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Synthesis and Mechanical Evaluation of Portland Cement Mortars Reinforced With Silicon Carbide Powder

J.F. Gamarra-Delgado[1], M.L. Benavides-Salinas, V.C. Bringas-Rodríguez[1], C.K. Palomino-Naupa, D.L. Mayta-Ponce[1], G.P. Rodríguez-Guillén[1], R.M. Zapana-Vilcapaza[1] and F.A. Huamán-Mamani[1]
[1]Grupo de Investigación en Ciencia y Tecnología de Materiales, Departamento de Ciencias Naturales, Universidad Católica San Pablo, Arequipa, Perú
Urb. Campiña Paisajista, Quinta Vivanco s/n, Arequipa 04001, Perú
frank.gamarra23@gmail.com; mirandabenavides7@gmail.com; veronicawnh@gmail.com; cpalominon@unsa.edu.pe; dlmayta@ucsp.edu.pe; gprodriguez@ucsp.edu.pe; mzapana@gmail.com; fhuaman@ucsp.edu.pe

Abstract – Portland cement mortars reinforced with silicon carbide (SiC) powder were manufactured in this study. The volume of SiC powder added to the mixtures ranged from 0 to 8 vol.% of the total volume of the mixtures studied, in addition the volume of SiC powder added replaced equivalent volumes of fine sand, within a standard mix of Portland cement mortars. (75 vol.% of fine sand and 25 vol.% of Portland cement). SiC powder used was manufactured in the laboratory from the reuse of wood waste following wood pyrolysis processes to obtain carbon powder, followed by thermodiffusion of metallic silicon into pyrolyzed carbon powder.
All manufactured mortars were studied physical, microestructural and mechanically by helium pycnometry tests, optical microscopy and uniaxial compression, respectively. The average real density found for all mortars was 2.1 g/cm^3. The microstructure observed in mortars suggests the presence of three well-differentiated phases (Portland cement, fine sand and SiC particles), while the mechanical data found shows higher values of maximum resistance in mortars with 4 vol% SiC added, which would appear to be the most suitable amount of SiC powder to be added to the Portland cement mortar mixture.

***Keywords*:** silicon carbide, mechanical resistance, wood, powder, fine sand, reinforced agent

1. Introduction

Fabrication of biomorphic silicon carbide is made from wood precursors through pyrolysis process followed by silicon infiltration.

The compressive strength of these biomorphic composites was found to be strongly dependent on their bulk density and decreased as the test temperature increased [1,2]. Currently the wood industry in Peru generate large amounts of waste such as shavings, sawdust and large and small cuts of wood. Many times, these wastes are reused in certain types of industries as components or basic additives. It is starting to consider such waste as possible precursors for the manufacture of advanced materials [3,4].

Silicon carbide manufactured from wood precursors (biomorphic SiC or bioSiC) has advantages due to its low production cost, the diversity of microstructures, as well as being able to generate elements with complex shapes. Biomorphic SiC is a material of proven potential in applications as structural reinforcers [5].

Biomorphic Silicon Carbide (SiC) has been widely used in industries due to its unique biological structure produced by natural wood. SiC exhibits excellent low density strength. The importance of the fabrication of SiC using wood precursor powders is based on the fact that the SiC ceramic produced is denser and the SiC is more homogeneous [6]. The demand for repair and strengthening of concrete structures is a current issue in civil construction [7]. The selection of an applicable strengthening material and method is essential in strengthening operations [8].

Deng [8] indicated that applying Highly ductile fiber-reinforced concrete (HDC) to strengthen the compression zone of an over-reinforced concrete beam is a highly effective method to change its brittle failure and improve the ductility showing an increase in flexural capacity and deformation.

A number of studies have been reported that the use of high ductile and high-performance cementitious fiber-reinforced composites mortar such as Engineered Cementitious Composites (ECC) mortar can significantly enhance the brittleness of concrete [9]. Fischer and Li [10,11] applied Engineered Cementitious Composites (ECC) mortar to improve the seismic performance of reinforced concrete columns and the effect of ductile deformation behavior of ECC. Resulting that the application of ECC to reinforced concrete members improves the deformation and load-carrying capacities.

2. Materials and methods

Portland cement mortars reinforced with SiC powder were manufactured in two stages: (i) first, silicon carbide powder was manufactured from wood residues, through consecutive processes of pyrolysis of wood residues (in an inert atmosphere, 850 °C , 1 hour isotherm), thermodiffusion of metallic silicon into pyrolyzed carbon powder (in vacuum, 1450 °C, 1 hour isotherm) and oxidative pyrolysis (500 °C, in air, 1 hour isotherm) and (ii) then Portland cement mortars reinforced with SiC powder were manufactured, according to the volumetric compositions of table 1. The mortar manufacturing process began with the dry mixing of the three components (table 1), then water was added in a water: cement ratio of 0.5 and mixing was continued until a plastic and workable paste was obtained. The plastic mortar mixture was pressed at 10 MPa in a 20 mm diameter metal mold, then allowed to set in water for 28 days.

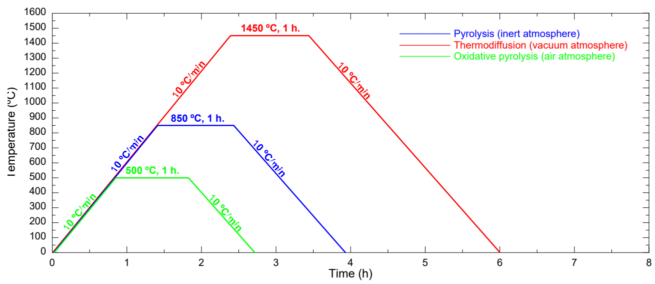

Fig. 1: Thermal profiles for inert pyrolysis (blue line), thermodiffusion (red line) and oxidative pyrolysis (green line) processes

Table 1: volumetric composition of the mortar mixtures studied

sample	fine sand (vol.%)	portland cement (vol.%)	SiC powder (vol.%)
A	75	25	0
B	73	25	2
C	71	25	4
D	69	25	6
E	67	25	8

All manufactured mortars were physically, microstructurally and mechanically characterized. The physical characterization consisted in the determination of real density by the technique of pycnometry, in this work a calibrated glass pycnometer and distilled water were used. The microstructural characterization was carried out on polished surfaces of the manufactured mortars. The preparation of the samples for microscopy began with a fine grinding of the surfaces, using SiC abrasive paper of # 600, # 800 and # 1200 grain, then the surfaces were polished using diamond paste (6, 3 and 1 micron) and lubricating liquid. The polished surfaces were cleaned with plenty of distilled water and allowed to air dry, no grain development technique was used. Microstructural observations were made in an AMSCOPE brand light microscope (50X - 500X), model ME320B-PZ (USA).

The mechanical tests consisted of uniaxial compression tests at a constant compression speed of 0.05 mm/min, in an air atmosphere and were executed in a universal testing machine, MICROTEST brand, model EM1/50/FR, (Spain). Samples for compression tests consisted of 10x5x5 mm3 parallelepipeds and were obtained from cylindrical samples of hardened mortars. Force and displacement data were obtained from the mechanical tests, which were then converted into stress vs. strain.

3. Results and Discussion

3.1. Physical and Microstructural Characterization

The real average density for all the materials studied was 2.1 g/cm3. Fig. 2 shows optical microscopy micrographs of the five types of mortars studied, two well differentiated phases could be appreciated, on one hand, a continuous phase in dark gray contrast that corresponds to the agglomerating phase of Portland cement, and on the other hand, individual particles dispersed within the continuous phase are seen, corresponding to fine sand particles (light gray phase) and SiC particles (bright white phase). In the micrograph of the mortar with 8 Vol% SiC powder, the identified phases are indicated (FS: fine sand, PC: Portland cement and SiC: silicon carbide powder)

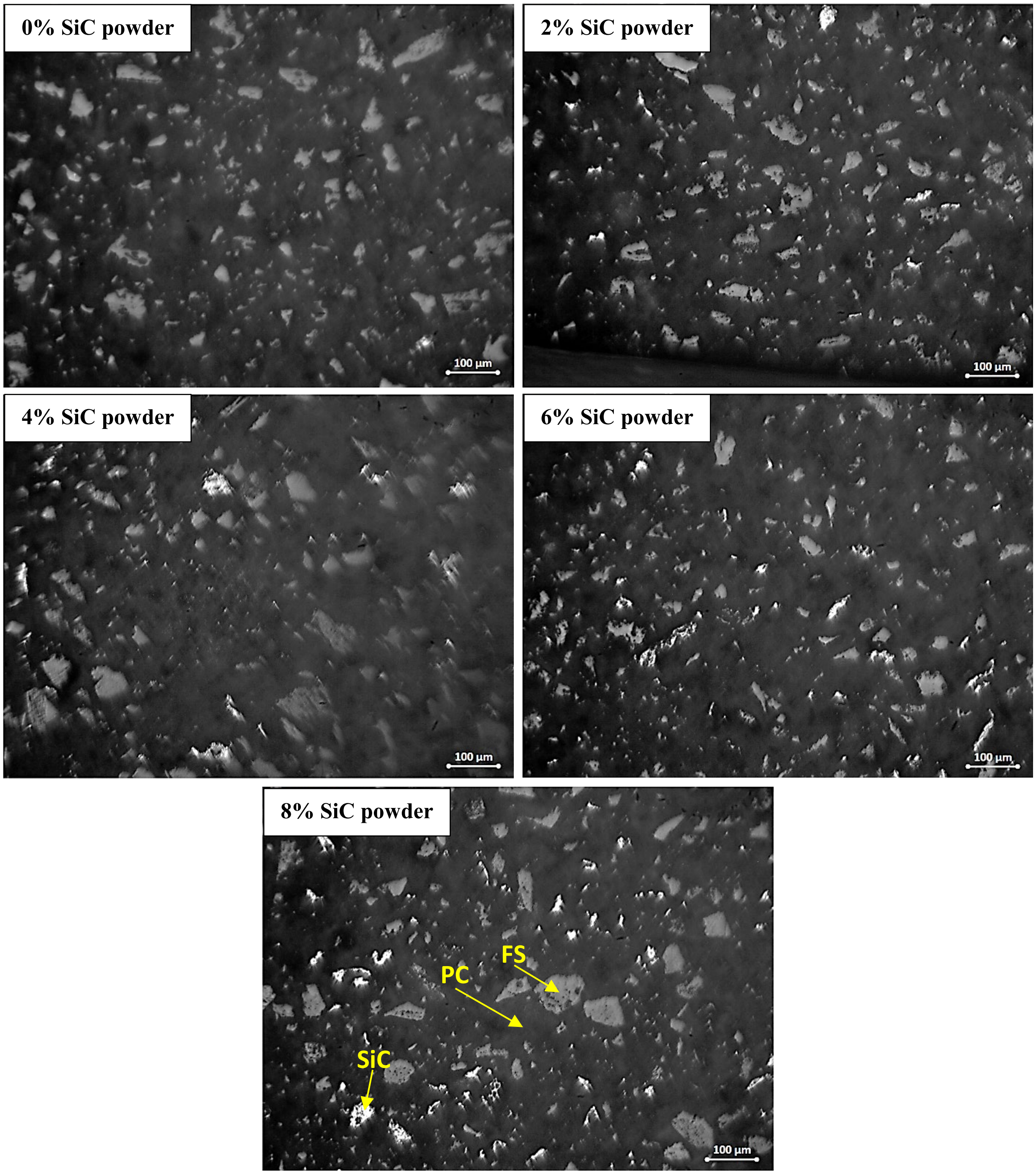

Fig. 2: Optical microscopy micrographs of cement Portland mortars with various percentages of SiC powder added.

3.2. Mechanical Characterization

Fig. 3 (a) presents stress vs. average strain for the five types of mortars studied, from these curves a slight increase in the deformation of mortars with added silicon carbide powder was observed, compared to mortars without the addition of SiC powder (curve in blue). It was also possible to observe a systematic increase in the average maximum resistance, as the percentage of SiC powder added to the Portland cement mortar mixtures increased, up to 4 Vol.% of SiC powder added. On the other hand, Fig. 3 (b) shows the relationship between the average maximum resistance and the percentage of SiC powder added, a maximum value of increase in mechanical resistance could be clearly appreciated (in comparison with mortar without SiC powder added) in mortars with 4 vol%. of SiC powder added, however, increases greater than 4 Vol.% SiC powder added led to a reduction in average maximum strength.

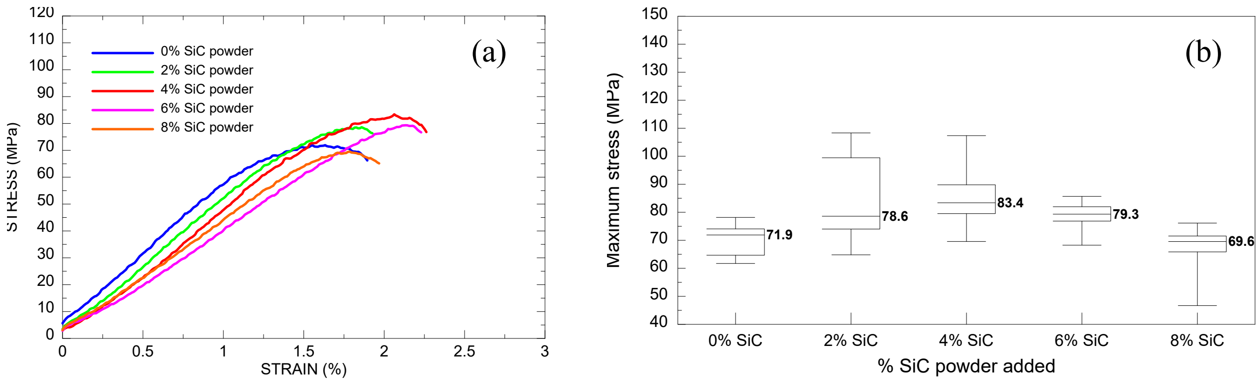

Fig. 3: (a) Stress vs. strain curves for the five types of mortars studied, (b) relationship between the maximum stress and the percentage of SiC powder added.

4. Conclusions

Portland cement mortars reinforced with silicon carbide powder, in various percentages, were successfully manufactured.

The average density found for all the mortars studied was 2.1 g/cm3, which indicated that the addition of SiC particles to a mixture of conventional Portland cement mortar does not lead to increasing or reducing the density of the material after setting.

The microstructural evaluation revealed the presence of two well differentiated phases, on one hand, a continuous phase that corresponded to the agglomerating phase of Portland cement and, on the other hand, individual particles dispersed within the continuous phase, corresponding to the sand particles. fine and SiC powder.

The systematic increase of the average maximum resistance was evidenced, by increasing the percentage of SiC powder added to the Portland cement mortar mixtures, up to a value of 4 Vol.% of SiC powder added, from which the maximum resistance decreases.

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