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Effect of substitution of wood shavings by barley straws on the physico-mechanical properties of lightweight sand concrete

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HIGHLIGHTS

- Resolution of problems posed by wood sand concrete.
- Substitution of wood shavings by barley straws in sand concrete.
- Existence of strong relations between the thermo-physical and mechanical properties.
- The presence of straws and wood together is better than the existence of each of them alone.
- Obtained results have been confirmed by microstructure study.

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ABSTRACT

The paper mainly aims to study the effect of the incorporation of barley straws and wood shavings on the physico-mechanical properties of sand concrete intended for the construction in arid zones. Basing on the study at fresh state, the experimental work has been firstly devoted to searching for optimal compositions of the composite. Then, a second study has focused on the physico-mechanical characterization of sand concrete without lignocellulosic materials. Finally, a special experimental program has been devoted to the study of sand concrete with lignocellulosic materials. The obtained results show that it is quite possible to develop a lightweight sand concrete by the incorporating, separately and in combination, of barley straws and wood shavings. Moreover, it has been noted that the combined addition of barley straws and wood shavings gives the best physico-mechanical results which were strongly confirmed by a microstructure study. With combined addition, the problem of shrinkage was relatively solved: decreases of about 11.76% and 39.02% were recorded in comparison with the cases where barley straws and wood shavings are taken separately. In addition, the thermal diffusivity has been reduced of about 35.47% with respect to the basic composition. Due to its higher deformability, the barley straw improves the toughness and ductility of sand concrete and reduces its dimensional variations. Indeed, the studied composites, offer to the local constructions important technical and economic interests: good thermal insulation and efficient energy saving and low cost of materials.

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1. Introduction

For climatic conditions in arid environments, new lightweight concretes intended for the construction of external walls and roofs are really needed to provide a better thermal resistance and to compete with the traditional construction materials. It is probable that, if it is easily maintained with highly reflective external finish, a new lightweight concrete might fare better than current materials (block, brick, etc.). Indeed, the rapid economic development in several countries characterized by an arid climate, such as Algeria, has led to the construction of a phenomenal number of new buildings during the past 10 years. In response to the severe summer and winter weather conditions, these new buildings are universally heated or cooled by means of mechanical systems. Indeed, although some thermal benefits are likely gained from the contemporary use of current building envelope elements, the energy burden imposed by the continued construction of thermally inefficient building stock is of a great concern to these countries. Energy burden is an important statistic for policy makers who

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are considering the need for energy assistance. Moreover, the environmental consideration requires the preservation of mineral aggregates and the use of vegetal waste [1]. A large amount of lignocellulosic waste coming from various sources is generated worldwide which causes various environmental problems. The use of such waste in the manufacture of cementitious building materials can resolve these problems [2]. However, the formulation of lightweight concrete based on local lignocellulosic materials is a way of contribution for sustainable development in the construction industry [1]. Therefore, the valorisation of local materials as well as agro-industrial waste could make an important contribution where a consensus is necessary for improving the performance and behavior of materials while minimizing costs as well as energy consumption [3]. It's in these two contexts that a research program have been established to investigate the physico-mechanical characteristics of a new concrete consisting of local materials and waste. It is noteworthy that, sand concrete based on wood shavings has already shown an interesting lightness; however, its dimensional variations are very important. In order to solve this problem, several studies have been performed using different treatments of wood shavings [4] in order to reduce the shrinkage to a value less than the target value generally recommended (1 mm/m) [5]. That is the reason for which the assumption to partially or totally substitute the wood shavings (coming from woodwork activity waste) by another local lignocellulosic material, characterized by a renewable and ecological character, is adopted. By definition, lignocellulosic materials are composed of the combination of lignin, cellulose and hemicellulose in the structural cells of woody plants [2]. Currently, the barley straws are excessively produced compared to their use, i.e. it is a natural product, inexpensive and easy to obtain in the majority of countries. Thus, the reuse of this material in the construction has significant interests and leads to economical, ecological and sustainable development [6]. Locally, around the city of Laghouat (south of Algeria), there are two main types of straws namely barley and wheat. Because it presents better thermal insulation than wheat straw, the barley straw was selected to be used in this study [7]. On the other hand, sand concrete, which is used as matrix in this case, is defined as a concrete which contains only sand as aggregates (without any gravels) and a cement content similar to that of ordinary concretes [8,9]. Thus, the incorporation of lignocellulosic materials in cement matrix aims to obtain a new lightweight concrete which is an important topic of research because of the interesting thermo-mechanical properties expected [10]. According to literature, several works have studied the incorporation of lignocellulosic materials in composites. Bouhicha et al. used barley straws in order to reinforce soil composites [11]. Li et al. used hemp fibers in cementitious composite [12]. Yang et al. used rice straws fibers and wood particles at different 'straw/wood' ratios in wooden construction materials [13]. Soroushian et al. used wheat straws instead of wood in cementitious composites [14]. As for Ashour et al., they used wheat and barley straws [7]. While Nozahic et al. used two aggregates of plant, the first was of hemp fibers and the second was the sunflower stem which has been selected as an alternative for byproduct of the lignocellulose due to its apparent similarities with hemp fibers [15]. Furthermore, Merta and Tschegg used hemp fibers, miscanthus grass and wheat straws [16]. Other authors used untreated and treated wood shavings [4,17–19]. Concerning the present work, a comparative study between the properties of four types of sand concretes: a sand concrete without lignocellulosic materials (SC-W-LM) which is considered as reference concrete, a sand concrete with wood shavings (SC-WS) where content of wood is 60 kg/m^3, a sand concrete with barley straws (SC-BS) and finally a sand concrete with both barley straws and wood shavings (SC-BS-WS) is provided. The only respected condition during this work is that, at fresh state, the last three concretes (sand concretes with lignocellulosic materials) have an equal workability (an Abrams cone slump value of 6 cm). In order to find the appropriate compositions, several preliminary experiments were performed in order to determine the optimal proportions of used lignocellulosic materials. Moreover, it should be noted that a quaternary binder obtained by the partial substituting of cement by three mineral additives was used in order to raise the economic level of the sought composites. It has been reported that the present work is only a continuation of previous studies and the effect of the quaternary binder is not the purpose of this paper. Finally, the main objective of this work is to study the contribution of two lignocellulosic materials, which are barley straws and wood shavings, to the development of a lightweight eco-sand–concrete based on river-dune sand and quaternary binder. In fact, this work deals with search of optimal compositions of insulating-bearer lightweight eco-sand–concrete intended for the construction in arid environments.

2. Materials and experimental methods

2.1. Raw materials

The studied composites are composed of sand concrete as matrix and barley straws or/and wood shavings as inclusions. The sand concrete consists of a mixture of sand, cement, fillers and water. Besides these basic components, it typically includes one or more admixtures [9]. The various used components introduced during this work are characterized hereafter.

The used sand (RDS) is a local material which consists of a mixture of two other local sands, river sand (RS) and dune sand (DS). Both of these sands are characterized by a continuous particle size distribution ranging from 0 to 0.63 mm and 0 to 5 mm respectively, contain a fraction of grains smaller than 80 μm below 5% and present rounded shapes of grains (Fig. 1). The high values of the "Sand Equivalent" show that RS and DS are clean and the X-ray Diffraction analysis demonstrates their essentially siliceous nature [20]. So the only difference between these two sands lies in their fineness modulus values; RS presents more coarse grains while DS presents more fine grains. This is why the fine part of the RS grading curve was corrected by the addition of DS according a mass ratio: (RS/DS) = 1.7 [20]. Table 1 lists the set of physical characteristics of all these sands. These results reveal that RDS is the denser and the most compact sand. Its modulus of fineness is 2.81. The fact that RS and SD are clean and of siliceous nature, RDS is therefore clean and siliceous. The visualization of the general appearance of sand grains shows that they are rounded with very low reasons of sustainable construction, the cement used is a Portland limestone cement (PLC) of type CPJ CEM/II A-L 42.5 R. This type of binder is a new class of cement that provides a similar performance to that of conventional Portland cement but emits less CO_2 (a reduction of up to 10%). Let us note that the use of PLC in North America is a proactive action to help mitigate climate change through energy savings and reduced emissions. The physical characteristics of the used cement are as follow: apparent density: 1030 kg/m^3, specific density: 3030 kg/m^3 and Blaine specific surface area: 444.9 m^2/kg. Moreover, the chemical analysis revealed the existence of the chemical products shown in Fig. 2 with the proportions presented in Table 2. On the other hand, the use of fillers in sand concrete composition is essential [8]. Their use is intended to complete the grading curve of sand in its finest part in order to obtain more compact concrete and reduce the cement content and therefore the cost of concrete. In this work, the used fillers have been obtained by sifting local crushing waste (to a sieve opening of 80 μm). It enters also within the scope of waste recovery. The X-ray

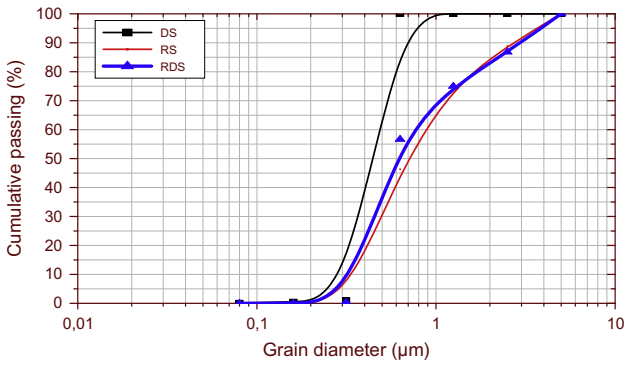

Fig. 1. Particle size distribution of used sands.

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