Mechanics of Materials 92 (2016) 223–234

Contents lists available at ScienceDirect

Mechanics of Materials

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

Advancements in mechanical and physical properties for marble powder–cement composites strengthened by nanostructured graphite particles

Mehmet Serkan Kirgiz*

Trakya University Architecture Faculty, 22100 Edirne, Turkey

ARTICLE INFO

Article history:
Received 24 January 2015
Revised 28 September 2015
Available online 9 October 2015

Keywords:
Nanostructured graphite particle
Marble powder–cement
Mortar composite
Physical properties
Flexural strength
Compressive strength

ABSTRACT

Since Portland limestone cements display some negative side effect such as the reduced strength, this non-budget research aims to develop novel marble powder–cement which overcome this negative side effect. This study uses the nanographite particle, pure Portland cement, super plasticizer, tap water, and standard mortar sand for preparing the marble powder–cement and marble powder–cement mortar. Examined properties are water absorption, apparent density, flexural strength, and compressive strength. Results reveal that since the nanographite particle and the super plasticizer are added for mortar containing 35% MP and 65% pure Portland cement, these mortars display comparatively important advances in the strength gain as well as water absorption and density. Nanographite particle and super plasticizer lead to increasing over 28% greater flexural strength and over 22% greater compressive strength in marble powder–cement mortar when compared to pure Portland cement mortar. Results show that cement containing the ground marble powder needs the nanographite particle and the super plasticizer for combining the marble powder and cement properly in mortar. Results also reveal that the use of nanographite particle is favorable for marble powder–cement in view of the water absorption, apparent density, flexural strength as well as compressive strength.

1. Introduction

Researches have suggested plenty of significant methods for activations of cement by NPs – such as nT, nZ, nC, nL, nCNT, nCL and nS, since 1999 (Kirgiz, 2014a, 2015a). These nano particles provide such some benefits as activation of cement hydration which could serve to reduce the $Ca(OH)_2$ formation, and increase the strength gain. Moreover, many researches focus on nS to demonsrate its effectiveness in enhancing the strength-related properties of substituted-cement (Kirgiz, 2014a, 2015a, 2015b, 2015c). However, a current study carried out by Hou et al. (2013) shows that nS may have negative effects on the properties of OPC. Researches primarily use LP as a filler to improve rheological properties of cement. Studies reveal that LP can accelerate hydration of cement by providing nucleation places for the CH and react

Abbreviations: nG, nanographite particle; NP, nanoparticle; nT, nanotitanium oxide particle (TiO_2); nZ, nanozinc particle; nL, nanolimestone particle; nCNT, nanocarbon–nanotube fiber; nCL, nanoclay particle; nS, nanosilicon oxide particle (SiO_2); CH, calcium hydroxide ($Ca(OH)_2$); OPC, ordinary Portland cement; MP–C, marble powder–cement; LP, limestone powder; C_3A, calcium aluminates; C_3S, tricalcium silicate; FA–C, fly ash–cement system; CNT, carbon nano tube; MW, marble waste; MP, marble powder; SP, superplasticizer; Ca, calcium; C, carbon; O, oxygen; RC, reference cement; RC1, reference cement1; RC2, reference cement2; RC3, reference cement3; $CaCO_3$, calcite; nC, nano calcium carbonat particle ($CaCO_3$); SEM, scanning electron microscope; MP–CM, marble powder–cement mortar; CS, compressive Strength; FS, flexure Strength; CaO, calcium oxide; SiO_2, silicon oxide; Al_2O_3, aluminum oxide; Fe_2O_3, ferrite oxide; MgO, magnesium oxide; SO_3, sulfur oxide; K_2O, potassium oxide; Na_2O, sodium oxide; LOI, loss on ignition.

* Tel.: +90 5396145238.
E-mail address: nakres42@yahoo.com

http://dx.doi.org/10.1016/j.mechmat.2015.09.013
0167-6636/

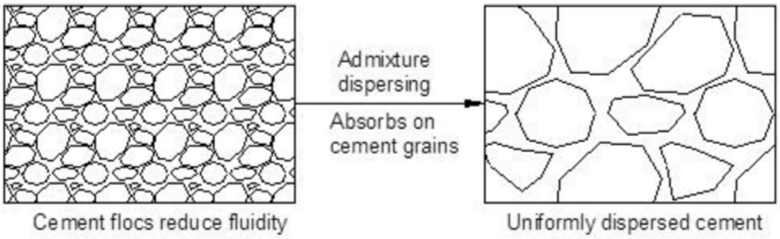

Fig. 1. Differences in dispersion statement of cement.

with C_3A and C_3S to produce calcium carboaluminate and calcium carbosilicate hydrate, respectively (Yuan and Guo, 1987). nCL significantly reduces lateral hydraulic pressure in formwork because this effect is previously tied to flocculation behavior which studies show the nCL increases for flocculation strength and flocculation size. Since nCL has a high water adsorption of 200% by mass, this property provides it for possible governing factor (Kirgiz, 2014a, 2015a, 2015b, 2015c). Additionally, nC displays a potential for offsetting negative side effects in FA–C – the reduced early strengths and the increased setting-times (Kirgiz, 2014a, 2015a, 2015b). To last researches on additions of different type of CNT, this additions achieve to increase flexural strength for OPC based materials with superplasticizer (Kirgiz, 2014a, 2015a, 2015b, 2015c). These are referred in researches to enhance for performances of pure Portland cements and reduce the necessary amounts of cement which ensure economic viability in construction applications.

Moreover, cement grain which is dispersed uniformly makes up no lumps and flocs in mortar mixture. Since the lumps and/or flocs trap for water within them, cement paste is lesser mobile and fluid than cement grain dispersed uniformly in the mixture. This is similar to the situation where ants walk along a narrow pavement together. If group of ant walks in one direction continously, it is, then, hard for other ants to cross. If ants stop walking together, it is, then, easy for other ants to cross. If nanoparticle is not distributed equally in mortar mixture, the strength gain does not develop at early age due to the flocculation of particles causing unhydrated grains. In view of this practical standpoint, effective use of nanoparticle relies on the ability to achieve uniform and stable dispersion of it (Mostafa et al. 2013, Nazari and Riahi, 2011a, Sato and Beaudoin, 2006, Chang et al. 2007, Gündoğdu et al. 2010, Shih et al. 2006, Nazari and Riahi, 2011b, Konstantin et al. 2009). Fig. 1 shows differences in dispersion statement of cement.

On the other hand, MW appears in marble cutting-plants which are established around the world. Out of 2.5 million tons of MW generates each year in Turkey as whole world, none of them is reused or recycled. MW is landfilled in rural lands according to municipality policy which will cause environmental problems in close future. MW has got chemical compositions which bar this landfilling (Table 1) (Kirgiz, 2007). BS EN 206–1:2000 (2001) describes MW as latent hydraulic addition in view of this chemical composition in order to enhance strengths of cement. *Although MW is a latent hydraulic activator for cement based materials, researches do not think to replace MW with OPC in mortar, paste, and concrete. Since ball mill grinds MW for 30 (min) to form powder, it is coded as MP. As high content MP is replaced by OPC, MP–C system exhibits the reduced initial strength gain. In order to increase the use of MP as limestone resource which provides plenty of much positive effect for pure Portland cement, there is a need to make better this aforementioned negative side effect. Additionally, blending of nT, nZ, nC, nL, nCNT, nCL, and nS also has a significant drawback on properties of substituted-cement. They do not increase early strength gain of substituted-cement.* Previously, author's article has shown that the use of nG increased compressive strength and flexural strength for FA–C system at early age (Kirgiz, 2014a, 2015a, 2015b, 2015c). This study motivates further exploration of using nG due to the increased strength in marble powder–cement at early age, too. *The study reported in this article aims to overcome the reduced strength gain in MP–C system. It presents innovations in MP–C system in view of nG and SP addition, water absorption, apparent density, flexural strength, and compressive strength. Results can be referred to further enhance the MP–C performance and reduce necessary amount of pure Portland cement for construction application which ensures its economic viability. The aforementioned reasons, this original non-budget research aims to develop mechanical and physical properties of marble powder–cement system with nano graphite particle.*

Table 1
Chemical compositions of the ground MP, nG, and CEM I 42.5 N cement (Kirgiz, 2007, http://nanoparticles-nanopowder.us/graphite_nanoparticles).

Chemical compositions (%)	MP	nG	OPC
CaO	53.79	–	63.5
SiO_2	0.388	–	19.90
Al_2O_3	0.11	–	5.20
Fe_2O_3	0.04	–	3.43
MgO	0.77	–	1.76
SO_3	0.05	–	2.84
K_2O	0.01	–	0.77
Na_2O	0.34	–	0.82
C (% mol)	–	75–93	–
O (% mol)	–	2.5–22	–
H (% mol)	–	4.5–5.5	–
LOI	44.15	7–25	0.0153

2. Experimental procedures

2.1. Materials

This present experimental non-budget research uses the ground MP, the nG, the CEM I 42.5N cement, CEN standard sand, tap water, and the SP for preparations of cement and mortar as constituent materials.