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Evaluate the influence of starch on earth/hemp or flax straws mixtures properties in presence of superplasticizer

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HIGHLIGHTS

- This work present the influence of starch on Earth/plante mixture in its fresh and hardened state.
- The added starch increase the water demand and increases mechanical strengths in present of superplasticizer.
- The studied earth/plante blocks is designed for the production of non-bearing blocks.
- Several studied blocks give mechanical characteristics satisfying the EN 12859 standard.

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ABSTRACT

In this paper, we study the influence of two types of starch on earth hemp or flax straw mixtures at fresh and hardened states. The main goal is to propose new non-load bearing earthen for indoor. The mass percentage of starch/binder (S/B) in mixtures was fixed at 1% of mass. The VEBE consistometer test has been used to fix a similar consistency between mixtures. The targeted workability has to allow an easy introduction of materials in the moulds. Adding both of starch has shown a positive effect on mixtures workability at the fresh state and mechanical resistances at the hardened state. At hardened state, mechanical and thermal-acoustic performances have been measured on laboratory samples and blocks at real scale. Results have shown a significant effect of starch on mechanical strengths.

1. Introduction

Currently, the return to more ecological values largely favours the renewed interest in sustainable and economical building materials such as Raw Earth Materials (REMs). REMs, used as building materials in a quarter of the world's dwellings and in more than a third of world heritage monuments, represent an interesting solution for ecological problems because it is a local resource and needs a little energy for its implementation. In addition, REMs give to walls properties of comfort in accordance with the criteria requested by the French current thermal regulations RT 2012. Indeed, REMs allow a regulation of the humidity in the rooms. It can also regulate the temperature due to its inertia and thus bring, in particular, summer comfort by phase shift. The hygrothermal regulation capacity and the limitation of energy consumption and greenhouse gas emissions during the manufacturing and the implementation of these types of products are major advantages in comparison with existing conventional products. Often associated with straw, a light material is obtained with interesting performances for thermal and acoustic insulation. REMs-straw association represents a way of using the REMs spread geographically for centuries. But ancestral practices are opposed to current industrial practices because of the long time needed to set up and dry these mixes, which must be moistened in order to work with the straw.

Nowadays the objective is to be able to build quickly and well. REMs-straw mixes can be developed and adapted to fit into a conventional distribution circuit where most building materials are purchased. In the past three decades, considerable efforts have been directed towards the use of various plant fibers, which are abundantly available in tropical and subtropical countries, for the production of cost-effective building materials for sustainable development. The earth-straw products must thus meet the constraints of prefabrication and short storage to be competitive in comparison with concrete or gypsum products. The handling of the material in the fresh state must be easier and the mechanical performance must be improved, while keeping the environmental benefits. Several investigations have been dedicated on the study

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of earth-straw mixtures to find the best mechanical and thermal properties of products made with unfired earth, stabilized or unstabilized. Dubois et al. [1] have studied the association of quarry fines-hemp to be used in the manufacturing of precast non-bearing products. Brouard et al. [2] have compared two types of vegetable aggregates (rape straw and sunflower) associated with earth in order to study the mechanical and hygrothermal behavior of plaster bio-composite. While Degrave-Lemeurs et al. [3] have studied and compared acoustical properties of hemp-clay samples with hemp-lime ones. Laborel-Préneron et al. have written a review on the use of plant aggregates and fibers in earth construction materials [4]. Other research studies have studied the association of clay-hemp [5], clayey soil-nature fibre [6], clay-straw [7,8], clay-wheat straw [9–11]. All these research works showed the benefits by associating the earth with plant aggregates especially to enhance the insulation performances.

Furthermore, with the environmental problems, researchers are focusing on renewable and bio-based resources to reduce the environmental impacts of building materials, which in return promote the development of eco-building materials. Thus the civil engineering is today in connection with the field of green chemistry, which develops bio-based additives made of plant origin such as the family of polysaccharides. Several research studies have outlined the benefits of using starch in construction. Starch is a homopolymer from polysaccharides family with 100% vegetable origin. It exists in several vegetables like tubers, cereals and legumes. Starch is composed principally of amylose and amylopectin, in addition to minor percentages of protein, lipids and phosphorus. It could be differentiated from other polysaccharides because of its amylopectin which has a strong influence on the dispersion and stabilization of particles [12]. A.T. Le et al. [13,14] have replaced, in the composition of hemp concrete, lime by starch to obtain a lighter dry density (between 170.8 and 158.9 kg/m^3), resulting in a satisfactory compressive strength (between 0.4 and 0.5 MPa), knowing that for hemp concrete, the average of compressive strength varies from 0.1 to 0.8 MPa for a dry density between 330 and 470 kg/m^3. They also showed up that starch/hemp cannot be used as a construction material because of their very low Young's modulus (between 1.47 and 2.16 MPa) for these range of densities. Akindehinde et al. [15] have studied the influence of two types of starch (maize and cassava) on certain properties of concrete. The results of the mechanical tests up to 180 days of cure showed that both starches have a positive impact on the concrete especially in the short term (up to 28 days): for example, adding 1% of starch by weight of cement gave an increase of 5.3% and 4,9% in the compressive strengths with corn and cassava starch, respectively. On the other hand, increasing the percentage of starch from 1% to 1.5% or even 2% has a less important or even negative effect from 28 days of treatment. Other studies show that the addition of starch improves the workability of cement pastes and can be used as a replacement for petrochemical adjuvants reducing water [16].

In previous research work, Alhaik et al. [17] showed that starch improves the mechanical strengths of clayey materials. The addition of starch has also increased the thixotropic index up to four times. This study comes as a continuing of previous research work [17], which had shown that starches have a very important effect on the rheological and mechanical properties of earth paste. Therefore, the main goal of the present work is to evaluate the influence of two types of starch on earth/plant mixtures at fresh and hardened states.

2. Materials

In this section, the characteristics of materials used in this work are shown.

2.1. Quarry fines (QF)

Earth materials used in this work are quarry fines furnished by "Carrières du Boulonnais", which is a company located in the north of France. These quarry fines come as a result of aggregates washed in the quarry to respect the European standard EN 12620 [18]. The analysis by X-ray diffraction according to the European standard EN 13925-2 [19] carried out by the company "Carrières du Boulonnais" has shown a majority of limestone and clay. Therefore, these materials are defined as Ap (low plastic clay) according to the USCS classification. Table 1 presents the properties of the quarry fines measured by Carrières du Boulonnais. Despite a relatively small proportion of clay in these materials (19%), they present the physical behavior of clay. The clay part is composed of kaolinite (12%) and illite (7%), which have low sensitivity to swelling phenomena. The granular distribution of QF performed by the laser diffraction methods [19] shows that these quarry fines have grain sizes ranging from 0.1 to 100 μm, with dominant sizes (60%) between 0.1 to 20 μm.

2.2. Starch

The starch used in this study has grain sizes of 1–100 μm in the form of a white powder. Starches vary in size and shape according to their botanical origins [20]. Based on the results of previous research work [17], two starches (D and H) have been chosen for this study, according to their efficiency to improve both of rheological and mechanical proprieties. The first starch (mentioned D) is a native starch while the other one (mentioned H) is a pregelatinized starch which had been cooked in hot water according to its gelling temperature. During the process of gelatinization, particles of starch lose their semi crystalline structure, then they change their viscosity according to their vegetable origin as well as their percentage of amylose and amylopectin. This process is irreversible and gives a soluble starch (about 98%) in water at ambient temperature. Both types of starches were prepared and furnished by Roquette which is a company specialized in the starches production.

2.3. Hemp and flax straws

Two by-products "hemp and flax straws" have been chosen for this study. Their apparent densities, measured in laboratory, are 121.2 kg/m^3 and 105.8 kg/m^3 for hemp and flax straw, respectively. Fig. 1 shows the particles observation of hemp and flax straws. The maximum size of hemp or flax straw particles is up to 40 *mm*. Hemp and flax straws have a high porosity and their porosity induces a large and fast water absorption, with water absorption of 130% (mass ratio: water/dry straw) one minute after

Table 1
Properties of the quarry fines.

Properties	Values
Proctor test	
Optimum moisture content	14 %
Maximum dry density	1860 kg/m^3
Atterberg limits	
Liquid limit LL	33 %
Plastic limit PL	21 %
Plasticity index PI	12 %
Particle size distribution	
Sand (2–0.063 mm)	1.5 %
Silt (0.075–0.002 mm)	81.3%
Clay (<0.002 mm)	17.2%
Organic content	2.17 %