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Influence of the clay on mechanical properties of construction made of rammed earth

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Abstract. The article is focused on the monitoring of mechanical properties of rammed earth made from two types of clays. Due to a change in the composition of the mixture, there are changes in the material properties that are important for the design of the rammed earth structures. The resulting values of the properties of the individual are compared with each other. The mechanical properties of compression and bending compression are compared in the paper.

1 Introduction

Rammed unfired earth is currently part of the minority group of building materials. Nonetheless, clay has been the main building material for several millennia [1]. Over the centuries, building materials have evolved and in the last two centuries there has been a significant change in the properties of building materials. The construction industry went on the path of retreating from the use of unfired clay. Unfired earth found itself outside the main attention of building materials.

Despite the diversion of attention, earth is still used as a construction material. Recently we may encounter a renaissance of this material, which is caused by ecological reasons. Undoubtedly, rammed earth is a significantly less energy-intensive material than most others [2].

Loss of attention to this material is the reason that today we do not know much about unfired clay. This building material can contain potential, usable even today. The lack of information on the characteristics of this material is an obstacle to design.

Rammed unfired earth is a building material that consists of clay, sand and water. The clay has a binder function in the composite, water is needed to start the binder properties and sand is used as a filler. The types of clays vary according to their ability to bind water and their ability to form a watertight structure. The Czech Republic has several deposits of clearly defined clay types. The types of clays can be divided into Kaolinitic, Ilitic, Ilitic-Kaolinitic and Mortmonillic. The first and last mentioned types are not entirely suitable for construction use due to specific properties. This paper focuses on the comparison of Illitic and Ilitic-Kaolinitic clay as a binder used for the construction of rammed unfired earth. There are many material properties that can be compared. It is envisaged to use rammed earth to build vertical structures that are subjected to pressure from vertical loads.

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2 Material properties

Experiments were focused on the search for material properties such as compressive strength and flexural strength. Rammed earth was formed from different composition ratios using Illitic clay (AGL in the text) and Illitic-Kaolinitic clay (KR in the text), as is possible see in Table 1.

Table 1. Mixture for rammed earth.

Label	Clay	Sand	Water / clay
AGL 3	20	80	0.40
AGL 5	20	80	0.37
AGL 8	20	80	0.29
AGL 9	20	80	0.45
KR2	20	80	0.37
KR7	20	80	0.25
KR 11	20	80	0.4

The water coefficient refers to the ratio of water to clay weight. For the test materials ranged from 0.29 to 0.45. Sets AGL3, AGL 8, KR2, KR7 and KR 11 were tested in compression test. Sets AGL3, AGL5, AGL9 and KR7 were tested in tensile test in bending.

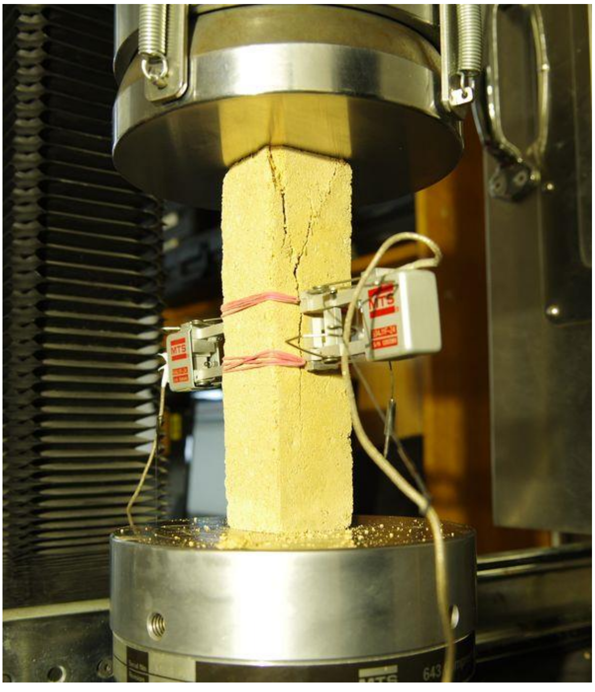

Fig. 1. Compression test of rammed .earth with extensometers oriented in axial direction.

The preparation of the bodies consisted in the production of fresh mixture and its placement in moulds [3]. The mixture was deposited in metal moulds in approximately 3 layers and rammed. Prisms of 40 × 40 × 160 mm were produced using this procedure. Rammed earth gains strength by drying. The specimens dried in laboratory conditions at 20° C. Before the compression and flexural testing, the specimens were placed in an air conditioning chamber and left at 20 ° C and 50% relative humidity.

Each set of compression and bending tests contained 3 bodies. The specimens in the compression test were loaded perpendicular to the compaction direction. The following data were recorded in compression: deformation of the whole specimen, force, axial deformation on the specimen by means of two contact deformation sensors, see Fig. 1. Thus, two bodies from each set were measured under compression. The third specimen was fitted with one extensometer in the axial direction and the other extensometer in the transverse direction, as shown in Fig. 2.

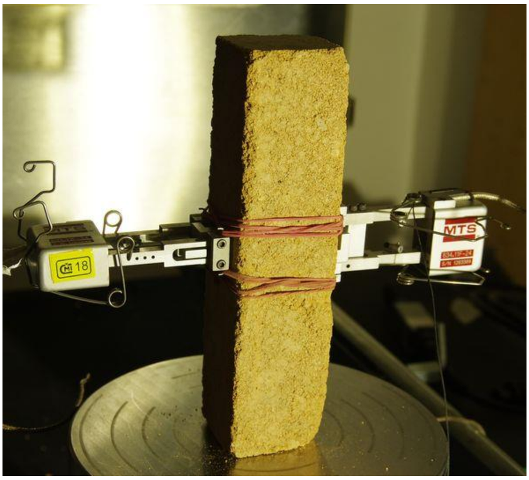

Fig. 2. Compression test of specimen prepared from Illitic clay with set of extensometers for detection of Poisson ratio.

The bending test was carried out on specimens of the same dimensions. The flexural tensile strength was tested in a three-point bend. Load, beam deflection and tensile deformation at the lower surface of the body were recorded., see Fig. 3.

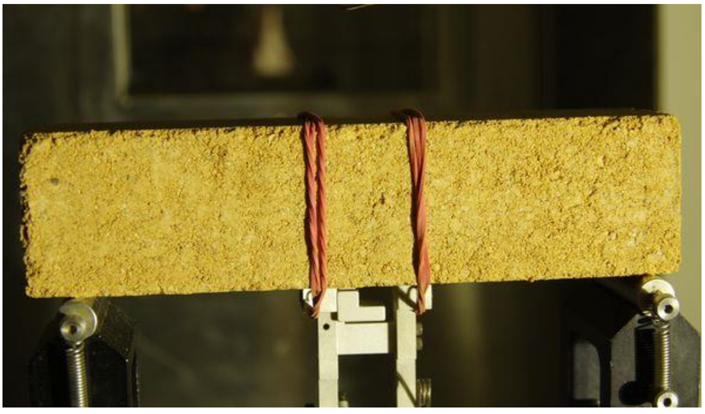

Fig. 3. Bending tension test of prism specimen prepared from Illitic-Kaolinitic clay.

3 Results of measurement

The working diagrams are related to the deformation of the whole height of the specimens. Conversely, the modulus of elasticity can be determined from measurements with surface sensors on the prism surface. The working diagrams are very similar in shape to the concrete slab diagrams, see Fig. 4.

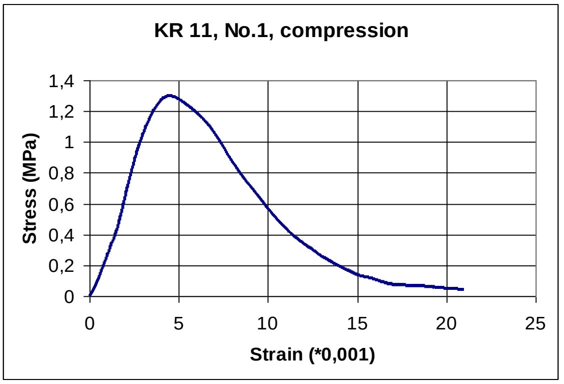

Fig. 4. Stress-strain diagram of compression test of specimen prepared from Illitic-Kaolinitic clay.

The density of all prepared sets ranged from 2000 to 2100 kg/m³. Materials with higher density achieved higher values of compressive strength and flexural strength, regardless of the clay used. This can be seen very well when comparing the graphs of strengths achieved and those of the bulk density, Fig. 5-7.

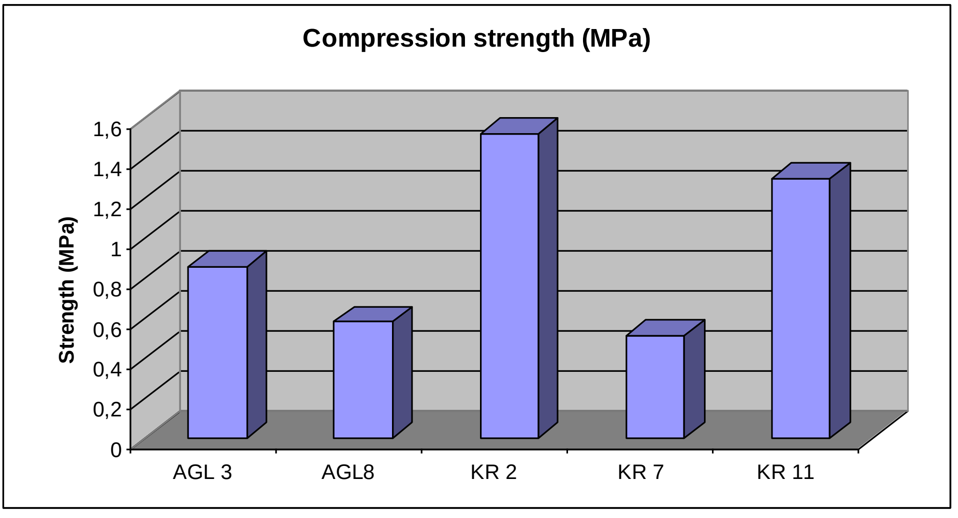

Fig. 5. Results of compression tests for all tested sets of rammed earth.

Taking into account the effect of the water coefficient, it is apparent from Fig. 5 that the lowest values of compressive strength were obtained for mixtures with the lowest water coefficient. The mixture AGL 8 and KR7 had a water coefficient of 0.29 and 0.25. At the same time, the KR 7 had a lower density. The low value of flexural tensile strength is also evident from Fig. 7 for the KR7 set. In contrast, AGL8 also achieved low compressive strength, although its bulk density was close to 2100 kg/m³.

Excluding the effect of the low water coefficient, it is apparent from the comparison of the compressive strength that the mixture of KR prepared from Illitic clay was higher. This is very well represented by a mixture of KR2 and KR11. This applies to compressive strengths. A comparison for the case of flexural tensile strength is not possible because the KR and AGL test sets differed by the water coefficient.

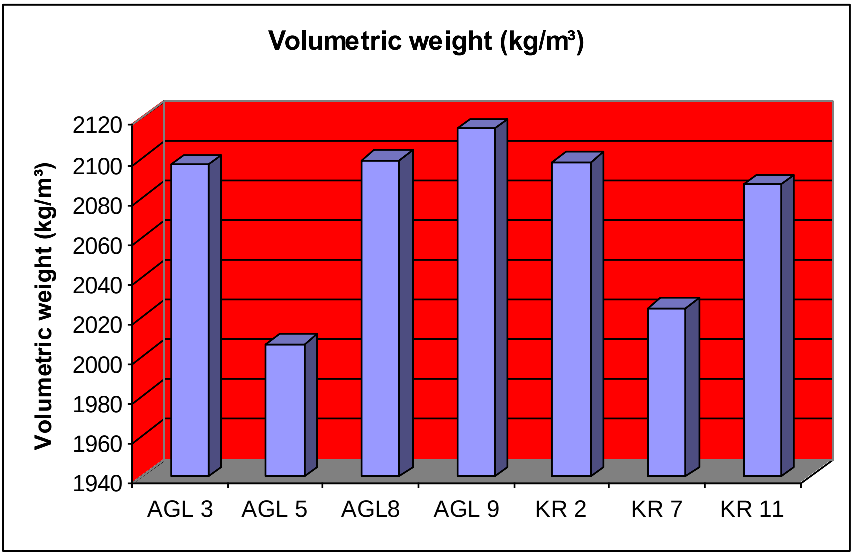

Fig. 6. Results of volumetric weight of tested sets.

The flexural tensile strengths can be compared within mixtures prepared from Illitic clay. It can be seen on Fig. 7 that the flexural strength increases with the magnitude of the water coefficient. The AGL 3 and AGL9 mixtures achieved higher strengths than the AGL5 mixture, which had a water coefficient of 0.37. A small change in the water content leads to a significant increase in flexural strength. This is convinced by a mixture of AGL3 with a water coefficient of 0.4. The volume density of AGL5 was lower than that of AGL3 and AGL8, see Fig. 6.

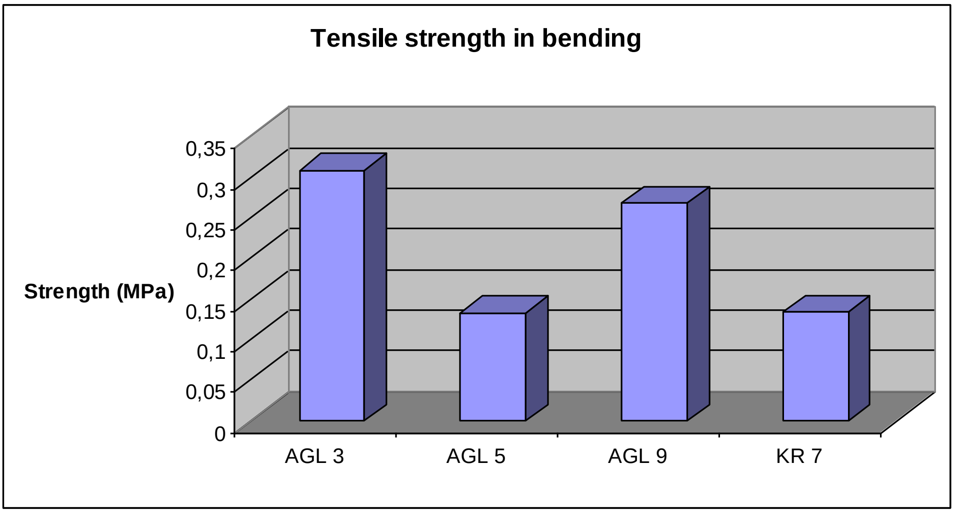

Fig. 7. Results of tensile strength from bending tests for all tested sets of rammed earth.

4 Conclusions

Rammed unfired contains many secrets. The present study demonstrates that it is important to choose clay as a binder. Meanwhile, the Illitic-Kaolinitic clay seems more suitable in terms of compressive strength. This is also the case with rheological properties [4,5]. The bulk density has a significant influence on the achieved strength. Proper compaction of the mixture can significantly affect the strength achieved. It is advisable to achieve a bulk density of mixtures close to 2100 kg/m³. Proper compaction can be achieved with a sufficiently plastic mixture. As the flexural tensile strengths show that water to clay ratio 0.4 or higher is suitable for mixture. Lower water to clay ratios cause insufficient coating of sand grains with clay and higher porous structure.

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