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Shrinkage of Rammed Unfired Earth in Long Term Observation

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Abstract: The paper is devoted to the creep and shrinkage of compacted unfired earth. The creep of illitic-kaolinitic clay has been monitored for a long time. The initial measurement was focused on the initial course of creep. The long-term measurement took place for almost 4 years. The compacted clay was prepared using a water coefficient of 0.295, when the amount of illitic-caolinitic clay used in the mixture was 30%.

Keywords: rammed unfired earth; illitic-caolinitic clay; shrinkage; creeping of material; water ratio.

1 Introduction

Rammed unburned earth has been a traditional building material since time immemorial. In recent centuries, however, modern materials such as concrete, steel and fired ceramic products have been used. Rammed earth has receded into the background of modern materials [1]. However, there are still applications where unburned earth is useful in building structures. A weakness at present is the little knowledge of the properties of rammed unburned earth needed for the design of load-bearing structures.

For construction purposes, rammed unfired earth is a material for which it is advisable to focus not only on strength properties, but also on rheological characteristics. An important factor for monitoring the rheology of unfired clay is the need for mixing water during the creation of the mass. Creep and shrinkage are rheological properties of clay that have a significant effect on the long-term behavior of the structure.

The goal of creep measurement is to determine the behavior of the material over time. The rheological properties of compacted clay and their measurement are dependent on the knowledge of the material properties, especially the compressive strength. Knowing the material properties allows us to correctly set the amount of load for measuring creep. Fresh compacted clay increases its compressive strength by gradual drying, i.e. the release of loosely bound water, which is necessary for high-quality processing during the preparation of the mixture.

2 Tested Material

The pressed clay was prepared from sand, illitic kaolinitic clay and water. The mass ratio of water to illitic kaolinitic clay was 0.295. The ratio of sand and clay was 70:30. The samples for creep and shrinkage testing were prepared together with the samples intended for material tests.

The ratio of water to total solids of the mixture was 0.4. The ratio is expressed by the coefficient w - water coefficient. The amount of solids is the sum of the weights of clay and sand used. Sand plays the role of filler in the mixture, clay has the function of binder. The binding function of clay consists of covering the grains of sand with a layer of clay. It binds the water in the mixture and creates a suitable binder structure of the mixture. If the water content in the mixture is lower, the necessary binding structure of the binder is not formed. On the contrary, if the amount of water in the mixture is higher than the amount needed to create the binding capacity of the clay, the water remains outside the binding space. This water disappears during drying and after the free water, an imperfectly dense - more porous structure of compacted clay is formed. The tested mixture belonged to the area with a higher ratio of water and clay.

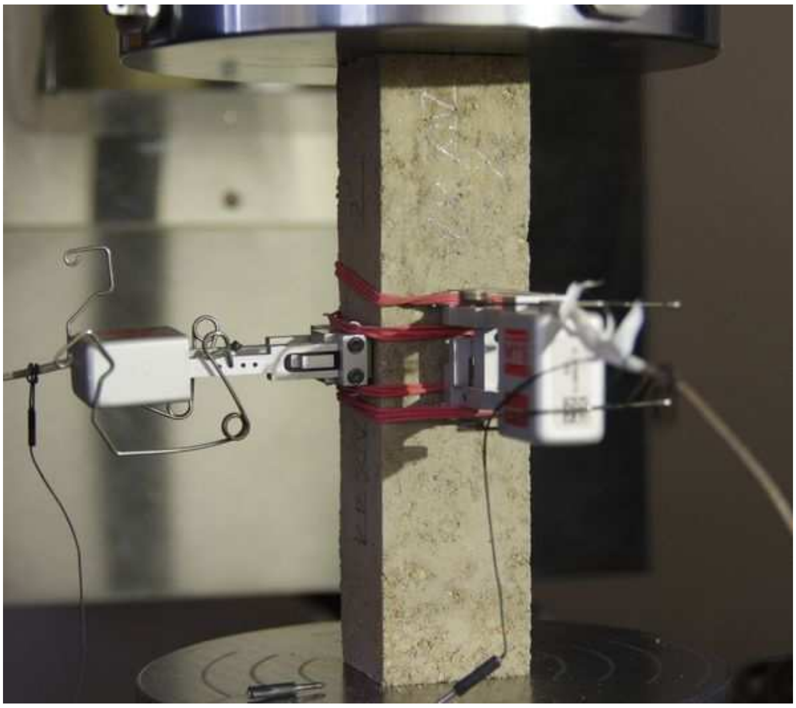


Fig. 1: Illitic kaolinitic clay prism specimen in compression test with sand clay ratio 70 : 30.

The material properties were investigated on prisms 40 × 40 × 160 mm Fig.1., which were produced simultaneously with the bodies for creep. The creep specimens had a hexagon-shaped base with a distance of 20 mm from opposite edges. The height of the specimens was 70 mm due to the installation in the lever measuring mechanism, as is seen in Fig. 2. The measurement was started on 6 specimens, where 3 samples were intended for creep measurement and 3 samples for shrinkage measurement.

Fig. 2: One of the specimens of illitic kaolinitic clay after creep test.

The production of both types of samples took place by making a mixture of clay, sand and water. The mixture was placed in layers in steel molds and compacted [2]. After filling the mold and compacting the last layer, the specimens were removed from the molds and left to dry naturally in laboratory conditions. The bodies intended to measure creep and shrinkage were immediately placed in the lever mechanisms and the measurement was started.

3 Instrumentation of Experiment

The creep specimens had a hexagon-shaped base with a distance of 20 mm from opposite edges. The height of the specimens was 70 mm. All tests took place in lever mechanisms. A lever mechanism for measuring creep applied a load to the specimen of 53 N. Shrinkage was measured in a lever device that was used only to clamp the strain sensors. These specimens were not subjected to force, as in the case of creep measurements. The size of creep and shrinkage was recorded using optoelectronic probes SM 12. 3 sensors were placed around each specimen in the axial direction of loading of the samples, see Fig. 2.

The specimens were immediately inserted into the test devices and started with the measurement. The data has been collected in a locally placed PC file. Creep measurement was carried out on 3 specimens. Shrinkage was measured on two specimens. One specimen that was intended for creep measurement was damaged during instrumentation. A total of 5 specimens were used for measurement.

During the measurement period, the temperature at the place where the samples were tested was recorded. During the first 4 months, measurements were recorded regularly. In the following period, the measurement was recorded sporadically, while the location of the electrical supply of the probes was maintained throughout the measurement period. However, the actual data storage was very sporadic as time progressed. Data recording during regular measurements was carried out every 5 minutes.

The continuous measurement period was 1557 days. However, the data recording was sporadic, as can be seen in Fig. 3, where the evolution of the temperature during the measurements in the laboratory is shown in Fig. 3.

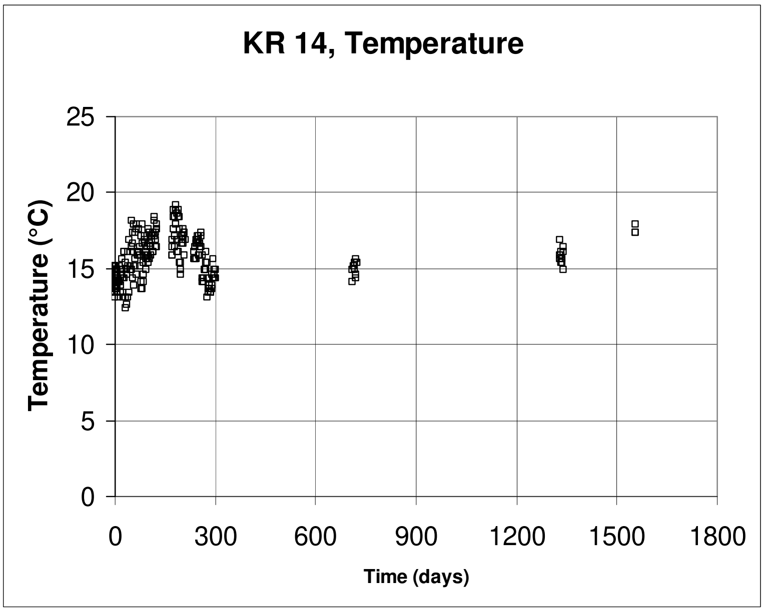
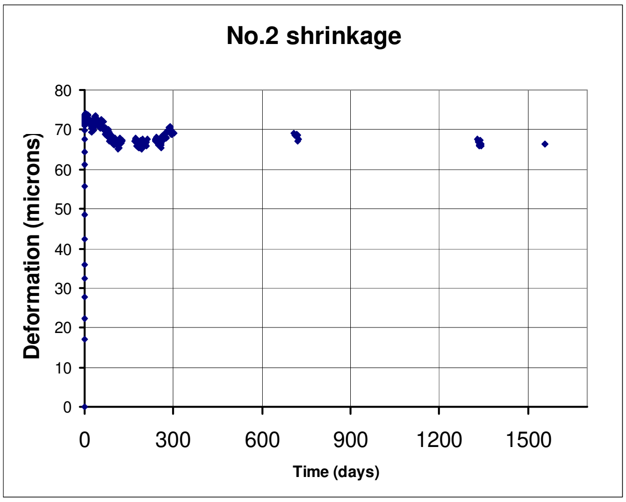


Fig. 3: Evolution of temperature during the testing.

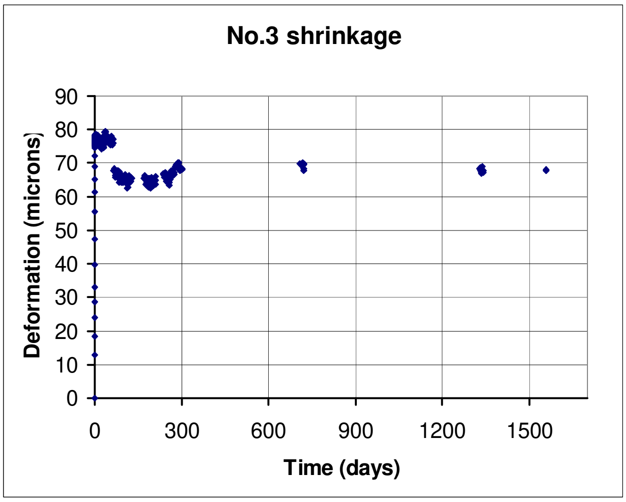
4 Results

Figures 3 to 6 show measured data from a long-term measurement. The method of connecting the measured values into a curve was not used for the display, but only the measured values in the graphs would be left. The data has been reduced so that the creep and shrinkage values are shown in the graphs in the number of one record per day. In the initial phase, the measured values are more frequent.

The temperature varied between 14 and 17 °C during the measurement. The oscillation that is visible in the first year of measurement can be explained by the increased temperature between autumn and spring. The beginning of the measurements was carried out in the summer months. Heating during the winter months in the laboratory was important for changing the temperature. If we were to use all the recorded values, we

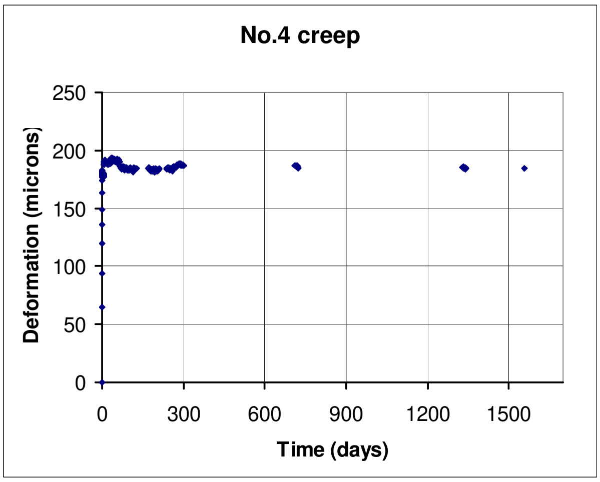


a) Shrinkage curve of rammed earth prepared from illitic kaolinitic clay, water ratio 0.4

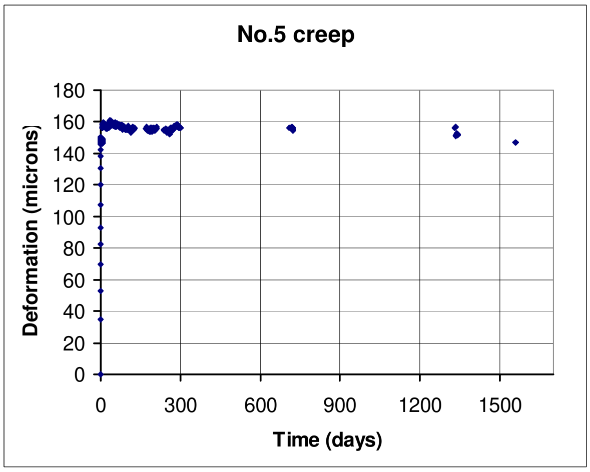


b) Shrinkage curve of rammed earth prepared from illitic kaolinitic clay, water ratio 0.4

Fig. 4: Curves of shrinkage for rammed unfired earth with ratio of clay and sand 30 : 70 and water ratio 0.4.



a) Creep curve of rammed earth prepared from illitic kaolinitic clay, water ratio 0.4



b) Creepe curve of rammed earth prepared from illitic kaolinitic clay, water ratio 0.4

Fig. 5: Curves of creep for rammed unfired earth with ratio of clay and sand 30 : 70 and water ratio of 0.4.

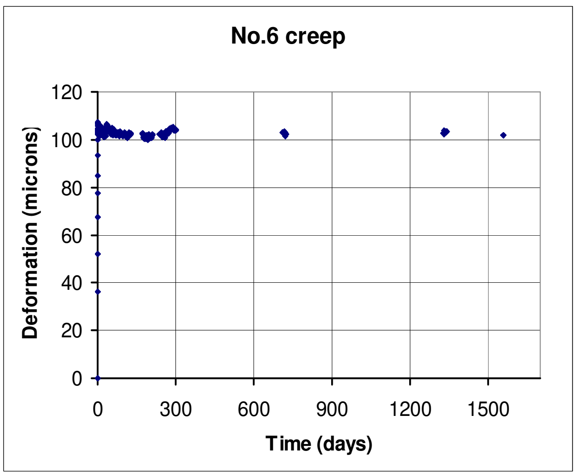


Fig. 6: Creep curve of rammed earth prepared from illitic kaolinitic clay, water ratio of 0.4.

would find that the temperature fluctuation with a difference of 3°C is more likely due to the daily change of temperatures and the ability of the air conditioner to regulate the temperature change during the day. The temperature change is comparable to, for example, the temperature change recorded during a similar measurement [3].

Shrinkage that occurred during the measurement is most noticeable at the initial time of data recording. At the beginning, the material dries out, which is accompanied by a change in the thickness of the specimens. In both cases of the specimens shown in Figure 4, the shrinkage value was around 70 microns at a length of 70 mm. This means that the relative strain has a value of $1 \cdot 10^{-3}$.

After drying, i.e. evaporation of free bound water and constant temperature in the laboratory, the shrinkage remained at the achieved value of 70 microns.

In the case of the creep measurement, the evolution of the deformation was similar to the deformation from shrinkage. The graphs in Figures 5 and 6 show an increase in deformation at the beginning of the measurement and the subsequent steady development of the measurement throughout the measurement period.

The largest deformation values were achieved at 180, 158 and 103 microns. The highest values were recorded around the 40th day of measurement. Subsequently, the size of the deformation did not increase. This is in contrast to the shrinkage measurements where the highest values were reached on the second day from the start.

5 Conclusion

The result of the measurement is a comparison of the creep and shrinkage of the crushed adobe material, which contained a significant amount of mixing water. The very plastic material resulted in damage to one specimen during instrumentation in the measuring device, as well as considerable deformation of the material at the beginning of the measurement. The result of the experiment can be summarized in the following points:

- The size of the water coefficient has a significant effect on the amount of shrinkage and creep of the material.
- Shrinkage was 50% of the average creep value of unfired clay (70 microns / 147 microns).
- After reaching strength, i.e. evaporation of loosely bound water, there is no significant change in the amount of creep and shrinkage even during long-term observation.
- Illitic kaolinitic clay in the mixture has a stable mixture behavior. The amount of creep was significantly affected by the large water factor. For less saturated mixtures, the amount of creep is up to 10 × smaller. After reaching the strength, the deformation of the material hardly changes.

Acknowledgement

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