CHARACTERIZATION AND COMPARISON OF DIFFERENT TYPES OF CLAY POWDERS

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ABSTRACT

From tennis through volleyball to athletic sports, clay plays important role as subsoil. The bulk material, clay, is cheap, because it is recycled product made at low cost by crushing bricks and clay tiles. Due to its compressibility and friction properties, it is an ideal material to produce clay courts. Therefore, friction parameters, compressibility factors and flowability were investigated. These mechanical-physical properties are also important for the practical handling of these materials, such as storage and transport of the material. For this purpose, three basic types of clay powder were characterized and compared. Experimental work was performed using Schulze RST-01 rotary shear tester, Powder Rheometer FT4, laser particle analyzer Cilas 1190 and particle analyzer CAMSIZER. Shape analysis of the samples was also performed. The subject of the research was how the volume changes depending on the applied normal stress, and the dependence of the internal friction angle. Initial results showed that variations in the shape and size of the clay particles can cause differences in the behavior of the tested powders.

Keywords: Clay; Particle size distribution; Angle of internal friction; Flowability; Compressibility.

1 INTRODUCTION

Clay is already a recycled product created by crushing bricks and fired tiles. The final product is divided into several groups according to the manufacturer. Product chosen for the characterization is made by company CIVAS Ltd. The final product is divided into three groups according to different particle size distributions, into coarse clay with the designation CN4 [1], standard CS1 [2] and powder CP05 [3]. These products will be used as input materials for this research. Standard clay CS1 and powder clay CP05 are used for tennis and volleyball courts, athletic tracks, softball fields etc. The difference between samples is mainly in the content of dust and the use of the given type. In contrast to the aforementioned clay CN4 is more likely to be used for spreading paths, as a substrate for growing and bedding for pets. CP05 clay with a higher content of dust particles is produced by grinding oversized sorting from the production of CS1 clay in a high-speed mill (around 3000 rpm). The smaller size of the input grain into the mill and the high speed of the mill rotor with grinding hammers, result in a finer grain size than CS1 clay. This type is directly used for the construction of sports fields. CS1 clay is produced in a mixed continuous grain size with a maximum grain size of up to 2 mm, given by sieving all produced clay through a sieve. It is mainly used for maintenance of sports ground surfaces and repair of playground surfaces, during which it replaces the removed part of the old clay and returns the surface to its original quality. For practical handling of these materials, it is necessary to know their mechanical-physical properties [4]. These include size and shape of particles, shear properties (angle of internal and wall friction), flow properties and bulk properties (compressibility). Shear and bulk properties are influenced by the amount of air contained, which affects the mutual interaction of particles, and therefore also their flow and handling (storage, transport, packaging, processes etc.) [5]. Based on the knowledge of the abovementioned properties, you can modify the product process and qualitatively compare different production batches of the manufacturer or modify the possibilities of storage and material handling. Therefore, the work compares at the first sight the same two clay powder, but their properties suggest otherwise. The particle size distribution, the shape of the particles and subsequently the friction parameters closely related to their flow are determined for each of them. Compressibility seems to be an interesting process determination, which shows how the density of powders with applied normal load changes. This property is one of the important factors when used in practice.

2 MATERIALS AND METHODS

Three samples of clay powder from CIVAS s.r.o. were used for characterization tests. These are samples of CP05 powder, CS1 standard and CN4. Materials are shown in Figure 1. The materials were purchased in bags of 33.4 kg in the company DEK (www.dek.cz). CP05 clay is a very fine (powder) clay with a continuous grain size according to the manufacturer with a content of at least 25% of the content below 0.05 mm and at least 70% of the content below 0.5 mm. According to the manufacturer, clay CS1 is a fine clay with a proportion of up to 25% of grains below 0.05 mm and up to 70% of a proportion of grains below 0.5 mm. It is characterized by a lower powder content compared to the CP05 clay. In contrast to the previous two samples, CN4 clay is considered to be rather coarse-grained and devoid of fines. In CN4 clay there is a maximum of 5% below 2 mm and a minimum of 80% below 4 mm.

Figure 1. *Clay powder samples*

Measurement of the clay particle size distribution was performed on two device, laser particle analyzer Cilas 1190 and particle analyzer CAMSIZER. For Cilas 1190 is method based on determining passing material through a dispersion beam, which analyze the sample particles size. Measuring particle size distribution by the dispersion beam method is widely used in many different industries [6]. The wet method using water as the medium was chosen for the measurement. The results were interpreted on the basis of Fraunhofer's theory [7]. The Retsch device CAMSIZER is an opto-electronic instrument designed for assessing the size and morphology of granular materials within the 30 µm to 30 mm range. It features a vibrating feeder, a flat light source, two CCD cameras for particle analysis, and a computer. The CAMSIZER analysis software is utilized for processing and interpreting the measurement data [8].

For samples CP05 and CS1, the measurement principle consisted in separating only one fraction up to 0.180 mm, which was measured on a Cilas 1190 and the remaining fraction was measured on a CAMSIZER. Subsequently, the measured data were evaluated. The CN4 material was measured completely on the CAMSIZER equipment. Each measurement was repeated 10 times.

Compressibility (or compressibility factor) was measured using FT4 Powder Rheometer. The parameter is measured as change in a volume (density) depending on the normal force. The data obtained are quantified by expressing the percentage of compressibility for normal loads [9].

Measurements of the angle of internal friction effective (AIFE), and flowability ffc were performed on the Shulze Shear Tester RST-01.pc. This instrument allows a quick and easy analysis of the flow behavior of powder in an industrial environment. The bowl is placed on the measuring table and a lid is placed on top of it. The cap is connected to the strain gauges using crossbeams, attached to weights and counterweights. The measurement is then fully automatic, and the readings are entered into tables and graphs and can then be exported [10]. Jenike flow index ffc is defined as ffc = σ1/σc. The relationship between ffc and the flowability - not flowing materials (ffc<1), very cohesive (ffc<2), cohesive (ffc<4), easy flowing (ffc<10), free flowing (>10) [11].

3 RESULTS AND DISCUSSION

3.1 Particle size distribution

Particle size distribution is one of the main parameters that influence flow behavior of the bulk materials. Clay samples were evaluated and plotted to determine relative weight and particle size. As shown in the graph in Figure. 2, the largest relative mass fraction of particles is in the range of 0 - 80 µm for the sample CP05 (47%) and for the sample CS1 (35%). As can be seen, the main differences between these samples is in the content of dust particles. It is also clear that the CN4 sample does not contain a fraction below 1 mm. The particle sizes of this sample range from approximately 1 to 4 mm.

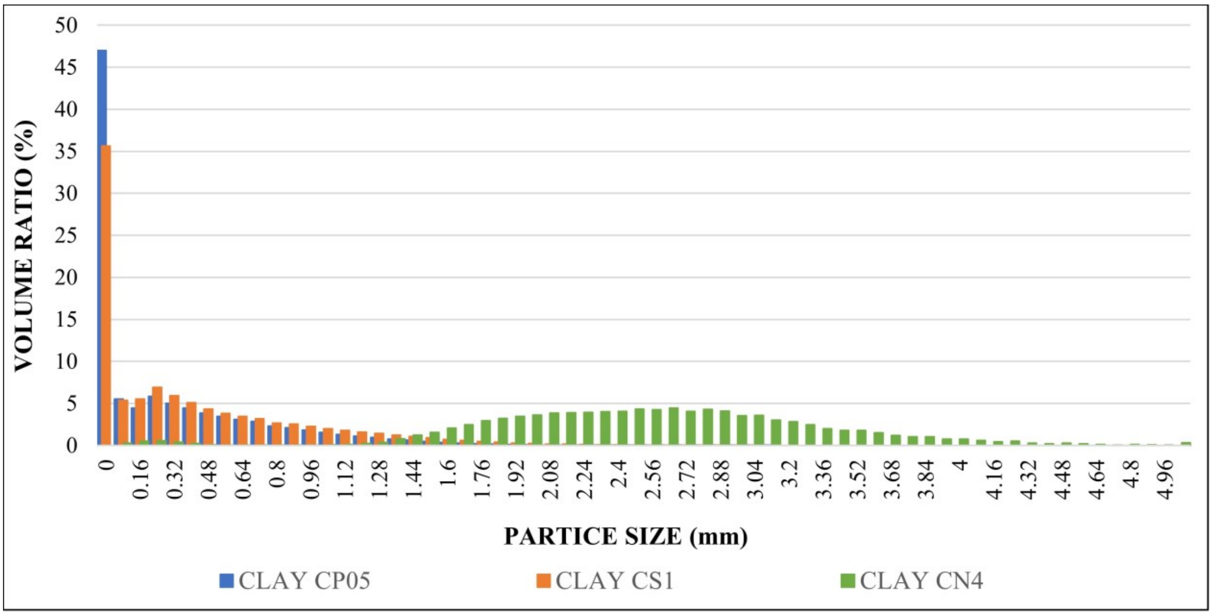

Figure 2. *Particle size distribution*

3.2 Compressibility

Compressibility is a measurement of how the volume changes depending on the normal load up to 15 kPa. This property of bulk materials is affected by many factors, such as particle distribution and shape, cohesion, particle stiffness etc. The measured data for the compressibility parameter are shown in Figure 3 and given in Table 1.

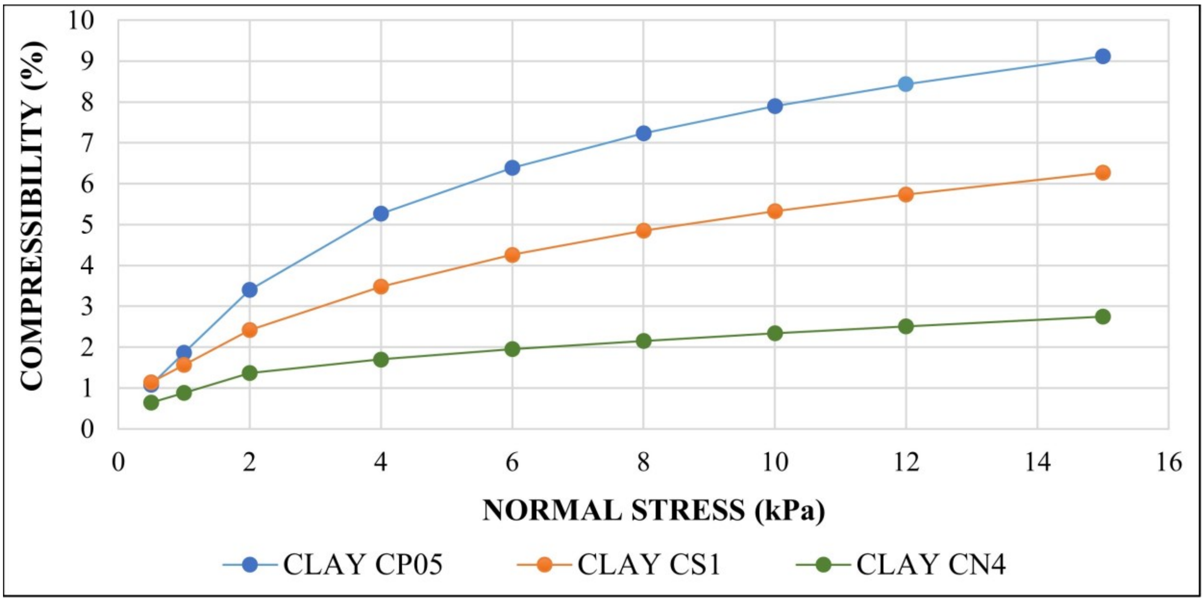

Figure 3. *Particle size distribution*

The measured results of the compressibility factors show the difference between samples CP05 and CS1. The difference of the compressibility factor between individual samples increases with increasing normal load up to the value of 2.85% (CP05 - CS1), 3.52% (CS1 - CN4) and 6.37% (CP05 - CN4), which is at a normal load of 15 kPa. The value for sample CP05 at 15 kPa slightly exceeds 9% compressibility. The value for sample CS1 is about one third less around 6% compressibility and the value for CN4 is less by about three quarters that is after 3%.

According to the results and the depicted dependences, the clay samples show a medium compressibility. Susceptibility of this property is often associated with the slightly cohesive properties of powders. Most fine powders fall into this category.

Table 1. *Parameters of compressibility*

CPS Compressibility (%)									
	0.5 (kPa)	**1 (kPa)**	**2 (kPa)**	**4 (kPa)**	**6 (kPa)**	**8 (kPa)**	**10 (kPa)**	**12 (kPa)**	**15 (kPa)**
CLAY CP05	1.08	1.86	3.4	5.27	6.39	7.23	7.9	8.43	9.12
CLAY CS1	1.14	1.57	2.42	3.48	4.26	4.85	5.33	5.73	6.27
CLAY CN4	0.643	0.885	1.37	1.7	1.95	2.15	2.34	2.51	2.75

3.3 Angle of internal friction, flowability and wall friction

Figure 4 shows the dependence of the internal friction angle effective (AIFE) on Major principal consolidating stress σ1. It is clear from the graph that samples CP05 and CS1 are in a similar range of AIFE. A decreasing tendency of AIFE curves can be observed on increasing load Major principal consolidating stress, which is interesting result. Sample CN4 also has similar characteristics, but the difference is that its AIFE is higher compared to samples CP05 and CS1 by approximately 10–15%. The ffc flowability data of the clay powders are show in Figure 5. Samples CP05 and CS1 for normal loads of 10, 15 and 20 kPa fall into the easy-flowing category, for normal loads of 5 kPa they are on the borderline of cohesive materials and easy-flowing. Sample CN4 shows better flow properties, with values on the border of easy-flowing and free-flowing.

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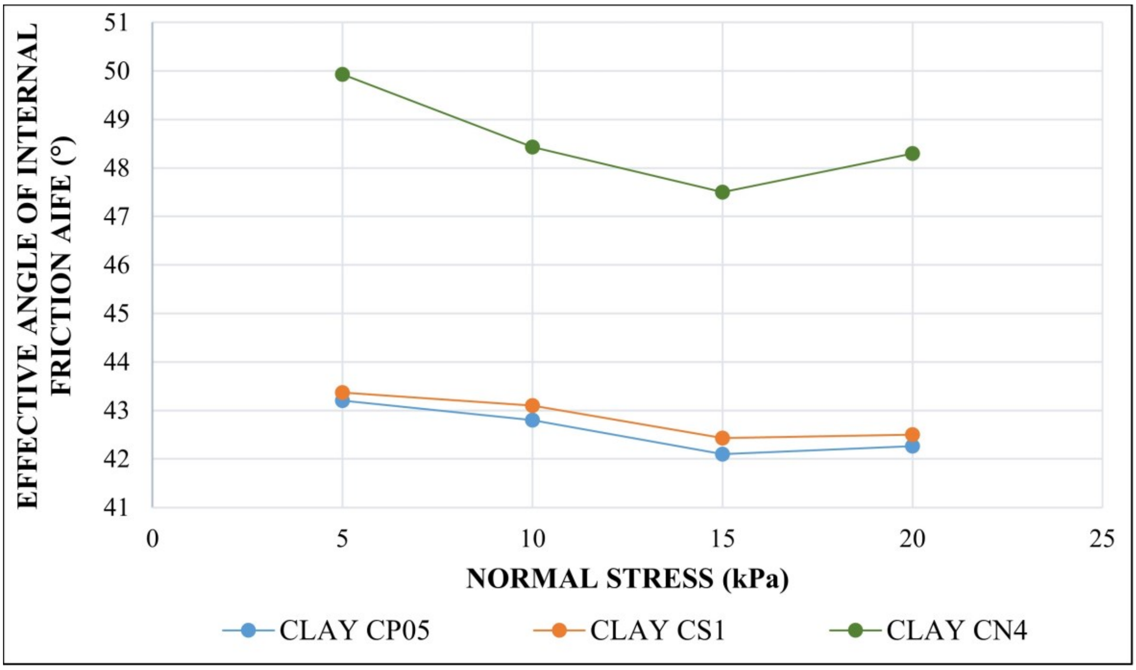

Figure 4. Dependence AIFE on Major principal consolidating stress σ1

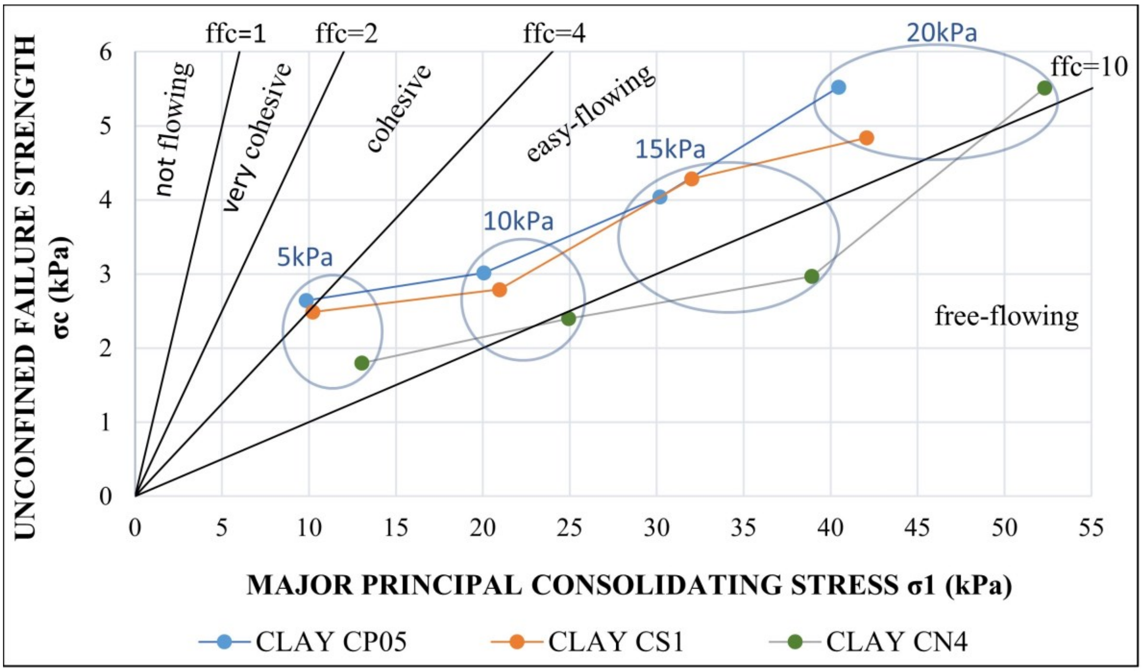

Figure 5. *Flow curves depending on normal stress*

4 CONCLUSION

The paper shows the characterization of powdered clay using mechanical and physical properties of bulk materials such as, particle size distribution, compressibility, flowability, internal friction angle. Three different types of material from CIVAS Ltd. were used. Due to the measured distribution curves, it could be assumed that samples

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CP05 and CS1 would have similar mechanical and physical properties. However, more detailed characterizations did not confirm this hypothesis.

In particular, the particle distribution of sample CS1 and CP05 ranges from 0 mm to 1.5 mm. In contrast, the fraction of sample CN4 ranges from approximately 1 mm to 4 mm. The results of shear properties AIFE show that samples CS1 and CP05 are similar. Therefore, the storage and handling facilities for these materials will not differ. In contrast, the AIFE of CN4 specimen is larger and in the range of 10% to 15%. The variance of AIFE of CS1 and CP05 specimens is around 1° and this difference became even smaller as the normal stress increased.

The flowability of samples CS1 and CP05 differs slightly, when the bulk materials are subjected to lower normal stresses, they behave as cohesive powders with respect to their ffc. The flowability of both samples improves with increasing normal stress and the ffc changes to easy-flowing. The most significant difference between the samples studied is compressibility, the measured data show a clear difference between samples CP05 and CS1. With increasing normal stress up to 15 kPa, the difference in compressibility coefficient between the samples increases up to 2.85%. The results differ by one-third for both samples, with CS1 having a 6% compressibility coefficient and CP05 having a 9% compressibility coefficient. In contrast to samples CS1 and CP05, the ffc of sample CN4 differs by up to two-thirds. There is one exception, and that is at a normal load of 20kPa. When the ffc of all three samples approaches a similar value in the range of 2–14%.

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