Construction and Building Materials 159 (2018) 463–472

Contents lists available at ScienceDirect

Construction and Building Materials

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

Durability performance of CNT and nanosilica admixed cement mortar

Han Seung Lee [a], B. Balasubramanian [b], G.V.T. Gopalakrishna [c], Seung-Jun Kwon [d], S.P. Karthick [a], V. Saraswathy [a,e,*]

[a] Department of Architectural Engineering, Hanyang University, 1271 Sa 3-dong, Sangrok-gu, Ansan 426791, South Korea
[b] Department of Civil Engineering, Mother Terasa College of Engineering and Technology, Pudukottai, Tamil Nadu, India
[c] Department of Civil Engineering, PSNA College of Engineering and Technology, Dindigul, Tamil Nadu, India
[d] Department of Civil Engineering, Hannam University, Daejeon 306-791, South Korea
[e] Corrosion and Materials Protection Division, CSIR-Central Electrochemical Research Institute, Karaikudi 630003, Tamil Nadu, India

HIGHLIGHTS

- The synergistic effect of NS with CNT composite cement mortar was investigated.
- Strength and durability properties were enhanced by the addition of NS and CNT.
- Polarization study revealed that the corrosion resistance was enhanced.
- SEM and XRD confirmed that NS and CNT accelerated the hydration process and resulted in denser microstructure formation.

ARTICLE INFO

Article history:
Received 3 August 2017
Received in revised form 3 October 2017
Accepted 3 November 2017

Keywords:
Nano silica
Carbon nanotube
Rock dust
Strength
Durability
Electrochemical studies

ABSTRACT

In the recent years, development and use of nanomaterials are gaining importance in the construction industries due to the advancement of science and technology. In the present investigation, nanosilica (NS) was synthesized from rice husk ash and characterized using XRD, Particle size analysis and SEM techniques. 1% NS by weight was used in cement mortar along with carbon nano tube (0.01%–0.07%) as a cement replacement materials and rock dust (RD) was used as a replacement for river sand. Five different mix combinations were formulated. Polycarboxylate based water reducing admixture was used for improving the workability of the mix. All the combination of mixes derived were subjected to compression, split tensile test, and durability studies such as sorptivity, water absorption, and chloride penetration test. Potentiodynamic polarization study was carried out to understand the corrosion performance of the composite cement mortar. SEM and XRD studies were carried out for the hydrated products of the composite cement mortar. The results showed that NS and CNT increased the compressive strength by 12%–76% and enhanced the corrosion resistance properties than the control.

1. Introduction

Durable concrete is the one which performs satisfactorily when it is exposed to the aggressive marine environment during its service life [1,2]. Concrete is a most durable material requiring no maintenance in normal environmental conditions. The alkaline environment of the concrete pore solution enables the formation of the protective passive film on the surface of the embedded rebar in concrete which acts as a barrier protective layer against corrosion [3]. But when it is exposed to the highly aggressive environmental conditions, the passive film gets destroyed, and initiation of corrosion of the embedded rebar occurs resulting in premature failure of the concrete structures [4–7]. The durability of the structures is mainly affected by the poor quality and improper selection of the materials, poor quality of construction, poor design, inadequate concrete cover and irregular maintenance [8].

Different methods are being adopted to enhance the service life of the reinforced concrete structures, which include coatings to the concrete surface, coatings to the reinforcement, cathodic protection, chloride removal, corrosion inhibitors and blended cements etc. [9,10]. The basis for sustainable concrete industry lies on three aspects: reducing CO_2 emissions by using the industrial wastes such as slag, fly ash, silica fume as a substitute material for cement, and conserving the natural resources by replacing part of the coarse aggregate with recycled construction waste [11]. Many researchers have studied the durability performance of blended

* Corresponding author at: Corrosion and Materials Protection Division, CSIR-Central Electrochemical Research Institute, Karaikudi 630003, Tamil Nadu, India.
E-mail address: vsaracorr@cecri.res.in (V. Saraswathy).

https://doi.org/10.1016/j.conbuildmat.2017.11.003
0950-0618/

cement using fly ash, rice husk ash, slag, micro silica, marble sludge powder and bagasse ash [12–18]. Several researchers [19–22] have reported that the use of the ternary cement is advantageous when compared to both binary cements and OPC. In addition, waste materials like quarry rock dust could be used as a replacement material for fine aggregate [17], copper slag could be utilized as a substitute material for both fine and coarse aggregate for producing pavement blocks, platforms, etc. [23–25].

Recently, application of nanomaterials has received significant attention in the construction industry. Engineering applications include fire insulator, sound absorber, water repellents, air purifier, nanosensors, UV reflective coating, self-cleaning agent, anti-fouling coating, solar cells etc. Studies reported that nano-SiO_2, nano-Fe_2O_3, nano-TiO_2, nano-Al_2O_3, nano-ZnO_2, nano-CuO, nao-$CaCO_3$ are the commonly used nanoparticles in concrete [26–33]. But nano-SiO_2 is the most widely used nano-particle with extensive application in concrete due to the high activity and greater specific surface area leading to higher pozzolanic reactivity forming a denser CSH gel which is responsible for increased strength and enhanced durability [34–36]. Studies revealed that the hybrid effect of CNT and nano-clay increased the compressive strength [37], decreased the conductive properties of the composites [38] and resist the crack formation by acting as a fiber in the cement-aggregate interface based on its bonding, bridging and mesh filling effect [39–41].

Many of the developing countries like India are facing acute shortage of river sand to meet its infrastructural development. The waste materials are being effectively utilized in the construction industry either as a replacement for coarse aggregate or fine aggregates or as a substitute for cement, which may be useful for not only from the economy point of view but also to preserve the environment as well.

In the present investigation, rock dust (RD) was used as a fine aggregate replacement material. The composite/synergistic effect of nanoparticles such as nanosilica (NS) and carbon nanotubes (CNT) along with RD in cement mortar was formulated using the different combination of designed mortar mix and the strength and durability performance was assessed through mechanical properties and accelerated corrosion tests. The electrochemical behavior of the mortar mix was assessed by potentiodynamic polarization measurements. The hydrated products were characterized by XRD, scanning electron microscopy (SEM) and the results were compared with the conventional ordinary Portland cement mortar.

Table 1
Chemical composition of the materials used.

Components	OPC (%)	NS (%)	Rock Dust (RD) (%)
SiO_2	23.50	98.5	75.25
Al_2O_3	5.50	–	15.63
Fe_2O_3	4.80	–	5.22
CaO	61.50	0.7	1.26
MgO	0.50	–	1.30
K_2O		–	1.34
Na_2O		–	
SO_3	2.2	0.2	
LOI	2.0	0.6	
Bulk density	1600 kg/m^3		1750
Specific gravity	3.15		2. 70

2. Experimental

2.1. Materials and methods

Ordinary Portland Cement (OPC) conforming to IS 8112 was used for the investigation. The composition of OPC, NS, and RD is given in Table 1. RD is a by-product obtained from the granite industry during the crushing process in quarrying activities. The specific gravity of RD is 2.83. SEM/EDAX results of RD are shown in Fig. 1(a) and (b). Polycarboxylate based SP (Viscoflex-SR-40%) supplied by Apple Chemie, was used as a high range water reducing admixture (0.2–1.2% by weight of cement). Thermo mechanically treated (TMT) rebar of 12 mm dia. and 50 mm length was used.

Nanosilica (NS) was synthesized from rice husk ash by precipitation method [42] and subjected to XRD, particle size, and SEM. The XRD, particle size, and SEM image of nano- SiO_2 are shown in Fig. 2(a–d). From the figure, it is observed that the NS particle size ranging from 20 nm to 50 nm were observed. XRD pattern confirms the amorphous nature of the NS particles.

From SEM (Fig. 3(a) and (b)) images it is evidence that the CNT particle size ranging from 1 to 2 μm length and 30 to 80 nm diameter were observed. The CNT particles are found to contain fibrous structures which are closely interlinked with each other. CNT purchased from Fischer Scientific was used for the investigation.

Mortar mix ratio of 1:3 with w/c 0.45 was used for the investigation. Various mix proportions investigated are given in Table 2. Prior to casting, NS and CNT were mixed together in a beaker containing a required quantity of water for casting each specimen and sonicated well to avoid agglomeration of nanoparticles. The superplasticizer dosage was varied from 0.5 to 1.0% and was added

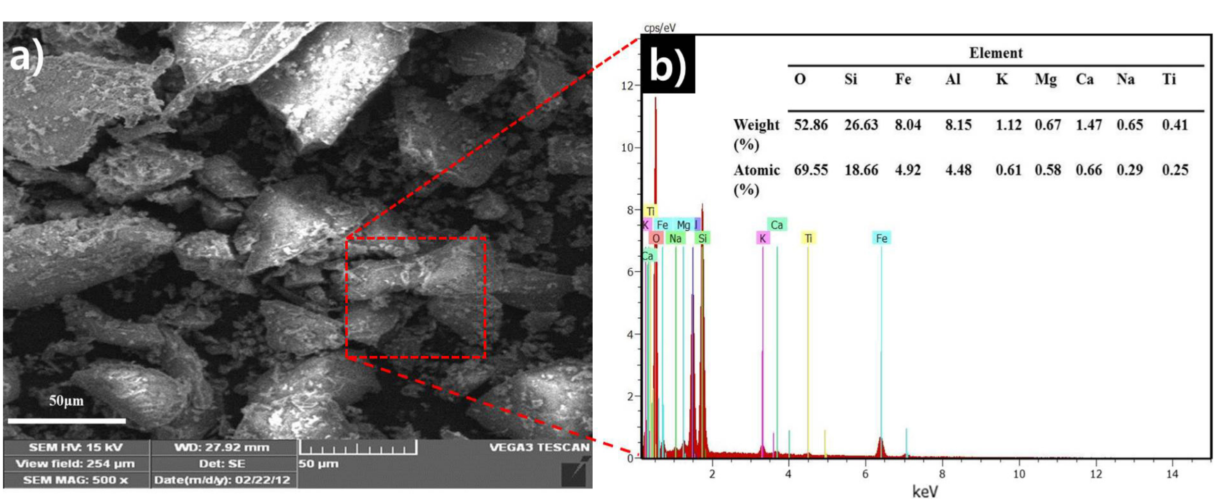

Fig. 1. SEM image (a) and EDAX (b) results for CRD.