A Study of Mechanical and Microstructures Properties of Autoclaved Aerated Concrete Containing Nano-Graphene

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ABSTRACT

In recent years, the autoclaved aerated concrete (AAC) has been widely used in the building construction industry, especially for construction of infill walls. However, the AAC suffers from several drawbacks such as low compressive and tensile strength, high water absorption as well as insufficient resistance against impacts. To address such issues, this study evaluates the mechanical properties of the AAC blocks in which, the cement has been replaced with nano-graphene. For this purpose, various replacement ratios (0.2, 0.4, and 0.8) were selected and different tests such as compressive and tensile strength (cylindrical specimens with the size of 10×20cm), impact resistance and water absorption (cubic specimens), scanning electron microscope (SEM) and X-ray diffraction (XRD) were carried out. Promisingly, the results indicate that incorporation of the nano-graphene improves the compressive and tensile strength as well as the impact resistance by 45, 81, and 130% compared to the control specimen. Moreover, the water absorption of the specimens was reduced up to 61%. Based on the SEM results, inclusion of the NG in the AAC, makes the grains stick together firmly and also, downsizes the grains by 30%.

KEYWORDS

Autoclaved Aerated Concrete (AAC), Nano-Graphene, Tensile and Compressive Strength, Water Absorption, Impact Resistance, Scanning Electron Microscope (SEM), X-ray diffraction (XRD) .

1. Introduction

To reduce the seismic actions developed in structures, production of lightweight materials such as the AAC has increased [1]. The AAC is a special type of lightweight concrete that is composed of cement, lime, water, fine-grained sand, and aluminum powder. In some cases, pozzolans such as silica fume and fly ash are also incorporated in the AAC [2].

Due to low density (400 to 800 kg/m3), the AAC benefits from better thermal insulation properties compared to the ordinary concrete (OC) [3]. Some of the other notable features of the AAC are as follows [4-7]:

Much lower density compared to the OC (1/3 to 1/6)

Appropriate sound and thermal insulation (volume of voids in an AAC block: 30 to 90%)

Recyclability

Low energy consumption during the production process

2. Methodology

The AAC blocks whose cement was replaced with the nano-graphene at different ratios of 0.2, 0.4, and 0.8 (by cement weight) were taken into account. Accordingly, the compressive and tensile strength, water absorption, impact resistance, and SEM tests were carried out on the specimens. After building the blocks, all specimens were loaded by a jack to conduct the compressive and tensile strength tests. Loading speed and capacity of the jack were set equal to 0.2-0.5 MPa/s and 2000KN, respectively. Cylindrical specimens with diameters and heights of 10 and 20cm, respectively, were used for the tensile and compressive strength tests. To conduct the water absorption and impact resistance tests, cubic specimens with the size of 5cm, were built. the specimens that had been filled with slurry up to 60% of the formworks' height swelled upwards to the full height of the specimens.

The mix design of the produced concrete in each cubic meter is given in Table 1. One of the most important points in producing the AAC blocks in the factories concerns the slight differences in mix design in each mixer.

In other words, to avoid different material contents in the specimens, all concrete mixes were selected from a specific mixer at equal time intervals. Moreover, another notable point in the construction of the AAC blocks is that if the height from which, the mortar is poured into the formwork, is greater than 25cm, after about 60 minutes, a portion of the slurry settles and violates the homogeneity of the concrete mix. In this respect, as the height of the standard specimens is at most 20cm, hence, this problem would not occur. It should be mentioned that hereafter, nano-graphene is shown by the GP symbol, and the number in front of this symbol represents the ratio of the cement replaced by nano-graphene.

Table 1: Mix Design of the AAC Blocks (kg/m3)

	Aluminum Powder	Plaster	Lime	Silica	Water	Cement	Nano Graphene
REF.	0.350	0.260	100	300	250	120	0
GP-0.2	0.350	0.260	100	300	250	119.76	0.24
GP-0.4	0.350	0.260	100	300	250	119.52	0.48
GP-0.8	0.350	0.260	100	300	250	119.04	0.96

3. Results and Discussion

Details of the behavioural parameters presented in Figure 1, such as compressive strength, modulus of elasticity (slope of a linear branch of the curve), energy absorption (area under the load-displacement diagram), and ultimate strain (maximum value on the horizontal axis) have been given in Table 2 for all specimens. As observed, compressive strengths of the control specimen and those containing 0.2, 0.4, and 0.8% GP, are equal to 1.61, 1.75, 2.2, and 2.33MPa, respectively. Hence, maximum compressive strength has been achieved at a replacement ratio of 0.8, which is 45% higher than that of the control specimen.

Based on the results, as GP content increases, the modulus of elasticity is reduced. Accordingly, value of the modulus of elasticity for the control specimen is equal to 19.1MPa/mm, which has decreased by 67, 92, and 97% when the cement has been replaced by 0.2, 0.4, and 0.8% GP, respectively. Thus, the initial (secant) stiffness of the specimens has decreased in return, which could be a reason for the reduction in the volume of the discarded materials as they are hardly crushed while being transported.

One of the other important parameters affecting the ductile behaviour of the blocks is the rate of energy absorption of the blocks, which has increased up to 24, 38, and 41% compared to that of the control specimen. Noteworthy, when the earthquakes struck the low-rise buildings, the infill walls act as the load-carrying elements, and actually, the use of the GP in the AAC blocks could dissipate 41% of the earthquake energy and finally, leads to less damage in the structural and non-structural elements.

Before conducting the compressive strength tests, an LVDT sensor was installed on the apparatus's jaw to record the rate of reduction in length of the specimens during the loading process. At the end of the testing, the rate of reduction in length of the control specimen and those containing 0.2, 0.4, and 0.8% GP, was measured 1.13, 1.35, 1.27, and 1.72%, respectively. Accordingly, the rate of reduction in length has increased concerning more ductile (softer) behaviour of the specimens and a decrease in their modulus of elasticity. This issue could be another factor aiding to better withstand the seismic loads and dissipate their energy.

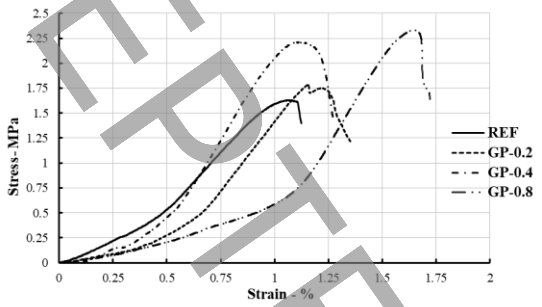

Figure 1: Stress-Strain Curve of the Specimens

Table 2: The values obtained from Stress-Strain Curve

	Modulus of elasticity (MPa/mm)	Energy Dissipation (N/mm)	Length reduction (%)
REF.	19.1	2.11	1.13
GP-0.2	6.37	2.61	1.35
GP-0.4	1.59	2.92	1.27
GP-0.8	0.54	2.98	1.72

4. Conclusions

- Based on the results of the compressive strength tests, replacing cement with nano-graphene at ratios of 0.2, 0.4, and 0.8 increased the strength by 9, 37, and 45%. Additionally, it was observed that the modulus of elasticity was reduced up to 67, 92, and 97%. Conversely, the inclusion of the nano-graphene positively contributed to the energy absorption rate and increased it by 24, 38, and 41%. Besides, after conducting the compressive strength test, the length of the control specimen, GP-0.2, GP-0.4, and GP-0.8 was reduced by 1.13, 1.35, 1.27, and 1.72%.

- Results on the tensile strength test indicated that inclusion of 0.2, 0.4, and 0.8% nano-graphene, increases the strength by 13, 27, and 81%. Furthermore, it was observed that the crack width of the control specimen and GP-0.2, GP-0.4, and GP-0.8 is equal to 1.5, 1.1, 0.85, and 0.5mm, revealing the fact that incorporation of the nano-graphene reduces the crack width to one-third of the control specimen's crack width.

- Fitting of the exponential function curves, resulted in equations Y=0.017X4.33 and Y=0.517X0.41, by which the compressive and tensile strengths could be estimated.

- Based on the results obtained from the water absorption tests conducted for exposure durations of 10, 30, and 90 minutes, maximum absorption occurred at 10 minutes. Moreover, it was observed that the reduction in water absorption rate of the GP-0.2, GP-0.4, and GP-0.8 is equal to 30, 49, and 61%.

- Results of the impact resistance tests on the nano-graphene-incorporated specimens indicated that incorporation of 0.2, 0.4, and 0.8 nano-graphene, boosted the resistance by 42, 95, and 137%. Moreover, these values for the ultimate resistance (ruptured specimen) are equal to 40, 90, and 130%, respectively.

- Results of the SEM and XRD tests revealed that as per the increase in nano-graphenecontent, the volume of the SiO_2 and $Ca_5(OH)_2Si_6O_{16}.4H_2O$ increased in the specimens, and also, the grains became smaller to nearly 30%.

4. References

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