

Jadwiga Kamińska\* , Mateusz Skrzyński\*

## PHYSICAL, CHEMICAL AND STRENGTH PROPERTIES OF DUSTS FROM THE BENTONITE SANDS TREATMENT PLANTS

### 1. INTRODUCTION

In the dry reclamation systems of spent sands even 10 weigh% of after reclamation dusts are formed. Significant amounts of remains of binders or clays removed from sand grains as well as sand abrasion products are cumulated in these dusts. In case of spent sands with resins these dusts often have high values of ignition losses (above 30%), which indicates the significant content of combustible parts. In such case the separated dusts are considered the dangerous waste, since there is a danger of an elution and penetration into the soil of dangerous substances during their storage. Some properties and the way of dusts form transformation decide on the possibility of the management of the after reclamation dusts. The most often the chemical composition, grain and phase composition and the in-fluence on the environment are taken into account [1].

The requirements of the European Union in the scope of the application the Best Available Techniques (BAT) force foundry plants to limit the amount of wastes or to manage them rationally [2].

### 2. SCOPE AND THE INVESTIGATION METHOD

The scope and sequence of investigations consisted of the following stages:

- 1 stage:** Determination of the active clay content, ignition losses and chemical reaction (pH).
- 2 stage:** Determination of the specific and bulk densities.
- 3 stage:** Determination of the grain composition of the tested dust.

---

\* M.Sc.: AGH University of Science and Technology, Faculty of Foundry Engineering, Krakow, Poland;  
e-mail: kaminska@agh.edu.pl

**4 stage:** Preparation of water-dust mixtures of a moisture content being in the range of 5–15 mass %.

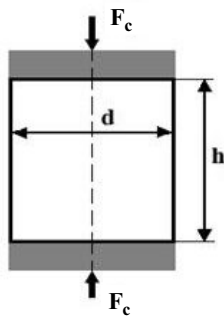
**5 stage:** Making standard shaped samples ( $\phi 50 \times 50$  mm).

**6 stage:** Performing the following examinations:

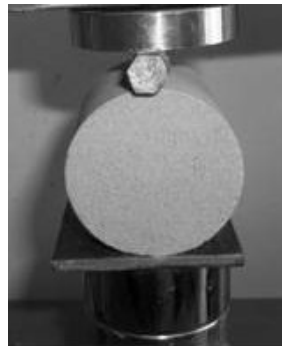
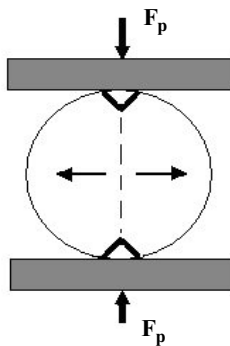
- compression strength under wet conditions ( $R_c^w$ ) and in the dry state ( $R_c^d$ ),
- splitting strength under wet conditions ( $R_p^w$ ),
- permeability ( $P^w$ ),
- compactibility under conditions of a static load ( $Z$ ),
- flowability by a shatter test ( $P_z$ ),
- friability ( $S$ ).

### 2.1. Testing of the compression and splitting strength

The compression and splitting strength was determined on the standard, roll shaped samples, in accordance with the PN-83/H-11073. The principles of the compression (Fig. 1) and splitting (Fig. 2) strength measurements are presented below.



*Fig. 1. Measurement of the compression strength: measurement principle and the view of the sample in the measuring apparatus*



*Fig. 2. Measurement of the splitting strength: measurement principle and the view of the sample in the measuring apparatus*

## 2.2. Determination of the montmorillonite content in bentonites by the copper complex method Cu-TET

To app. 2g of the moulding sand 35 ml of distilled water was added and dispersed by ultrasounds for a couple of minutes. The suspension was supplemented to a volume of 50 ml, and then transferred into a 100 ml beaker. During mixing 10 ml of the copper (II) complex solution was added. After 3 minutes of the reaction, the suspension was centrifuged in the laboratory centrifuge at a rotational speed of 5000 rpm for 12 minutes. The supernatant liquid was then carefully removed and its extinction measured at 620 nm in a 10 mm developing dish versus water as the zero sample. The measurements were performed by means of the spectrophotometer VIS ODYSSEY [3].

## 3. OBTAINED RESULTS

The obtained results of the physical, chemical and technological properties of the after reclamation dust and water-dust mixtures are placed in Tables 1 and 2 and in Figures 3–10.

Examinations were performed for four moisture contents of water-dust mixtures obtained by the determined water additions to dusts. The different initial water content in the investigated dust samples causes differences in the final moisture content in relation to the assumed moisture.

**Table 1.** Real moisture of water-dust mixtures

Amount of water added to the dust [%]	Real moisture of the water-dust mixture [%]
0	4.82
5	9.15
7	10.95
9	13.12
11	14.85

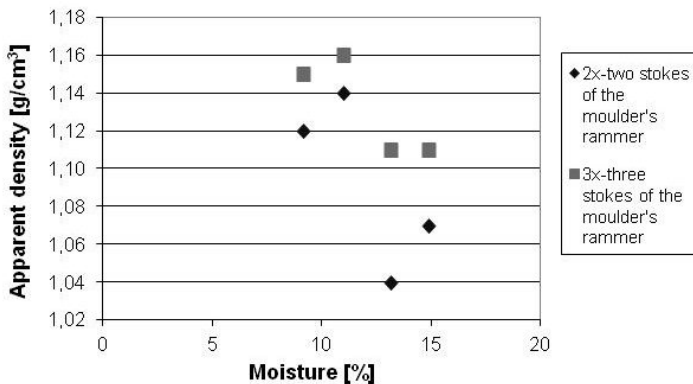
**Table 2.** Physical and chemical examinations of the after reclamation dusts

Examinations		Test results
Active clay content, %	Cu(II)-TET	38.74
	Methylene blue	39.29
Ignition loss LOI, %		14.74
Physical density $\rho$ , g/cm <sup>3</sup>		1.92
pH		8.61

### 3.1. Investigation results of the physical and chemical properties of dusts

The analysis of data contained in Table 2 indicates, that dust obtained from the bentonite sand processing plant contains a lot of active clay, the amount of which is determined by approximation (average from measuring by means of the complex Cu(II)-TET and the methylene blue adsorption) and equals app. 39%.

Changes of the apparent density of the water-dust mixtures in dependence of their moisture content are presented in Figure 3. The various states of the material compaction, obtained by two or three times compacting of the sample on the typical moulder's rammer, were taken into account. It was found that the highest density in both cases is obtained at moisture of 12%, while its decrease at moisture of 13%. The more compacted is the given mixture the higher its apparent density and thus the lower porosity.



*Fig. 3. Dependence of the apparent density of shaped samples on the moisture content of the water-dust mixture, 2× – two strokes of the moulder's rammer, 3× – three strokes of the moulder's rammer*

### 3.2. Grain composition

The results of investigations of dusts compositions (Tab. 3) determined by the laser diffraction methods in the Analysette 22 NanoTec apparatus of the FRITSCHE Company are listed in the measurement sheet.

### 3.3. Results of strength investigations of water-dust mixtures

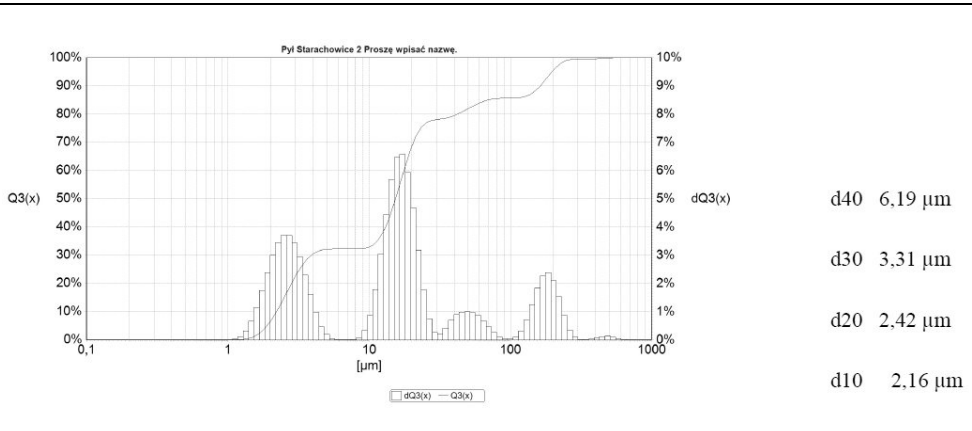
The results of the compression strength investigations of samples made of dust-water mixtures in a wet state and after drying are placed in Figures 4 and 5 – respectively. The samples were of standard dimensions  $\phi 50 \times 50$  mm. Dependence of  $R_c^w$  as the moisture content function (Fig. 4) is characterised by the maximum strength at moisture of app. 11%. Exceeding this value causes a negligible strength decrease. An initial moisture increase of the water-dust mixture in case of  $R_c^s$  curve causes the decrease of its value. When the moisture content exceeds app. 11% a quite fast strength increase occurs and achieves maximum at 13%. A comparison of the results of the compression strength  $R_c^w$  (Fig. 4) and the splitting strength  $R_p^w$  (Fig. 6) indicates nearly analogous shape of curves and a maximum shift to a higher moisture content. Values of  $R_c^w$  are nearly 10-times larger than  $R_p^w$ , which indicates that samples of the investigated mixture have a significant tendency to disintegrate under a load.

**Table 3.** Measuring sheet obtained from the laser grain analysis

Size Class	dQ3(x)	Q3(x)	Size Class Low	Size Class High	Q3(x)
	%	%		µm	µm
1.910	10.000	10.000	0.001	1.000	0.005
2.519	10.000	20.000	1.000	56.000	83.115
3.365	10.000	30.000	56.000	71.000	85.002
8.495	10.000	40.000	71.000	100.000	85.623
14.247	10.000	50.000	100.000	160.000	89.533
16.523	10.000	60.000	160.000	315.000	99.438
19.123	10.000	70.000	315.000	400.000	99.501
31.475	10.000	80.000	400.000	630.000	99.971
102.855	10.000	90.000	630.000	800.000	100.000
356.173	9.900	99.900	800.000	1 600.000	100.000

**Statistical calculations**

Model	Automat	Calculation error	0,7811057
Homogeneity	2,21	Deviation of the mean	46,08 µm
Surface area cm <sup>2</sup> /g	9715,21 cm <sup>2</sup> /g	Span	10,46
Diameter of the arithmetic	40,46 µm	Kurtosis	11,45
The geometric diameter	13,94 µm		
Diameter of the harmonic	6,18 µm		
Diameter square	80,53 µm		
Variance	4897,39 µm <sup>2</sup>	<b>MEASUREMENT</b>	
Coefficient of variation	172,97%	Cell positions	2
Modal	16,79 µm	Number of channels	102



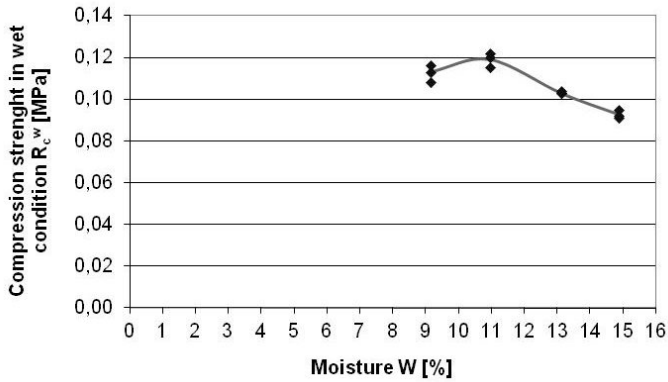


Fig. 4. Dependence of  $R_c^w$  on the water-dust mixture moisture content

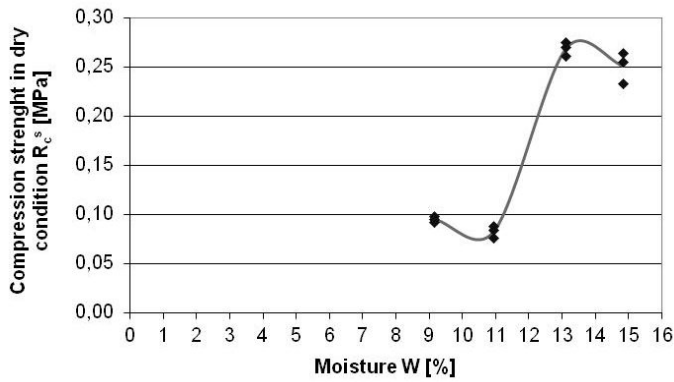


Fig. 5. Dependence of  $R_c^s$  on the water-dust mixture moisture content, roll shaped elements dried at a temperature of  $150^\circ\text{C}$  for 3 hours

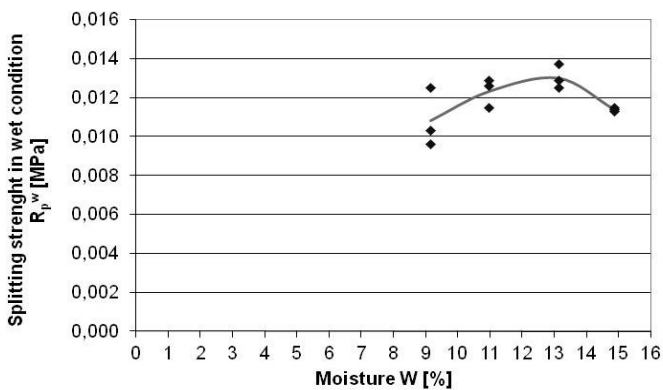
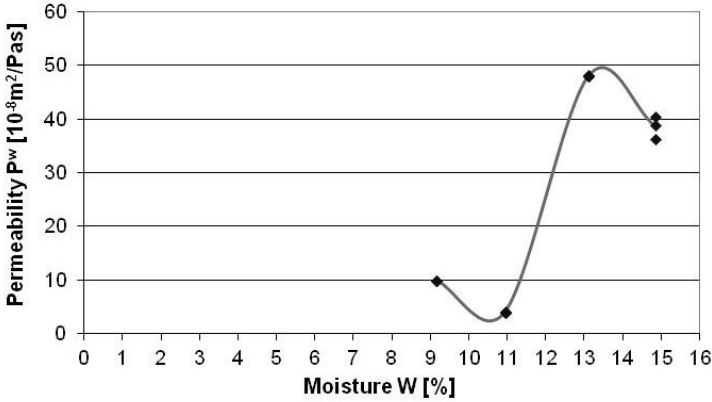


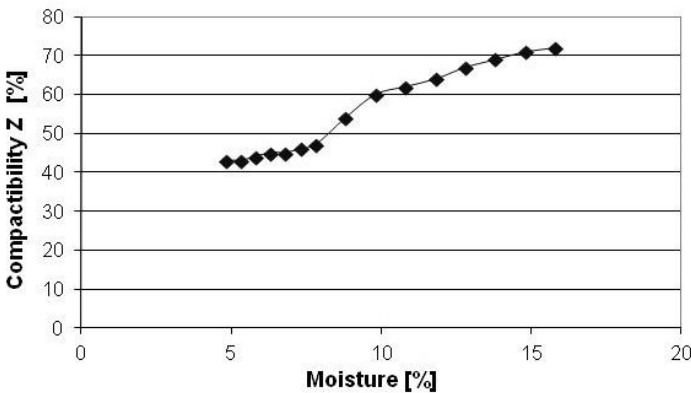
Fig. 6. Dependence of  $R_p^w$  on the moisture content of the water-dust mixture



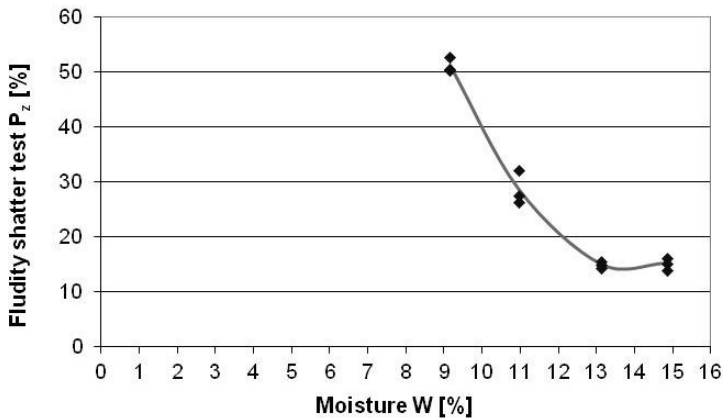
**Fig. 7.** Dependence of the permeability  $P^w$  on the moisture content of the water-dust mixture

Changes in permeability under wet conditions  $P^w$  in dependence of the moisture content are presented in Figure 7. A dust obtains the maximum permeability at the moisture being app. 13%. It can be noticed that the permeability curve ( $P^w$ ) is of an analogous shape as the compression strength curve in the dry state ( $R_c^s$ ).

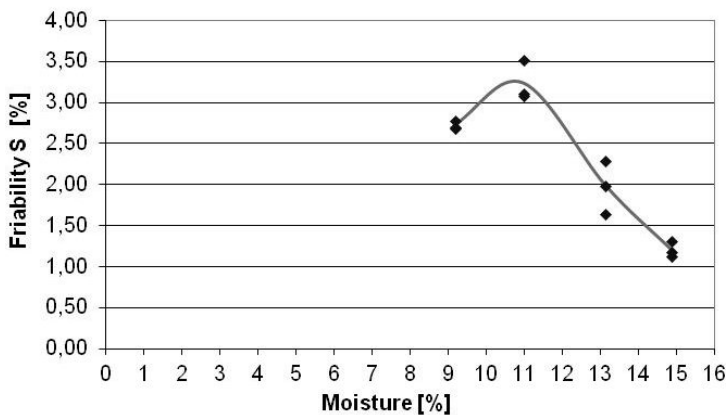
The indicator of the suitability of the tested material for press moulding is its compactibility. The compactibility changes depend on the amount and quality of clay in the mixture, including the water-clay ratio, while at the constant clay content on the water content in the mixture [6]. The dependence of compactibility on the moisture content of the water-dust mixture is presented in Figure 8. The performed tests revealed that the moisture content increase in the water-dust mixture causes its compactibility increase.



**Fig. 8.** Dependence of the compactibility on the moisture content of the water-dust mixture; the constant clay content = 75 parts by mass



*Fig. 9. Dependence of the flowability on the moisture content of the water-dust mixture; the constant clay content = 75 parts by mass*



*Fig. 10. Dependence of the friability on the moisture content of the water-dust mixture; the constant clay content = 75 parts by mass*

The sand ability of the uniform compactibility can be characterised by means of its flowability measurements. The flowability depends, first of all, on the water-clay ratio, and at constant clay content – on the moisture content in the sand. The flowability was measured by a shatter test and the results are presented in Figure 9. Increased moisture content to app. 13% causes the flowability decrease  $P_z$ , which in case of granulating dusty materials is a positive feature. Exceeding this moisture content causes a small flowability increase.

A property known as friability is a feature, which decides of the form durability of the material being granulated. This friability mainly depends on the kind of clay and the water-clay ratio, (at its constant content – on the water content in the material) [6]. Figure 10 presents the friability change in dependence of the moisture content. As can be seen, the



dust obtains the maximum friability at moisture of app. 11%, which decreases with the moisture increase.

#### 4. SUMMARY

The performed investigations of the strength properties of water-dust mixtures provide information essential for the determination of the expected ranges of the granulated products as well as for the selection of dust granulation parameters in the bowl granulator and their after the process properties.

The obtained results allow to state, that the assumed methods of the assessment of physical and mechanical properties of the tested dusts – analogous to the ones applied in moulding sands investigations – can be applied for the preliminary determinations of the range of moisturizing the after reclamation dusts containing water wettable components.

#### Acknowledgements

*The study was performed within the ‘Dean’s Grant’ 2011 No.15.11.170.417*

#### REFERENCES

- [1] *Kamińska J., Dańko J.*: Investigation of the selected properties of dusts from the reclamation of spent sands with bentonite, Archives of Foundry Engineering, 11 (2011) 4, 177–181
- [2] *Bobrowski A.*: Charakterystyka bentonitów i pyłów z suchego odpylania mas z bentonitem metodą spektroskopii w podczerwieni, Krakowska Konferencja Młodych Uczonych 2008
- [3] *Holtzer M., Grabowska B., Bobrowski A., Żymankowska-Kumon S.*: Methods of the montmorillonite content determination in foundry bentonites, Archives of Foundry Engineering, 9 (2009) 4, 69–72
- [4] *Lewandowski J.L.*: Masy formierskie i rdzeniowe, Wydawnictwo Naukowe PWN, Warszawa 1991

---

Received  
November 2011