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Improved microstructure of cement-based composites through the addition of rock wool particles

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ABSTRACT

Rock wool is an inorganic fibrous substance produced by steam blasting and cooling molten glass. As with other industrial by-products, rock wool particles can be used as cementitious materials or ultra fine fillers in cement-based composites. This study investigated the microstructure of mortar specimens produced with cement-based composites that include various forms of rock wool particles. It conducted compressive strength testing, rapid chloride penetration tests, X-ray diffraction analysis, thermo-gravimetric analysis, and scanning electronic microscopy to evaluate the macro- and micro-properties of the cement-based composites. Test results indicate that inclusion of rock wool particles in composites improved compressive strength and reduced chloride ion penetration at the age of 91 days due to the reduction of calcium hydroxide content. Microscopic analysis confirms that the use of rock wool particles contributed to the formation of a denser, more compact microstructure within the hardened paste. In addition, X-ray diffraction analysis shows few changes in formation of pozzolanic reaction products and no new hydrations are formed with incorporating rock wool particles.

1. Introduction

Cement-based composites have been applied in civil and architecture structures for many years and are also versatile and most popular construction materials. Unfortunately, cement-based composites are intrinsically porous and may deteriorate as a result of exposure to harsh environments, poor construction quality or chemical and even human factors [1,2]. The degradation of cement-based composites is considered a key factor in the durability of structures and a major concern for civil engineers. The composites deterioration usually involved movement of aggressive gases or liquids from the surrounding environment into the composites followed by physical or chemical reaction within its internal structure, possibly leading to irreversible damage [3]. It is generally agreed that the pore structure of cement-based composites is one of its most important characteristics and strongly influences both its mechanical behavior and its permeation properties [4].

On the other sides, it is effective to improve the pore structure of cementitious composites by reducing the water/cementitious ratio or adding some supplementary cementing materials (SCMs) such as fly ash, ggbs, and silica fume [5,6]. As with other SCMs, rock wool particles (RWP) can be reused and recycled to avoid environmental contamination and reduce carbon dioxide emissions in civil construction [7,8]. Cheng [7] described how the composition of RWP is similar to that of SCMs, making it a suitable substitute for coarse and fine

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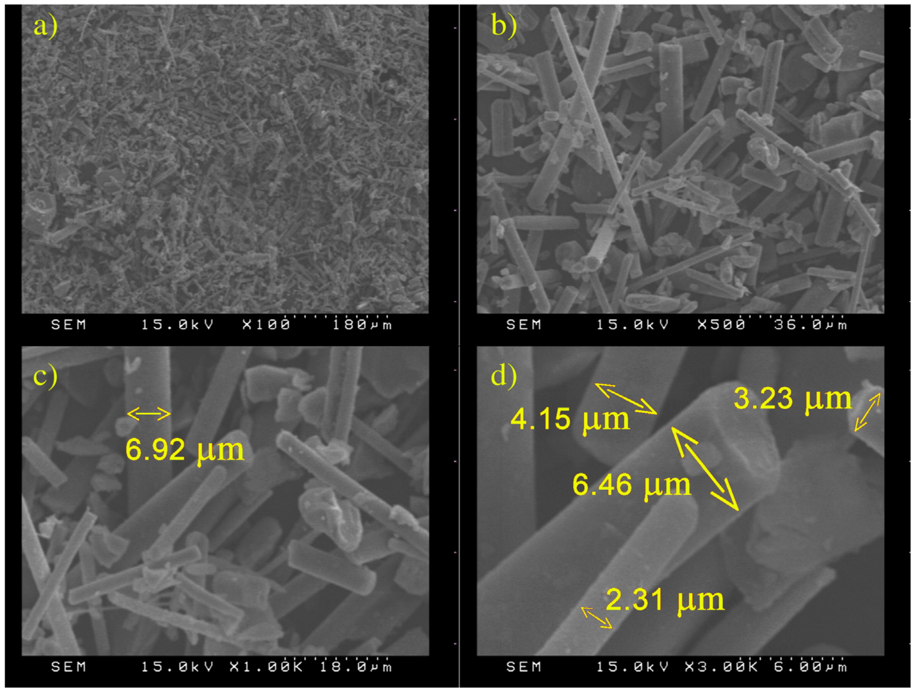

Fig. 1 – SEM observation of rock wool particles in a) ×200, b) ×500, c) ×1000 and d) ×3000.

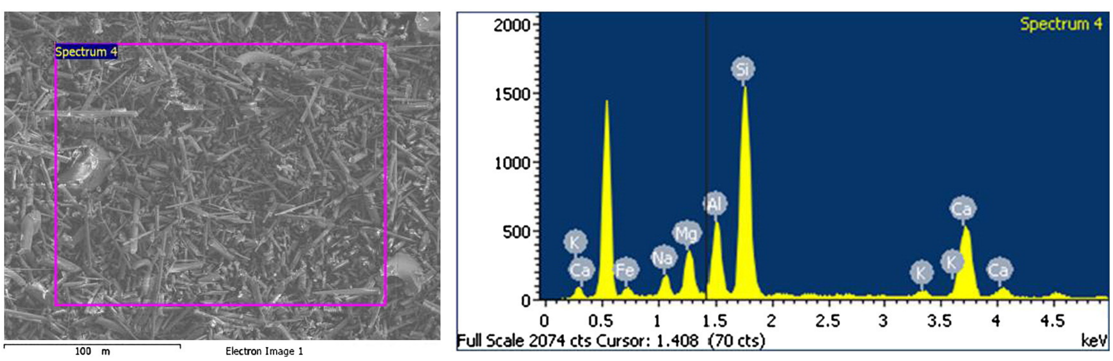

Fig. 2 – Energy dispersive X-ray spectrum of rock wool particles.

aggregates, according to its chemical composition and grain size. Lin [8] suggested that the RWP can be regarded as an SCM to replace a portion of the cement and enhance mechanical properties and durability. For the previous study, the inclusion of RWP in specimens also enhanced better performance on tensile strength and dry shrinkage than the control specimens [7,8]. In order to realize the micro-property of cement-based composites produced with RWP, the microstructure of RWP specimens should be studied further to determine and establish

Table 1 – Main elements of RWP (wt.%, at.%).

Element	Test 1		Test 2		Average	
	wt.%	at.%	wt.%	at.%	wt.%	at.%
Na K	3.95	5.54	3.94	5.51	3.95	5.53
Mg K	7.18	9.52	5.80	7.66	6.49	8.59
Al K	11.12	13.28	10.90	12.99	11.01	13.14
Si K	36.80	42.22	34.72	39.73	35.76	40.98
K K	1.54	1.27	0.00	0.00	0.77	0.64
Ca K	24.00	19.29	37.17	29.81	30.59	24.55
Fe K	15.41	8.89	7.47	4.30	11.44	6.60

Table 2 – Chemical and mineralogical composition of RWP, pozzolanic materials and Portland cement.

Chemical and mineralogical composition	RWP	Fly ash	GGBS	Silica fume	Portland cement
SiO_2 (wt.%)	38.7	54.0	33.5	91.5	21.2
Al_2O_3 (wt.%)	18.6	24.0	9.0	0.2	5.4
Fe_2O_3 (wt.%)	5.3	8.0	3.6	0.7	3.2
CaO (wt.%)	20.9	2.0	43.8	0.4	63.8
MgO (wt.%)	7.0	1.3	2.7	1.5	2.0
$K_2O + Na_2O$ (wt.%)	2.0	0.9	0.6	1.9	0.8
Other (wt.%)	7.5	9.8	6.8	3.8	3.6
Surface area (m^2/kg)	206	420	415	22,500	364