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Shrinkage of Rammed Earth Based on Illitic Clay

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Abstract. The paper is focused on testing rammed earth, prepared from illitic clay, sand and water. The rammed earth was used for testing in creep and in shrinkage test. Six specimens were used for preparation of tests. Temperature and weight of specimens were observed during testing, which was 100 days long. Finally, curves of measured parameters were established from measured data. The comparison of influence between creep and shrinkage on the deformation was realized.

Introduction

The lack of material properties of unfired and rammed clay is at the same time one of the main causes of its unpopularity in the building industry in Europe [1]. Rammed clay has its undeniable advantages over modern building materials [2]. The advantage is its ecological and energy modesty during construction [3]. Of course, this building material has its disadvantages. The unavailability of material characteristics and thus considerable design uncertainty is one of the drawbacks.

The paper seeks to explain the behavior of one type of rammed clay in terms of material properties. Attention is focused on material shrinkage and creep [4]. In parallel with the rheological properties, mechanical properties of the clay are needed, because deformation of construction made from unfired clay can be relatively large. The process of shrinkage of unfired clay is coupled with changes of content of the water in material [5]. On the other hand creep of material depends on the loading of material.

Fig.1 The specimens used for measurement material properties, prepared from illitic clay

About of material

The experiment was realized with earth prepared form illitic clay, sand and water. The sand was composed of two fractions, 0-1 and 1-2 mm [6]. Smooth line granularity was created using of both fractions in the ratio of 60 : 40 (fine and coarse part). The clay was in a mixture represented 20 %, and sand accounted for 80 % of the dry mixture. The water ratio, defined as the relation between clay and water weight had size 0.37.

Preparation of mixture is basic step for production of quality material [7]. Firstly, sand was mixed with little content of water. Next step was in addition of full plenty of clay to sand. After then the sand and clay was blended by stirring attachment. During blending the remainder of water was added to the mixture. After a mixing process the mixture was knead in hands. Finally, the mixture was mixed by stirring attachment for 1 minute.

The mixture was placed into the moulds and rammed in several layers. The dimension of small specimens used for testing of creep was 20 × 20 × 70 mm. The specimens for compression testing had length 100 mm and same cross section area. Testing of bending stress was realized on specimens with dimension 40 × 40 × 160 mm. Compaction of small specimens was realized around in 5 layers. Bigger specimens included approximately 6 layers of compacted material.

The specimens were removed from moulds in same day like their production. All specimens were placed in climatic chamber to condition 20°C and relative humidity 50 %. Drying of material is process for increasing of its material properties. The weight changes of specimens were observed [4]. Creep of rammed specimens was started 6 hours after their production.

Test of material

Material tests were realized on the 12 specimens of different age, see Fig. 1. Creep test was carried out on the 3 specimens and shrinkage was measured on the 3 specimen, too. Loading area of specimens was octane with distance of opposite edges approximately 20 mm. Length of specimens for measurement was 70 mm. Length of measurement of rheological properties was 100 days. Temperature and humidity were measured in laboratory room in whole length of measure, see Fig.2.

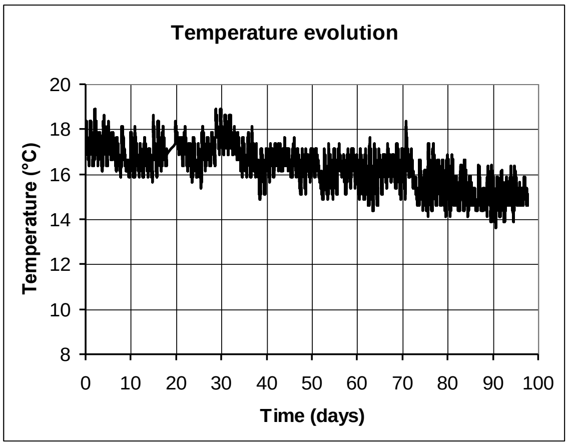

Fig.2 The curve of evolution of temperature during the test

Principle of measurement is in the placing of specimens into the levers mechanisms and measurement its axial deformation [8]. One lever mechanism is used for measurement of the one specimen. Deformation of whole length of specimen is measured by three deformation sensors with accuracy 0.0001 mm. The measurement of shrinkage is realized in the lever mechanism, too, but without loading of mechanism. The specimens are able respond on changes of temperature and their humidity, it is decreased during measurement. Maturation process is related with drying of material. Compression strength depends on the content of free water in the rammed unfired earth.

The specimens were not covered for ability of change of humidity. Weight of same specimens placed in area of measurement was measured, because weight of measured specimens is not possible measuring. These changes of weight were assigned to changes of weight of creep and shrinkage tested specimens. The deformation caused by creep contains deformation from shrinkage. If we want know pure impact of load on the deformation, than is necessary separate impact of shrinkage. Effect of separation of shrinkage is possible express by Eq.1, where δ_{cr} is pure creep, δ_{all} is deformation included creep and shrinkage and δ_{sh} is shrinkage of material.

$$\delta_{cr} = \delta_{all} - \delta_{sh}. \tag{1}$$

Results

Results are summarized in the graphs. Specimens No. 1 – 3 represents loaded state and specimens 4 – 6 were used for measurement of shrinkage, see Fig.3. As is possible see, for the shrinkage is important humidity and temperature condition. The main change took place in first ten days, see Fig.4. The specimen No.4 had expansion 0.015×10^{-3} milistrain. The specimens No. 5 and 6 had expansion near to 0.019 and 0.022×10^{-3} milistrain. The specimen No. 4 had different course of development to specimens No. 5 and 6 on beginning part of measurement.

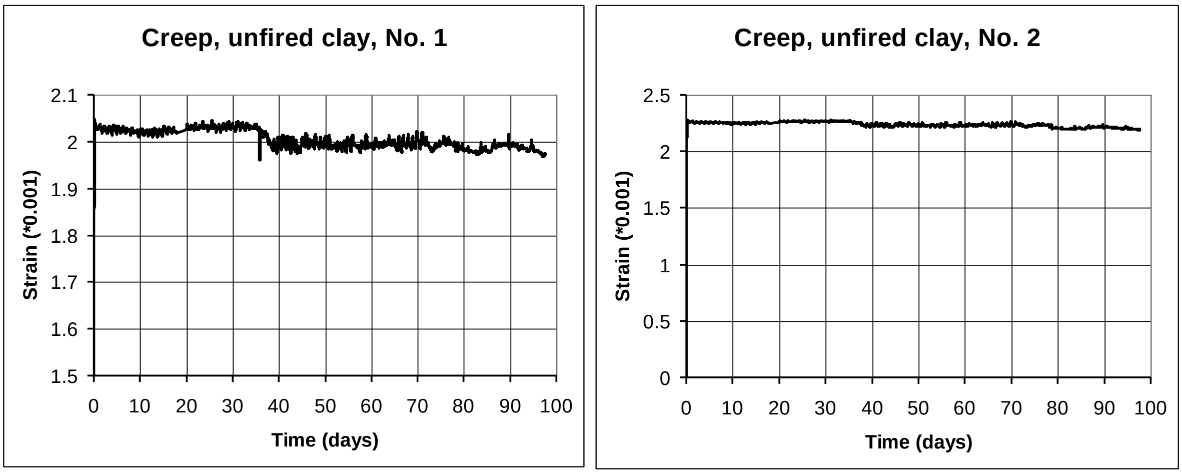

Fig.3 The curves of the creep included shrinkage of specimens 1 and 2

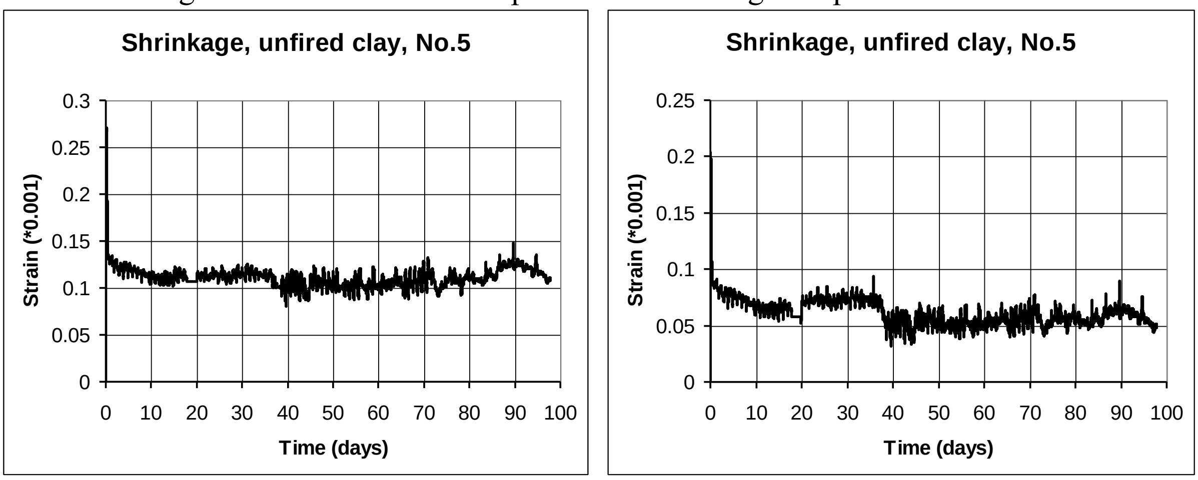

Fig.4 The curves of the shrinkage of specimens 5 and 6

The creep included shrinkage (δ_{all}) had size of strain stable during whole time of loading. Little changes relates with temperature changes, which are is possible see in graph of temperature evolution. The change of interior temperature in laboratory had occurred at 37 and 77 day of measurement, as is possible see on Fig.2. The temperature decreased about 1 °C in both cases of change. Of course, these sizes of creep included the shrinkage and do not reflect only influence of creep.

Using the Eq.1 is possible achieve pure creep. It is displayed in graphs in Fig.5 expressed creep without shrinkage for specimens 1 – 3. Influence of shrinkage was calculated by measurement on specimen No. 5. The deformation of specimens firstly increases due to loading in compression direction. Next, during one day the deformation is decreasing near to half level of initial deformation after the loading. Further development of deformation is possible characterized as a significant slowdown of deformation changes. The process change of the creep deformation ceases after 10 days from start of measurement. The size of this small change is near to 0.03×10^{-3} milistrain. Next evolution of deformation caused from pure creep is stopped.

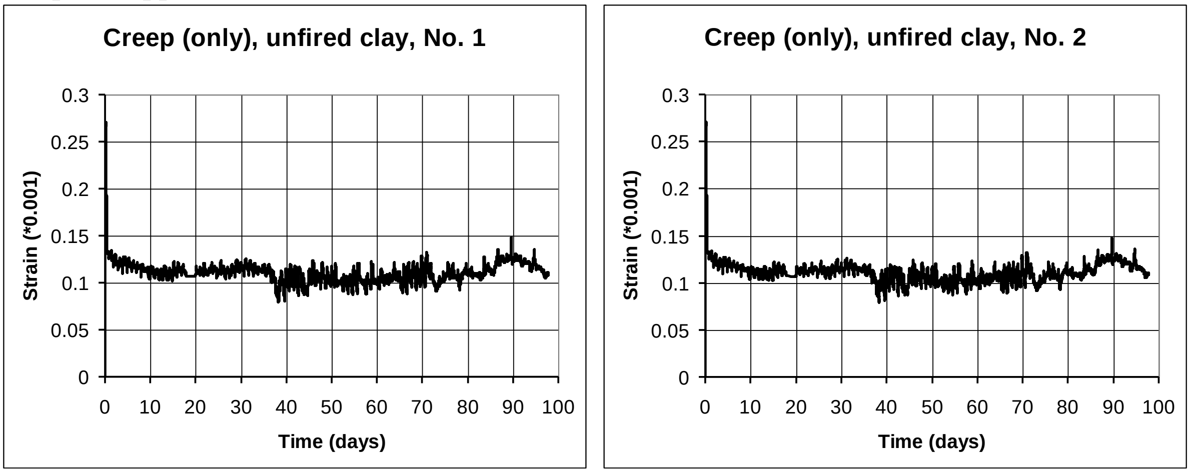

Fig.5 The curves of the creep without influence of shrinkage of specimens 1 and 2

Conclusions

Rammed earth has a very interesting perspective of creep properties. Totally interesting result is the size of shrinkage and creep after 100 days. This reached a value of 0.03×10^{-3} milistrain in the direction of compression for shrinkage, and approximately 2×10^{-3} for creep in same direction, see Fig. 2. But this value is influenced by shrinkage. The creep without shrinkage achieved value of strain 0.11×10^{-3} milistrain from initial deformation after loading. The evolution of creep and are very influenced of the reaching of compression strength. Iimportant influence on the size of deformation of rammed unfired clay has a shrinkage of material as is possible see from graphs and measured date. The end of creep is related with increasing of strength of material. The strength of material depends on rate of drying unfired clay. The curves of shrinkage are influenced by changes of humidity in first days of measurement. Next changes of shrinkage depends on the increased or decreased temperature of environment [9]. Results are comparable with material prepared from same ingredients but in another one relation [10].

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