Promoting the physical and the mechanical properties of concrete using nano and waste materials

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Abstract: the industry of producing Portland cement concrete (PCC) depends on Portland cement (PC) as a major element. One of the main usages of the PCC is producing concrete members. The use of waste materials in concrete manufacture could be useful to improve the properties of concrete and reduce production costs by replacing the cementous material with waste materials. Researchers had invested efforts in investigating the effect of using nanomaterials as an add-on to the concrete mixture on the mechanical properties of concrete. As a result, it was concluded that nanomaterials have a considerable impact on promoting the compressive and flexural strength of the PCC. This research illustrates the effect of utilizing nanomaterials, as an add-on to the concrete mixture, combined with using waste materials, as a replacement to PC, to improve the mechanical properties of plain concrete with different types of materials in different dosages. The experimental part has been carried out by using waste materials and nano-based material. The used waste materials were ceramic waste (CW), and marble powder (MP). The nano-based materials that were used were Carbon Nanotubes (CNTs) and Graphene oxide (GO). The results were compared in terms of compressive strength and flexure strength to the control concrete mix. These tests aim to investigate the impact of the modified mixtures on the mechanical properties after elapsing 7 and 28 days to obtain the maximum partial replacement percentage of cement with waste and nano-based materials. It could be concluded that using CW and MP combined with either CNTs or GO could be effectively utilized as a replacement of cement in PCC.

KEYWORDS: Waste Material, Cement, Marble powder, Ceramic Waste, graphene oxide, Carbon Nanotubes.
1. INTRODUCTION

Portland cement concrete (PCC), as a construction material, is widely used to resist loads with sufficient compressive strength. Adding waste and nano-based material could lead to obvious enhancement in mechanical properties. The necessitates achieving obvious enhancement in the mechanical properties cannot always be achieved using conventional mixes. Another challenge is to reduce the amount of the Cementitious material in order to reduce the production cost of PCC without reducing the concrete performance, especially for big projects that require a large amount of PC [1–3].

Efforts have been made to search for admixtures to enhance the performance of the concrete. According to experimental trials, waste materials could be used in the concrete to achieve better performance and better mechanical properties. Using Waste materials in concrete could lead to improve the properties of concrete, and reduce the cost of production as a replacement of PC with waste materials. If locally available waste materials are used, it may be possible to reduce the cost of various construction works. Using waste material as a replacement for cement in concrete has a positive side as it reduces energy consumption; moreover, it has a noticeable positive impact on the environment. Furthermore, it also has an effect on the economic side by decreasing concrete costs as the cost of Cementous material approximately equals more than 45% of PCC cost. [4].

The waste of ceramic is about 15%-30% of the material generated from the total production. Out of total waste, a large amount disposed as waste. Ceramic waste (CW) can be categorized into two types, waste earthenware and fractured during the industrialization process. Ceramic waste can be considered a harmless waste that possesses pozzolanic characteristics. [5,6].

On the other hand, the marble and granite industry are common materials that are widely used in the construction industry. Some studies estimate that approximately 20–25% of the total production of marble and granite are produced in the powder form. Dumping these stones' wastes is a major environmental issue because of its highly alkaline nature, and its manufacturing techniques, which cause a health hazard to the surroundings. [7–9].

Nowadays, the application of nanotechnology has shown a remarkable result in solving numerous engineering-related problems. Nanomaterials could enhance material properties, for example, thermal, electrical, and mechanical. When Compared to the micro/macro-sized particles, the aspect ratio (surface area to volume ratio) of the nanoparticle is higher; thus, Nanomaterials could enhance the cementitious material properties.[10–15]

Graphene is recognized as a material that has an outstanding material property, and it is known to have a high possibility of being used in many industries, for example, electronics, optics, sensors and polymer composites. Graphene is much more robust than steel about 200 times, Graphene Oxide (GO) is derived from graphene. Graphene oxide has a noticeable effect on cement's microstructure and mechanical properties. GO has unique physical properties that could make it an effective material to be used in concrete mixture as a replacement for cement.[16]

CNTs is getting increasing scientific and commercial attention because of its particular chemical, and physical characteristics that qualify it to be an appropriate option for that could be used in many fields, for instance, electronic materials, energy, chemistry, and In Civil Engineering applications due to its unique mechanical properties, low specific weight, and high resistance to corrosion. In addition to their unique strength, which is approximately equal 100 times that of the tensile strength of steel at one-sixth of the weight, CNT has shown an outstanding array of other properties. As a result, CNT is efficiently used in various research works.[17]
Many research efforts have been made recently in order to investigate the effect of implementing nanotechnology in recent researches, and it has been reported that nanomaterials have a notable effect in enhancing the strength and durability of PCC. Furthermore, many researches have been conducted on using waste material to improve the mechanical properties and to reduce the cost of using the Cementous material. This paper investigates the possibility of using both waste material (ceramic waste and marble powder) and nanomaterials (graphene oxide and nanocarbon tubes) as a blend in different dosages in order to be used as a replacement for cement for waste material and as an add-on for nanomaterial.

Accordingly, this proposed work aims to evaluate the impact of utilizing CW and MP in varying percentages as a partial replacement of PC and utilizing Go or NCT as an add-on to the modified concrete mix. The experimental work has been carried out in three phases. In phase 1, CW and MP were used separately with 5%, 10%, 15%, and 20% by weight of cement while in phase 2, the best ratio of CW and MP was used separately in conjunction with a constant ratio equal .05% of nanocarbon tube by weight of cement. In phase 3, the best ratio of CW and MP was used separately in conjunction with a constant ratio equal .05% of Graphene oxide by weight of cement.

2. PROPERTIES OF MATERIALS

The materials which have been used in this study are coarse aggregate, fine aggregate and additives such as superplasticizer, with (Naphthalene Formaldehyde Sulphonate) as a chemical base, Ceramic Waste (CW), Marble Powder (MP), Carbon Nanotubes (CNTs) and Graphene oxide (GO). The properties of these materials were verified and tabulated.

In order to design the concrete mix of PCC, American code for concrete mix, ACI-211-11, was used. The CW and MP were obtained from an industrial sector in Egypt. Specimens of wastes were gathered manually and stored according to the standard specification.

2.1 Cement

The cement used in this research is manufactured by a local cement factory in Egypt and known commercially as “Beni Suef cement.” 52.5 grades (ASTM Type II) of the ordinary Portland cement have been utilized. Table 1 represents the physical properties, and Table 2 represents the chemical composition of the used sample of cement.

| Table 1. Physical Properties of Cement |
|----------------------------------------|
| Property                              | Value   |
| Specific Gravity                      | 3.15    |
| Initial Setting Time (min)            | 45      |
| Final Setting Time (min)              | 600     |
| Autoclave expansion                   | ≤ 0.16 (%) |
| Fineness                              | ≥ 2900 (cm²/g) |

| Table 2. Chemical Compositions of Cement |
|------------------------------------------|
| Material      | Weight (%) |
| SiO₂          | 26.02      |
| Fe₂O₃         | 0.10       |
| CaO           | 67.95      |
| Al₂O₃         | 5.86       |
| MgO           | 0.07       |
2.2 Coarse Aggregate (Crushed Basalt Rock)

In this research, the coarse aggregate used is fractions of maximum size of 10 mm obtained from Suez crushed Dolomit rock, Egypt. The physical properties of coarse aggregate were determined following the test methods specified in ASTM as shown in Table 3.

Table 3. Physical Properties of Coarse Aggregates

| Property               | Value |
|------------------------|-------|
| Specific Gravity       | 2.22  |
| Bulk Density (kg/m$^3$)| 1527  |
| Water absorption (%)   | 0.15  |

2.3 Fine Aggregate

The fine aggregate used in the experimental works is a fine aggregate river sand for Beni Suef, Egypt. The fractions of the fine aggregate are of a max size 2.7. The physical properties of fine aggregate were determined ASTM as shown in Table 4.

Table 4. Physical Properties of Fine Aggregate

| Property               | Value |
|------------------------|-------|
| Specific Gravity       | 2.86  |
| Bulk Density (kg/m$^3$)| 1642  |
| Water absorption (%)   | 2     |

2.4 Waste Materials

2.4.1 Ceramic Waste (CW)

CW used in this experimental study were obtained from The manufacturing waste of the "Ceramica Cleopatra" factory. To get the collected samples ready to be used as a powder, Broken pieces were crushed and then ground with an air jet mill. Finally, the resulted powder was sieved through 200 a 75-lm (200 mesh) sieve. Table 5 shows the chemical compositions of CW.

Table 5. Chemical Compositions of CW

| Material   | Weight (%) |
|------------|------------|
| SiO$_2$    | 65.36      |
| Fe$_2$O$_3$| 4.52       |
| K$_2$O     | 1.72       |
| Na$_2$O    | 1.99       |
| CaO        | 1.56       |
| Al$_2$O$_3$| 18.42      |
| TiO$_2$    | 0.74       |
| MnO        | 0.07       |
| P$_2$O$_5$ | 0.03       |
| SO$_3$     | 0.06       |
| MgO        | 0.77       |
| LOI        | 1.23       |
2.4.2 Marble Powder (MP)

Table 6. Chemical Compositions of MP

| Material   | Weight (%) |
|------------|------------|
| SiO₂       | 1.12       |
| Al₂O₃      | 0.73       |
| Fe₂O₃      | 0.05       |
| CaO        | 83.22      |
| MgO        | 0.52       |
| SO₃        | 0.56       |
| K₂O        | 0.09       |
| Na₂O       | 1.12       |
| Free CaO   | 0.15       |
| L.O.I      | 2.5        |
| Ins.R      | 0.89       |

2.4.3 Carbon Nanotubes (CNTs)

The CNTs have been synthesized by using chemical vapor deposition (CVD) method which is developed at HBRC, Egypt. The CNTs had inner diameters of 9 nm and functionalized with COOH functional groups via strong acid treatment. More details regarding synthesis process can be found in our previous work [18,19].

2.4.4 Graphene oxide (GO)

Graphene oxide has been synthesized from graphite flakes by modified Hummer method. All details related to the synthesizing process were reported in our previous work [18,20][21].

3. EXPERIMENTAL INVESTIGATION

The objective of this research is to achieve the maximum percentage of the partial replacement of cement using different dosages of CW, MP, combined with a constant ratio of CNTs and GO as an add-on to the modified mix. Furthermore, we investigate the impact of modified mixtures on the mechanical properties after 7 days and 28 days.

Subsequently, concrete mixes using various mix proportions for ceramic powder and marble powder were implemented. Then, CW and MP were used separately in conjunction with a constant ratio equal .05% of either CNTs or GO. Different PCC concrete mixes were optimized using waste materials and nono materials in three phases and were used in this research.

3.1 Mix Types and Proportion

The experimental work, using CW, MB, CNTs, and GO conducted in three phases as follows:

- **Phase 1**,
  - A- CW was used with 5 wt %, 10 wt%, 15 wt% and 20wt% of cement as a replacement of PC
  - B- MP was used with 5wt %, 10 wt %, 15 wt % and 20 wt % of cement as a replacement of PC

- **Phase 2**,
A- CW with 20 wt %, of cement as a replacement of PC, was used in conjunction with a constant ratio equal .05 wt % CNTs of cement as an additive.

B- MP with 20 wt %, of cement as a replacement of PC, was used in conjunction with a constant ratio equal .05 wt % CNTs of cement as an additive.

- Phase 3,
  A- CW with 20 wt %, of cement as a replacement of PC, was used in conjunction with a constant ratio equal .05 wt % GO of cement as an additive.
  B- MP with 20 wt %, of cement as a replacement of PC, was used in conjunction with a constant ratio equal .05 wt % GO of cement as an additive.

In addition to the mentioned three phases, a control mix was molded with zero percentage of CW, MB, CNTs, and GO. It is noteworthy that phase 3 was designed based on the results of phases 1 and 2, as described later in this research. Table 7 summarizes the different phases mix.

### Table 7. Mix Types and Proportion

| Phase | Mix Type | Cement, % | CW, % | MP, % | CNTs, % | GO, % |
|-------|----------|-----------|-------|-------|---------|-------|
|       | Control Mix | 100 | 0 | 0 | 0 | 0 |
| Phase (1) | 1-A-1 | 95 | 5 | | | |
|         | 1-A-2 | 90 | 10 | | | |
|         | 1-A-3 | 85 | 15 | | | |
|         | 1-A-4 | 80 | 20 | | | |
|         | 1-B-1 | 95 | | 5 | | |
|         | 1-B-2 | 90 | | 10 | | |
|         | 1-B-3 | 85 | | 15 | | |
|         | 1-B-4 | 80 | | 20 | | |
| Control Mix | 100 | 0 | 0 | 0 | 0 |
| Phase (2) | 2-A-4 | 80.00 | 20 | | 0.05 | 0 |
|           | 2-B-4 | 80.00 | 0 | | 20 | |
| Control Mix | 100 | 0 | 0 | 0 | 0 |
| Phase (3) | 3-A-4 | 80.00 | 20 | | | 0.05 |
|           | 3-B-4 | 80.00 | 0 | | 20 | |

3.2 Mixture Design

ACI-211-11 was used as a reference to design the mixture. The values of the binder content and water to cement ratio (W/C ratio) were chosen to be constant and equal 350 kg/m$^3$ and 0.5, respectively.

Standard slump cone was used to measure the fresh concrete workability according to the slump test methodology as per ASTM C 143. In the beginning, the coarse and the fine aggregate were mixed, then cement, waste material, nanomaterial, superplasticizer, and water were added.

In order to confirm that the nanomaterials (CNTs and GO) have been entirely dissolved in the water, nanomaterials were dispersed in water for 10 min using ultrasonic process model VCX 500.
3.3 Compressive and Flexure and Strength

Steel cubic molds with dimensions (10X10X10cm) were used for casting the test samples that were used for compressive strength test. Wooden forms with dimensions (10X10X50cm) were used as molds for casting the test sample to be used for investigating the flexure strength. The specimens were well compacted using a vibrating table. The specimens were left in the mold for 24 h then they were removed from the molds. A water tank at a temperature of 21° C was used for the curing process of the specimens. The specimens were left in the tank until the testing time. Casting, compaction, and curing were performed as per ASTM C 192.

The compressive strength was obtained at 7 and 28 days and the flexure strength at 28 days. For all mixes, the compressive strength was specified by obtaining the average of three cubes.

3.4 Instrumental Analyses

- The surface morphology of casted concrete samples was investigated by the scanning electron microscope (SEM). The SEM microphotographs were obtained with Inspect S (FEI Company, Holland) equipped with an energy dispersive X-ray analyzer (EDXA).
- The microstructure of the utilized nano materials (CNTs and GO) was examined by HRTEM model FEI Philips Tecnai G2 S-Twin operated at 200 keV.
- The Raman spectroscopy as a powerful diagnostic technique for the identification of various types of carbon nano based materials was utilized. The spectra is collected by (SENTERRA–Bruker, Germany) instrument with laser source (Nd:YAG) at wavelength of 532 nm.

4. RESULTS AND DISCUSSIONS

4.1. Structural analysis

The HRTEM photo of CNTs represented in fig. 1a exhibited a tubular structure with internal hollow cavity. The photo confirmed that the CNTs are of multi walled carbon nanotubes (MWCNTs). Fig. 1b depict he microstructure of GO as examined by HRTEM. The examined GO has thin wrinkled and corrugated morphology. This morphology is due to the oxidation process and transformation of planar sp² carbon sheets to sp³-hybridized carbon sheet.

![HRTEM photos](image)

Fig. 1: HRTEM of a) graphene oxide, and b) CNTs
4.2. Phase 1

Group 1A

The curves of compressive strength of 1A group at 7 and 28 days are shown in figure 2, while the reduction and increment in compressive strength as compared to control mix is represented in fig. 3. It can be seen that from fig. 3 at the age of 7 days, the compressive strength of the group 1A (containing CW) increases up to 10% replacement of CW, then at 15% CW the compressive strength decreases, with further increases in the amount of CW up to 20% the strength regained approximately the same value as 10% CW replacement. While after 28 days of hydration, the compressive strength was increased with increasing the amount of CW until 10% replacement. With further increasing in the amount of CW the compressive strength starts to deteriorate. When compared to control mix an enhancement up to 3% in compressive strength has been recognized for 10% CW replacement after 28 days of hydration as represented in fig. 3.

The increment in compressive strength up to 10% CW replacement could be explained based on the good pozzolanic nature of CW as it contains a high amount of silica. When OPC is mixed with water it forms C-S-H gels and liberates Ca(OH)\textsubscript{2}. The liberated Ca(OH)\textsubscript{2} reacts with SiO\textsubscript{2} constituent of CW to form secondary C-S-H gels. This in turn will result in consuming harmful Ca(OH)\textsubscript{2} thereby reducing the porosity and hence increasing the compressive strength [22]. The decrement in compressive strength for 1-A-3 and 1-A-4 could be attributed to the presence of high amount of silica that can not find a sufficient amount of Ca (OH)\textsubscript{2} to react with, in addition to other agglomeration of the CW resulted from its high replacement ratio in the concrete matrix [23].

The flexural strength as represented in fig. 4 increases up to 10% CW replacement or cement, with further increases in the amount of CW, the flexural strength decreases. This behaviour is in a good agreement with compressive strength data.
Figure 4: Flexure Strength for Different Mixes of Phase 1-A

Fig. 5: SEM image of control mix
The SEM image of control mix represented in fig. 5, show to some extent the presence of micropores, cracks, separation between the aggregate and the other concrete components. All of these features led to lack of homogeneity and compaction of the structure. The deterioration in the mechanical strength, at 20% CW can also confirmed using SEM as represented in fig. 5. The SEM image exhibited a loose structure with agglomerated CW particles which have irregular and angular morphology that analogous to the morphology of cement grain. It was also observed that the size of voids have been increased in addition to the separation between matrix and CW became more prominent.

**Group 1B**

The compressive strength curves of the group 1B that contains MP after 7 and 28 days of hydration is depicted in fig. 6. It was observed that after 7 days of hydration the compressive strength starts to decreases with 5% MP replacement, then at 10% MP the compressive strength has the same value of control mix. With further replacement in MP, the compressive strength deteriorated again. Generally speaking based on the obtained results, at the early stages of hydration (after 7 days) the compressive strength decreases. Also the compressive strength of all specimens of group 1B decreases as the MP replacement level increased. The major component of MP is calcium oxide as indicated in table 6. The CaO reacts with mixing water and forms Ca(OH)$_2$. The formed Ca(OH)$_2$ results in lowering the early strength of concrete [24].

The strength of the MP sample after 28 days of hydration increases with increase the amount of the MP up to 10% MP replacement, then decreases. The maximum increment of compressive strength of 6% as compared to the control mix has been achieved at 10% MP as replacement of cement as depicted in fig 7. However the main component of MP is CaO, but it also contains a remarkable amount of SiO$_2$. As explained earlier the CaO reacts with mixing water to form Ca(OH)$_2$, which in turn reacts with SiO$_2$ to produce more CSH gel in the structure thereby enhancing the compressive strength. At high level of MP more than 10%, the generated Ca(OH)$_2$ cannot find sufficient SiO$_2$ to react with. As well known the excess amount of MP deteriorate the compressive strength of the concrete. Flexural Strength for different Mixes of Phase 1-B is expressed in fig. 8. As shown in fig. The Flexural Strength results have the same trend as that of the compressive strength after 28 days of hydration. The maximum gain in flexural strength was obtained at 10% MP replacement.

![Figure 6: Compressive Strength for Different Mixes of Phase 1-B](image-url)
The SEM micrograph of 1-B-4 sample is depicted in fig. 9. The SEM image exhibited a lack of hydration products especially CSH gel responsible for the consistency and the mechanical performance of the structure. This in turn led to a deterioration in the packing and homogeneity of the structure, thereby deteriorate the mechanical performance. It is apparent that the MP particles is not tightly bound to the concrete matrix, and located individually.

4.3. Phase 2

This phase of the proposed work comprises study the effect of CNTs on mechanical properties and microstructure of samples 1A-4 and 1B-4. As confirmed earlier, the addition of 20% CW and 20% MP to the concrete as replacement of cement led to deterioration in mechanical properties. So the main objective of this phase is to promote the mechanical properties using CNTs. A fixed ratio of CNTs (0.05%) was incorporated in concrete matrix.
This proportion ratio was determined based on previous studies [25]. The compressive strength values of 1A-4 and 1B-4 at early and later stages of hydration are shown in fig. 10, while fig. 11 represents Reduction/increment in Compressive strength. It was observed that at early stage of hydration the compressive strength as compared to control mix was decreased to 4.1 MPa and 2.2 MPa for 2A-4 and 2B-4 samples respectively, this may be explained as; at the early stage of curing, the hydration reaction was incomplete and still in its early stages, so the hydration products weren’t strongly formed, especially C–S–H, which is responsible for the strength gain, especially the CNT has no chemical contribution in enhancing the concrete strength [26].

With further increment in a hydration time the compressive strength has been increased, this could be due to the hydration reaction was in its final stages and almost completed, which led to dense and strong hydration products in addition to the CNTs inhibiting the propagation of micro and nano cracks [27].

The flexural strength results are graphically presented in fig.12 The flexural strength results showed the same trend as that of the compressive strength at both early and later stages of hydration.
The SEM micrographs of 2-A-4 sample (Fig. 55a) and 2-B-4 sample (Fig. 13) are depicted in fig. 9. The microstructure of 2-A-4 and 2-B-4 contain CSH, CNTs, some CW and MP particles respectively. It was observed that the CSH gel for both samples become predominant, which led to a compact and homogenous structures with less apparent pores [28]. Also, the incorporation of CNTs bridged the micro cracks. The previous reported reasons led to a conspicuous improvement in the mechanical properties.

Figure 12: Flexure Strength for Different Mixes of Phase 2

The SEM micrographs of 2-A-4 sample (Fig. 55a) and 2-B-4 sample (Fig. 13) are depicted in fig. 9. The microstructure of 2-A-4 and 2-B-4 contain CSH, CNTs, some CW and MP particles respectively. It was observed that the CSH gel for both samples become predominant, which led to a compact and homogenous structures with less apparent pores [28]. Also, the incorporation of CNTs bridged the micro cracks. The previous reported reasons led to a conspicuous improvement in the mechanical properties.
4.4. Phase 3

The third phase of this work is concentrated on evaluating the effect of GO on the mechanical performance and microstructure characteristics of concrete samples 3A-4 and 3B-4. The compressive strength data are presented in fig. 14, while the reduction/enhancement ratios compared to the control mix are shown in fig. 15.

From the presented figures, it is obvious that the mechanical performance of concrete reinforced with 0.05 wt% of GO has the same trend as its counterpart concrete reinforced with CNTs, where after 7 days of curing, the replacement of cement by 20 wt.% of CW and MP respectively, caused a reduction in the compressive strength by 3.1 and 1.4% for CW and MP concrete samples respectively, although the presence of GO.

Whereas after 28 days of curing, the compressive strength of CW and MP concrete samples in presence of GO increased by 11.7 and 14.6% respectively, compared to the control mix. Which can be attributed to the lack of hydration products especially C–S–H phase that is responsible for the strength of concrete due to the incomplete hydration reaction after 7 days of curing.

While after 28 days, the hydration products were strongly formed due to the closer from the completion of the hydration reaction in addition to the presence of GO which has two functions in improving the compressive strength; one through chemical interactions between oxygenated functional groups and hydration products that led to promoting the hydration process and formation of strong interfacial forces, second is the high aspect ratio, 2D sheet-like structure of GO and its wrinkled morphology that led to significant improvement in mechanical interlocking.

The flexural strength results are graphically presented in fig.16, while the reduction/enhancement ratios compared to the control mix are shown in fig. 17. The flexural strength results exhibited the same behavior as that of the compressive strength at both 7 and 28 days of curing.

![Figure 14: Compressive Strength for Different Mixes of Phase 3](image.png)
Fig. 15: Reduction/increment due to using Graphene Oxide (GO) as additive to (20% marble OR 20% ceramic (cement replacement))

Figure 16: Flexure Strength for Different Mixes of Phase 3
The SEM micrographs of fig. 18a and 18b represent the 3-A-4 and 3-B-4 samples respectively. It is clear that the presented images contain the ordinary hydration phases in addition to GO sheets and some CW and MP particles. It was observed that the CSH gel for both samples becomes the most widespread phase in the matrix, which in turn resulted in a more dense and consistent structures with less microcracks. Also the incorporation of GO acts as a nucleation centers for the growth of hydration products in addition to the interlocking behavior that prevent the propagation of cracks. It also apparent that, there is no separation between the aggregates and other concrete components. This in turn confirms the developments obtained in the mechanical properties.

Fig. 17: Reduction/increment in Flexure strength due to using CNTs OR GO as an additive to (20% marble OR 20% ceramic (cement replacement))

The SEM micrographs of fig. 18a and 18b represent the 3-A-4 and 3-B-4 samples respectively. It is clear that the presented images contain the ordinary hydration phases in addition to GO sheets and some CW and MP particles. It was observed that the CSH gel for both samples becomes the most widespread phase in the matrix, which in turn resulted in a more dense and consistent structures with less microcracks. Also the incorporation of GO acts as a nucleation centers for the growth of hydration products in addition to the interlocking behavior that prevent the propagation of cracks. It also apparent that, there is no separation between the aggregates and other concrete components. This in turn confirms the developments obtained in the mechanical properties.

Fig. 18: SEM image of a) 3A-4 sample and b) 3B-4 sample
5. CONCLUSION:

1- MWCNTs and GO have been utilized to improve the mechanical properties of concrete containing CW and MP.
2- An enhancement up to 3% in compressive strength has been recognized for 10% CW replacement of cement content after 28 days of hydration.
3- The deterioration in the mechanical strength, at 20% CW is confirmed using SEM. The SEM image exhibited a loose structure with agglomerated CW particles which have irregular and angular morphology that analogous to the morphology of cement grain.
4- The strength of the MP sample after 28 days of hydration increases with increase the amount of the MP up to 10% MP replacement, then decreases.
5- The compressive strength values of 1A-4 and 1B-4 at early stages of hydration was decreased. With further increment in a hydration time the compressive strength has been increased, this could be due to the hydration reaction was in its final stages and almost completed.
6- The effect of GO on the mechanical performance and microstructure characteristics of concrete samples 3A-4 and 3B-4 has been examined. The compressive strength of CW and MP concrete samples in presence of GO increased by 11.7 and 14.6% respectively, compared to the control mix.

REFERENCES

[1] Aly M, Hashmi M S J, Olabi A G, Messeiry M, Abadir E F and Hussain A I 2012 Effect of colloidal nano-silica on the mechanical and physical behaviour of waste-glass cement mortar Materials and Design 33 127–35
[2] Meyer C 2009 The greening of the concrete industry Cement and Concrete Composites 31 601–5
[3] Rashad A M 2013 A preliminary study on the effect of fine aggregate replacement with metakaolin on strength and abrasion resistance of concrete Construction and Building Materials 44 487–95
[4] Umapathy U, Mala C and Siva K 2014 Assessment of Concrete Strength Using Partial Replacement of Coarse Aggregate for Waste Tiles and Cement for Rice Husk Ash in Concrete 4 72–6
[5] Dayalan J and Beulah M 2014 Effect of Waste Materials in Partial Replacement of Cement Fine Aggregate and Course Aggregate in Concrete 33–6
[6] López V, Llamas B, Juan A, Morán J M and Guerra I 2007 Eco-efficient Concretes: Impact of the Use of White Ceramic Powder on the Mechanical Properties of Concrete Biosystems Engineering 96 559–64
[7] Ergün A 2011 Effects of the usage of diatomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete Construction and Building Materials 25 806–12
[8] Kaplan H 2007 Influence of marble and limestone dusts as additives on some mechanical properties of concrete Scientific Research and Essays 2 372–9
[9] El-Haggar S M 2007 Sustainable Industrial Design and Waste Management
[10] Shah S P, Hou P and Konsta-Gdoutos M S 2015 Nano-modification of cementitious material: Toward a stronger and durable concrete Journal of Sustainable Cement-Based Materials 5 1–22
[11] Amanullah M and Al-Tahini A M 2009 Nano-technology- its significance in smart fluid development for oil and gas field application Society of Petroleum Engineers - SPE Saudi Arabia Section Technical Symposium 2009
[12] Patil R and Deshpande A 2012 Use of nanomaterials in cementing applications Society of Petroleum Engineers - SPE International Oilfield Nanotechnology Conference 2012
[13] Ershadi V, Ebadi T, Rabani A ., Ershadi L and Soltanian H 2011 The Effect of
Nanosilica on Cement Matrix Permeability in Oil Well to Decrease the Pollution of Receptive Environment International Journal of Environmental Science and Development

[14] Li H, Xiao H G, Yuan J and Ou J 2004 Microstructure of cement mortar with nanoparticles Composites Part B: Engineering

[15] Zhang R, Cheng X, Hou P and Ye Z 2015 Influences of nano-TiO2 on the properties of cement-based materials: Hydration and drying shrinkage Construction and Building Materials

[16] Wang Q, Wang J, Lu C X, Liu B W, Zhang K and Li C Z 2015 Influence of graphene oxide additions on the microstructure and mechanical strength of cement Xinxing Tan Cailiao/New Carbon Materials

[17] Siddique R and Mehta A 2014 Effect of carbon nanotubes on properties of cement mortars Construction and Building Materials 50 116–29

[18] Morsy M, Yahia I S, Zahran H Y, Meng F and Ibrahim M 2019 Portable and Battery Operated Ammonia Gas Sensor Based on CNTs / rGO / ZnO Nanocomposite Construction and Building Materials 48 7328–35

[19] Morsy M, Helal M, El-Okr M and Ibrahim M 2015 Preparation and characterization of multiwall carbon nanotubes decorated with zinc oxide Der Pharma Chemica 7 139–44

[20] Salama T M, Morsy M, Shahba R M A and Mohamed S H 2019 Synthesis of Graphene Oxide Interspersed in Hexagonal WO 3 Nanorods for High-Efficiency Visible-Light Driven Photocatalysis and NH 3 Gas Sensing Construction and Building Materials 7 1–14

[21] Ibrahim M 2018 Low Cost Alcoholic Breath Sensor Based on SnO 2 Modified with CNTs and Der Pharma Chemica 73 1437–43

[22] Mohammadhosseini H, Lim N H A S, Tahir M M, Alyousef R, Samadi M, Alabduljabbar H and Mohamed A M 2020 Effects of Waste Ceramic as Cement and Fine Aggregate on Durability Performance of Sustainable Mortar Arabian Journal for Science and Engineering 45 3623–34

[23] S. El-Dieb A, R. Taha M and I. Abu-Eishah S 2019 The Use of Ceramic Waste Powder (CWP) in Making Eco-Friendly Concretes Ceramic Materials - Synthesis, Characterization, Applications and Recycling

[24] Ban C C, Sern L J and Jasme N 2019 The mechanical strength and drying shrinkage behavior of high performance concrete with blended mineral admixture Journal Teknologi 81 59–67

[25] Gao Y, Jing H, Zhou Z, Shi X, Li L and Fu G 2021 Roles of carbon nanotubes in reinforcing the interfacial transition zone and impermeability of concrete under different water-to-cement ratios Construction and Building Materials 272 121664

[26] El-Feky M S, El-Khodary S A and Morsy M 2019 Optimization of hybrid cement composite with carbon nanotubes and nano silica using response surface design Egyptian Journal of Chemistry 62

[27] Morsy M, Shoukry H, Mokhtar M M, Taha N A and Morsy M S 2020 Systematic investigation into mechanical strength, pore structure and microstructure of high performance concrete incorporating nano-hybrids IOP Conference Series: Materials Science and Engineering 956

[28] Morsy M S, Rashad A M, Shoukry H, Mokhtar M M and El-Khodary S A 2020 Development of lime-pozzolan green binder: The influence of anhydrous gypsum and high ambient temperature curing Journal of Building Engineering 28 101026