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Ceramic waste influence on dune sand mortar performance

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HIGHLIGHTS

- Influence of ceramic waste incorporation in mechanical properties of dune sand mortar.
- Mortar based on dune sand with recycled crushed ceramic waste presents adequate structural performance.
- The use of ceramic waste in dune sand mortars has technical and environmental advantages.

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ABSTRACT

The present paper studies the properties of mortar made with dune sand from Djelfa, an Algerian desert region. It aims at evaluating the effect of the incorporation of recycled fine aggregates obtained from crushed earthenware (floor and wall tiles) and sanitary ware.

The effect of these recycled materials was studied in an experimental programme through several tests taking into consideration the durability of these modified mortars to the chemical attack of sulphuric and hydrochloric acid, and evaluated with respect to workability and mechanical properties in different curing environments as compressive and flexural strength, and modulus of elasticity.

The results obtained mention the ability to evaluate the influence of the two types of ceramic waste in dune sand mortar. These modified mortars present the best mechanical performance under different curing environments. In addition, the compressive and flexural strength of ceramic waste mortar increases with ceramic waste content to be optimum at 50% for the control mortar, as well as the modified mortar based on dune sand with 50% addition of ceramic sanitary is the one with the best performance of all the modified mortars particularly in terms of higher strength and lower water absorption. Moreover, the results show that the durability of the modified mortars is more resistant to the sulphuric and hydrochloric acid solution attack.

1. Introduction

Dune sand mortar has relatively low compressive strength and very low tensile strength. For this reason, it is usually reinforced with materials to make it sound in tension (often fibre metallic, pozalanic, fine Marble. . ...). Hence, production of quality mortar and concrete is quite difficult with low quantity of quality ingredients. So, recycling, reuse and substitution of ingredients are one solution to overcome shortage of quality aggregates. Recycling is one of the better options and research work has already started on recycled aggregates. The strength of the mortar composite is based on the strength of different constituents used in the preparation of mortar. The use of secondary materials may not completely remove the problem of the resulting shortage of aggregate but it could alleviate it to certain extent. There is an interest mounting up to the usage of waste materials as an alternative aggregates and significant research was performed on the use of many different materials as aggregate substitute such as coal ash, fibre glass waste materials, waste plastics, rubber waste and blast furnace slag. The waste aggregates can be used as well as in mortar and concrete. These waste materials can solve few problems like lack of aggregates in construction sites and environmental problems [1].

The recent industrial and economic growth of the developed countries has brought a considerable increase of waste. Factors, as environment, economy, land space, and no availability of high-grade materials, require the necessity to develop methods that enable the use of waste materials [2].

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Due to the increase of materials resources needs and the environmental conversation requirements, facing the durable development, it becomes necessary and relevant to prospect and explore all the possibilities to reuse and recover waste and industrial products especially in civil engineering field [3].

The ceramic industry can be divided into two sub-groups, according to the materials produced: red ceramic (bricks, structural wall and floor tiles, roof tiles) and white ceramic that includes sanitary ware (washbowls, lavatory pans, bidets, bathtubs) [5].

The term 'ceramic' defines the 'nature' of the materials constituting the tile. It is traditionally applied to products obtained starting from mixes of clay, sand and other natural substances. These mixes, after suitable preparation, are shaped in the desired size (via dust pressing or extrusion) and fired at high temperatures (ranging from 1000 to 1250 °C, depending on the type of product). The firing causes substantial modification in the structure of the raw materials and gives to the ceramic tile its typical and well known characteristics of hardness, mechanical resistance, and chemical and physical inertness (in terms, for example, of essentially not being effected by water, fire, most chemicals with which tile may come into contact, etc.).

There are some recent studies on the incorporation of grinded sanitary ware and earthenware ceramic in construction materials. The performance of incorporation of the white and red ceramic as aggregates in mortar or concrete [4–9] was evaluated. However, the incorporation of sanitary and earthenware "floor and wall tiles" waste as fine aggregate in mortars based on dune sand in Algeria has not been analysed before.

Due to the environmental benefits, the topic on cementitious materials made with dune sand has aroused increasing interest. During the past decade, a number of researches have been conducted to study the characteristics of dune sand as well as the properties of cementitious materials incorporating it. Fu Jia Luo et al. [10] have investigated the effect of very fine particles (VFPs) on workability and strength of concrete made with dune sand from Australian desert; results showed that the VFPs modify the properties of concrete by different mechanisms depending on the level of S/C ratio and has no negative effect on workability and, the strength of dune sand concrete is comparable or even higher than that of river sand concrete (RSC). Allaoua Belferrag et al. [11] have investigated the improvement of the compressive strength of mortar in the arid climates by valorization of dune sand and pneumatic waste metal fibers. They have studied the effect of the addition of a new type of metal fibers, resulting from used tires, on the compressive strength of dune sand concrete. The results obtained show an improvement of the compressive strength for the metal fibre reinforced sand dune concrete (MFSC) compared to the concrete without fibers. Krobba et al. have investigated the effect of natural microfibers added to mortar on their properties such as density, mechanical strength, shrinkage, modulus of elasticity and bonding strength. The results obtained showed an enhancement in the mechanical and physical properties of mortar with natural microfibers compared to those of mortar based on the dune sand (without Alfa natural microfibers) tested in the same conditions [12].

The use of waste from the ceramic sanitary ware industry as coarse aggregate to manufacture structural concrete has been widely studied by the authors of the present paper, who observed that concretes with 25% recycled aggregate have higher splitting tensile and compressive strength than the conventional material [13–15].Mortars with incorporation of fine aggregates from construction and demolition waste have many advantages over mortars with sand only. This research analyses the incorporation of fine sanitary ware waste in percentages of 0%, 10%, 15% and 20%, in order to have mortars with better performance than the conventional ones and, at the same time, the modified mortar with 20% addition of grinded fine sanitary ware (GSWF) was the one with the best performance of all the modified mortars, in particular in terms of higher strength and lower water absorption [16].

There is also a series of studies [17,18] which have analysed the feasibility of incorporating recycled ceramic material or mixed recycled aggregates as a substitute for natural aggregate (both fine and coarse) in the production of concretes destined for various uses (prefabricated blocks, road fill, non-structural and structural concretes), obtaining satisfactory results for different percentages of substitution and different properties.

Studies on concrete containing sanitary and technical ceramic waste, have confirmed advantages brought by such aggregate. Strength parameters of the obtained concrete approximated or even exceeded parameters of concrete with traditional aggregate [18–22].

Dune sand mortar with incorporation of ceramic waste aggregates generated from construction and demolition waste and ceramic industries have many advantages over mortars with dune sand only. This research presents the results of a study devoted to the use of ceramic sanitary and earthenware "floor and wall tiles" waste as aggregates in dune sand mortars. The incorporation of 10–50% (by weight of dune sand) of ceramic waste in the investigated mortar mixtures, in order to have mortars with better mechanical chemical performance than the dune sand mortar ones.

The use of recycled aggregates, namely ceramic, in new structural concrete, is beneficial from the viewpoints of environment protection and reduction of natural resources consumption. However, to entirely embrace the use of recycled aggregates in the production of new concrete, it is necessary to fully understand the performance of this type of concrete [4].

2. Experimental program

2.1. Materials used

The materials used for producing the different mortars were natural dune sand, recycled ceramic waste (sanitary, earthenware) aggregate, water and cement.

2.1.1. Cement

Portland cement: the cement used for mixing the mortar was CEM II/B 42.5, in accordance with standard EN 197-1, with a content in clinker greater or equal 65–79 %, and with 35–21% additional components. The cement is from Lafarge factory (M'sila). Apparent density = 1030 kg/m^3 and specific density = 3050 kg/m^3.

2.1.2. Dune sand

The investigation was mainly concerned with the utilization of dune sand which is available in abundant quantities in desert areas. The dune sand material was brought from Oued Zaafrane (Djelfa, Northern Algerian Sahara). It is composed of sub-rounded and sub-angular grains with smooth texture.

The specific apparent density and the absorption test were carried out in accordance with NF P 18-554. Sieve analysis and fineness modulus (FM) coefficient of uniformity were conducted in accordance with NF P 18-560. Sand equivalency (SE) was carried out according to NF P 18-598. The Methylene blue was carried out according to NF P 18-595. The grain size distribution curve of Djelfa dune sand is shown in Fig. 1 and Table 1 respectively.

It is a fine golden sand with a maximum dimension of coarse grains is 0.5 mm, the diameter of the finest particles is of the order of 0.04 mm. The uniformity coefficient (C_u) is of the order of 2.0 and the curvature coefficient (C_c) is about 0.96. It is therefore very fine poorly graded sand. The Fineness Modulus is the most commonly computed factor for fine aggregates, which is used to