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IMPROVING THE PROPERTIES OF UNBURNED EARTH TO CONTROL THE INTERIOR MICROCLIMATE

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Abstract. The article concerns the problematics of unburned earth used as material for moulding formwork or clay plaster with lowered contraction, especially about interior unburned earth plaster with the heightened percentage of clay and therefore improved sorption abilities. By adding a plasticizer, it is possible to modify the fluidity of the mixture. With lessening the amount of water it is possible to lower the shrinkage. Furthermore, we can increase the ratio of clay to sand and thus we can control the indoor microclimate. This is because the clay provides adsorption properties. Unburnt clay has been widely used as a building material in the past around the world. In the last century, this material was rather despised. Nowadays, however, this trend is reversing and the unburnt clay is experiencing a renaissance. Increasingly people emphasize ecology, a healthy and balanced indoor climate, and demand buildings with low operational and energy intensity. All this can be offered by unburnt clay, because it is energy-efficient in production, easily accessible in almost all parts of the world, harmless, and beneficial to human health, as clay can contribute to the improvement of the internal microclimate to a much greater extent than other building materials, as confirmed by many scientific findings.

Keywords: Earth, clay, microclimate.

1. Introduction

Unburned earth can be defined as building material held together primary by clay. Unburned earth is a common material in the building industry around the world. But the European building norms don't know this material. Unburned earth can be defined as soil or a mixture of soils with added ingredients suitable for building purposes which compose of fine-grained fractions of clay particles as the primary binder and dust particles, further composed of sand and gravel fraction used as filler. Also other materials can be used in the mixture such as scattered reinforcement formed by a fibrous admixture, pigment and secondary binders and stabilizers, all used in the right amount. The primary source of the binding ability is clay materials. Clay is also the main source of the positive features as sorption, especially the regulation of the indoor microclimate. Depending on the physicochemical properties, it occurs mainly in the kaolinite group, the montmorillonite group and the illite group. These clay minerals are often forming mixed clay sediments. The structure of clay minerals is layered. It consists of layers of oxygen tetrahedra with a silicon atom in the middle and layers of oxygen octahedra with an aluminum atom in the middle and an interlayer space (see Figure 1).

Water penetrates into this interlayer space, especially in the case of montmorillonibte, which causes swelling. Swelling and thus shrinkage during drying is the lowest in kaolinite, higher in illite and highest in montmorillonite. If the water recedes from this intermediate layer, the electrostatic attractive forces, which are the essence of the binding ability of clay minerals, will increase. It is, therefore, not a chemical binder and the process is reversible.

Water is also important when moving the components of unburned earth, including mineral plates and their arrangement during drying. Here the water can be partially replaced. Kneading the mixture or vibration helps to ensure a good arrangement. This can reduce the required amount of water needed for the mixture. However, these procedures are mostly associated with the technology used, and they can often not be replaced or used at all, especially for plasters.

In terms of soil classification according to ČSN EN ISO 14688-2 [1], the result is most often soils siSa, clSa, grsiSa, grclSa, grsasiS, grsaclS, sagrsiS and sagrclS. For practical reasons, they are often mixed from Cl, siCl, clSi soils in practice called clay or loess and Sa, grSa soils in practice called mortar sand. For some techniques, Gr, saGr in practice called gravel or gravel sand is added. We can thus determine the ratio of individual components. By choosing clay minerals and choosing the ratio of individual components, we influence the binding and shrinkage during drying.

In terms of soil granularity according to ČSN EN ISO 17892-4 [2], clay represents a fine-grained fraction up to 0.063 mm consisting of clay and dust particles, mortar sand represents a sand fraction from 0.063 to 2 mm consisting of fine, medium and coarse sand particles and gravel fraction. From 2 to 63 mm consisting of fine, medium and coarse gravel particles. Granulometry in the fine-grained fraction is not interesting

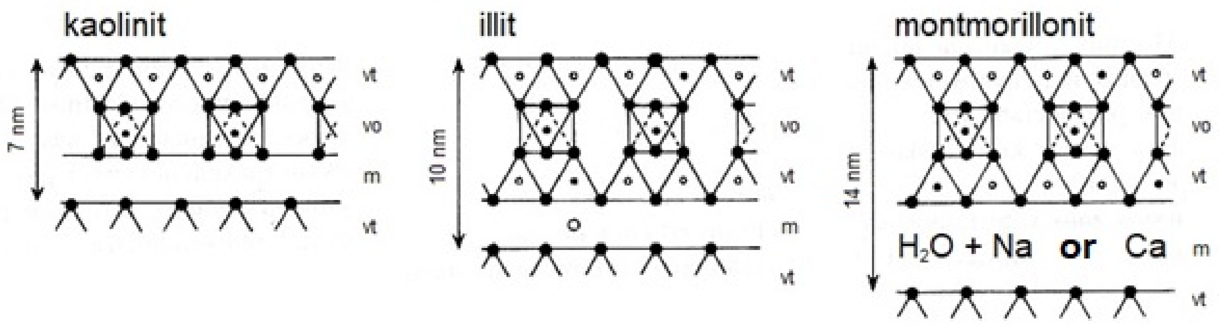

Figure 1. Structure of clay materials.

because it does not say whether and what type of clay particle it is. Granulometry together with the shape of the particles is very interesting for the sand and gravel fraction of the filler. Its suitable curve can positively affect drying shrinkage and strength.

Sorption is a general term for absorption, adsorption. Absorption is the sorption of one substance into another in its entire volume. Adsorption is the binding of a gaseous or liquid substance to the surface of another substance. There are two types of adsorption. Physical adsorption arises from Van der Waals attractive forces. Chemisorption is stronger than physical adsorption, it is formed by chemical bonds. In the context of unfired earth or clay particles, we speak of physical adsorption.

1.1. Ratios of primary components

WO2005092816 (A2) entitled "Use of polymer powder compositions which can be redispersed in water for loam construction materials" discloses a clay dose of 10 to 30 % by weight [3]. Bricks, blocks, mortars for masonry, plaster or are poured or smoked into formwork are made of unburned earth. The amount of clay typically depends on the type and origin of clay or earth, the content of clay fraction or clay minerals, the type of clay minerals, their binding ability and their effect on shrinkage or swelling in contact with water, granulometry of other particles, but especially on the purpose the use of a clay mixture and the associated dose of mixing water. In the case of the use of unburned earth as clay plasters, the approximate proportion of clay is from 10 to 15 % by weight. The proportion from 15 to 30 % by weight is suitable for clay mixtures with a lower water content for stamping into formwork. The values of the proportion approximately above 30 % are suitable at most for mixtures for the production of bricks, where shrinkage does not carry out such a role, because shrinkage takes place outside the structure. The use of a suitable fibrous admixture such as cuttings, shives, etc. makes it possible to positively increase the doses of clay. The clay dose is determined according to the tests below.

The basic binder in unburned earth is clay. Pure clay has a high binding capacity. The minimum binding capacity of the mixture is stated by Vlastimil Havlíček and Karel Souček in the book: "Buildings made of unfired clay" as 250 g/5 cm^2 [4]. Binding capacity is tested on 8-shape samples with defined moisture (see Figure 2).

However, the clay shrinks during drying due to the evaporation of water. This can cause cracks in the unburned earth during drying. Therefore, it is necessary to add dust and sand or gravel particles to the clay as a filler which reduces the total shrinkage to a tolerable limit of approximately 2 % in length.

At higher total shrinkage, for example, cracks begin to form in clay plasters, and separation may also occur from less adhesive substrates. When measuring shrinkage, Havlíček and Souček [4] start from a poor initial consistency. This corresponds broadly to the consistency for steamed clay.

In accordance with the procedures from the book "Building with Earth" by Minke [5], the measurement of shrinkage must be based on the initial consistency for processing according to the technique, and thus on the amount of water in the mixture, which is always given technologically. For clay plasters, Gernot Minke states a consistency with a pour of 180 mm according to DIN 1060-3, which it further reduces to 140 mm [5]. In this article, total shrinkage means shrinkage, which is based on determining the consistency of fresh mortar according to ČSN EN 1015-3 [6] and the prescribed pour value according to ČSN EN 1015-2 [7] and thus for mixtures over 1200 kg/m^3 pour value 175 ± 10 mm. Spill values are measured on a shaker table (see Figure 3).

This value corresponds to measurements performed in practice, where several observations and samplings from several craftsmen were made just before the plaster was applied.

The measurement of total shrinkage is performed either according to Havlíček and Souček [4] in steel or wooden forms measuring 25 × 40 × 220 mm on marks 200 mm distant or according to Minke [5] in metal forms of the same dimensions according to DIN 18952 on marks 200 mm distant or in metal forms size 40 × 40 × 160 mm provided in the faces with pins for measurement according to ČSN EN 12617-4 [8] or by measuring the resulting length dimension of formed beams from metal forms size 40 × 40 × 160 mm

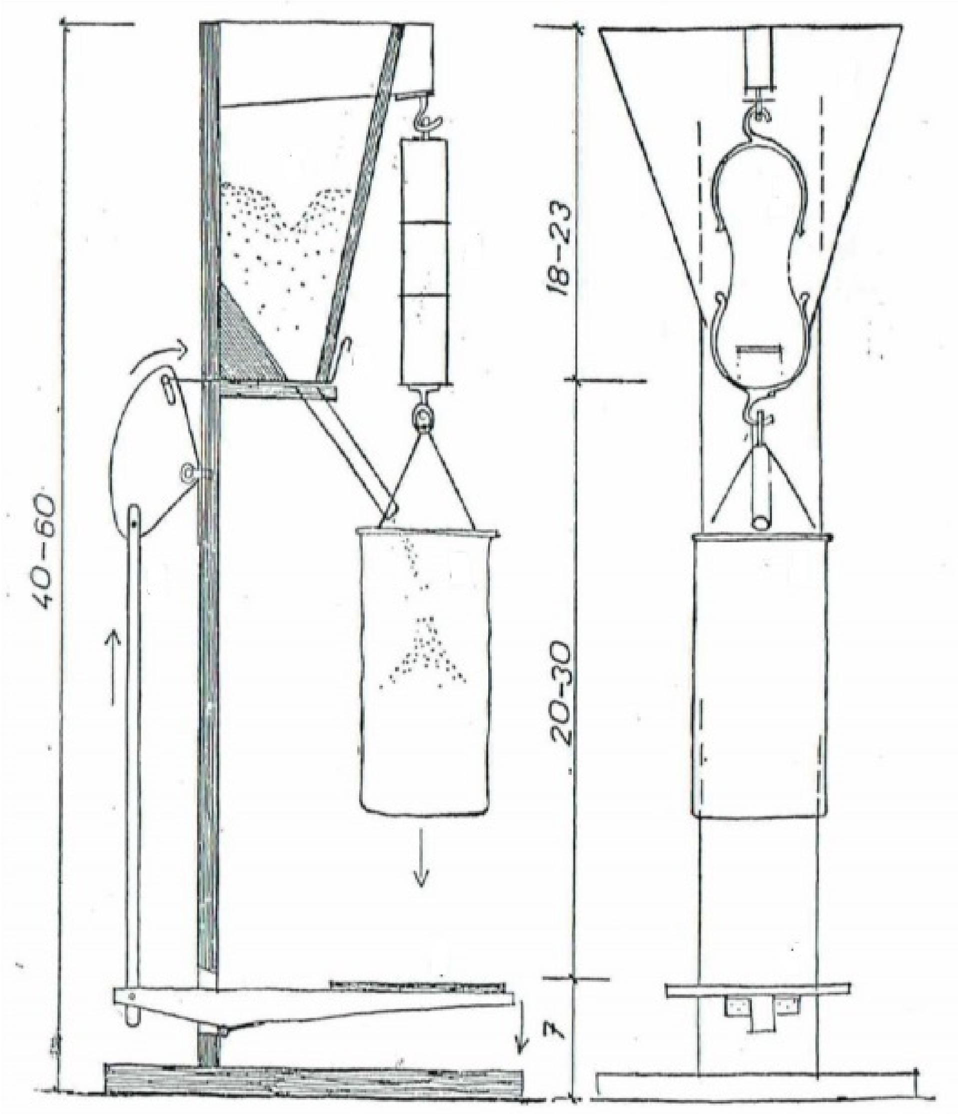

Figure 2. Test of binding capacity

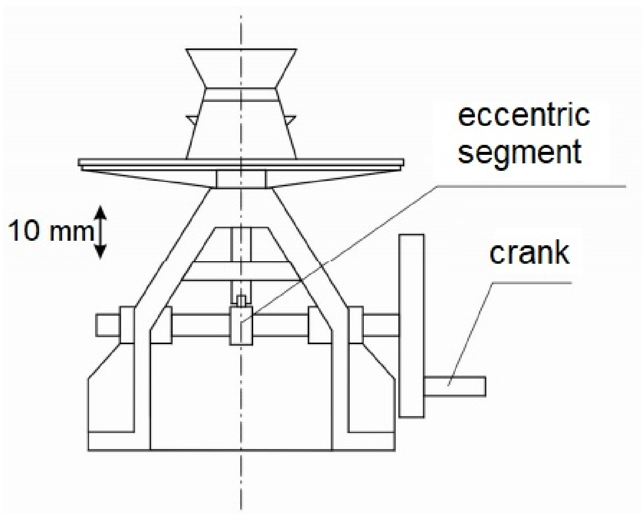

Figure 3. Manual flow table.

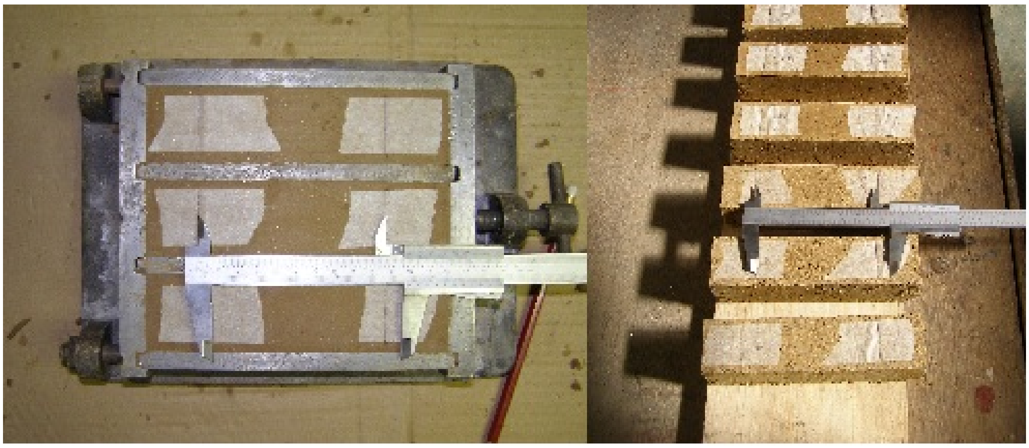

Figure 4. Test of shrinkage.

according to ČSN EN 1015-11 [9] (see Figure 4). The total shrinkage is measured from the above initial consistency of 175 ± 10 mm corresponding to the processing state to the stabilization of the shrinkage at the equilibrium humidity state of the unfired clay. The shape of the form does not affect the result. Total shrinkage is expressed in %.

The ratio between clay and other particles is thus more or less dependent on the technologically given amount of water in the mixture. Another is the dose of water and therefore the consistency for bricks and steamed clay, and it is different for screeds and plasters that need more water for processing and shrinkage causes more problems. The result is that the smallest ratio of clay to other particles is put into the plaster. Although this reduces the overall shrinkage, which is essential especially for plasters, it also reduces the binding ability or bonding and reduces other positive effects of the clay. So it is always a compromise between shrinkage and bonding. This compromise can be improved by suitable granulometry.

Clay in plasters is also a carrier of positive properties such as the adsorption of odours, dusts, allergens, but especially air humidity. Moisture is adsorbed by the clay in clay plasters when there is an excess of ambient air and when it is deficient in the ambient air it is evaporated again. Thus, clay plasters regulate air humidity in rooms. It is therefore desirable to produce plasters with a higher clay content, which is currently not possible due to shrinkage and process ability.

1.2. Ingredients and admixtures

Further improvements can be achieved by replacing part of the filler with a fibrous admixture. This helps in addition to shrinkage reduction and a better and more even distribution of cracks. At the same time, it increases compressive and bending strengths which is especially desirable for plasters. Fibres up to approx. 4 cm are suitable for plasters. Higher doses of fibrous admixtures can impair processability. Longer fibres and larger quantities can be used especially for lightweight structural or filling clay or for levelling layers. Dosing is usually performed by volume. In laboratory conditions dosing is often complicated by the size of the forms.

Other additives such as secondary or stabilizing binders can be added to unburned earth, which can reduce the reaction to the effects of water or improve the strength characteristics or increase the adhesion to the substrate, as stated in CZ document PV 2008-663 entitled "Unburned earth stabilized with polymers" [10].

Bc. Kateřina Nováková mentions the use of plasticizers in her diploma thesis "Research binding capacity of unburnt earth in time" [11] or fluxes that reduce internal friction. However, specific plasticizers are not mentioned, and reference is made in the literature below.

The issue of processability of clay as a raw material for the production of fired ceramic goods is well known in the ceramic industry. Certain analogies can be found between the ceramic and clay industries, but the nomenclature, composition of the clay and use differ. As Gernot Minke states on page 39: "In the ceramic industry, fluid thinning mediums are used to attain higher liquidity, thereby allowing less water to be used (in order to reduce shrinkage). Typical thinning media are sodium waterglass ($Na_2O \cdot nSiO_2$), Soda (Na_2CO_3), and humus acid and tannic acid. Tests conducted at the BRL at the University of Kasselshowed that these methods were of very little relevance to earth as a building material. But tests with whey were successful." [5].

In the field of clay, cheap natural substances are traditionally used to reduce shrinkage, as stated by Ivana Žabičková in the book "Hliněné stavby" on page 31: "Je známo též užití koňské moči, která účinně eliminuje trhlinky a zvyšuje odolnost proti erozi." [12] which means in English: It is also known to use horse urine, which effectively eliminates cracks and increases resistance to erosion.

In the book "Hliněné stavby novej generacie" [13] on page 83, Petr Suske mentions the use of recesses to reduce internal friction.

1.3. Chemical additives for building materials

In the concrete industry plasticizers are used to reduce internal friction. The highest effect is achieved with polycarboxylate-based plasticizers. Tests of their use for unfired clay have shown their unsuitability. Therefore, it is assumed that unfired clay cannot be combined with concrete plasticizers.

2. Solutions

The above-mentioned disadvantages of unburnt earth are solved by the unburnt earth with controlled shrinkage according to the invention “Unfired clay with controlled shrinkage.”. According to it, the mixture contains 95 to 99.99 % by weight. Unburnt earth and 0.01 to 5 wt. at least one plasticizer selected from the group: lignosulphonate-based, naphthalene-based and melamine-based [14].

2.1. Unburned earth for casting

In the first step, using the addition of a plasticizer, we can increase the plasticity or flow ability of the unfired clay without increasing the shrinkage during drying. This can be used wherever the shape of unfired clay adds formwork.

The process for producing unburned controlled shrinkage earth for casting is as follows: first, a dry mixture of unburned, shrinkage-controlled earth containing from 10 % to 30 % by weight is produced. Clay by determining the proportion of clay in the unfired clay as a maximum in the range of 10 to 30 % by weight in the first step of the total shrinkage test, while maintaining the total shrinkage of the unburned earth up to 2 %, then in the second step by the fresh mortar consistency test using of the shaking table determines the optimal dose of plasticizer in the range of 0.01 to 5 % by weight, at which the spillage of unburned earth is maximum and in the third step the dose of plasticizer determined in the second step is made up to 100 % by weight. Unburned earth with a clay content determined in the first step and into the resulting mixture in an amount ranging from 66.7 to 90 % by weight. Water is mixed in an amount in the range of 10 to 33.3 % by weight, determined by a consistency test using a shaker table, so that the amount of water added to the original mixture from the first step corresponds to a pour of 175 mm [14].

2.2. Unburned earth for plasters with reduced shrinkage

In the next step, in addition to the addition of the above-mentioned dose of plasticizer, we can reduce the amount of mixing water so that the consistency again corresponds to the plaster. This will create a plaster with reduced shrinkage during drying.

The process for the production of unfired controlled shrinkage clay for plasters with reduced shrinkage is as follows: first, a dry mixture of unburned earth with controlled shrinkage containing from 7.5 % to 20 % by weight is produced. Clay by determining the proportion of clay in the unburned earth as a maximum in the range of 7.5 to 20 % by weight in the first step of the total shrinkage test, while maintaining the total shrinkage of the unfired clay up to 2 %, then in the second step by the fresh mortar consistency test using a shaking table, the optimum dose of plasticizer is determined in the range of 0.01 to 5 % by weight at which the spillage of unburned earth is maximal and in the third step the dose of plasticizer determined in the second step is made up to 100 % by weight. Unburned earth with the proportion of clay determined in the first step and in the resulting mixture in an amount ranging from 66.7 to 90 % by weight. Admixed water in an amount in the range from 10 to 33.3 % by weight so that the shake table consistency test shows a spillage of 175 mm [14].

2.3. Unburned earth for plasters with increased sorption

In the last step, the addition of the above-mentioned dose of plasticizer and the reduction of mixing water, which would otherwise cause a reduction in shrinkage, can be used to increase the ratio of clay to sand so that shrinkage is maintained. This will cause a plaster with increased sorption. Clay is the main carrier of sorption abilities. The plaster thus helps to clean the air and especially to regulate the humidity microclimate.

The process for the production of unfired controlled shrinkage clay for plasters with increased sorption is as follows: first, a dry mixture of unburned, shrinkage-controlled earth containing from 20 % to 50 % by weight is produced. Clay by determining the proportion of clay in the unburned earth as a maximum in the range of 19.99 to 49.99 % by weight in the first step of the total shrinkage test, while maintaining the total shrinkage of the unburned earth up to 2 %, then in the second step by the consistency test fresh mortar using a shaker table determines the optimal dose of plasticizer in the range of 0.01 to 5 % by weight, at which the spillage of unfired clay is maximum, then in the third step the total shrinkage test is performed on the mixture of unburned earth according to the first step and plasticizer according to the second step, determines the increased proportion of clay as a maximum in the range of 20 to 50 % by weight, while maintaining the total shrinkage of this mixture up to 2 %, and in the fourth step the dose of plasticizer determined in the second step is made up to 100 % by weight. Unburned earth with an increased proportion of clay, determined in the third step and into the resulting mixture in an amount ranging from 66.7 to 90 % by weight admixes water in an amount in the range from 10 to 33.3 % by weight so that the shake table consistency test shows a spillage of 175 mm [14].

2.4. Results of experiments

Figure 5 shows an approximate behavior curve of a melamine-based plasticizer in a clay mixture.

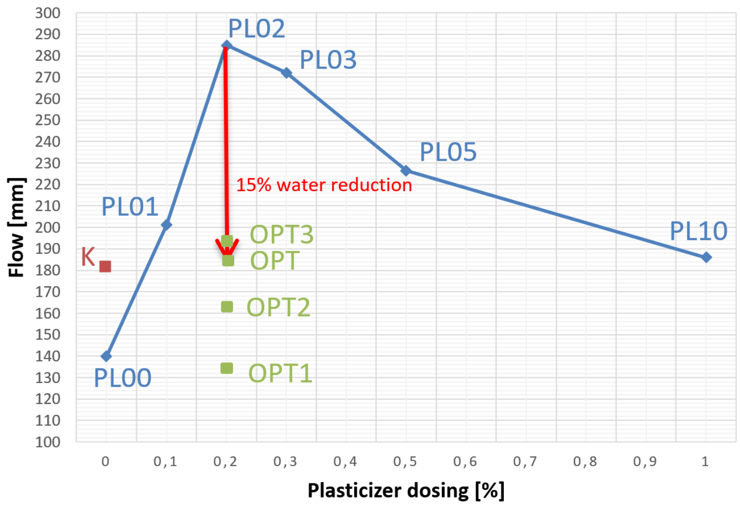

Figure 5. Evaluation of the effect of melamine-based plasticizer [15].

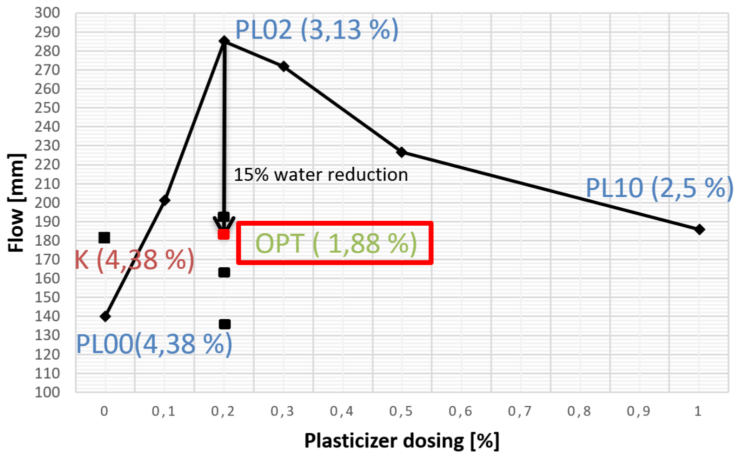

Figure 6. Shrinkage of clay mixtures [15].

The K mixture is a control mixture, with excessive shrinkage and therefore with an excessive dose of clay. Commonly we would reduce the ratio of clay to sand. But this is not desirable from the point of view of the microclimate.

The PL00 mixture has a lower water dose and a melamine-based plasticizer is metered into the other PL mixtures.

The reaction of the clay plaster mixture to the gradual addition of a melamine-based plasticizer can be observed on the blue curve. Figure 5 shows that the plasticizer had the highest efficacy at a dosage of 0.2 %. After optimizing the amount of mixing water, with a final spill of 184 mm, we can observe a decrease of 15 % [15].

In Figure 6, the mixtures are assigned the appropriate shrinkage in percent. The maximum acceptable shrinkage for earthen plasters is 2 %.

The results show the possibilities to increase the fluidity of the mixture, further reduce water by 15 % and reduce shrinkage from 4.38 % to 1.88 %. This can be used to increase the clay to sand ratio and thus control the interior microclimate.

3. Conclusion

Unfired clay is widely used in ecological construction. It is suitable for the preparation of unburned earth for casting and plaster. It is then used in the production of external and internal plasters with reduced shrinkage during drying. It will then use the unique properties in the production of internal plaster with increased sorption. This makes it possible to better regulate the cleanliness and humidity of the indoor air and thus have a beneficial effect on the microclimate.

The specific resulting effect on the interior microclimate will be the subject of further research. However, it is already certain that the ratio of clay to sand can be increased without increasing shrinkage, which is limiting for clay plasters.

Acknowledgements

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