to clay used for the production of roofing-tiles improved water absorption by ceramic sinter.

The reason for failure in those publications is the natural tendency for sewage sludge to degas in the process of heat treatment. This characteristic was considered an advantage by the authors of this paper, provided that the purpose is to obtain high-porous sinters. An example is a sintered aggregate of LECA type, which is widely applied (building industry, road engineering, gardening).

The formulated hypothesis was proved by the laboratory tests and the next step was a test in an industrial plant.

The aim of the research presented hereafter was to prove the results of the laboratory tests under industrial conditions and to demonstrate that such a method of sewage sludge utilization does not pose any threat to the environment.

LECA is produced by burning out the expanding clay in a rotary kiln at 1100–1200 °C. The emitted gases are blocked in pores due to a high viscosity of the liquid phase. The liquid phase blocked in the pores causes the expansion of granules [11]. If natural raw materials do not meet technological requirements, technological additives are used [4].

2. MATERIALS AND METHODS

The industrial test was conducted in "Keramzyt PKL", Ceramic Plant in Mszczonów, and lasted 8 hours. The clay extracted in a plant mine ("Budy Mszczonowskie" deposit) belongs to a clay category of low technological parameters (low expanding factor). Therefore, it was decided to add sewage sludge instead of other technological additives to the raw material mass to obtain a highly porous texture in the process of ceramic material sintering.

The sewage sludge was taken from the storage yard at Sitkówka-Nowiny sewage treatment plant near Kielce. The characteristics of raw materials, i.e. clay and sewage sludge, used in the industrial test are presented in table 1.

Due to the level of sludge moisture and admissible moisture of the charge (not higher than 26%), the mass fraction adjusted to a dry matter basis of the sewage sludge in a raw material mixture equalled 4%. This was equivalent to 15% mass fraction in the state of sewage natural moisture. 120 Mg of clay and 21 Mg of sewage sludge (of natural moisture) were used in the industrial test. During this test, 75 m^3 of aggregate were produced.

Table 1

Characteristics of sewage sludge and clay used in research on technological scale

Parameter	Unit	Sewage sludge	Clay
Moisture content*	%	80.3**	18.9
pH	–	7.5	–
Organic matter	% d.m.	65.2	2.0
Pb	mg Pb/kg d.m	39.9	6.4
Cu	mg Cu/kg d.m	31.9	1.8
Zn	mg Zn/kg d.m	820.1	82.9
Ni	mg Ni/kg d.m	8.0	8.5
Cr	mg Cr/kg d.m	49.8	35.7
Hg	mg Hg/kg d.m	0.0	0.0
Fe	mg Fe/kg d.m	824.5	16328.6
Mg	mg Mg/kg d.m	36807	852.6
Ca	mg Ca/kg d.m	22222***	1651.4
Na	mg Na/kg d.m	–	162.6
K	mg K/kg d.m	–	1971.4

* In the case of clay – the moisture in the natural state.
** High moisture of sludge was the result of long and intensive snowfalls before the sludge was taken from the storage yard.
*** High concentration caused by sludge liming.

The kiln was 40 m long (diameter: 2.5 m). The raw material was kept in an industrial rotary kiln for 45 minutes, in this, 10 minutes in the area of a maximum temperature of 1170 °C. The temperature at the kiln inlet was 550 °C, and 200 °C at the outlet. The kiln operated under oxygen conditions.

2.1. EMISSION OF GASEOUS POLLUTANTS

During industrial test, the pollutant emission into the atmosphere was measured (figure 1). The sampling point was located on the chimney behind the fabric filters. In order to determine the emission level of gaseous pollutants in combustion gases, a combustion gases microprocessor analyzer with a combustion gases dryer was used.

The measurements of heavy metal content in the emitted dust were made by collecting the dust samples in quartz filters. Next, metal content was determined with the atomic absorption spectrophotometer (SHIMADZU AA-660 type). The results presented are the averages of 3 measurements.

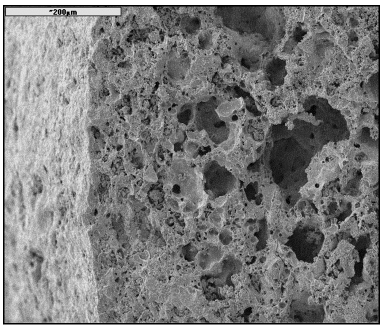
2.2. LEACHING STUDY

The procedure used in extract preparation from the sinters for the chemical analysis was maximum leaching (ML), the method described in [18]. The leaching process lasts 5 hours, pH of leaching medium is 4.0, and a sample is ground up to < 125 μm and processed in a shaker.

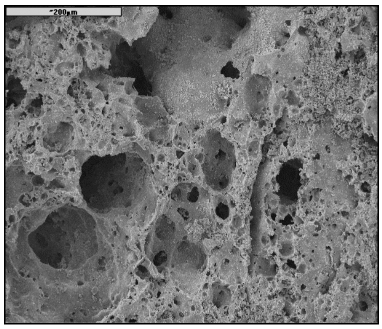
A quantitative determination of chemical elements in water extracts was made with an atomic absorption spectrophotometer. The results obtained are the averages of 3 measurements.

3. RESULTS AND DISCUSSION

Our aim was achieved: sewage sludge added to the aggregate raw mass radically increased both aggregate porosity (up to 63.4%) and the expanding factor, which was proved by the microscopic examination (photo).



a)



b)

SEM of polished sections of modified aggregate:
a) edge of grain; b) middle of grain, magn. 200×

In the combustion gases emitted from the rotary kiln, a greater stream of dust mass was observed during the burning out of the raw material with an addition of sewage sludge (table 3). This was a consequence of a slightly increased fuel consumption due to a greater moisture of the raw material mixture caused by the addition of wet sewage sludge and a slightly lower calorific value of the fuel used in the day of the industrial test (table 2).

During burning out the raw material mass mixed with sewage sludge a larger quantity of SO_2 was emitted because of a higher sulphur content in the fuel (table 2).

Table 2

Parameters of fuel used for heating industrial kiln in "Keramzyt" PKL plant

Parameter	Hard coal dust (< 1 mm fraction)	
	Industrial test	Commercial aggregate production
Calorific value	22 MJ/kg	23.5 MJ/kg
Ash content	15%	15%
Sulphur content	0.8%	0.7%

Table 3

Emissions of gaseous pollutants determined by industrial test in comparison with production of commercial aggregate and permissible levels

Pollutants	Industrial test aggregate (kg/h)	Commercial LECA (kg/h)	Permissible value [9]* (kg/h)
Dust	1.289 ±0.1403	0.574 ±0.0298	21.206
SO_2	9.455 ±0.9015	7.278 ±0.8596	20.48
NO_x	5.472 ±0.3751	6.572 ±0.3761	16.568
CO	3.116 ±0.1873	5.956 ±1.3758	32.994
Zn	0.0018 ±0.0005	0.0001 ±0.0001	0.018
Pb	0.0009 ±0.0008	0.0012 ±0.0009	0.011
Cd	0.00007 ±0.00005	0.00007 ±0.00005	0.002
Cr	0.0009 ±0.0004	0.0002 ±0.0001	0.127
Cu	0.0004 ±0.0002	0.0001 ±0.0000	0.141

* According to decision of Mazowieckie Voivodeship Governor (20.08.2001); currently the standards applied in "Keramzyt" PKL are being adjusted so as to comply with the UE directives.

Any of the pollutants emitted did not exceed the permissible values given in [9], and in the case of nitrogen oxides, carbon oxide and lead, they were lower than the emissions recorded during the production of the commercial aggregate (table 3).

As regards the extracts preparation method according to the ML procedure, it must be noticed that LECA used in building industry, gardening and environmental engineering is not exposed to such destructive conditions as grinding (<125 μm) and strongly acidic environment (pH = 4) (table 4).

Table 4

pH value and electrical conductivity of water extracts obtained from ceramic sinters

Water extracts acc. to ML method [9]	pH of water extract	Electrical conductivity of water extract (μS /cm)
Modified aggregate* fraction, 0–40 [mm]	6.45	7.69
Commercial LECA** fraction, 0–40 [mm]	6.45	15.5

* Lightweight Expanded Clay Aggregate (LECA) obtained during industrial test.

** Comparative test.

Full protection against the leaching of heavy metals from ceramic sinters is guaranteed by conducting the process at a temperature providing a sinter of a high glass phase fraction. Reaching such a state is in contradiction with the aim, which in the case of LECA is to obtain a sinter of high porosity.

Table 5

Leaching of metals from aggregates according to ML method [18]

Heavy metals	Industrial test aggregate (mg/dm^3)	Commercial LECA (mg/dm^3)	Permissible limits in surface water acc. to [21] (mg/dm^3)	
			Recommended	Permissible
Cu	0.000 ± 0.000	0.000 ± 0.000	0.02	0.05
Pb	0.001 ± 0.001	0.004 ± 0.001	–	0.05
Fe	0.013 ± 0.006	0.005 ± 0.006	0.1	0.3
Zn	0.008 ± 0.003	0.009 ± 0.003	0.5	3.0
Cd	0.001 ± 0.001	0.001 ± 0.000	0.001	0.005
Cr	0.006 ± 0.002	0.004 ± 0.001	–	0.05
Ni	0.001 ± 0.002	0.006 ± 0.002	–	0.05
Hg	0.000 ± 0.000	0.000 ± 0.000	0.0005	0.001
Mn	0.022 ± 0.004	0.016 ± 0.013	0.05	0.05

4. CONCLUSIONS

The conducted research allows the following conclusions to be drawn:

• Sewage sludge added to the aggregate raw material mass increases the porosity of sinters.

• The level of pollutants' emission into the atmosphere during the production of aggregate with the addition of sewage sludge does not pose a threat to the natural environment.

• The solubility of the sinter components measured conductometrically decreased in consequence of the sludge used.

• The leaching of heavy metals from the LECA sinter matrix is within the allowable limits.

• The composition of sewage sludge, especially heavy metals' content, does not make the sludge useless in the production of aggregate, as it does in the case of agricultural or natural neutralization of sludge.

• The technology proposed is a waste-free method of utilizing sewage sludge; ash matter is embodied within the ceramic sinter structure.

ACKNOWLEDGEMENTS

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WPŁYW DODATKU OSADÓW ŚCIEKOWYCH NA POROWATOŚĆ KERAMZYTU
I POZIOM WYMYWANIA METALI CIĘŻKICH Z MATRYCY CERAMICZNEJ

Przedstawiono wyniki badań nad wykorzystaniem komunalnego osadu ściekowego jako komponentu porowatego spieku ceramicznego. Spiek charakteryzuje się zwiększoną porowatością i może znaleźć wielorakie zastosowanie. Uwagę skoncentrowano na aspekcie ekologicznym.

Podano wyniki emisji zanieczyszczeń gazowych zmierzone podczas próby technicznej w zakładzie przemysłowym. Badano także ługowanie metali z otrzymanego produktu. Stwierdzono, że metale zostały unieruchomione w strukturze spieku. Substancja popiołowa zwarta w osadzie wbudowała się w fazę stałą.