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THE ENRICHMENT OF THE CERAMIC CLAYS FROM THE WASTES OF THE ZEBRZYDOWA MEVE

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ABSTRACT: The reserves of the largest Polish deposit of the ceramic stoneware clays are decreasing. A further exploitation of this deposit is connected with the large costs of purchase of the wooded land Taking over the forests consequently generates an irreversible land degradation

The growth of the loam production is possible only in the case of the utilization of clays which, according to the current criteria, are the wastes. It is necessary to enrich the wastes collected on dumps during 27 years of the mining activity of the Zebrzydowa mine. The wastes are loamy sandy-gravelly binds, clays below the standard requirements due *to* their size under 5; 1 ; 0.06 mm, clays with lignite inclusions and brown coal binds The average content of the clay material grained below 0.06 mm is near 50%.

In the paper the conditions and results of the investigations on wastes washing, screening, classification in hydrocyclones, sedimentation, filtration and centrifugation of finegrained clay suspensions have been described. A proposal of technological system of the *wastes* enrichment has been presented The application of this system contributes to obtaining a very plasticity stoneware clay of high refractory and bending strenght.

1. INTRODUCTION

Stoneware clays are plastic clay rocks which can be well-sintered at 1000-1300°C and which, after burning, result in ceramic products of sintered structure, characterised by low absorbability, high mechanical strength and chemical resistance. They are the basic *component of* ceramic bodies *used* for manufacturing of acid-resistant stoneware for the chemical industry, construction stoneware (wall and floor tiles), stoneware sanitary fittings, sewage fittings and household vessels.

No processing of stoneware clays has been applied in Poland so far (except blending) Only these parts of the deposit were mined whose raw material could be directly applied by buyers (i e. ceramic factones) At present, since the cfay deposits are decreasing, it is necessary to enrich the dumped wastes which contain large quantities of clays An appropriately selected scheme of wastes processing is the condition of recovery of the clay material.

2. CLAY WASHING AND SCREENING

The process of washing of clay rocks is one of significant elements of the technological process in the plants producing clay concentrates and the plants utilitizmg clay raw materials (eg ceramic factories). This process is labour- and energy-consuming, and m many cases it may cause technological losses resulting from dumping the unwashed parts. The present manufacturing *experience* contributes *to* the statement saying that the higher is the content of the clay concertrate in the raw material, the higher plasticity and strength of the clay raw material, the more difficult is the course of the process of washing *out. In practice, slime* is a *suspension of* the clay substance which can be screened through a sieve The definitions of „clay substance" mention screening through the sieve of the meshes d_T = 0,04 or 0 063 mm In fact, to differentiate slimes from conglomerates it is enough to use the *sieve of the* meshes of d_r = 1 or even 2 mm. Fine conglomerates (< 2 mm) wash out easily and quickly.

The washing out of the waste clay of Zebrzydowa was performed *m* the drum washer of 120 dm* capacity The number of drum rotations was 24 per minute. The variable conditions of the process were as follows

- content of solid parts in the feed - a_r [%],
- time *of process duration - t [min]*

After the process of washing out which lasted from 10 to 60 minutes the suspension was transported onto the laboratory vibrating screen with water spiay and the screen meshes were d_r- = 1 *mm* The screen area was 12 m x 02 m. The experiments used - 1 Mg of wastes The samples representative for determinations of the content of particle classes smaller than 1 mm and 0.063 mm ($a_{u<1}$, $a_{u<0.063}$) were taken from the upper screening products The total masses of the upper products were used for calculating the yields of these products - g_u and, simultaneously, for determining the yields of lower products - gi. The lower products of screening (<1 mm) were collected in special containers for further use. The content of the clay class in these products ($a_{l<0.063}$) was calculated from the balance of this class in the feed and the upper product

In order to evaluate the results of screening the authors calculated, among others, the process effectiveness indicators:

$$S = \frac{\gamma_l}{a_{f<1}} \quad [\%]$$

where: $o_{/<1}$ = content of the class < 1 mm in the screening feed equal to 77.4%, and the recovery of the clay parts in the lower product:

$$\varepsilon = \frac{\gamma_l \cdot a_{l<0.063}}{a_{f<0.063}} \quad [\%]$$

where: $o_{f}{}^{\wedge}{}_{006}$, - content of the clay class in the feed equal to 44 93%.

The values of effectiveness of screening S and recoveries of clay parts e depending on the content of the solid phase in the washed-out feed and the time of washing out are presented in Tables 1 and 2,

Table 1 Dependence of effectiveness of screening of the washed out clay on a and t

Time of washing out t Tminl	Screening effectiveness S [%1				
	a_r \%]				
	20	30	40	50	60
10	62.0	64,1	63 6	63.3	63 0
20	73 3	78.3	78 0	74.0	72.1
30	76.5	81 1	81 3	78.8	79,3
40	79 7	84.0	83 5	84 0	84 0
50	83 3	89 1	86 2	86 7	85 8
60	85.0	91 9	88.9	88 9	88.2

The analysis of the results of investigations of washing out and screening contributes to the following statement

- The yield of the lower product of the subsequent process of screening, the effectiveness of screening and the recovery of the clay fraction in. the lower product increase with the rise of time of clay washing out while the losses of this fraction in the upper product decrease. In the industrial conditions, however, the time of washing out cannot be too long since the process efficiency goes down
- Higher values of the basic technological indicators (gı, S, e) are usually obtained at lower contents of the solid phase in the suspension (a = 20 - 30%), In the course of investigations it was observed that at the high suspension density a = 56 - 60% the secondary aggregation of grains occurred and pellets of the diameter up to 50 mm were formed.
- In order to achieve a satisfactory effectiveness of the process of washing out of the waste stoneware clays of Zebrzydowa this process should be carried out at the content of solid parts in the feed not higher than a = 30% in t = 30 minutes.

Table 2. Dependence of the recovery of the clay class in the lower product on a and t.

Time of washing out t [mini	Recovery of the clay class e \%\				
	ar r%l				
	20	30	40	50	60
10	71.0	72,4	71.3	71.6	70.9
20	87 1	89.3	86.3	81.2	79.6
30	92.6	91.8	90.7	86.5	85.4
40	95.4	92.3	91.4	»7.8	88.2
50	97,0	94.5	90,1	89.6	87.0
60	97.1	95.4	92.9	91.1	87,2

3 CLASSIFICATION OF THE CLAY SUSPENSION IN HYDROCYCLONES

The lower product of screemng of the clay washed out in the drum washer constituted the feed of the classification process The particle size of the suspension solid phase was 0 - 1 mm. The content of the clay class (particles < 0 063 mm) was - 65%, Several series of tests of the single - and double - stage classification of the suspension in the hydrocyclones of f 80, 100 and 200 mm at different hydrocyclone underflow nozzles and different contents of the solid phase in the separated feed were' carried out The aim of the investigations was to determine the construction and movement parameters of hydrocyclone operation which will enable a large overflow yield to be obtained of the

< 63 mm particle content of 99% minimum The hydrocyclone outflow should be characterised by a low content of the clay class.

It was observed that obtaining the assumed separation results will be provided by one stage of classification in the hydrocyclones of the cylinder diameter of 100 mm and the outflow nozzle diameter d_w = 25 mm. The content of the solid parts in the feed passed to the hydrocyclone should be ~ 20%. In order to decrease the losses of the clay fraction passing to the outflow of hydrocyclones (~ 25% of particles < 63 mm) the authors proposed additional washing of this product in a spiral classifier or a hydrocyclone of a larger diameter, e g- 200 or 350 mm. The HC 200 overflow could be directed to the feed container before the hydrocyclones

4. SEDIMENTATION AND FILTRATION OF THE ZEBRZYDOWA CLAY SUSPENSION

Introductory investigations showed that the suspension of the Zebrzydowa clay was characterised by very unfavourable sedimentation properties The fine - particle solid phase of the suspension settles very slowly and the formed sediment cannot reach a satisfactory concentration. If was decided to increase the sedimentation velocity by adding the magnafloc flocculating agents manufactured by Allied Colloids. After many tests and according to the observations of forming of floes and clarity of water the optimum set of coagulating and flocculating agents was selected. The highest efficiency was revealed by Magnafloc 1697 coagulant + Magnafloc 919 anion flocculant.

The overflow of the f 100 mm hydrocyclone of particle size below 63 mm (content of the < 2 mm class * 60% and content of the a solid phase = 12%) was subjected to coagulation and flocculation Also the sedimentation of suspensions of lower concentrations (10 and 5%) was tested For example. Table 3 presents the effects of concentrating of the suspension of the 12% content of the solid phase after 24 hrs of sedimentation with different additives As the data of the Table show, the concentrations of the suspension of the initial content of the solid phase of a = 12%, regardless the number of agents applied, are slightly higher even after 24 hrs of sedimentation and are, on the average, ~ 17%, i e the same as the concentration of the sedimenting suspension without added agents.

The following statements can be formulated

- the sedimentation process of the Zebrzydowa class suspensions is low-effective,
- proportioned amounts of agents do not change significantly the particle settling velocity and final concentration,
- possible increase of adding of coagulating and flocculating agents will rise their amount in the over - sediment water which must be returned to circulation which, consequently, will deteriorate the conditions of clay washing out and classification.

Table 3. The results of the suspension sedimentation of the Zebrzydowa clay

a [%]	12						
r [kg/m^3]	1082						
b [g/dm^3]	130						
Amount of coagulant MAGNAFLOC 1697 [ml]	0	0	10	10	10	10	10
Amount of coagulant MAGNAFLOC 1697 [g/Mg]	0	0	77	77	77	77	77
Amount of flocculant MAGNAFLOC 919 [ml]	0	30	5	10	15	20	30
Amount of flocculant MAGNAFLOC 919 [g/Mg]	0	230	38	77	115	155	230
a_{24h} [%]	17	15	16 5	17	18	18	18
r_{24h} [kg/m^3]	1139	1101	1115	1119	1126	1126	1126
b_{24h} [g/dm^3]	193	166	196	193	203	203	203

a_{24h} = mass per cent content of the solid phase in the suspension after 24 hours of sedimentation,
r_{24h} = density of the suspension after 24 hours of sedimentation;
b_{24h} = amount of the solid phase in 1 dm^3 of the suspension after 24 hours of sedimentation

The filtration of the Zebrzydowa clay suspensions was earned out by means of the laboratory pressure filter of 170 mm diameter The filtration pressure was 883 kPa The concentiated (without agents, a = 17%) overflow of the f 100 mm hydrocyclones was subjected to filtration Alao the suspensions of lower contents of the solid phase (12 and 10%) were attempted to be filtered. The investigations of filtration with and without coagulating and flocculating agents were carried out

It was observed that

- moisture contents of „filter cakes" are high (~ 50%), regardless the fact whether the filtration was performed with or without coagulating and flocculating agents,
- after the filtration without the agents the filtrates are characterised by the high content of the solid phase,
- the filtrates obtained in the process for which the coagulant and flocculant were proportioned (regardless their amounts) do not practically contain the solid phase

Consequently, it appears that the additions of coagulating and flocculating agents do not decrease the moisture content of the filter cake but they increase significantly the punty of the obtained filtrate

If can be expected that in the filtration process without agents, in industrial conditions, with the use of filtration presses and because of clogging of the filter cloth the final content of the solid phase in the filtrate should not exceed 1% The higher pressure of filtration should also enable a cake of a lower moisture content to be obtained

5 CONCENTRATING THE SUSPENSION IN THE MANTLE CENTRIFUGE

Unfavourable sedimenting and filtering properties of the Zebrzydowa clay suggested the authors to investigate the suspension concentration process in the VS 150x300 classifying - concentrating centrifuge, manufactured by Humboldt Wedag, with a cylindncally conical drum and worm-type remowal of the underflow The overflow of the f 100 mm hydrocyclones was the centrifuge feed The aim of the investigations was, first of all, to determine the distribution of yields of both separation products (g„ g„), moisture content of the undeiflow (M_u) and the content of the solid phase in the overflow (a_0) of the cenlnfuge 1 he tests were carried oui at the optimum construction parameters (for the concentration process), if the high oveiflow cd^c long sedimentation /one and a large mimher *of* drum i evolution;„ tubulin with the separation rate

$$\varsigma \quad \frac{\omega^{2} r}{g} \quad 1253$$

Table *A* picscnls ihc conditions and ıı suits of tum expcnmenls Andl\smj-> liiem it win IK nl)Mt\ni lh.ıl

- the distribution of yields of concentration products is not favourable, only in the conditions of experiment 4 the outflow yield exceeded 50%,
- the majority of very fine particles are passed to the overflow of the centrifuge, ımprovershıng the underflow product,
- the overflow containing large amounts of very fine particles must be returned to circulation, e g to the tossing process,
- the outflow of the ~ 30% moisture content are obtained (while the required walue is 25% maximum)

Table 4 Results of concentrating of the suspension in a centrifuge

	V_r [dm³/min]	a_r %	M_u %	a_o %	g_u %	$a_{u<5}$ %
1	20	14 56	?8 57	8 60	35 32	60 15
2	10	14 56	32 63	8 13	43 69	61 73
3	20	4 90	30 23	2 94	43 34	57 50
4	10	4 90	36 ?4	2 25	51 86	65 29

V_r = intensity of the flow oi suspension through the centrifuge,
a_r = feed concentration,
gs„ = underflow yield,
$a_{u<}$, = content of the < 5 mm class *w* the underflow,
M_u = moisture content of the unden nw,
a„ - overflow concentration

The attempt to apply the coagulating an I flocculating agents in order to concentrate the suspı ısion in the centrifuge gave no positive results In on lo athtvc the overflow not containing the solid tse very large amounts of agents should lı. • been proportionated (- 1000 g/Mg of dry matcit \) I he addition of agents did not decrease the m ıslını* content of the underflow

6 THE PROPOSED TECHNOLOGY Oh (1 Y ENRICHMENT

fhe proposed scheme of enrichment in Sinology d clay coming from the Zebrzydowa Mine (lumps ı presented on Figure 1 An expenmenlal hait h ni enriched clays was produced in one ot ıhı clay processing plants Consequently, the anılmış obtained a filter cake of 33% moisture conlcnl and 99% content of the < 63 mm particles Ihc liln.ik did not practically contain the solid phase Ihc tum of processing of the suspension into Ihc presses was very long The emu lied day was directed to UIL

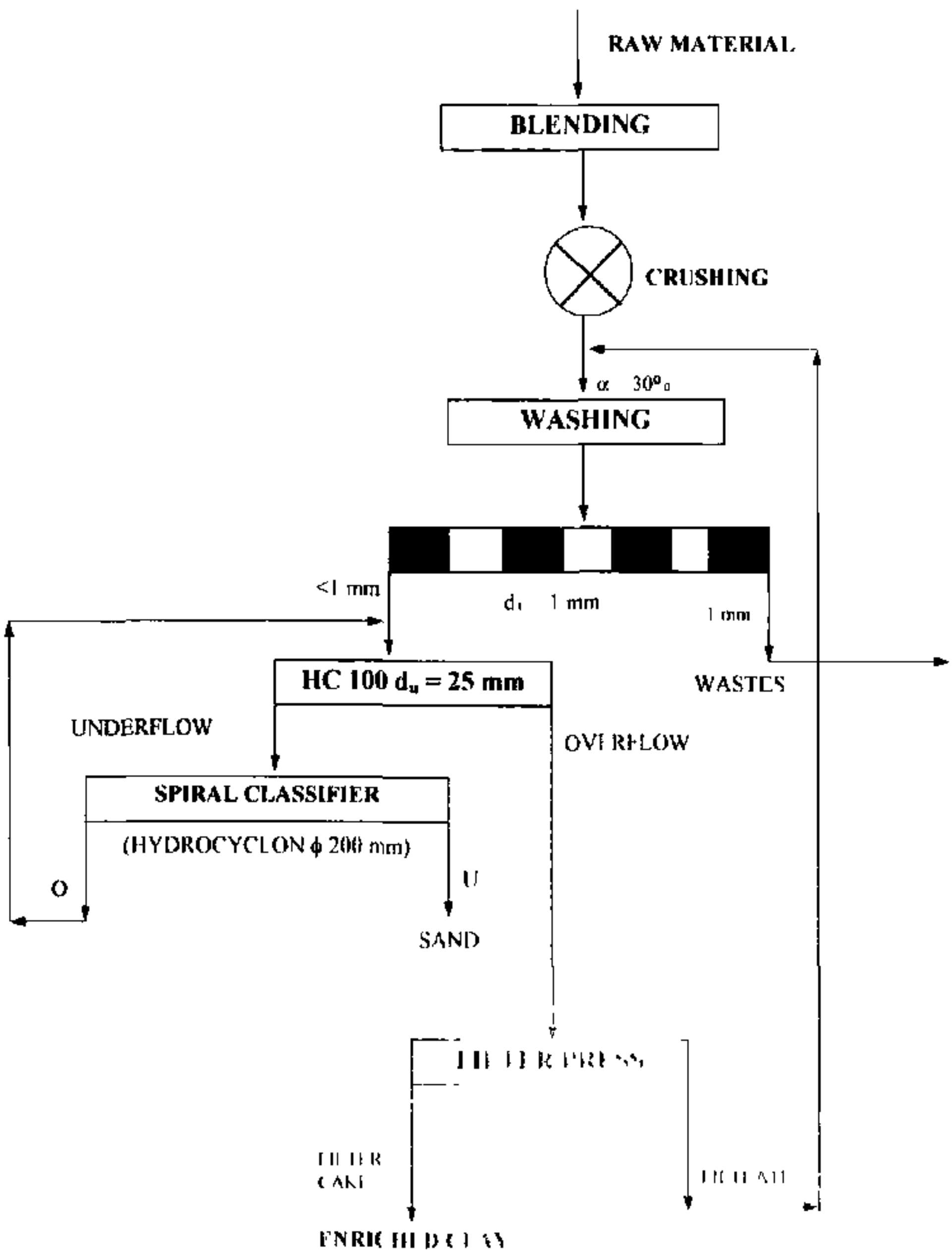

Fig. 1 The proposed scheme of enrichment technology

ceramic plant where its applicability was esümated Table 5 presents the properties of the enriched clay.

Table 5. Ceramic properties of the enriched clay

1.	>63 mm	0,6%
2.	Drying contraction rate	5,1%
3.	Bending strength after drying	5.12 MPa
4.	Drying contraction rate after buring -temp 1120°C -temp. 11S5°C - temp. 1240°C	 4,7% 6 1% 8.5%
5.	Absorbability after burning -temp, I120°C -temp. 1185°C -temp. 1240°C	 8.7% 3.8% 0.3%
6.	Bending strength after burning -temp. 1120°C -temp. 1185°C -temp 1240°C	 17.1 MPa 28 4 MPa 33.3 MPa
7.	Deformation after burning	13 mm

7 CONCLUSIONS

The following general conclusions can be formulated according £o the results of investigations of separate technological operations of stoneware clay processing

1 The enrichment technology of stoneware clay consists of 4 basic processes washing out, screening, classification of the suspension in hydrocyclones and concentration of the suspension.

2. The properly selected operation parameters of the machinery used in the first three operations ensure maintaining the required and stable separation products. Due to very unfavourable sedimenting and filtrating parameters of clay the problem of dewatering is difficult to solve
3. The single-stage concentrating of the suspension to the moisture content not higher than 20% is not possible It is proposed to study a possibility of applying the atomizing drier for final dewatering of clay

The ennched clay is characterised by very high quality; it is a ceramic material of high bending strength after drying (> 5 MPa), high plasticity ans low absorbability If can be used for making wall and floor tiles as well as colour semi-vitreous Chinaware. If can be also used for manufacturing of sanitary fitting The demand for this clay is very large