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Clay Mortar Performance Improvement by Modifying the Physical Characteristics of Wheat Straw

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Abstract

Wheat straw is a waste in agriculture, which most often are burnt in the fields, thus contributing to higher emissions of carbon dioxide. Clay-based plaster began to win over the specialists because of the advantages it presents and that are natural materials, environmentally friendly.

The aim of this study is to find a way to improve the mechanical characteristics of plaster based of clay with wheat straw, by saturating straws before placing them in mortars, considering the results obtained in a previous study.

The study's objective is to increase mechanical resistance on plaster based on clay with wheat straw. Due to high water absorption capacity of straw, straw saturation was proposed prior to their introduction into the mix. We studied how saturated straw influenced the mechanical characteristics of mortars.

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1. Introduction

Since ancient times, clay plasters have been a genuine building material. To eliminate or reduce possible defects, such as fissures or cracks, the introduction of wheat straw mortar is suggested. The present study aims at increasing the mechanical performance in the case of clay mortar. In a previous research, organic clay-and-wheat-straw-based mortars were studied. Since the results have not brought added value, studying different ways to increase mechanical

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performance using saturated wheat straw was proposed. This study represents a fundamental research, which justifies through a complex-method-based investigation the beneficial contribution made by placing straw in a saturated solution.

In the construction field, clays are defined as binders, a powdery substance that, when mixed with water, forms a viscous-plastic paste. Under the effect of physical-chemical processes, this paste hardens over time. Due to this characteristic, they are used for binding in a unitary whole granular materials, such as sand and gravel, or various ceramic or concrete products.

Using clays as binders is a quite limited method due to the sensitivity to variations in moisture, which cause their contraction and cracking. To eliminate this drawback, stabilizing clays by physical and chemical methods is suggested. Stabilizing by physical methods can be made with degreasers through hydrophobization and combustion. When using clay as a building material, the stabilization method with degreasers is recommended. The most commonly used degreasing materials are sand, firebrick, ash, wheat straw, rice husks, etc. [1]

In the presence of degreased particles, such as wheat straw, the water films from the clay paste are reduced, leading to reduced plasticity, and thus, to reduced drying shrinkage. The amount of degreased material has to be metered in order to reduce plasticity, but at the same time, to keep a convenient workability that can ensure the possibility of compaction.[2]

The results obtained in the previous studies have shown that straw creates inhomogeneous structures in clay mortars, structures which lead to a decrease in mechanical strengths. Based on these results, the focus was on the absorption capacity of wheat straw, their saturation being suggested before placing them in the mortar.

2. Materials and Methods

2.1. Materials

The proposed material is the clay plaster with added saturated straw of two different sizes. The way in which the geometrical characteristics of wheat straw and in which the degree of saturation influence the properties of the analyzed material was observed.

There were used two types of straw from the August 2013 production: straw length (1-2) cm and chopped straw with the dimensions of (0.1 to 0.2) cm.

Cereals represent the phytotechnical group of plants with the highest area of distribution in all growing areas of the globe, including Romania as well. In Table 1 below we can see the chemical composition of the wheat straw:

Table 1. Chemical composition of the wheat straw

The main components	Percentage %
Crude proteins	2-4
Crude fats	1-2
Non-nitrate extractables	33-40
Cellulose	30-40
Ash	3-12

The ash present in the wheat straw is composed of 70-80% silica and 10-13% potassium. [3]

Four recipes with saturated straw were made. We used two types of clays: commercialized clay and clay extracted from the region of Năsăud. These recipes were compared with those analyzed in the research **Green plastering mortars based on clay and wheat straw**, where straw was introduced dry.

Clays are hydro-aluminosilicate complexes with variable chemical composition and specific physical structure made of lamellar particles with the dimensions between 1 to 5 microns. Clays are mostly made from mixtures of hydro-aluminosilicates having the general formula: $mSiO_2 \circ nAl_2O_3 \circ pH_2O$.[4]

2.2. The Preparation of Composites

A composite material consists of matrix (clay paste) and reinforcement material (i.e. wheat straw). In this paper, we propose studying the 4 recipes of clay mortar with added saturated wheat straw. [3] The properties of the straw depend on its shape and influence in turn the properties of the composite material in a determinant way. Straw of two dimensions was used: straw with the dimensions of (1-2) cm in size and chopped straw of (0.1 to 0.2) cm. Before placing them in the mortar, the wheat straw was saturated.

Out of these:

- Two use ProCrea commercialized clay, meaning:
  - A3 recipe - ProCrea clay mortar with added saturated straw (1-2) cm;
  - A8 recipe - ProCrea clay mortar with added saturated chaff;
- Two use clay extracted from the Năsăud region, as follows:
  - A6 recipe - clay mortar extracted from the ground with added saturated straw (1-2) cm;
  - A10 recipe - clay mortar extracted from the ground with added saturated chopped straw;

The entire process started from personal recipes to which saturated wheat straw was added. The determination of the physical characteristics was performed according to the standards from the Construction Materials Laboratory of the Faculty of Construction.

The mortars were prepared according to the recipes shown in the table 2 below:

Table 2. Clay Mortar Recipes

Recipe	ProCrea Clay [%]	Clay N [%]	Water [%]	Hydraulic bad [%]	Saturated straw 1-2cm [%]	Saturated chopped straw [%]
A3	70		25		5	
A6		20	14	60	6	
A8	80		14			6
A10		14	20	60		6

Prisms of 4x4x16 cm dimensions were cast from the recipes thus prepared. Saturated 12-month-old wheat straw was used with the above specified dimensions.

2.3. Methods

2.3.1. Traditional Methods

The physical and mechanical properties of the mortar were determined according to EN 196. On the prisms thus obtained, bulk density, flexural tensile strength and compressive strength were determined. First, the samples were tested in tension through bending. Then, compression testing was performed on the resulted halves. The samples were prepared and stored according to EN 196. The tests were conducted in order to determine their resistance at 28 and 90 days since their preparation.

The Determination of Bulk Density

The determination was carried out at 28 and 90 days. Prisms were weighed, L, l and h prism dimensions were measured, and then apparent volume and bulk density were calculated. Table 3 indicates the common values:

Table 3. Bulk Density

Recipe	A3	A6	A8	A10
$\rho_{a\ med\ 28\ days}$ [g/cm^3]	1.700	1.690	1.266	1.572
$\rho_{a\ med\ 90\ days}$ [g/cm^3]	1.673	1.680	1.251	1.569

The Determination of Flexural Tensile Strength

It was achieved with the device for determining the flexural tensile strength on three prisms from each recipe with 40x40x160 mm dimensions, in the Construction Materials Laboratory of the Faculty of Construction. Shockless loading was applied at uniform speed in the range of 10 N / s and 50 N / s so that the rupture occurs in a period of 30 seconds to 90 seconds. The maximum applied load is recorded in Newtons. Table 4 below shows the usual results:

Table 4. Values of Flexural Tensile Strength

Recipe	A3	A6	A8	A10
$R_{ti\ med\ 28\ days}$ [N/mm^2]	0.500	0.760	0.580	0.800
$R_{ti\ med\ 90\ days}$ [N/mm^2]	0.810	0.900	0.600	0.890

The Determination of Compressive Strength

The determination of resistance to compression is performed on the remains of the prism resulted after the flexural tensile test, by using hydraulic press.[5]

The Scrap Light Compression Test

Prisms were tested perpendicular to the casting direction. A progressively growing shockless loading was applied with an increasing load rate of about 50 N / s up to 500 N / s so that a rupture occurs within a period of 30 seconds to 90 seconds. A maximum applied load was registered in Newtons. The Table 5 below shows the results:

Table 5. Values of Compressive Strength

Recipe	A3	A6	A8	A10
$R_{c\ med\ 28\ days}$ [N/mm^2]	1.230	1.760	0.760	1.050
$R_{c\ med\ 90\ days}$ [N/mm^2]	1.230	1.900	0.780	1.660

2.3.2. Modern Methods of Investigation Applied to Plaster Mortars Made of Clay with Added Straw

Nuclear Magnetic Resonance Measurements

NMR measurements of the samples were performed using a 20 mq minispec Bruker working at 19.7 MHz. The temperature of the samples was measured during the measurements, and it was 20.3° C. One-dimensional pulse sequences of type CPMG (Carr-Prucell-Meiboom-Grill) were used in order to obtain distributions of NMR relaxation times and bi-dimensional of type T2-T2 and T1-T1 to obtain some molecular exchange folders in porous and correlation environments. [6]

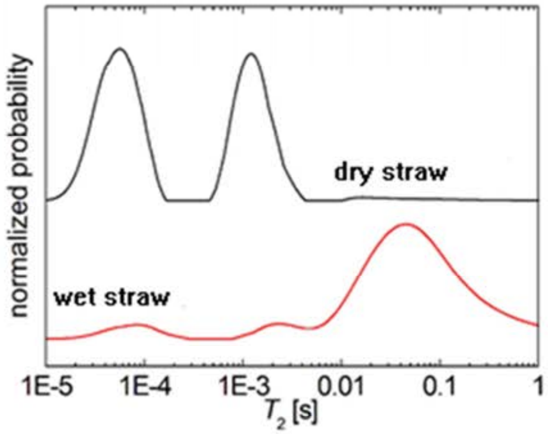

Fig. 1. Normalized probability of wet and dry straw

The above Fig. 1 compares dry straw with wet straw. Three drippings can be noticed with both types of straw. In the case of dry straw we can talk about two main drippings, one centered at a microsecond, in which the hydrogen is related to soft solids, and one dripping centered at 60 microseconds, which corresponds to rigid components. One can notice a small and very widely centered dripping at about 20 milliseconds.[7]

For wet straw, the water effect is major. In this sense, we can notice again three drippings, but those with small values, i.e. hundreds of microseconds, have a much smaller percentage compared to the main dripping centered at 50 microseconds. It can be said that water mainly came into the pores of average size. It can be seen that water influences only in a minor way the rigid components. While watching these results, straw saturation was suggested before placing it in the mortar.

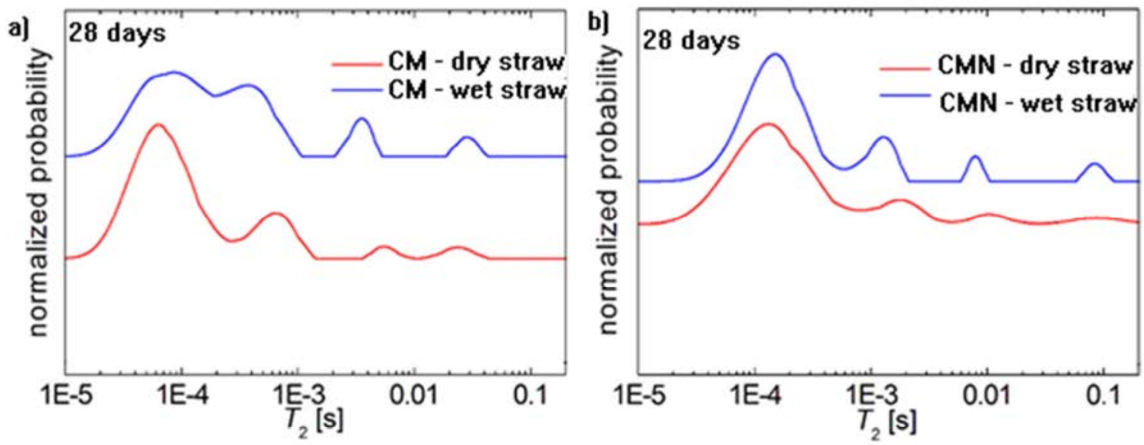

Fig. 2. a) Normalized probability of ProCrea clay mortars with wet and dry straw; b) Normalized probability of extracted clay mortars with wet and dry straw

In Fig. 2 a and b clay mortars are compared with dry straw and saturated straw after 28 days. In both cases, dry straw introduces the highest inhomogeneities. Most of the water is located in tanks, which can be associated with the rigid components. The effect of the wet straw introduced in the mortar is different from the effect of the dry straw. Wet straw acts less on medium and large pores, in the sense that it does not significantly alter the local environment.

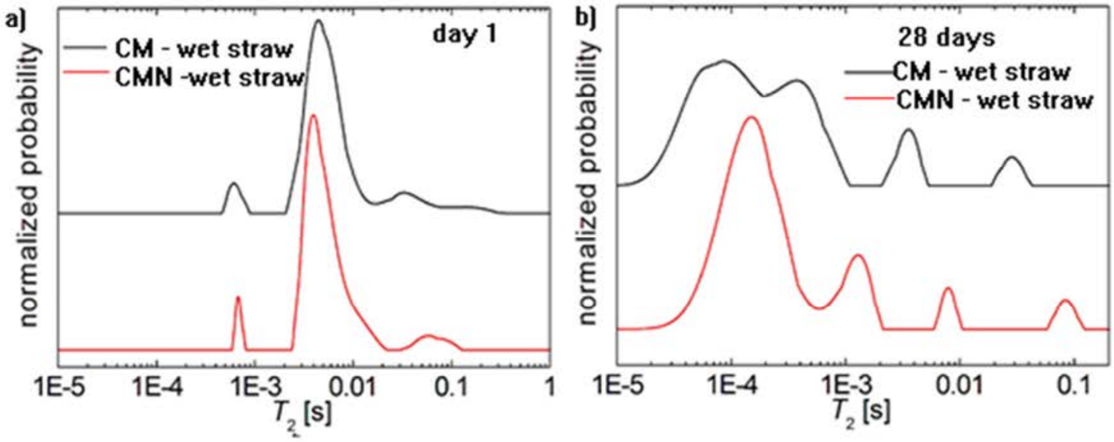

Fig. 3. a) Normalized probability of ProCrea an d extracted clay mortars with wet straw at 1 day; b) Normalized probability of ProCrea and extracted clay mortars with wet straw at 28 days

The Fig. 3 above compares the mortars made of the two types of clay, after one day and after 28 days. If we look at the two distributions, the effect of saturated straw is much lower than the one of dry straw. For both types of clay, after only one day, the wet straw doesn't have enough time to act dramatically on the small pores or on the hydration Comps. The effect of wet straw can be observed especially on commercialized clay, in the case of large pores, by the appearance of the fourth dripping. Fig. 3 a) can tell the difference between the two types of clays, the one extracted from the ground exhibiting very well solved drippings. Large, medium and small pores have larger dimensions than the commercialized clay, which claims that the mechanical strengths of the extracted clay mortars are higher than those of the commercialized clay mortars due to the narrower distributions.

3. Results and Discussions

As a result of the performed determinations, saturated straw has increased the clay mortar resistances. Compared with the results of the previous study on clay mortars with added dry straw, one can observe a significant increase of the resistances. The graphics below show the resistance variations at 28, respectively 90 days, depending on the recipe.[8] The Fig. 4 illustrate the mortars using ProCrea commercialized clay with added dry and saturated straw.

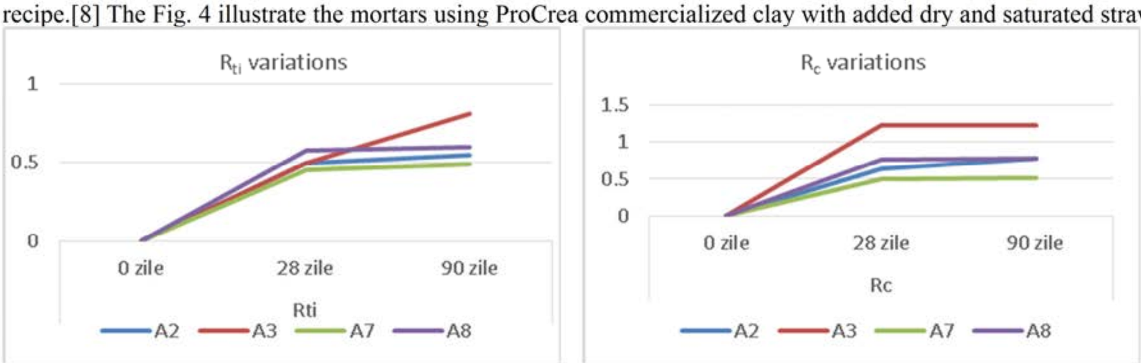

Fig. 4. Resistance variations at 28 and 90 days

The recipes have been compared:

- ProCrea A2 clay mortar with added dry straw (1-2) cm;
- ProCrea A3 clay mortar with added saturated straw (1-2) cm;
- ProCrea A7 clay mortar with added dried chopped straw;
- ProCrea A8 clay mortar with added saturated chopped straw.

One can notice both in the case of chopped straw and the one with sizes between (1-2) cm, that if they were first saturated and then placed in the mortar, they positively influenced the values of flexural and tensile resistance to compression. It can be easily noticed that saturated straw mortars after 90 days, had approximately 60% higher resistances than those with dry straw. The Fig. 5 show mortars made after personal recipes, using clay from the region of Nasaud with added dry and saturated straw.

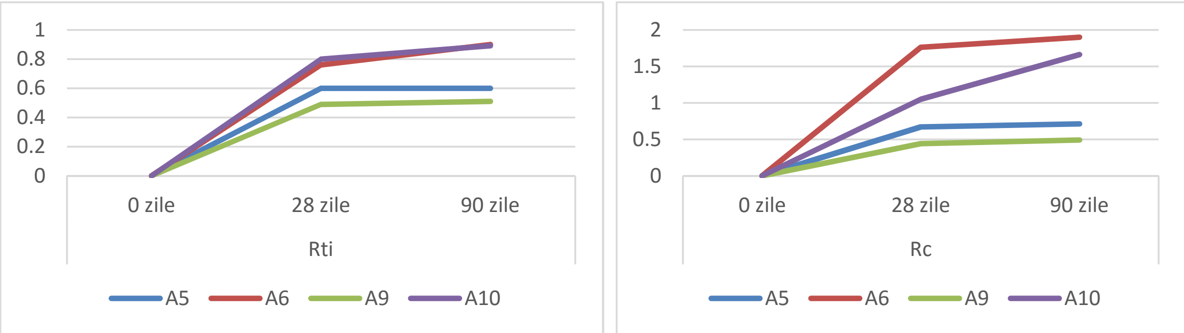

Fig. 5. Resistance variations at 28 and 90 days

The recipes have been compared:
- A5 extracted clay mortar with added dry straw (1-2) cm;
- A6 extracted clay mortar with added saturated straw (1-2) cm;
- A9 saturated extracted clay mortar with added chopped straw;
- A10 saturated extracted clay mortar with added chopped straw.

For mortars made after personal recipes with clay extracted from the area of Nasaud it has been registered an increase of approximately 167% in the compressive strength when adding saturated straw.
It has been found that the usual results after 90 days for all the tested recipes were better, the resistance values being higher.

4. Conclusions

The effect of saturated straw is positive, both when the straw has a size between (1-2) cm and when it was chopped, mechanical strengths having experienced significant increases.

Inhomogeneity given by placing straw in mortars and observed in MRI tests is offset by the positive effect saturated straw brings.

Since the studied material is a plastering mortar, one of the essential conditions is to avoid or limit the cracks on the item the plaster is applied. In this regard, straw has led to increased flexural tensile strength, where its use is recommended in the underlying layers of plaster, A10 recipe indicating the highest values.

The performed tests demonstrate that there are new possibilities for the use of agricultural waste, respectively, of the wheat straw in the production of new building materials.
By using wheat straw, new building materials can be obtained, with similar characteristics to traditional materials.

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