Construction and Building Materials 169 (2018) 794–799

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Effects of hemp fibers on characteristics of cement based mortar

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HIGHLIGHTS

- Effects of hemp fibers on properties of cement based mortars were studied.
- Hemp fibers reduce workability.
- 2–3% amount and 12 mm length of natural hemp fiber give the optimum results.
- More studies are should be done about the usage of hemp fibers.

ARTICLE INFO

Article history:
Received 6 November 2017
Received in revised form 26 February 2018
Accepted 1 March 2018

Keywords:
Hemp fiber
Cement mortar
Strength
Microstructure

ABSTRACT

In recent years, using addition of fibers with plant origin in concretes has increased significantly. They not only enhance the mechanical characteristics of cement mortars, but also they are renewable, easy to access and cheap and this makes the use of plant fibers more widespread. Hemp fiber is a plant, which is planted in many places of the world and obtained in large amounts, is environmentally friendly and also used in manufacturing of composite materials. In this study, hemp fiber reinforced cement mortars with different ratios (0%, 1%, 2%, 3%) and different lengths (6 mm, 12 mm and 18 mm) were manufactured. Density, water absorption, compressive strength, flexural strength, compressive strength after flexural tensile and splitting tensile strength tests were performed on manufactured samples. Also, in order to determine the inner structural characteristics of samples, SEM analysis was conducted. As a result of the study, it was determined that cement mortars reinforced with 2–3% amount and 12 mm length of natural hemp fiber give the optimum results.

1. Introduction

Nowadays, biological composite materials have been the focus of academic and industrial investigations. Usage of plant fibers in composite materials as reinforcement materials increases in a wide range of industries such as packaging industry, automotive and construction [1].

Natural fibers are preferred compared to artificial fibers, as they are renewable, easy to access and cheap. Many studies are conducted to get use of plant natural fibers in the manufacturing of low-cost construction elements. Studies demonstrate that natural fibers have higher toughness, improved impact and higher deformation capacity [2]. On the other hand, there have been lots of studies about the artificial fibers such as steel, polypropylene, basalt, glass and hybrid fibers [3–7].

Hemp is an annual wood-like plant close to stinging nettles, belonging to *cannabinaceae* family. This plant, whose origin is Asia, had spread to the entire world by following several ways. Today, it has two subspecies. These are *cannabissativa* and *cannabisindica*. The species used for fiber production and that has industrial importance is *cannabissativa* [8–10].

Hurd and fibers obtained by processing of hemp stem are used in manufacturing of bio-composites, concretes and insulation mats in construction industry as they have good physical, chemical and mechanical properties [11].

In a research it is stated, the tensile properties of hemp fibers were found to be good enough to be used as reinforced in composite materials. However, the issues of relatively high moisture content of fibers, variability in fiber properties, and relatively poor fiber/matrix interfacial strength were identified as factors that can reduce the efficiency with which these fibers can be utilised [12].

Agopyan at all, taking into account the fibers mechanical properties, with an adequate mix design, it is possible to develop a

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https://doi.org/10.1016/j.conbuildmat.2018.03.029
0950-0618/

material with suitable properties for building purposes. In order to improve the durability of vegetable fibers, this paper presents the approach adopted in the research which is directed towards the development of alternative binders, with controlled free lime, using ground granulated blast furnace slag [13].

Adding fibers to a concrete matrix has been long recognized as a way to enhance the energy absorption capacity and crack resistance of regular concrete [14]. Natural fibers have also been reported to improve concrete insulation properties by a reduction in its thermal conductivity by 25–35% enabling for a potential reduction in a building's heat consumption [15].

In literature, several studies were performed on hemp reinforced concretes' and cement mortars' mechanical and physical characteristics [16–22], durability [23,24], insulation [25], microstructural characteristics [26,27] and also usage of them in sustainable concretes [28] and on analyzing them by statistical methods [29,30].

In this study, cement mortars reinforced with different ratios (0%, 1%, 2% and 3%) and different lengths (6 mm, 12 mm and 18 mm) of hemp fiber were manufactured. Besides determination of physical and mechanical characteristics of the manufactured samples, SEM analyses were also performed.

2. Material and method

2.1. Material

2.1.1. Cement

CEM I 42.5R type Portland cement manufactured in accordance with TS EN 197-1 [31] standard was used in the study.

2.1.2. Silica sand

40-45 AFS (Fineness Index) silica sand was used in the experiments. Cumulative percentage curve and particle distribution graph of silica sand are given in Fig. 1 and Fig. 2, respectively.

2.1.3. Water

Potable water from municipal water system was used as water for mixture.

2.1.4. Plasticizer

To increase the processability of mortars with fiber when they are fresh, the brown colored, liquid, polycarboxylate based, high performance, new generation, super plasticizer concrete additive with 1.04 kg/l density, in a ratio of 1.34% of cement weight was added to the mixture.

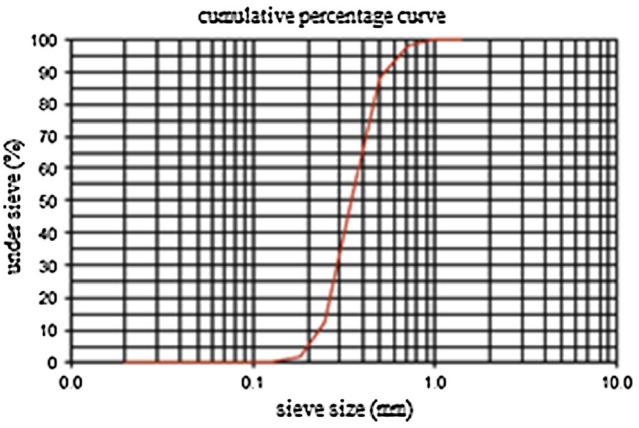

Fig. 1. Cumulative percentage curve of silica sand.

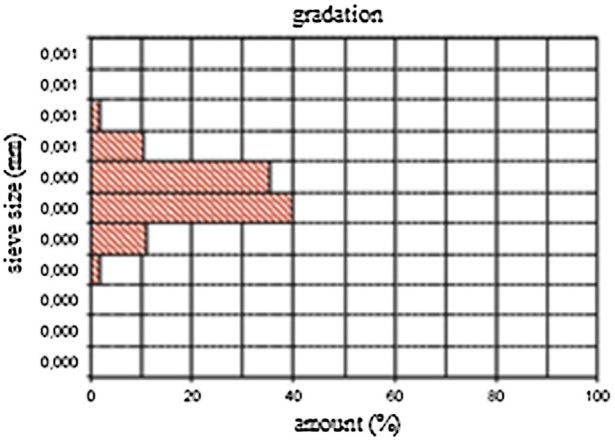

Fig. 2. Particle distribution graph of silica sand.

2.1.5. Hemp

Hemps generally have a fiber length of 40–45 mm. It reaches to 2 m depending on the length of the plant. In its chemical composition, there are 78% cellulose, about 9% lignin and pectin. As its lignin ratio is more than flax, it is in the form of more rough fibers. It is bright yellow or dark colored [32]. Carded hemp fiber is shown in Fig. 3-d.

During the study, long hemp fibers were cut into 6 mm (Fig. 3-a), 12 mm (Fig. 3-b) and 18 mm (Fig. 3-c) lengths. Obtained hemp fibers were added to mortar mixtures in 1%, 2% and 3% ratios of the mixture volume.

2.2. Method

2.2.1. Preparation of mortars

During the study, cement mortars were produced by using cement, plasticizer, water, silica sand and hemp fibers. By reducing from silica sand in 1%, 2% and 3% ratios, hemp fibers were added to the mixture. Sample codes and amount of materials for mixtures are given in Table 1.

In preparation of mixtures, mixing procedure in TS EN 196-1 [33] standard was applied. In preparation of mixtures, firstly water and cement were added to the mixing container. The mixture was started to be mixed at low speed (1st cycle), and after 30 s sand was continuously added for 30 s. The mixer was adjusted to high speed (2nd cycle) and mixing was continued for 30 s. more. The mixer was stopped after 1 min. 30 s. and the mortar that adhered to the walls and base of the container were scraped by rubber

Fig. 3. (a) Hemp fiber in 6 mm length, (b) Hemp fiber in 12 mm length, (c) Hemp fiber in 18 mm length (d) Carded hemp fiber.