Construction and Building Materials 150 (2017) 459–466

Contents lists available at ScienceDirect

Construction and Building Materials

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

Effect of coral filler on the hydration and properties of calcium sulfoaluminate cement based materials

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HIGHLIGHTS

- The effect of coral filler on properties of CSA cement based materials is studied.
- Coral filler can promote the formation of hemicarbonate.
- Coral filler can improve the mechanical properties of CSA cement based materials.
- Coral filler and CSA cement hydration products are closely linked.
- The activity of coral filler decreases with the addition of anhydrite.

ARTICLE INFO

Article history:
Received 6 December 2016
Received in revised form 19 March 2017
Accepted 23 May 2017

Keywords:
Coral filler
Calcium sulfoaluminate (CSA) cement
Hydration kinetics
Setting times
Mechanical properties

ABSTRACT

In this research, the feasibility of using coral filler in Calcium sulfoaluminate (CSA) cements based materials is investigated, targeting at reducing transportation cost for the marine construction. Properties including setting time, mechanical properties and hydration kinetics are investigated. Two blended materials groups with and without anhydrite are tested. Then, their properties are compared with the plain CSA cement clinker samples (with and without quartz filler). The obtained results indicate that coral filler decreases the hydration heat and generates hemicarbonate instead of monosulfate. Moreover, the replacement of CSA cement clinker by coral filler can slightly decrease the setting time and improve the strength development of sulpho-aluminous cement based materials with limited anhydrite. However, the activity of coral filler decreases with the addition of anhydrite. In the group with sufficient anhydrite, the replacement of CSA cement clinker by coral filler has limited effect on the CSA cement hydration, and can decline the long-term mechanical properties of CSA cement based materials.

1. Introduction

With the rapid developments of marine industries in the past recent years (such as aquafarm, open sea breeding and island tourism), construction projects on islands far from the lands have been a major topic around the world. However, due to the restriction of distance and complex natural condition, the materials used for construction activities in coral islands are expensive (e.g. the transportation cost of 1 m^3 construction material is more than 1000 RMB [1]) and the transfer can be easily attacked by stormy waves [2]. Therefore, there is an urgent requirement to search some cheap and reliable substitute materials for the marine construction [3–5].

Coral is a special rock-soil that mainly includes aragonite and high-Mg calcite, with more than 96% $CaCO_3$, and it is abundant in the sea islands [6,7]. Based on previous studies [8–12], using coral sand and coral reefs can be considered as an effective way in constructing and repairing concrete without destroying the local environment. Howdyshell [8] concluded that it was feasible to form concrete with coral aggregate. Arumugam et al. [9] investigated the developing rules of the concrete made with coral on the cube compressive strength. The results showed that the strength of the coral sand concrete increased rapidly in the early stages but slowed its pace in the later stages. Pan et al. [10] investigated the effect of cement categories on the compressive strength cube compressive strength of coral sand concrete. The results demonstrated that the coral sand concrete with sulfate resistant cement had relatively good performance and high strength than with ordinary Portland cement. Previous study also investigated the effect of the addition of coral sand on the chloride resistance ability, and

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http://dx.doi.org/10.1016/j.conbuildmat.2017.05.194
0950-0618/

Table 1
The chemical compositions of CSA cement clinker, Anhydrite and coral filler.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Fe_2O_3	L.O.I.
CSA	0.07	1.6	29.14	10.0	0.08	8.88	1.06	45.45	1.54	1.57	0.39
Anhydrite						56.47		39.53			
Coral	1.96	2.47	0.11	0.36	–	0.69	–	47.68	–	0.04	44.78

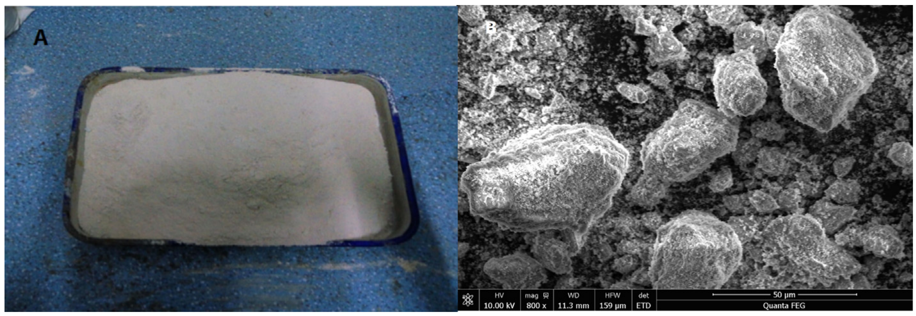

Fig. 1. Digital (A) and SEM pictures (B) of used coral filler.

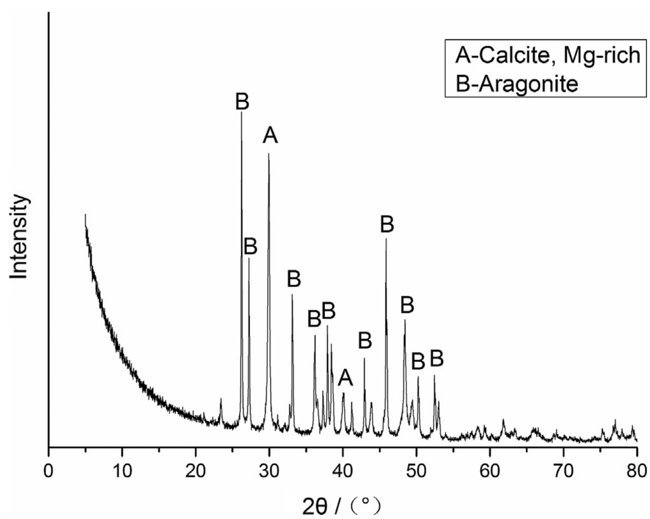

Fig. 2. X-ray diffraction (XRD) patterns of coral filler.

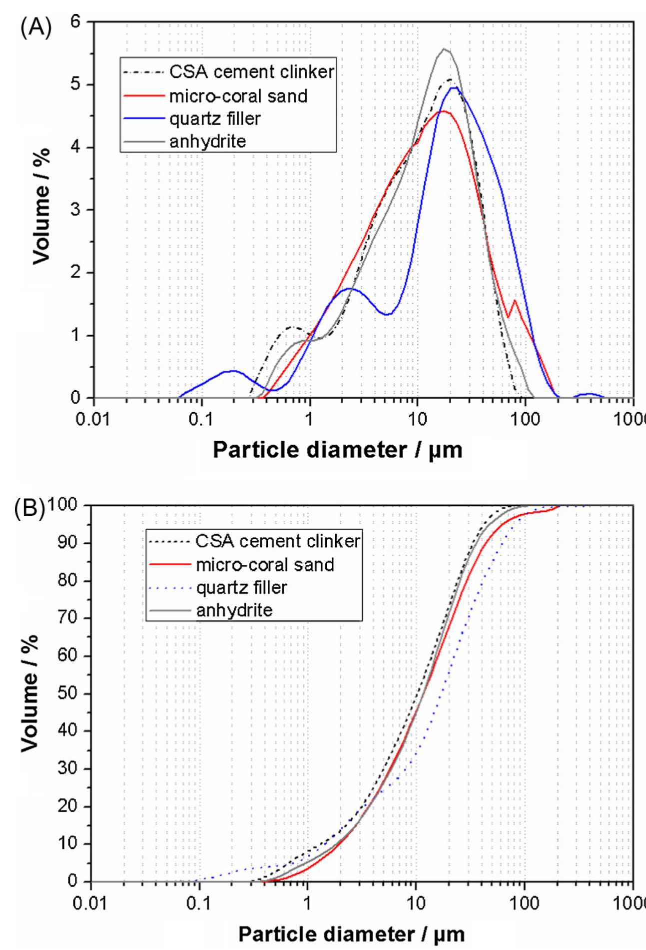

Fig. 3. Particle size distributions of the applied constituents: (A) differential particle size distribution. (B) Cumulative particle size distribution.

the results showed that concrete made of coral had enhanced chloride resistance ability due to the promoted interfacial transition zone [11]. The enhanced microstructure was also confirmed by Wang et al. [11]. Chen et al. [10] systematically investigated the performance of coral sand concrete compared with the same mixing ratio parameters of river sand concrete. The results showed that the compressive strength of coral sand concrete was lower than river sand concrete, while flexural strength and splitting strength remained the same. Based on the previous studies, it can be noticed that a large amount of research concentrate on utilizing coral as inactive aggregates (with relatively large particle size). Actually, there are a number of abandoned coral filler [6] dug up from construction of docks and dredging waterways. However, by far, very limited studies address the reasonable and efficient use of the coral filler.

One potential method is to blend coral filler with sulfoaluminate cement based materials, since improved performance (rapid hardening and better compressive strength development) of CSA cement based materials can be obtained with the addition of calcium carbonate based minerals [12–15]. Calcium sulfoaluminate (CSA) cements have been produced, used and standardized in China for over 30 years [16–18], which can generate lower CO_2 emissions [19–21] and contribute better early strength [22]