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Effects of the colloid graphite Nano-Particle on the properties of fuel ash-green cement composite

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Abstract

This current study aims at comparing properties of conventional cement composite and of green cement composite (CPFA-GCC) including pulverized fuel ash of class C (CPFA) and nano particle of graphite (GNP) and colloid nano particle of graphite (CGNP) each other. The laboratory based research has prepared samples of green cement paste composite and of green cement mortar composite made of class C pulverized fuel ash (CPFA), pure cement, graphite nano particle (GNP), colloid GNP (CGNP), CEN standard sand, and tap water to analyze and compare with the properties each other. The tested physical and mechanical properties were specroanalitical quantity of CGNP with the optical atomic absorption spectroscopy (OAAS), the setting-period of green cement paste composite, the flow, and the apparent density of green mortar composite as well as the compressive stress at 1 day (d), 2d, and 3d. Results indicate that the CGNP accelerates the stiffness-time and increases the compressive stress. Consequently, the CGNP is useful for the properties of CPFA-GCC when compared to the properties of class C pulverized fuel ash-green cement composite and of pure cement composite made with and without the CGNP.

Keywords: Graphite nano particle; Colloid graphite nano particle; Blended cement; Pulverized fuel ash; Physical properties; Mechanical strength; Flow; Durability properties.

Introduction

In view of valuable oxide content of the CPFA such as calcium, silicon, aluminum, and iron, the CPFA, which power plants generate with burning of high-calorie charcoal in the manufacturing of electrical energy, is a very valuable artificial pozzolanic material for the cement industry. The CPFA is light-brown color and includes more than 10% calcium oxide content (CaO). ASTM standards classify this pulverized fuel ash as class C according to the CaO content[1,2]. This ash has a number of pros for cement-based green binder materials used in engineering applications such as the reinforced-concrete column, beam, floor, found, structural curtain wall, mortar, and grout and so on. For example, decreasing the demanding of mixing water and the partition of mixing materials and the rising of water between mixing materials and the temperature in contacting water with binder and the magnetic flux; improving the fresh features and the stress gain in compression at 90d; increasing in such durability features as adverse chemical environments and freezing-and-thawing cycle. In addition, the replacing the CPFA with cement may also exhibits some cons e.g., increasing dormant period and loss on early stress gain in compression in the cement based materials[3,4]. In order to increase using the CPFA in green cement binder composite material, which is described as the replacement of 35-50% mineralogical materials for conventional cement, there is a need to overcome the cons aforementioned.

The studying would explain the effectiveness of colloid GNP on class C pulverized fuel ash-cement composite (CPFA-CC) because it improves some physical and mechanical properties of the CPFA-CC. Since GNP is a metallic mac carbon particle, whose dimension lower than $1x10^2$nm and of $25x10^{-1}$nm in thickness and of 1-1.5µm in radius, and water-fearing, unpile, and leafleting, the GNP could overcome disadvantages mentioned previous paragraph[4]. There are plenty of much comprehensive studying regarding on adding the nano materials into preparation of mortar, grout, stucco, and concrete for developing their technological and performance features, e.g., physical, mechanical, durability, and firing resistance[6-23].

The purpose of the studying reported in this article compares new properties of the CPFA-CC modified by either the GNP or the CGNP to better explain the differences between the GNP using and the CGNP using. It also concludes the effectiveness of GNP and colloid GNP on the development of optical atomic absorbance spectra, stiffness-period, and flow, and apparent density as well as early age compressive stress.

Constituent Materials and Testing Methods: Constituent Materials: Type I binder of ASTM, graphite nano particle, and pulverized fly powdery residue are bulk constituent materials that are in different particle size. To measure interaction of nano particle of graphite (GNP) and of colloid nano particle of graphite (CGNP) with the bulk materials, this study prepared new eco-friendly binder combination, paste, and grout composite.

Materials and methods

Synthesis of the Colloid GNP (the CGNP): Since it is noted that the GNP could hang into the water by itself for temporarily, the working firstly dispersed nano particle of graphite (GNP) into water including no another liquid, e.g., surfactant. After one hour stirring of GNP into water with horn-ultrasonicator, the dispersing of GNP was not as the working expected. Therefore, the working tried to disperse nano particle of graphite (GNP) into solution, which consisted of tetra-block copolymer and water. After one-hour ultrasonic stirrer of the solution, the GNP was accumulated too. The working carried out last dispersing into new solution, containing sodium, through same ultrasonic stirrer. Since last ultrasonic stirrer process achieved thirty times greater distribution of the GNP when compared to previous two-dispersing of nano particle graphite (GNP), it was concluded that the working of dispersing of GNP was successful. Preparation of the liquid uses following steps; (1) add $4x10^0$g nano particle of graphite (GNP) into $18x10^1$mL water consisting of one percent sodium mac liquid in a stainless steel bowl; (2) place this mixture under a horn-ultrasonicator for stirring; (3) apply the dispersing process during 60 (min) at $4,8x10^1$ (W) power stage; (4) cool the stainless steel bowl with an ice container during the distribution process. After the dispersing, , colloid nano particle of graphite was rotated with centrifuge at 7500 (rpm) for 30 (min) with to protect the solution from clumps.

Mixture proportions, design, and manufacturing of green cement binder combinations, paste, and mortar composites: The green binder combinations and paste composites and mixing design of composite and quantity of CGNP for three Vicat mold is given in the Table1. The green binder combinations and mortar composites and mixing design of mortar composites and quantity of CGNP is presented in the Table2 in Kg/m^3 and/or L/m^3.

Table-1: The green binder combinations and paste composites and mixing design of composite and quantity of CGNP, as kilogram and/or mL for three Vicat mold.

Types of Cement and Green Binder	Types of Paste	Mixing Design						
		Cement (g)	CPFA (g)	Water (mL)	GNP (g)	CGNP (mL)		
						GNP (g)	Surfactant	Water
ASTM type I cement	Control	500	0	127	0	0	0	0
1GNP-ASTMI	P1	500	0	128	1	0	0	0
1CGNP-ASTM I	P2	500	0	81	-	1	1.8	44.2
35CPFA-ASTM I	P3	325	175	128	-	-	-	0
35CPFA-1GNP-ASTM I	P4	325	175	128	1.3	0	0	0
35CPFA-1CGNP-ASTM I	P5	325	175	81	0	1	1.8	44.2

Table-2: The green binder combinations and mortar composites and mixing design of mortar composites and quantity of CGNP in Kg/m^3 and/or L/m^3.

Types of Cement / Green Binder	Types of Mortar	Mixing Design							
		Cement	CPFA	Water	Sand	GNP	CGNP		
							GNP	Surfactant	Water
ASTM type I cement	Control	380	0	292	1757	0	0	0	0
1GNP-ASTMI	M1	380	0	292	1757	1.3	0	0	0
1CGNP-ASTM I	M2	380	0	225.7	1757	0	1.3	1.3	65
35CPFA-ASTM I	M3	380	205	292	1757	0	0	0	0
35CPFA-1GNP-ASTM I	M4	380	205	292	1757	1.3	0	0	0
35CPFA-1CGNP-ASTMI	M5	380	205	225.7	1757	0	1.3	1.3	65

Characterization of the CGNP: The optical atomic absorbance spectra equipment, which estimates the mass of GNP through vacuum filtration, measures the quantifying degree of ultrasonication-dispersed CGNP. The concentration of CGNP dispersion was relatively compared the optical atomic absorbance spectra measured by a spectrophotometer. Mass of ultrasonication-dispersed CGNP was estimated further by sedimentation onto a filtering mixed cellulose esters membrane with 50 (nm) pore size (EMD Millipore), and the collected GNP particle was weighed after drying overnight. The diluted CGNP was used to prepare the green based construction material containing 65% type I cement of ASTM and 35% CPFA with constant liquid-to-binder ratio (l/b) of 0.76. Composite preparation process that was mentioned in *"Mixture proportions, design, and manufacturing of green cement binder combinations, paste, and mortar composites"* section used a planetary medium mixer to homogenize the green cement binder combination and to stir the paste and mortar composite. After mixing, this study placed mortar composite sample in 50.8x50.8x50.8 (mm) cubic mold. After 1-d casting in a vapor curing cabinet, the mortar samples were removed from the casting and put into aqueous and humid medium- 22 ± 3ºC and 98% humidity till analyzing.

Measurement of stiffness-time: Vicat equipment measures stiffness-period of paste samples of construction material that was prepared as the Table-1 being. The mold-filled paste was placed on base-plate in the Vicat equipment in a container having water at 22 ± 3ºC. The Vicat needle was lowered gently until it was in contact upper surface of the green binder paste. The penetration was repeated on the same specimen at 10 (min) intervals until the needle sinked no more than 5 (mm). This time of 5 ± 2–mm–sink was recorded as an initial stiffness-time. The time at which the needle first penetrates only 0.5 (mm) was recorded for a final stiffness-time, together with the time from zero[24].

Measurement of flow: The working was measured the flow of fresh samples of construction material and of green binder mortar composite prepared in Table-2 according to the reference of[24].

Measurement of apparent density: The apparent density testing was performed with some laboratory tools such as a digital weighing scale which has have a precision of 0.01g, LCD digital vernier caliper, and a digital furnace which could dry plenty of much sample at the same time. Before the testing, the samples were dried by furnace at 105 ± 5 ºC until each one shows constant mass. The constant mass of mortar composite sample was designated by a precise digital weighing scale, and it was recorded as W_d g. Volume for the sample of mortar composite was measured by the LCD digital vernier caliper, and it was recorded as V_d cm^3. The apparent density (d) is calculated by W_d / V_d as g/cm^3[25]. Average of eighteen apparent densities value specifies the descriptive apparent density in Table-3 and following figures.

Measurement of compressive stress: Mechanical axial compression force testing evaluates the compressive stress of pure cement mortar composite and of green binder mortar composite containing either the CGNP and water or water and GNP as presented in Table-2. For each type of mortar composite at each age (Table-2), three samples of totally fifty-four samples were tested. Average of the compressive stress value specifies the descriptive compressive stress of green binder mortar composite in Table-3 and following figures. Equation1 calculates the compressive stress that was defined by the $R_c = \{(F_c / 2580.6)\}$. Where the R_c is a compressive stress of mortar composite, in MPa, the F_c is compression force up to fracture, in N[24].

Results and Discussion

Table-3 summarizes types of green cement binder paste composite, types of green cement binder mortar composite, the stiffness-time of green binder paste composite, the flow, the apparent density, and the compressive stress of green binder mortar composite. Next figures specify the effect of nano particle of graphite (GNP) and of colloid nano particle of graphite (CGNP) on physico-mechanical properties of construction materials prepared in the working.

Optical atomic absorbance spectra (OAAS): For colloid nano particle of graphite (CGNP), its starting dimension is well determined as 35x10^{1}nm, pointing that the concentration of colloid nano particle of graphite is greater than that of the nano particle of graphite within water. Generally, the quantity of the OAAS relates to the quantity of colloid nano particle of graphite (CGNP) concentrated- i.e., the greater intensify demonstrates the greater adsorption of particle is in sample. Between the length of wave of 35x10^{1}nm and the length of wave of 9x10^2 nm, it is measured that the OAAS of the colloid nano particle of graphite (CGNP) concentrated is over 15 times greater than that of colloid nano particle of graphite (CGNP) obtained without concentrating process. It also unveils that the quantity of OAAS of CGNP concentrated is greater than the OAAS quantity of GNP within water. This increase in the absorbance is nearly five times, from 6x10^{-1} to 3x10^1. Meaning of the absorbance increasing is that the colloid nano particle of graphite manufactured in the study does not include clump.

Stiffness–period: Figure-1 shows the effect of nano particle of graphite and of colloid nano particle of graphite on the setting period of the paste composites. Figure1 also presents an important evidence for stiffness-period that the CGNP accelerates it. The greatest impressive reason regarding on the green binder- Portland cement doped pulverized fuel ash is that the P5 green binder paste composite was waken up by the colloid nano particle of graphite, and its stiffness-period is 21 minutes earlier than that of the P3. In other word, although the dormant period increased with replacement of the CPFA with cement, the effect of nano particle of graphite and of colloid nano particle of graphite led to loss on the stiffness-period seemingly (Table-3 and Figure-1).

Table-3: Green binder paste composites, green cement binder mortar composite, the stiffness-time of green binder paste composite, the flow, the apparent density, and the compressive stress of green binder mortar composite.

Types of Testing		Types of Green Cement Binder Paste Composite					
		Control	P1	P2	P3	P4	P5
Stiffness-Time (min)	Initial	125	90	110	241	230	210
	Final	210	150	210	353	340	310
Types of Testing		Types of Green Cement Binder Mortar Composite					
		Control	M1	M2	M3	M4	M5
Flow (mm)		165	145	140	186	165	167
Apparent Unit Mass (Density) (g/cm^3)		$18x10^{-1}$	$2x10^0$	$19x10^{-1}$	$2\ x10^0$	$2\ x10^0$	$2\ x10^0$
Compressive Stress (MPa)	1-d	3.4	3.7	4.6	4.2	3.7	4.8
	2-d	4.6	5.1	5.8	9.3	8	8.7
	3-d	7.7	7.3	8	9.6	9.1	10

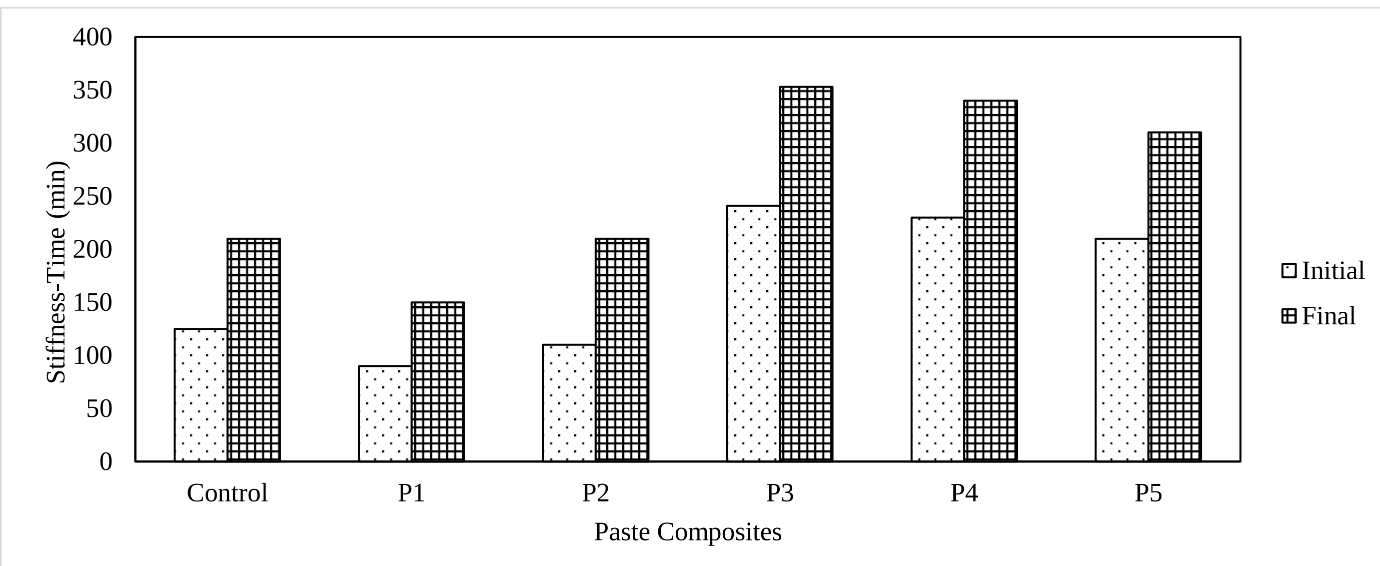

Figure-1: The effect of nano particle of graphite and of colloid nano particle of graphite on the setting period of the paste composites.

Sample called the P1 blended cement paste composite, containing only 1 (gr) GNP, demonstrates the fastest setting-period in the paste composites made of the type I cement of ASTM along with GNP. A similar supportive result, like the ASTM/GNP and the CGNP pastes composite, is reached for stiffness-time in the green CPFA-C binder pastes composite (Table 3 and Figure 1). This means that the CGNP eases to reduce the increased stiffness-time in the paste composites of green binder. The result is probably because of the ability effect of reaction of pure carbon-based metallic, hydrophobic, plateletless and leafy CGNP on the oxide of calcium in the CPFA green binder and pure cement. Similarly, this accelerator effect could overcome to reduce the increased stiffness-time in the green cement binder that contains free CaO content, more than 10%.

Flow: Figure-2 shows the effect of the blending GNP and the colloid CGNP addition on the fresh state of pure cement mortar composite and of green binder mortar composite in Table-2. In the Figure-2 and the following figures, such abbreviations as

M1, M2, M3, M4, M5, and Control mean that the M1 samples contain the type I cement of ASTM, water, the GNP, and mortar sand; M2 samples contain the type I cement of ASTM, water, the CGNP, and mortar sand; M3 samples contain the type I cement of ASTM, the fuel ash of class C, water along with mortar sand; the M4 samples contain the type I cement of ASTM, the fuel ash of class C, the GNP, water along with mortar sand; the M5 samples contain the type I cement of ASTM, the fuel ash of class C, the CGNP, water along with mortar sand; and the Control samples also contain only the type I cement of ASTM and water along with mortar sand. This is proved that there is obvious to see decreasing the flow as the GNP and the CGNP is increased for mixtures of pure cement mortar composite and of green binder mortar composite (Table-3 and Figure-2).

The highest decreasing in fluidity is in the M2. The percent of 2.2%-CGNP-to-water decreases the fluidity of M2, the decreasing is greater than over 17.5%. The highest growth in flow is the green binder composite mortar of M3 that is made of 35%-CPFA and 65% pure cement because it contains neither the GNP nor the CGNP. Substitution of CPFA for plain cement increases the fluidity of M3 green grout composite, the increasing is greater than over 12.5% (Table-3 and Figure-8). Therefore, the character of the CPFA is a flow increaser mineralogical artificial pozzolan for blending and substitution of hydraulic green binder in engineering applications. Since the GNP and the CGNP is blended in CPFA-C green mortar composite, the average flow of M4 and M5 green binder mortar composite is, respectively, over 12.7% and 11.3% lower when compared with M3 green binder mortar composite (Table 3 and Figure-2).

However, since the CGNP and the GNP is mixed for pure cement mortar composite, the average flow of M1 and M2 is, respectively, over 13.7 % and 17.8% lower when compared with control mortar composite (Table-3 and Figure-2). Difference between the mortar composite sample of M1, M2 type and the mortar composite of M4, M5 type is that as the M4 and the M5 includes the CPFA particle and the CPFA particle has increaser effect for the flow, the M1 and the M2 shows lower flow than that of the M4 and the M5. There was noted laboratory that as the CPFA spilled on the laboratory bench, the CPFA particle slips, and flow on the bench without binder and water. Similarly, the difference is between the control mortar composite type and the M3 mortar composite type, and there is obvious that the CPFA increases the flow as the M3 shows the greatest flow. Moreover, the stiffness reaction does not start as the mortar composite sample is fresh and not to be molded, this is last effect related to the difference between mortars that containing with and without the CPFA. The results imply that both blending of the GNP and of the CGNP decreases flow ability in mortar composite. However, use of the GNP and of the CGNP demonstrates the decreasing of the plasticity in hydraulic binder-based green engineering materials that would aid to react conventional hydraulic binder, such as cement, and CPFA formation to accelerate the beginning of setting-time.

Additionally, the beginning of setting-time could influence the quasi-static response of mortar mixing regarding on the process in construction as the lateral hydraulic formwork pressure shows the relationship. Evidence of the relationship indirectly was reported: there is no relationship between the laterally compression response based on flow in a mold and the solidity of forming associated with spread and dimension of the clumps[17,18]. However, the proper proportioning of class C pulverized fuel ash and a small addition of the GNP and the CGNP for CPFA-C green binder mortar composite and pure cement mortar composite can significantly reduce lateral hydraulic formwork pressure because the GNP and the CGNP does not allow to flocculate the CPFA particle and cement particle in the mortar composites material.

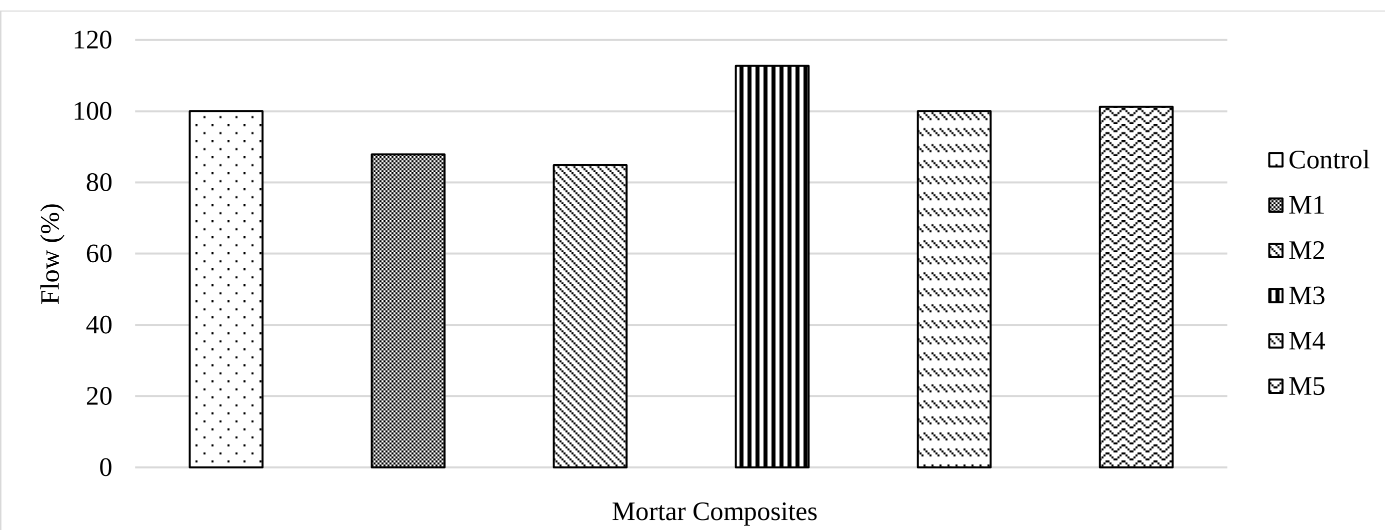

Figure-2: The flow effected with blending the GNP and adding the CGNP, control mortar composite, and green binder mortar composite used.

The result expresses how the CGNP reduces the feature of viscous whereas the CPFA grows this feature. The CPFA displays the lesser fraction of packing trend along with the lesser changing in the fraction of packing trend whereas nano particle of graphite and colloid nano particle of graphite show a contrary trend to them. Therefore, one can note from the result that the CGNP is an effective in decreasing the lateral hydraulic formwork pressure. New information from the test exhibits a direct connection between physical property and clump tending of particle for constructing long-life structural materials and for renewal of infrastructure built previously. Cement–based composite material industry can make further progress by adding the CGNP in engineering applications to decrease the clump tending of particle, forming an excellent composite material through advancing its properties.

Apparent density: Figure-3 presents the effect of the GNP and of the CGNP addition on the apparent density for the hardened state of green binder and of conventional mortar composite. The apparent density obtained from the hardened blended mortar composite (M1 and M2) is 1.97 (g.cm-3) that is over 5% greater than that of control mortar composite (Table-3 and Figure-3). The apparent density increasing of M1 and M2 sample depends on the chemical reaction, that was proved by author's studies[3,19], between the portlandite (Ca(OH)2) and GNP and/or CGNP. As the GNP and the CGNP is a carbon-based additive, it provides carbon element that is combined in the atmosphere as carbon di oxide (CO2) for the mortar composite. The carbon di oxide causes the occurring of calcium carbon tri oxide (CaCO3) that is known as limestone in the binder-based construction composite. The occurring of limestone process continues from years to tens of years, and the process creates greater apparent density for mortar composite that is made of Portland cement and lime binder in historical buildings. This study gives the carbon element directly so that the mortar composite does not react with the CO_2 in the atmosphere.

Scientific research related to mortar made with blended cement reports that the wet curing is necessary for properties of the apparent density of green binder mortar composite as well as strength development. The apparent density is influenced by other main mixture elements and preparation factors such as the size of fine sand, amount of fine sand, the liter of water, the bleeding of cement paste between fine sands, and the vibration method of fresh mortar in the mold. The average apparent density obtained from the hardened green binder mortar composite (M3, M4, and M5) is 2.06 (g.cm-3) that is 10% higher than that of control mortar composite (Table 3 and Figure 3). The pulverized fuel ash contains calcium oxide content among 20% and 25%. Since the GNP and the CGNP reacts with the calcium oxide, as explained previous paragraph, the increasing of apparent density of M3 and M4 sample depends on the chemical reaction. In other words, the GNP and the CGNP saturates the rest of calcium oxide that is 30% in the Portland cement and 20% CPFA to dense mortar sample. In the light of result, it is obvious that the GNP and the CGNP has increaser effect of the apparent density for the green CPFA-C mortar composite and the pure cement mortar composite.

Compressive Stress Gain: Figure-4 presents comparing the increasing ratios of compressive stress at 1d, 2d and 3d, and mortar diversity. One of the big advantages of the studying on early compressive stress measurement is that the cement based composite gains stress between twenty-four hours after the cement contacts with water. This means that the stress gain starts at early age, but the mortar composite does not carry the loads that is given by itself.

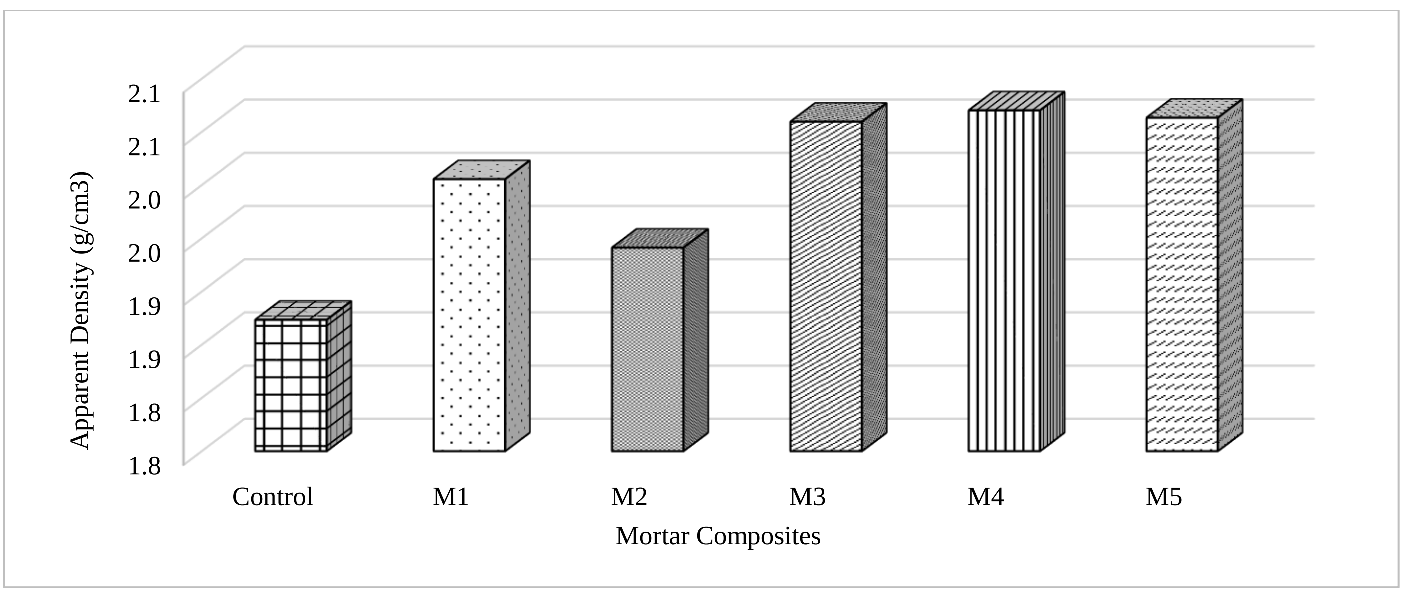

Figure-3: The effect of the GNP and of the CGNP addition on the apparent density for the hardened state of green binder and of conventional cement mortar composite.

Figure-4: Comparing the increasing ratios of compressive stress for green binder mortar composite and for pure cement mortar composite along with and without the GNP and the CGNP.

Second, may be lesser advantage when compared with the first, the early age stress gain monitoring shows the chemical reaction development in the mortar composite. Last advantage is that the continuously stress gain increasing from 1d to 3d indicates that the mortar composite, not surprisingly, will show greater later age compressive stress than that of early age as the early age stress development does not have a fluctuation. With regard to the aforementioned explanation, this study decided the monitoring of compressive stress at early age. The biggest stress gain of compression is observed in the green binder grout composite of M5 consisting of the CGNP, 35% CPFA, and 65% pure cement at both 1d and 3d (Table 3, Figure 4). At first day, compressive stress of M1 and M2 mortar composite is, respectively, over 8% and 35% greater than that of control mortar composite. The M3 and other green binder grout composite shows over 23%, 8%, and 41% bigger the stress gain of compression than that of control mortar composite (Figure-4). This study also reveals that the impact of GNP and of CGNP enables, respectively, over 8% and 35% higher compressive stress for plain cement while the CPFA only provides 23.5% higher the stress gain of compression for conventional cement at 1d. Whereas the coeffect of CPFA with GNP on the stress gain of compressive is 8% increase, the coeffect of CPFA with CGNP on the stress gain of compressive is 40% raising for pure cement mortar composite at 1d (Table-3 and Figure-4). After 2d, compressive stress related to M1 and M2 is, respectively, over 10% and 26% greater than that of control mortar composite. M3, M4, and M5 green binder mortar composite also presents similar strength growth, like M1 and M2 at 2d. Those is respectively over 202%, 73%, and 89% higher the stress of compressive than that of control mortar composite (Figure 4). The work reveals that the effect of GNP and of CGNP is, respectively, over 10.5% and 26% higher compressive stress for the pure cement while the effect of CPFA individually enables two times higher compressive stress for conventional cement at 2d. Whereas the coeffect of CPFA with GNP is 74% increase in the stress gain of compression, the coeffect of CPFA with CGNP is 89% raising in the stress gain of compression for pure cement mortar composite at 2d. After 3d, compressive stress of M1 shows the same strength gain of control mortar composite, and M2 mortar composite is over 3% greater than that of control mortar composite. The M3 and other green binder grout composite 24%, 18%, and 29% bigger the stress gain of compression than that of control mortar composite (Table 3, Figure 4). The work also reveals that the effect of CGNP on the stress gain of compression in the cement grout is 3.5% bigger than that of the effect of CPFA that provides 24.5% bigger the stress gain of compression at 3d. Whereas the coeffect of CPFA with GNP is 18% increase in the stress gain of compression, the combination effect of CPFA and of CGNP is over 29.5% raising for compressive stress gain in pure cement mortar composite at 3d. In the light of the results, both pure cement mortar composite and green binder mortar composite needs the GNP and the CGNP so that the engineering applications could use both of them widely.

Conclusion

Experimental results and calculations support following conclusions that: i. Characteristic result of the GNP and the CGNP provides the defining of certain effect as the stiffness accelerator, the apparent density increaser, the flow reducer as well as compressive stress gainer for green cement based composite at early age. In the light of conclusion, the use of the GNP and the CGNP is necessary for developing the mechano-physical features of green adhesive composite and green binder grout composite. Additionally, those is necessary for pure cement by means of the decreasing of lateral hydraulic formwork pressure and of rapid stiffness, and the increasing of early compressive stress gain. ii. In view of positive characteristic of the GNP and of the CGNP, those could be used such engineering applications as the green construction building, the infrastructure renewal, the construction retrofit, and the construction reinforcement for dramatically extend service life, that has taken advantage of the maintenance cost. iii. As explained in this article, the CGNP is the most logical, productive and sustainable additive to be used in manufacturing of the class C pulverized fuel ash-green cement binder and composite for saving the future of pure cement, making infrastructure safer, extending service life, reducing maintenance cost and natural resource use.

References

1. ASTM C593-19 (2019). Standard Specification for Fly Ash and Other Pozzolans for Use with Lime. ASTM International Publication, USA.

2. ASTM C618–19 (2019). Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. ASTM International Publication, USA.

3. Mehmet S. K. (2015). Advance treatment by nanographite for Portland pulverised fly ash cement (the class f) systems. *Composites Part B: Engineering*, 82(12), 59-71.

4. Tao, M., Yue, Y. & Zhongija, W. (2017). Effect of Nano-$CaCO_3$ Slurry on the Mechanical Properties and Micro-Structure of Concrete with and without Fly Ash. *Composites Part B: Engineering*, 117(5), 124-129.

5. Reza, A. & Hamed, M. (2012). Modeling the Compressive Strength of Cement Mortar Nano-Composites. Computers and Concrete. *An Int'l Journal*, 10(1), 49-57.

6. Nikolas, D.A. & Pantazopoulou, S.J. (2015). Microstructural behavior and mechanics of nano-modified cementitious materials. *Advances in Concrete Construction*, 3(1), 15-37.

7. Ashok, M., Parande, A.K. & Jayabalan, P. (2017). Strength and durability study on cement mortar containing nano materials. *Advances in Nano Research*, 5(2), 99-111.

8. Jayamaha, B. and Dissanayake, M.A.K.L. (2017). Vignarooban K, Vidanapathirana KP, Perera KS. Electrochemical double layer capacitors with PEO and Sri Lankan natural graphite. *Advances in Energy Research*, 5(3), 219-226.

9. Khater, H.M. (2016). Nano-Silica effect on the physicomechanical properties of geopolymer composites. *Advances in Nano Research*, 4(3), 181-195.

10. Khater, H.M. & Abd El Gawwad, H.A. (2015). Effect of firing temperatures on alkali activated Geopolymer mortar doped with MWCNT. *Advances in Nano Research*, 3(4), 225-242.

11. Kobayashi, H., Nakazawa, H., Maeda, T., Yasuda, Y. & Morita, T. (2017). Synthesis of metallic copper nanoparticles and metal-metal bonding process using them. *Advances in Nano Research*, 5(4), 359-372.

12. Mahdikhani, M. & Ramezanianpour, A.A. (2014). Mechanical properties and durability of self consolidating cementitious materials incorporating nano silica and silica fume. *Computers and Concrete, An Int'l Journal*, 14(2), 175-191.

13. Nouri, A.Z. (2018). The effect of Fe_2O_3 nanoparticles instead cement on the stability of fluid-conveying concrete pipes based on exact solution. *Computers and Concrete, An Int'l Journal*, 21(1), 31-37.

14. Ostrowski, K., Sadowski, Ł., Stefaniuk, D., Wałach, D., Gawenda, T., Oleksik, K. & Usydus, I. (2018). The Effect of the Morphology of Coarse Aggregate on the Properties of Self Compacting High-Performance Fibre-Reinforced Concrete. *Materials (Basel)*, 11(1372), 1-16.

15. Seghir, N.T., Mellas, M., Sadowski, Ł., Krolicka, A., Żak, A. & Ostrowski, K. (2019). The Utilization of Waste Marble Dust as a Cement Replacement in Air-Cured Mortar. *Sustainability*, 11(2215), 1-14.

16. Sharon, M., Nandgavkarand, I. & Sharon, M. (2017). Platinum nanocomposites and its applications: A review. *Advances in Materials Research*, 6(2), 129-153.

17. Mehmet, S.K. (2016a). Strength gain mechanism for green mortar substituted marble powder and brick powder for Portland cement. *European Journal of Environmental and Civil Engineering*, 20 (Issue Sup1: Supplement: Green Binder Materials for Civil Engineering and Architecture Applications), 38-63.

18. Mehmet, S.K. (2016b). Fresh and hardened properties of green binder concrete containing marble powder and brick powder. *European Journal of Environmental and Civil Engineering*, 20 (Issue Sup1: Supplement: Green Binder Materials for Civil Engineering and Architecture Applications), 64-101.

19. Mehmet, S.K. (2016c). Advancements in Mechanical and Physical Properties for Marble Powder-Cement Composites Strengthened by Nanostructured Graphite Particles. *Mechanics of Materials*, 92(1), 223–234.

20. Kırgız, M. S. (2019). Advancements in Properties of Cements Containing Pulverised Fly Ash and Nanomaterials by Blending and Ultrasonication Method (Review-Part II). *Nano Hybrids & Composites*, 24, 14-20.

21. Mehmet, S.K. (2018). Pulverized Fuel Ash Cement Activated by Nanographite. *ACI Materials*, 115(6), 803–812.

22. Mehmet, S.K. (2018). Green cement composite concept reinforced by graphite nano-engineered particle suspension for infrastructure renewal material. *Composites Part B*, 154(12), 423-429.

23. Kırgız, M. S. (2018). Effect of mineralogical substitution raw material mixing ratio on mechanical properties of concrete. *ZKG International*, 10, 30-41.

24. Kırgız, M.S. (2002). Usage of The Wastes of Marble and Brick Industries in Cement Manufacturing as Mineralogical Additive. Master of Science thesis, University of Gazi, Ankara, Turkey.

25. Kırgız, M.S. (2007). Determination of Physical and Mechanical Properties of Kırşehir Kaman Demirli Area Marbles. PhD thesis, University of Gazi, Ankara, Turkey.