Dependence of Compressive Strength of Rammed Earth on Used Clay Composition

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Abstract: This article is focuses on compressive strength of rammed earth. The mechanical properties depend on an amount of mixture water and an amount and type of clay minerals. The clay minerals play role of a binder similarly like a cement in concrete. This paper is focused on a compressive strength and its dependence on the species and quantity of clay minerals. Three earth mixtures were tested. Mechanical properties were examined on small test bodies made of the mixtures. The mechanical properties of the mixtures are compared at the end of the paper.

Keywords: Rammed Earth; Clay; Compressive Strength; Clay Mixture; Load-bearing Construction.

1 Introduction

This article focuses on a usability of unburned clay for rammed constructions where bonding component is illitic-kaolinit clay. An introduction of the article is dedicated to summary of reasons why to concern with clay construction materials in an age of modern ones. First reason is reconstruction of already built clay buildings. Clay buildings comprise considerable part of housing development in the Czech Republic and many of these building are historically valuable. Although clay structures form considerable part of traditional development there is a lack of information about the material itself [1, 2].

The second reason is conformity of clay building with principles of sustainable construction. Usage of a clay in modern constructions is an effort to apply environmentally friendly materials. Generally are these efforts connected to usage of natural materials with minimal energy demand for their preparation, usage of recyclable construction materials and usage of materials with minimal combination with synthetic substances [3, 4].

The third reason is an influence of unburned clay to human health. Main advantage of unburned clay is a quick reaction to air moisture changes and maintaining it in a level favorable to human health [5, 6].

2 Design and Manufacture of Test Bodies

The provided results concerns with clay mixtures processed by technology of ramming. A clay suitable for building constructions consists from three main components: sand (grain size 0.06-2 mm), dust particles (grain size 0.002-0.06 mm) and clays (grain size smaller than 0.002 mm). Clays are mostly composed of clay minerals which fulfill function of bonding agent similarly as a cement in a concrete. The water is added to clay mix which activates bonding ability of the clay and allows for good mixture processing. The clay minerals assure material strength and together with water are responsible for material shrinkage [6, 7].

A compressive strength of the material should rise with increasing amount of clay minerals. An amount of water in mixture may influence final strength of the material in a positive manner (better clay mix processing) or in a negative manner (higher pore count) [5, 6].

The experimental clay mix was produced by mixing of sand, clay and water. The used clay was illitic-kaolinite one (provided by the company LB MINERALS, s.r.o.). Six testing batches were produced varying by mass ratio of sand and clay (see Tab. 1). For each test batch was six test bodies produced of size $4 \times 4 \times 16$ cm and four to six test bodies of size $2 \times 2 \times 10$ cm. That bodies were created using a technology of ramming material into steel molds (see Fig. 1)

Tab. 1: Composition of the Clay Mixture Batches

set	Clay	Sand/clay ratio	Water/clay ratio
S_I	Illite, kaolinite	75/25	0.37
S_{II}	Illite, kaolinite	80/20	0.37
S_{III}	Illite, kaolinite	85/15	0.37
S_{IV}	Illite, kaolinite	75/25	0.295
S_V	Illite, kaolinite	75/25	0.335

(a) Test Bodies Ramming

(b) Clay Test Bodies

Fig. 1: Manufacture of Test Bodies

3 Dependence of Compressive Strength on the Amount of Illitic-kaolinite Clay

The hypothesis that increasing amount of clay leads to increase of compressive strength was not confirmed. There were three test batches probed from which each contained six test bodies. From measured values of testing bodies compressive strength was average amount calculated (see Tab. 2).

The compressive strength dependence on an amount of a clay the average value of compressive strength 2.43 MPa for set S_I (sand/clay ratio of 75/25, w = 0.37), 2.87 MPa for set S_{II} (sand/clay ratio of 80/20, w = 0.37) and 0.59 MPa for set S_{III} (sand/clay ratio of 85/15, w = 0.37) (see Fig. 2)

Although it was not unambiguously proved that increasing amount of clay in a mix increase compressive strength, it is from measured values of test batch S_{III} clear that the compressive strength is by low amount of clay minerals influenced radically. Testing bodies from set S_{III} demonstrated high crumbliness already before beginning of compressive strength tests even though the technology and method of processing were same in all three batches.

Tab. 2: Compressive Strength of Test Bodies Dependence on the Amount of Clay in the Mixture

Set	Clay	Sand/clay ratio	Water/clay ratio	Number of test bodies	[MPa]
S_I	Illite, kaolinite	75/25	0.37	6	2.43
S_{II}	Illite, kaolinite	80/20	0.37	6	2.87
S_{III}	Illite, kaolinite	85/15	0.37	6	0.59

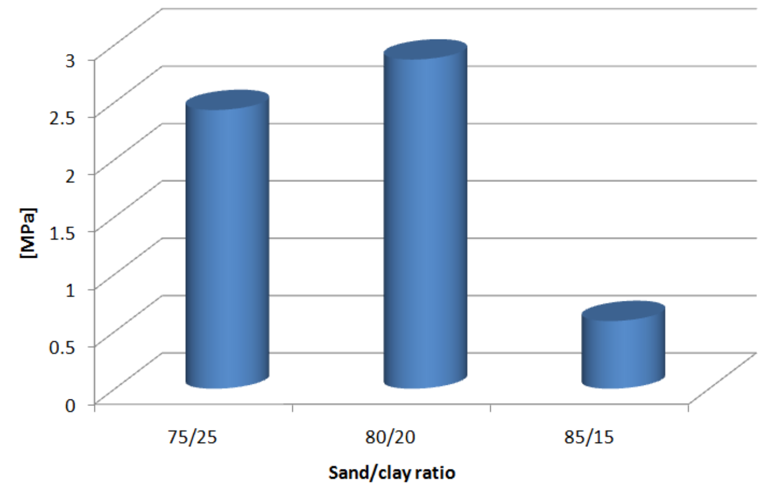

Fig. 2: Dependence of Compressive Strength on the Amount of Clay in the Mixture

Tab. 3: Compressive Strength of Test Bodies Dependence on the Amount of Mixture Water

Set	Clay	Sand/clay ratio	Water/clay ratio	Number of test bodies	[MPa]
S_I	Illite, kaolinite	75/25	0.37	6	2.43
S_{IV}	Illite, kaolinite	75/25	0.295	4	1.96
S_V	Illite, kaolinite	75/25	0.335	4	2.09

4 Dependence of Compressive Strength on the Amount of Mixture Water

The hypothesis that increasing amount of mix water leads to increase of compressive strength was confirmed. There were three test batches probed from which each contained four to six test bodies. From measured values of test bodies compressive strength was average value calculated (see Tab. 3).

The compressive strength dependence on an amount of a mixture water the average value of compressive strength 2.43 MPa for set S_I (sand/clay ratio of 75/25, w = 0.37), 1.96 MPa for set S_{IV} (sand/clay ratio of 75/25, w = 0.295) and 2.09 MPa for set S_V (sand/clay ratio of 75/25, w = 0.335) (see Fig. 3)

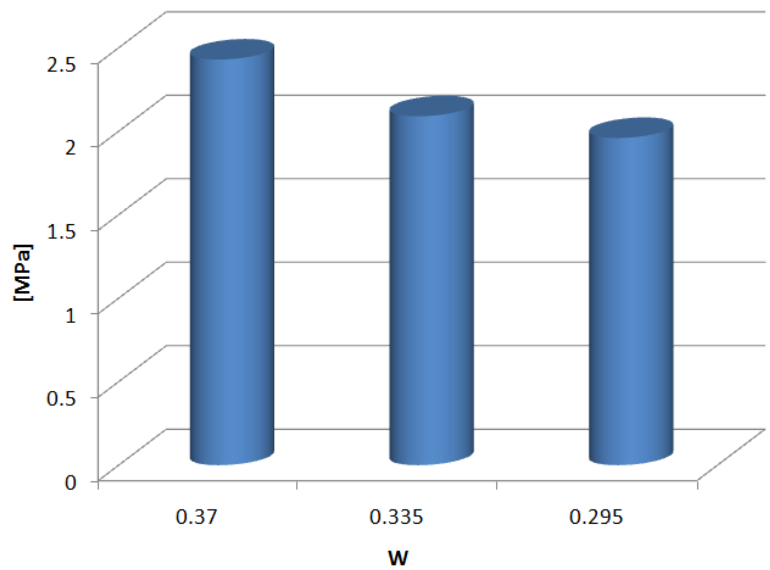

Fig. 3: Dependence of Compressive Strength on the Amount of Mixture Water

We are able to establish that increasing amount of mixture water increase compressive strength of clay material. Probable reason of this dependence is better mixture treatment and higher activation of clay minerals with mixture water increase.

However, there is a water mixture ratio point (Water Coefficient) above which the compressive strength starts to drop. All our tested bodies ware made from clay mixtures that had water coefficient much below of this critical point.

5 Conclusion

The dependability of the compressive strength on an amount of used illitic-kaolinite clay was not unambiguously proved. From measured values could be concluded that considerable change of clay amount in a mix leads to change of shrinkage and compressive strength. The hypothesis that decreasing of a clay amount decrease shrinkage during drying and compressive strength was proved for the batches with minimal and maximal amount of clay.

The compressive strength value raises with increasing of water mixture ratio. It was found from previous research that increasing amount of water mixture ratio also increase shrinkage during drying [8]. Unfortunately, these two factors are contrary to each other. It is difficult to find an optimal choice between strength and shrinkage. It is on an engineer to conclude which material parameter is more important for a given construction. Aim of the submission was to outline a sight on an area of illitic-kaolinite clay usage for load-bearing constructions from rammed unburned earth.

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