



Plaster composites modified morphology with enhanced compressive strength and water resistance characteristics

A.A. Khalil, A. Tawfik*, A.A. Hegazy

Refractories, Ceramics and Building Materials Department, National Research Centre, P.O. 12622, Dokki, Cairo, Egypt

HIGHLIGHTS

- Gypsum-slag composite increased the compressive strength with 30% after the water immersion.
- Additives increased water resistance.
- 3 wt% of either CaCO₃ or PVA improved the compressive strength by about 14 and 19% of water-cured samples, respectively.
- Generally changing in gypsum morphology increased the water resistance of the produced gypsum composite.

ARTICLE INFO

Article history:

Received 28 November 2017
Received in revised form 18 January 2018
Accepted 27 January 2018

Keywords:

Gypsum plaster
Composites
Solid wastes
Phase composition
XRD
FTIR
SEM-microstructure
Water resistance
Strength

ABSTRACT

Due increasing attention for non-conventional building materials, modified gypsum plaster composites were studied to assess their water resistance when blended with different additives and their effect on the strength properties. The plaster-composites were formed by dry mixing of fine or ultrafine sand, silica fume, silica gel, rice husk, slag, calcium carbonate or polyvinyl acetate (PVA). Their phase composition was investigated using FTIR and XRD with crystallite size data to be correlated with their microstructure morphologies as elucidated by SEM for the air- and water-cured samples.

Results clarified that the morphology and some grain dimensions of set plaster composites have changed leading to improve their compressive strength and water resistance. The set plaster grain dimensions altered from long acicular crystals to short compact thin one. Composites with almost all additives reveal resistance to water whereas silica gel showed lower effect, due to its higher affinity to humidity. The compressive strength and softening coefficient of the water-cured plaster-slag composite increased by about 30% compared with air-cured blank sample due to the hydration of slag in gypsum composite matrix. Either calcium carbonate or PVA usage (3 wt%) in gypsum composites improved the compressive strength by about 14 and 19% of water cured samples, respectively. The synthesized plaster composites are promising building units for various applications when lightweight, high porosity, water resistant building units are needed.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Hundreds centuries ago, gypsum products were and still used for various applications whereas most of the building indoor surfaces now are either made from or lined with gypsum products chosen by architects for their excellent performance and distinguishing characteristics [1]. Gypsum is also, an essential constituent in dental investments, Portland and supersulphated cements besides various medical applications ... etc [2,3]. However, due to the low strength and water resistance characteristics of plaster products, they can't support the severe modern building

applications e.g. 3D printing technology [4]. Higher water demand in re-crystallization process of plaster setting produced more porous gypsum matrix [5,6]. Thus, many researches paid attention to get water resistance plaster via composites formation among water proofing admixtures such as organic emulsion which can be selectively adsorbed on the gypsum crystal surface, inhibiting the crystal growth along C axis producing compact gypsum matrix [7,8]. Also, some authors used the industrial wastes, activated pozzolana, slag, and cement as water proofing agents in plaster blocks to modify the water resistance properties of gypsum composites [9–11]. It was claimed that fibrous additives enhanced the mechanical properties of the gypsum products by conventional fiber strengthening mechanism besides holding their structures from corruption and disintegration [12–15]. Silicates based natural or artificial

* Corresponding author.

E-mail address: at.ahmed@nrc.sci.eg (A. Tawfik).

by-products, of different industries, were and still blended with gypsum to reduce shrinkage and minimize cracking; among these additives vermiculite is commercialized [16]. Moreover, silica fume or fly ash reduces the amount of dehydrated water during heating gypsum under fire exposure to be more thermally stable than the original plaster composites-based products [17].

Generally, fine amorphous alumino-silicate additives to plaster form calcium hydrosilicates coated layers for plaster grains affecting on the hydration process and enhancing their physical and mechanical properties [18].

In our previous works, the physico-mechanical properties of plaster composites, using different forms of silica among other additives were studied including normal consistency, setting time, apparent porosity, bulk density and compressive strength. Results concluded that different additives decreased the bulk density, increased the normal consistency, setting time, apparent porosity, and to some limited extent, the compressive strength of the plaster composites. The compressive strength improvement was due to the existence of the additive particles in the interstitial pores in the hardened plaster matrices [19,20]. The present article deals with some selected composites including; plaster- silica sand, silica fume, silica gel, rice husk, slag, calcium carbonate and PVA, which revealed improved mechanical properties to throw more light on their phase composition and microstructure. Moreover, their water resistance was assessed by softening coefficient determination to be correlated with their FTIR, XRD and SEM-microstructure.

2. Experimental

2.1. Materials

The materials used in the present composites are gypsum plaster which was dry blended with some additives; e.g. natural sand, silica fume, silica gel, rice husk, ground granulated blast furnace slag, calcium carbonate or commercial poly vinyl acetate polymer (PVA). Gypsum plaster was produced and provided by the Sinai Gypsum Company at Sinai, Egypt. The sand, a ball-milled natural rock, was supplied by Plena Group Co., Egypt whereas two sizes were used by separate grinding and sieving to form a fine (<90 μm) and ultra-fine (<75 μm) sand samples. Moreover, silica fume was given by Sika Co., Egypt and the chromatographic column silica gel was manufactured by Merck, Darmstadt, Germany. The chemical constitutions and some properties of the starting materials were previously investigated using DTA, XRD, FTIR, XRF and BET isotherms surface area and summarized in Table 1.

It was concluded that they are almost pure fine-grained materials while their detailed results are published elsewhere [21].

2.2. Methods

Gypsum plaster composites were prepared by blending plaster with 0.2 to 10 wt% of each additive for about 15 min; their composition is given in Table 2. After air-curing for 14 days, the composites were investigated for their phase composition, using XRD and FTIR and correlated with their microstructure as elucidated by SEM. Moreover, their water resistance was assessed via determining their softening coefficient by dividing the compressive strength data of the 14-days water-cured samples by their corresponding strength after air-curing for similar period [22,23]. The water cured samples were further assessed using FTIR spectra while some selected samples were further studied using XRD and SEM tools.

The FTIR analyses of the composites were carried out using 2-mg of the fine solid sample, thoroughly mixed with 198 mg of a chemically-pure KBr and pressed to form a transparent disc used in a thin layer Si window. Spectra were followed using Jasco FTIR 6100 spectrometer whereas spectra were collected over a range of 4000–400 cm⁻¹ using a 4 cm⁻¹ spectral resolution.

XRD analyses of the composites were studied using an automated diffractometer (X'Pert PRO θ-θ) at a step size of 0.02°, scan rate of 2° per minute at a range of 4–45° (2θ). XRD patterns were manipulated and interpreted using the instrument software package whereas the inter lattice spacing (d, Å) and relative intensities (I/I°) were thoroughly calculated and correlated with the standards data. Moreover, XRD crystallite size data were calculated using Scherrer's formula [24].

$$D = \frac{k\lambda}{\beta \cos \theta}$$

Where

Table 2
Composition of studied composites.

Composite composition	Additives	
	Type	%
Neat plaster	Blank	0.00
Plaster-fine sand	fine sand	5.00
Plaster-ultra fine sand	ultra fine sand	5.00
Plaster-silica fume	silica fume	1.00
Plaster-silica gel	silica gel	1.00
Plaster-rice husk	rice husk	0.40
Plaster-slag	Slag	10.00
Plaster-calcium carbonate	calcium carbonate	3.00
Plaster-PVA polymer	PVA polymer	3.00

Table 1
Chemical constitution (%) and BET surface area of the starting materials [21].

Element oxides	Plaster	Natural sand	Silica fume	Silica gel	Rice husk	Slag	Calcium carbonate
SiO ₂	0.46	97.70	92.75	94.44	17.94	32.10	0.53
Al ₂ O ₃	0.12	0.52	1.14	0.072	0.90	9.35	0.14
Fe ₂ O ₃	0.05	0.25	2.47	0.068	0.09	1.54	0.07
TiO ₂	Nil	Nil	0.03	Nil	Nil	0.64	Nil
CaO	37.61	0.61	0.37	0.378	0.77	35.10	54.91
MgO	0.12	0.20	0.4	0.187	0.95	5.03	0.59
BaO	Nil	Nil	Nil	Nil	Nil	5.14	Traces
SO ₃	53.66	0.06	0.01	0.047	0.12	3.34	0.15
Na ₂ O	0.03	Nil	0.45	0.673	0.6	1.32	0.05
K ₂ O	Nil	Nil	0.60	0.047	1.56	0.56	Nil
Cl	Nil	Nil	0.01	0.090	0.15	0.03	0.02
Loss on heating at 260 °C	6.16	Traces	Traces	Traces	7.82	2.12	1.15
Loss on heating at 1000 °C	7.75	0.4	1.35	3.88	67.78	–	42.37
BET (m ² /g)	35.34	A = 10.38, B = 13.34	90.61	201.20	45.84	10.61	12.34

BET for: A-fine sand (<90 μm) and B-ultra fine sand (<75 μm).

Download English Version:

<https://daneshyari.com/en/article/6714881>

Download Persian Version:

<https://daneshyari.com/article/6714881>

[Daneshyari.com](https://daneshyari.com)