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Mechanical Properties of Rammed Earth with High Water-Clay Ratio in Tensile Bending Test

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Abstract. The paper is focused on mechanical properties of rammed earth with illitic clay and high water-clay ration in tensile bending test. The modulus of elasticity and tensile strength in bending were measured and evaluated. Three different mixture of rammed earth were designed and tested. The amount of water and binder is one of the key properties of the rammed earth, the amount of the water is expressed by the water-clay ratio. Mechanical properties of the earth material highly depend on the composition of sand, clay and water. The prescription AGL III with 80 % of sand, 20 % of clay and 0.4 water-clay ratio seem to be optimal.

Introduction

The rammed earth is nowadays considered as a sustainable way for modern building. The article is focused on illitic rammed earth with high water-clay ratio. The mechanical properties that were searched are modulus of elasticity and tensile strength in bending.

Fig. 1: Producing the mixture and final specimens

Producing the mixture. The material is a mixture of sand, clay and water. The amount of water and binder is one of the key properties of the rammed earth, it is similar to concrete, so the amount of the water is expressed by the water-clay ratio. The type of the clay is another important factor. In this case all prescriptions were made with illitic clay, so that the volume of water-clay ration can be evaluated just to one clay. Three different prescriptions were designed

and tested for determining mechanical properties of rammed earth with high water-clay ratio. The AGL sets III (80 % of sand, 20 % of clay and water-clay ratio 0.400), V (85 % of sand, 15 % of clay and water-clay ratio 0.370 – set with minimum amount of clay), and IX (80 % of sand, 20 % of clay and water-clay ratio 0.450 – set with the highest water-clay ratio), are all with illitic clay.

Table 1: Tested specimens and their prescription and results

Prescription	Sand/clay – water-clay ratio	Modulus of Elasticity [MPa]	Tensile Strength in Bending [MPa]
AGL III	80/20 – 0.400	68.742 ± 28.224	0.059 ± 0.002
AGL V	85/15 – 0.370	49.056 ± 15.171	0.028 ± 0.003
AGL IX	80/20 – 0.450	27.038 ± 7.597	0.051 ± 0.001

Building of rammed earth. The process of building rammed earth wall is as follows: first of all, the framework is built, then the first layer of rammed earth is filled in. Secondly the layer of moist earth is compressed by a tamper. Than next layers of moist earth are added and compressed up to the top of framework. Finally, the framework is removed. [1, 2] In the same way laboratory specimens were made. This process can be seen in Fig. 1.

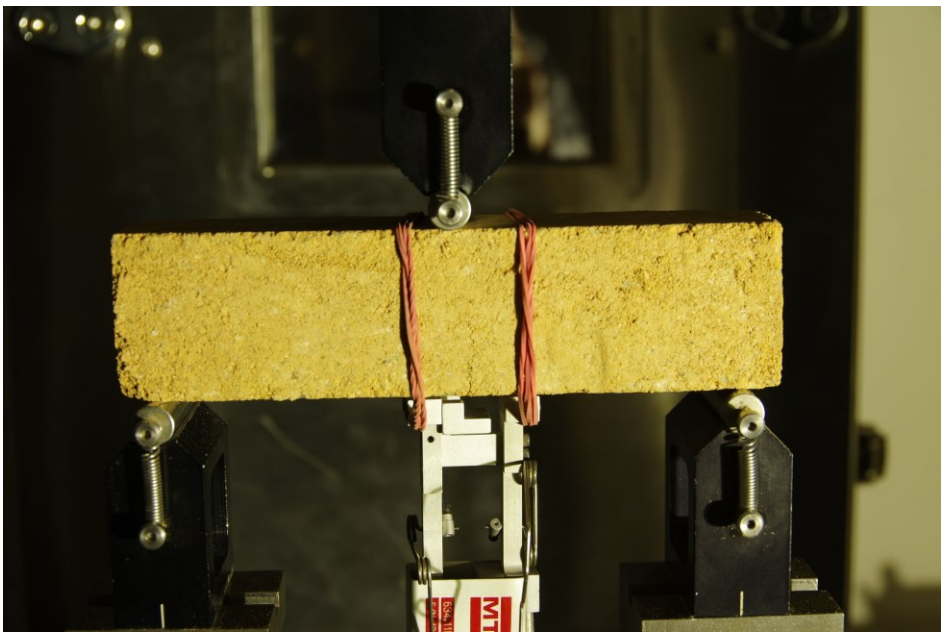

Fig. 2: A rammed earth specimen during a tensile bending test

Evaluation of Measured Data

The evaluated data are shown in the table 1. In the columns there are stated the name of the tested set, a composition of the mixture (ratio of sand and clay – in summary it gives 100 % and water-clay ratio), the mean value of modulus of elasticity, a standard deviation of the data and the mean value of tensile strenght in bending and standard deviation of the data.

The maximal force in the test and then tensile stenght in bending was measured. The modulus of elasticity was evalueted from the force displacement curve. The curve was croped at the beging and the it was possible to evalueted the modulus. [5, 6] The maximal and minimal values are shown in the table 1., they represent the mean values and their standart deviation, in the text the standart deviation are missed out. The maximum of tensile strength in bending is 0.059 MPa (AGL III) and the maximum modulus of elasticity is 68.742 MPa (AGL III). The set AGL III

have the maximal values of both observed mechanical properties. The minimum of tensile strength in bending is 0.028 MPa (AGL V) and the minimum modulus of elasticity is 27.038 MPa (AGL IX). In contrast with the same set AGL III with both maximal values, the minimal values differs for modulus of elasticity and tensile strenght in bending. From this point of view the prescription AGL III with 80 % of sand, 20 % of clay and 0.400 water-clay ratio seem to be the best composition.

In comparison to the other tests that were already done [3,4], the values of tensile strength in bending is lower at the prescription with high water-clay ratio.

Discussion

As a problem that seem to be characteristic for this material is a quite big range of measured data, big value of the standard deviation – especially in the case of modulus of elasticity up to 41 %. The manufacturing of the specimen is very exacting and several types of tests are made, three pieces for the bending test are used. One reason can be the small number of tested specimens and secondly, the other reason can be that the rammed earth is a quite brittle material. On the other hand, the standard deviation of the tensile strenght is only up to 9 % and very simillar to all prescription

Conclusion

The mechanical properties of the earth material highly depend on the composition of sand, clay and water. The amount of water and binder is one of the key properties of the rammed earth, it is similar to concrete, so the amount of the water is expressed by the water-clay ratio. The water-clay ratio 0.400 seems to be optimal with the composition of 80 % sand and 20 % clay.

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