International Journal of Engineering and Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 12 Issue 5 May 2023 || PP 53-66

Effect of Marble and Glass Industrial Wastes on the Properties of High Strength Concrete Containing nano-Silica

Khaled M. Osman[1], Magdy. A. ALyamanya[2], Saleh Abd El-Aleem[3]and Amany SH. Ragab[4]
[1]*Associate Professor, Fayoum University, Faculty of Engineering, Civil Department, Egypt*
[2]*Professor of Properties and strength of Materials, Faculty of Engineering, Fayoum University, Egypt*
[3] *Professor of Applied Inorganic Chemistry, Faculty of Science, Fayoum University, Egypt*
[4]*MSc Student, Faculty of Engineering, Fayoum University, Egypt*
Corresponding Author: Khaled M. Osman

ABSTRACT: *The purpose of this study is evaluating the effect of cement replacement with four industrial wastes; marble waste powder (MWP), granite waste powder (G_rWP), basalt waste powder (BWP) and glass waste powder (GWP) with three different percentages (10, 15 and 20 Wt.%). Use of the best ratio of industrial wastes with a fixed ratio of nano-Silica (nS) to study its combined effect on concrete properties.* ***All the specimens of the experimental work (25 mixes) were casted and strengthened at Concrete Research and Material Properties Laboratory, "Faculty of Engineering, Fayoum University"****. Compressive and tensile strength were determined at ages of 7 and 28-days. The results indicated that, optimum percentage of cement replacement in compressive and tensile strength with all wastes was 15%. The compressive strength value at 28-days increased by 8.6% of control value with 15% MWP cement replacement. While the compressive strength is decreased by 10.3%, 16.6% and 5.96 % of reference value due to 15% G_rWP, BWP and GWP cement replacement, respectively. Adding 2% nS with 15% industrial wastes enhance HSC strength. the compressive strength increased by 2.9%, 2.2%, 9.6% and 17.7% of same mixes without nS for MWP, G_rWP, BWP and GWP cement replacement, respectively. The SEM and XRD results indicated that, regardless of waste powder type concrete cubes microstructure becomes denser and more homogeneous and compacted with nS addition. EDS analysis shows Regardless of waste powder type, nS-particles are homogenously distributed in concrete mixtures. SEM/EDS and EDS mapping observations are in a good accordance with compressive strength and XRD-results.*

KEYWORDS *-Marble waste powder, Granite waste powder, Basalt waste powder, nano-Silica, Compressive strength, Tensile strength, SEM analysis, XRD analysis, EDS analysis.*

Date of Submission: 10-05-2023 Date of Acceptance: 21-05-2023

I. INTRODUCTION

Concrete is the most widely and extensively used material in the world. The concrete industry generates severe environmental problems [1]. Cement manufacture is an energy-intensive and highly polluting process that gives about 5-8% to overall carbon dioxide (CO_2) emissions [2]. Concrete is one of the most important construction materials and it is widely used in many civil engineering applications. Concrete, thereby cement production consumes much energy and large amounts of natural resources [3].

Marble is the metamorphic form of limestone ($CaCO_3$) and WMP was chosen as cement substituent on account of its high calcium oxide content. MWP is byproduct of marble industry and is an environmental burden. Cement manufacturing of cement is also environmentally hazardous, owing to emission of greenhouse gases. Thus, the recycling of WMP in place of cement in concrete offers two ecological advantages. Otherwise, WMP has a specific gravity of 2.6 against that of 3.15 for cement, which reduces the weight of the finished products [4]. Seghir et al 2020 [5], present an experimental study on the assessment of the cement-based materials properties made with marble powder at different replacement ratios (0, 5, 10 and 15 Wt., %) of cement, and reached to the possibility of using WMP as a cement substitution up to 10% when the samples are cured in water.

Waste granite powder (WG_rP), is a by- product of granite processing industry, its specific gravity is 2.5 lower than that of the cement 3.2, the average diameter of cement is lower than that of granite powder and this can be considered as one of the reasons to decrease the mechanical characteristics of concrete [6].

Sengottaiyan et al. 2018 [7], replace cement by granite powder and fine aggregate by quarry dust in proportions varying from 5 to 20 Wt.,% of cement in concrete and reached to compressive strength increase with replacement of granite wastes, at 10% and is comparable to the normal concrete (47.06 N/mm^2).

The impact of BWP on the initial consistency and workability loss was studied. The effect of BWP on the shrinkage and compressive strength was also investigated. The results obtained show that the basaltic powder has a positive impact on the consistency of fresh cement composites and strength properties of the hardened composites [8]. Basalt powder has retardation effect on the hydration process of cement paste. The initial and final setting time were prolonged with BWP content. The replacement of cement by BWP leads to dilution effect on cement in blended pastes and the reduction of tricalcium silicate C_3S, which gives the hardening at early age of cement paste [9].

Today glass is used in many forms and it has a short life due to brittleness and ease of breakage. After breakage it either store until re-use or send to landfills, since the glass material is un-degradable so its stockpiling in landfills considered an unfriendly solution for the environments, thus there is great need to take advantage of GWP such as using in mortar and concrete as additive [10]. K.I.M. Ibrahim et al [11], Studied the variation of the GWP replacement ratios from cement (0, 5, 10, 15, and 20 Wt., %), and reached to that, cement can be substituted by GWP at a 5 Wt., % ratio without reducing compressive and tensile strength. But from 10 until 20 Wt., % GWP ratios, the compressive and tensile strength were reduced.

Addition of nS particles has important implications for the hydration kinetics and the microstructure of the paste such as (a) an increase in the initial hydration rate, (b) an increase of the amount of C-S-H gel of the paste through pozzolanic reaction, (c) reduction of porosity, (d) improvement in the mechanical properties of C-S-H gel itself [12]. The addition of SF and nS produces a greater demand for flow ability or workability due to their larger specific surface area. A polycarboxylate ether based superplasticiser was thus used to decrease the water demand while improving the workability of all the concrete mixes. The superplasticiser dosage was adjusted for each mix to ensure that no segregation would occur, the average compressive strength of cubes of HSC mixtures after 3, 7, 28 and 56 days, which shows that, the compressive strength developed in the concretes, containing nanoparticles was higher than that of the control specimens in all cases [13]. It was found that, [14] nano Silica (nS) and silica fume (SF) modified cement mortar protected the concrete surface while enhancing impermeability. The addition of NS to the cement materials can accelerate the early hydration of concrete, which is very useful for increasing the early strength of concrete.

High Strength Concrete (HSC) is a special type of concrete that has a specified compressive strength of 60 N/mm^2 or greater. HSC is a most economic concrete, realized when it is used in the columns of high-rise building, parking garages, bridge decks, and other installations requiring improved compressive strength and density [15]. Since the definition of HSC has changed over the years; the Committee defined a range of concrete strengths for its activities, as explained in ACI 363R-10. For the purpose of this guide, high-strength concrete is defined as having a specified compressive strength of 55 MPa (8000 psi), or greater, and it does not include concrete made with exotic materials or techniques. The word “exotic” indicates special concretes, such as polymer-impregnated concrete, epoxy concrete, or concrete made with artificial normal-weight and heavy-weight aggregates [16].

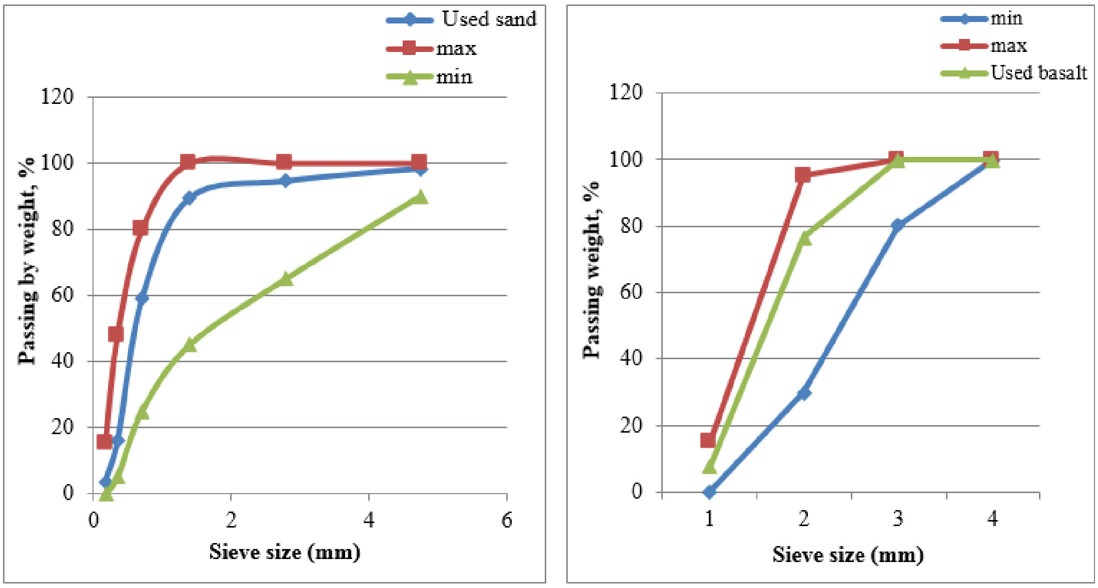
II. MATERIALS AND EXPERIMENTS

2.1 Cement

The cement used in this study was ordinary Portland cement (OPC) provided from Wadi El-Nile Cement Company, Beni-Swif, Egypt. The properties of the used OPC are as the following; Specific gravity, surface area, initial setting time, final setting time, compression strength after 7 days, and compression strength after 28 days, respectively, equal to 3.15, 2920 cm^2 /gm, 90 min, 145 min, 27.4 MPa, and 36.9 MPa.

2.2 Aggregate

Coarse aggregates used in this study were crushed basalt size number 2 from Elmina quarries and fine aggregate was natural sand from El Fayoum quarries. The physical properties of basalt and sand are as the following; specific gravity is 2.73 and 2.50, unit weight is 1.58 and 1.77 t/m^3, fineness modulus of sand is (2.24). Sieve analyses have been conducted on aggregate and meet the grading requirements of concrete aggregates as shown in Fig.1.



a) Fine aggregate b) coarse aggregate

Fig. 1: Sieve analysis of sand and basalt

2.3 Water

Clean and free of impurities tap water is used in casting and curing.

2.4 Admixtures

2.4.1 Sikament-163M

It can be used with all types of cement to reduce the water content and increase early strength. The normal dosage to be used ranges between 0.6 to 2.5 Wt., % of cement.

2.4.2 Viscocrete - 3425

It can be used with all types of cement to reduce the water content and increase early strength. The normal dosage to be used ranges between 0.2 to 0.8 % of cement.

2.4.3 Silica Fume

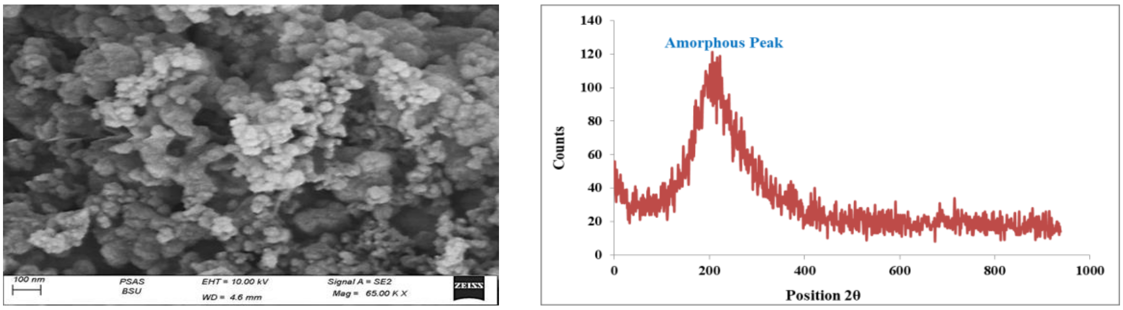
The normal dosage to be used ranges between 2 to 10 Wt., % of cement.

2.4.4 Nano-silica

Nano-silica specimen was tested by SEM at Beni Suef University, the sample contains not only crystalline SiO_2, but also alittle amorphous SiO_2 as shown Fig. 2.

2.5 Industrial wastes

Marble, granite, basalt and glass wastes are obtained from Egypt stones. It´s manual grinding up the grain size is passing on 90 µm sieve as shown in Fig. 3. Chemical composition of industrial wastes resulted of XRF test is represented in Table 1. The mineralogical composition, crystal structure and microstructure of industrial wastes were investigated by XRD, and SEM as illustrated in Figs. 4 and 5.

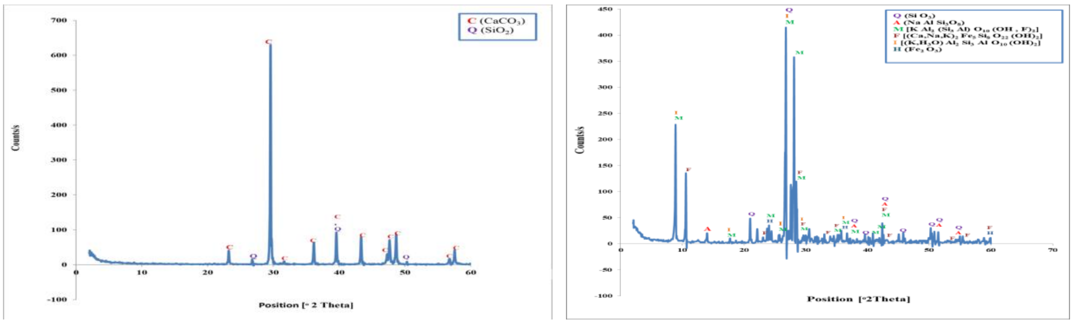


a) SEM-photo of nS b) XRD-pattern of Ns

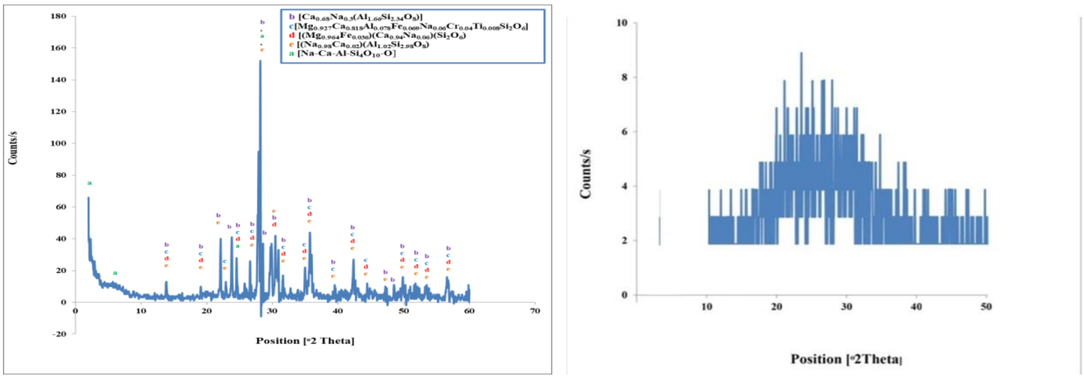
Fig. 2: SEM and XRD of Ns

a)MWP b)G_rWP c)BWP d)GWP

Fig. 3: Industrial wastes (passing through 90 µm sieve)

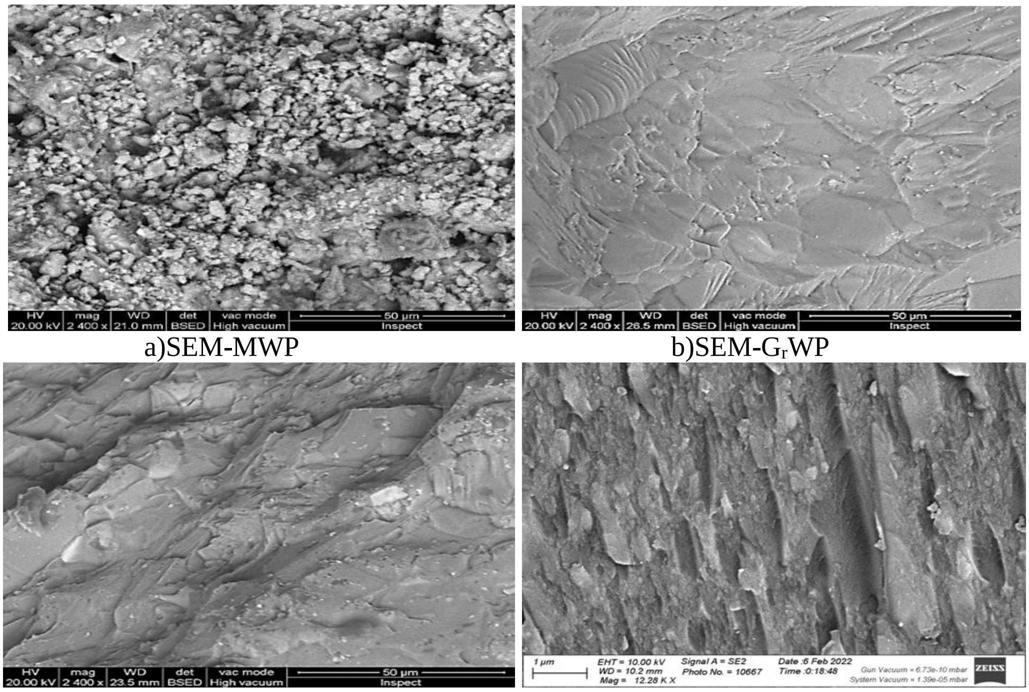


a)XRD-MWP b) XRD-G_rWP



c)XRD-BWP c)XRD-GWP

Fig. 4: XRD-industrial wastes



a)SEM-MWP b)SEM-G$_r$WP

c)SEM-BWP d)SEM-GWP

Fig. 5: SEM-industrial wastes

Table 1: Chemical composition of MWP, G$_r$WP, BWP and GWP

Composition (%)	MWP	G$_r$WP	BWP	GWP
SiO_2	4.22	66.18	60.00	78
Al_2O_3	0.88	15.3	16.4	1.00
Fe_2O_3	0.18	3.63	6.46	0.09
CaO	52.5	3.47	5.55	5.37
MgO	0.96	2.8	4.47	2.81
Na_2O	---	3.26	3.1	11.8
K_2O	0.05	1.72	0.39	0.02
SO_3	0.33	0.19	0.19	0.38
P_2O_5	0.25	1.24	0.45	0.03
TiO_2	---	0.56	1.42	0.06
MnO	---	0.08	0.11	---
Cr_2O_3	---	---	0.03	---
BaO	---	0.09	---	---
SrO	0.03	0.02	0.02	---
ZrO_2	---	0.03	---	---
CuO	---	---	---	0.01
Cl^-	0.07	0.05	0.07	0.07
L.O.I	40.5	1.37	1.3	0.31

2.6 Mix design

Eight Trial mixes were casted and tested in the Fayoum University's Concrete Research and Material Properties Laboratory - Faculty of Engineering to determine control mix (best high strength mix, M_0). For each mix casting six cubes of dimensions 150 mm × 150 mm × 150 mm to test compressive strength at 7 and 28 days as shown in Table 2.

Then, twelve mixtures (M_1-M_{12}) were prepared depending on cement substitution of M_0 with three different percentages (10, 15 and 20%) of four different industrial wastes as shown in Table 3. Also, four different concrete mixtures (M_{14}-M_{17}) containing a fixed ratio of nS (2%) with 15 % of individual industrial wastes (MWP, G$_r$WP, BWP, and GWP), and the engineering properties of each mixture were compared with those of M_{13} (reference mix for nS without cement replacement)..

Table 2: Trial mixes to determine best control mix design

No.mix	Cement Kg	Sand Kg	Basalt Kg	Water Kg	S.F	S.P	Compressive strength, N/mm^2	
							7 days	28 days
Mix(1)	700	682.5	904.5	127.19	15%wt.of cement 105	Sikment163M 2%wt.of cement 14	348.13	496.4
Mix(2)	700	682.5	904.5	127.19	15%wt.of cement 105	viscocrete 0.8% wt.of cement 14	367.4	432.33
Mix(3)	498	700	1098	135	6% wt.of cement 30	Sikment163M 2% wt.of cement 12.45	419.3	479.9
Mix(4) (M_O)	**513**	**550**	**1073**	**130**	**10%wt.of cement** **51.3**	**Sikment163M** **2.5% wt.of cement** **12.825**	**457.2**	**638**
Mix(5)	513	550	1073	130	10%wt.of cement 51.3	viscocrete 0.8% wt.of cement 4.104	419	480
Mix(6)	465.92	594.4	1037.22	161.029	10%wt.of cement 46.08	viscocrete 0.8% wt.of cement 3.73	303	441
Mix(7)	465.92	594.4	1037.22	161.029	10%wt.of cement 46.08	Sikment163M 2% wt.of cement, 9.32	367	468
Mix(8)	513	550	1073	130	10%wt.of cement 51.3	Sikment163M 2.5% wt.of cement+SF 14.11	438.85	506.4

Table 3: Concrete mix design (kg/m^3)

Mix	Cement	MWP	G_rWP	BWP	GWP	Water	Aggregate		S.F	S.P	nS	Slump (cm)
							fine	coarse				
M_0	**513**	**---**	**---**	**---**	**---**	**130**	**550**	**1073**	**51.3**	**12.8**	**---**	**2**
M_1	461.7	51.3	---	---	---	130	550	1073	51.3	12.8	---	10
M_2	436.05	76.95	---	---	---	130	550	1073	51.3	12.8	---	4
M_3	410.4	102.6	---	---	---	130	550	1073	51.3	12.8	---	2
M_4	461.7	---	51.3	---	---	130	550	1073	51.3	12.8	---	9
M_5	436.05	---	76.95	---	---	130	550	1073	51.3	12.8	---	3
M_6	410.4	---	102.6	---	---	130	550	1073	51.3	12.8	---	2
M_7	461.7	---	---	51.3	---	130	550	1073	51.3	12.8	---	10
M_8	436.05	---	---	76.95	---	130	550	1073	51.3	12.8	---	6
M_9	410.4	---	---	102.6	---	130	550	1073	51.3	12.8	---	2
M_{10}	461.7	---	---	---	51.3	130	550	1073	51.3	12.8	---	2
M_{11}	436.05	---	---	---	76.95	130	550	1073	51.3	12.8	---	3
M_{12}	410.4	---	---	---	102.6	130	550	1073	51.3	12.8	---	2
M_{13}	**513**	**---**	**---**	**---**	**---**	**130**	**550**	**1073**	**51.3**	**12.8**	**10.2**	**2**
M_{14}	436.05	76.95	---	---	---	130	550	1073	51.3	12.8	10.2	4
M_{15}	436.05	---	76.95	---	---	130	550	1073	51.3	12.8	10.2	3
M_{16}	436.05	---	---	76.95	---	130	550	1073	51.3	12.8	10.2	6
M_{17}	436.05	---	---	---	76.95	130	550	1073	51.3	12.8	10.2	3

2.7 Mixing Procedures

Mixing procedures of the different mixtures can be briefed in the following steps:

- Fine and coarse aggregate were mixed together for 30 seconds.
- Required powder materials (cement/industrial wastes/silica fume) were incorporated as designed and mixed for 2 minutes.
- nS (for Mixes M_{13} to M_{17}) was mixed with water and superplasticizer, and for remaining mixes (without nano-Silica) required mixing water was mixed with superplasticizer (Mix (1) to Mix (8) and M_1 to M_{12}).
  - 80% of estimated mixing water required and the determined superplasticizer quantity were added during mixing gradually and continued for five minutes.
  - The remaining 20 % of water added and mixed for 2 minutes.

2.8 Casting and curing

After mixing the concrete in the mixer, the slump cone test of each mix was performed immediately. It is clear that the particles of industrial wastes powder slightly decreased the slump when replaced with cement as industrial wastes powder. After the slump cone procedure, concrete was casted into moulds, 48 cubes to determine the control mix with dimensions 150 × 150 × 150 mm, a total of 72 cubes 100 × 100 × 100 mm and 72 cylinder 100 × 200 were casted to determine the best replacement ratio for all wastes powder and 30 cubes 100 × 100 × 100 mm and 30 cylinder 100 × 200 with add affixed ratio 2% nS. Immediately after casting, the concrete was compacted and the surface samples were smoothed. After 24 hours of casting, specimens were demoulded then immersed in a water tank until the indicated testing times.

2.9 Test methods

2.9.1 Compressive strength

Cubic concrete samples with a size of 150 × 150 × 150 & 100 × 100 × 100 mm were used to conduct the compressive strength test of concrete samples at 7 and 28-days of curing. The compressive strength value was the average of the three tested samples under the same conditions, using the following form: Compressive strength (kg/cm^2) = Load (kg) / Area (cm^2).

2.9.2 Splitting tensile strength

Splitting-tensile strength values of concrete specimens were also tested at 7 and 28-days of casting with dimensions 100 × 200 mm. splitting-tensile strength of each specimen (T) was determined by dividing twice the peak load (P) by the product of, arithmetic constant π, the diameter (D), and the length of the cylinder (L) as the following equation: $T=2P/(\pi d L)$.

2.9.3 XRD analysis

For XRD analysis, X'Pert PRO Monochromator with X-ray source of Cu radiation (λ = 1.542 Å) is used. Samples were prepared for XRD analysis by crushing the concrete samples to obtain a uniform powder size passing from 200-micron sieve to be ready for analysis.

3.9.4 Scanning electron microscope (SEM)

SEM test used to classify and describe the composition, morphology, and crystallography of the sample microstructure. Dimensions of samples don't more than 1 cm ×1 cm.

3.9.5 Energy dispersive X-ray spectroscopy (EDX)

EDX is analytical software used to describe and analyze the chemical elements of the specimens. Its technique depends on each element in the periodic table having its atomic structure, which permits unique groups of peaks on the spectrum of electromagnetic emission.

III. Results and Discussion

3.1 Compressive Strength

Table 4 and Fig. 6 illustrate compressive strength values of different concrete mixtures after 7 and 28 days of curing. From the results, optimum cement replacement ratio for all waste posers is 15%. Also, the compressive strength value at 28-days increased by 8.6% of control value with 15% MWP cement replacement. While it decreased by 10.3%, 16.6% and 5.96 % of reference value due to 15% GrWP, BWP and GWP cement replacement, respectively.

Table 4: Compressive strength values of different concrete mixes, containing industrial wastes at 7 and 28- days

Mix. No.	Compressive strength N/mm^2		Increase/Reduction in compressive strength	
	7-days	28-days	7-days	28-days
M_0	457.2	638		
M_1	311.8	493	-31.8%	-22.7%
M_2	416.6	693	-8.88%	+8.62%
M_3	248.7	400	-45.6%	-37.3%
M_4	398.4	452	-12.86%	-29.15%
M_5	454	572	-0.7%	-10.34%
M_6	358	419	-21.7%	-34.32%
M_7	358	463	-21.7%	-27.42%
M_8	410	532	-10.32%	-16.6%
M_9	265	355	-42.03%	-44.35%

M$_{10}$	353	427	-22.8%	-33%
M$_{11}$	393	600	-14.04%	-5.96%
M$_{12}$	312.4	322	-31.8%	-49.5%

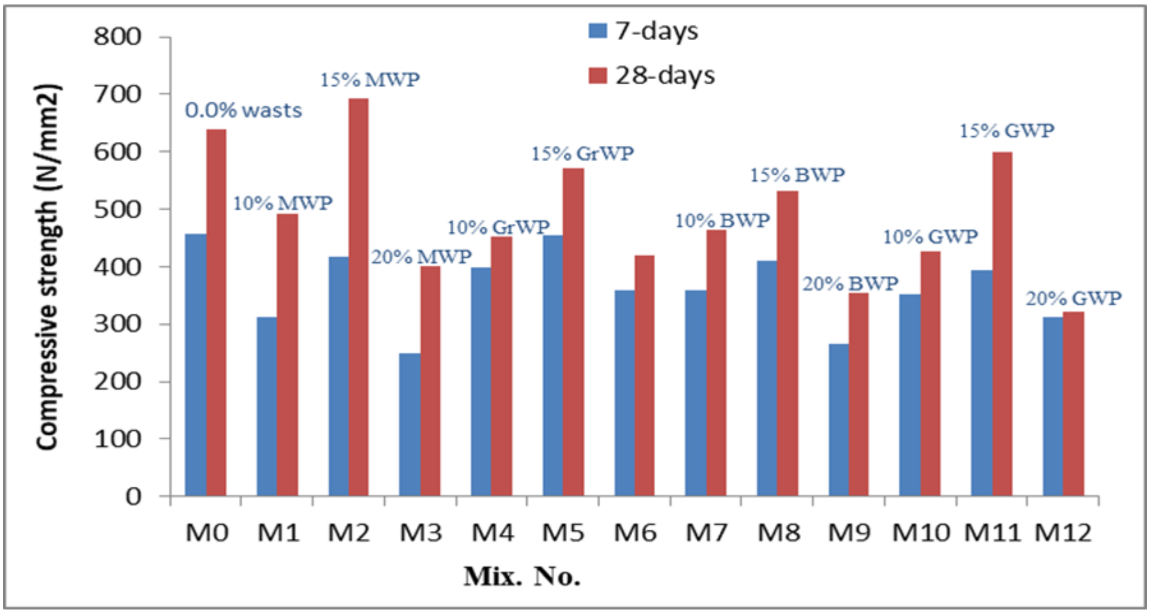


Fig. 6: Compressive strength values of different concrete mixes, containing industrial wastes

Also, Table 5 and Figs. 7 illustrate combined effect of using 2% nS with 15 % industrial wastes (MWP, GrWP, BWP and GWP) cement replacement on concrete compressive strength after 7 and 28-days of curing. The compressive strength at 28-days of mixes with 2% nS increased by 2.9%, 2.15%, 9.64% and 17.69% of that without nS for 15% cement replacement with marble waste powder, granite waste powder, basalt waste powder and glass waste powder respectively.

Table 5: Compressive strength values of different concrete mixes, containing industrial wastes with and without nS at 7 and 28- days

Mix. No.	Compressive strength N/mm^2		Increase/Reduction in compressive strength	
	7-days	28-days	7-days	28-days
M$_0$	457.2	638		
M$_{13}$	407	692	-10.9%	+7.8%
M$_2$	416.6	693		
M$_{14}$	398	702	-4.46%	+2.9%
M$_5$	454	572		
M$_{15}$	371.8	584.6	-18.1%	+2.15%
M$_8$	410	532		
M$_{16}$	429	588.8	+4.63%	+9.64%
M$_{11}$	393	600		
M$_{17}$	454	729	+15.5%	+17.69%

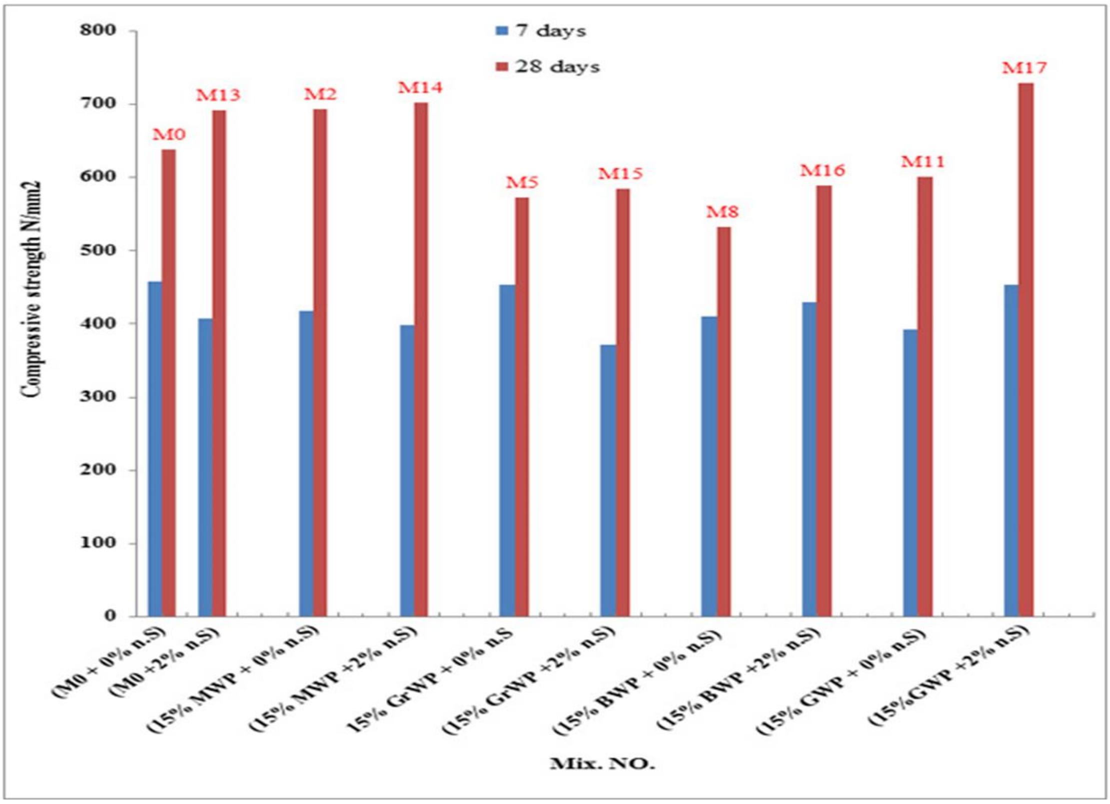


Fig. 7: Compressive strength values of different concrete mixes, containing industrial wastes with and without nS

3.2 Splitting tensile Strength

The average tensile strength values of different concrete specimens containing different percentages (10, 15, and 20 Wt., %) of industrial wastes (MWP, GrWP, BWP and GWP) and cured at 7 and 28-days for each mixture with and without nS are listed in Table 6 and 7 and plotted in Figs. 8 and 9 respectively. The results demonstrated that, optimum cement replacement ratio is 15% for all wastes powder. Also, best replacement waste powder is the glass waste. The splitting tensile strength at 28-days with 15% cement replacement with glass waste powder is increased by 4.3% of that without cement replacement. Also for samples with 2% nS and 15% glass waste powder replacement, The splitting tensile strength at 28-days increased by 11.14% of that with GWP and without nS.

Table 6: Tensile strength values of different concrete mixes, containing industrial wastes at 7 and 28- days

Mix. No.	Tensile strength N/mm^2		Increase/Reduction in tensile strength	
	7-days	28-days	7-days	28-days
M_0	42.3	46.9		
M_1	31.8	32.7	-24.8%	-30.2%
M_2	35.7	43	-15.6%	-8.3%
M_3	28	38	-33.8%	-18.9%
M_4	29	37	-31.4%	-21.1%
M_5	37.8	45.5	-10.6%	-2.98%
M_6	30.5	32.15	-27.8%	-31.4%
M_7	32	40.7	-24.3%	-13.2%
M_8	34	46.6	-19.6%	-0.6%
M_9	33.5	30.7	-20.8%	-34.5%
M_{10}	35.3	36	-16.5%	-23.2%
M_{11}	45.3	48.9	+7.09%	+4.26%
M_{12}	34.36	38	-18.7%	-18.9%

Table 7: Tensile strength values of different concrete mixes, containing industrial wastes with and without nS at 7 and 28- days

Mix. No.	Tensile strength N/mm^2		Increase/Reduction in tensile strength	
	7-days	28-days	7-days	28-days
M_0	42.3	46.9		
M_{13}	41	48.7	-3.07%	+24.02%
M_2	35.7	43		
M_{14}	36.25	44	+1.54%	+2.27%
M_5	38.7	45.5		
M_{15}	32.6	46.3	-15.7%	+1.72%
M_8	34	46.6		
M_{16}	34.3	47.3	+0.88%	+1.48%
M_{11}	45.3	44		
M_{17}	47.4	48.9	+4.63%	+11.14%

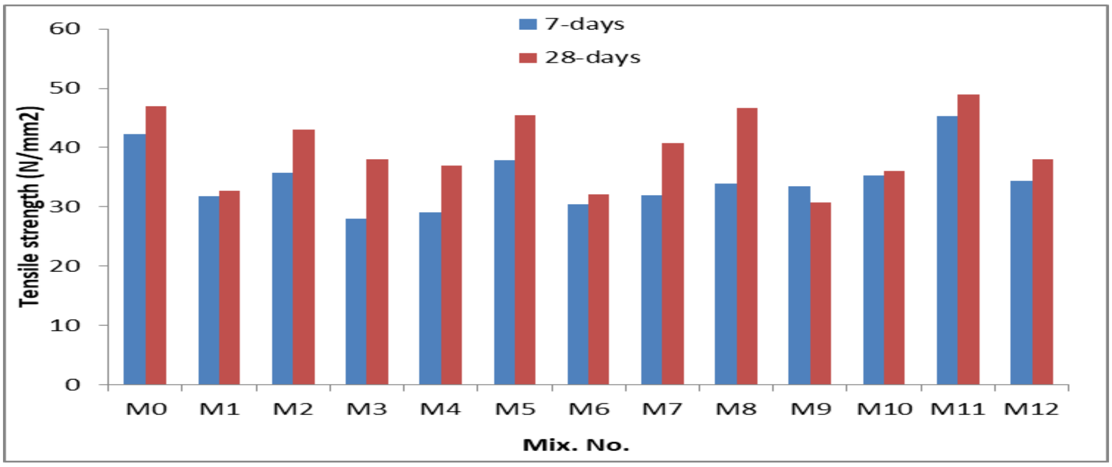


Fig. 8: Tensile strength values of different concrete mixes, containing industrial wastes

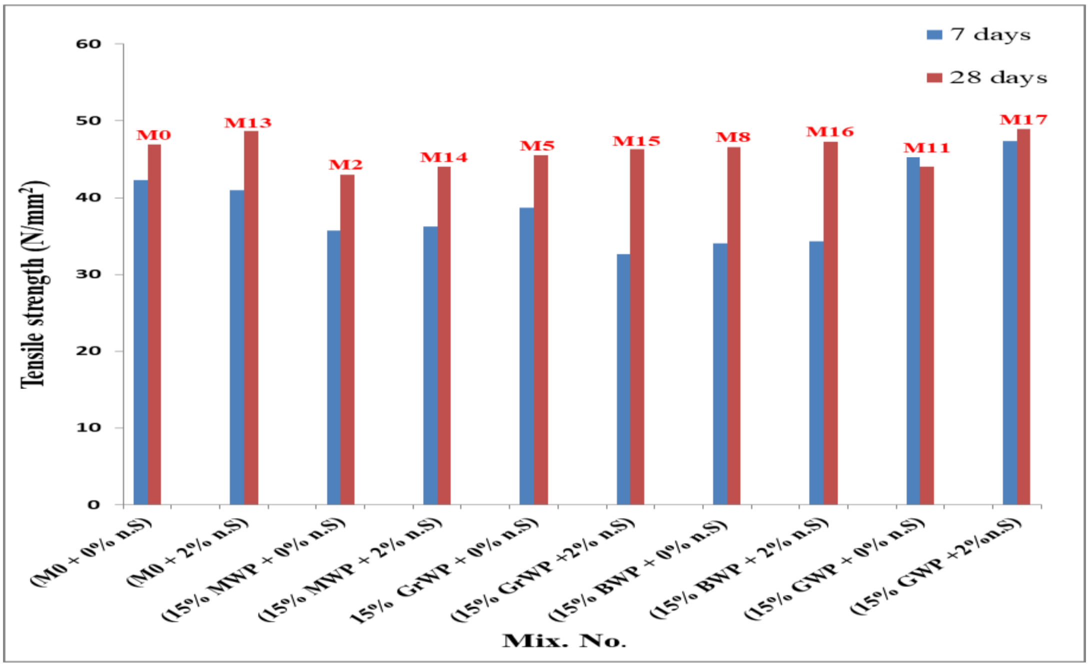
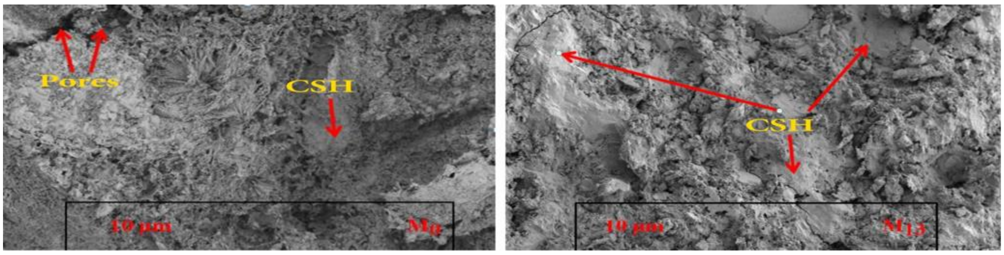


Fig. 9: Compressive strength values of different concrete mixes, containing industrial wastes with and without nS

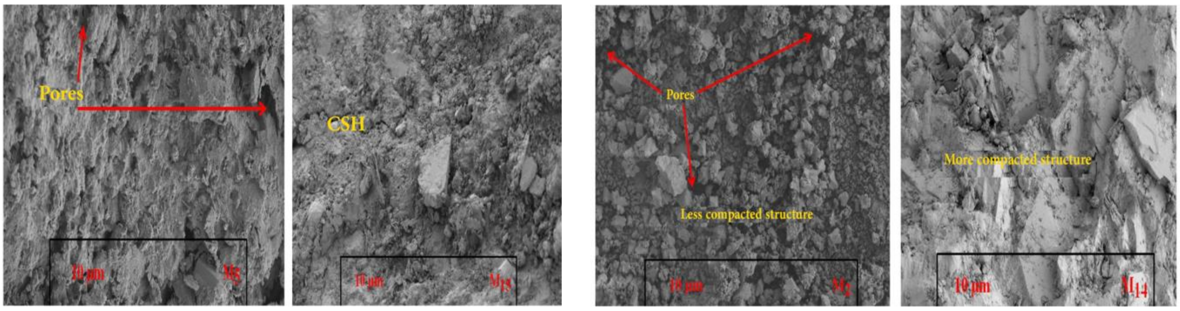
3.3 Scanning electron microscope (SEM) photographs and energy dispersive X-ray spectroscopy (EDX)

3.3.1 Scanning Electron Microscopy (SEM)

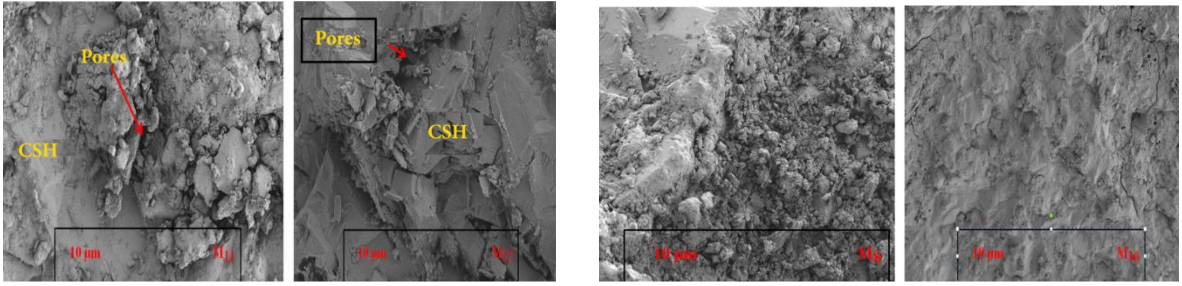
The SEM and EDS analyses are used to shed more light on the impact of nS-addition and waste utilization on concrete microstructure. The SEM images and EDS mapping of the fabricated concrete mixtures hydrated for 28-days are shown in (Fig. 10). It is clear that, regardless of waste type, concrete cubes microstructure becomes denser and more homogeneous and compacted with nS addition. The EDS curves confirm that, this enhancement in microstructure is mainly due to the increase in CSH-phase formation, which is the main phase responsible for strength properties. This confirms the fact that, nS can be effectively used for enhancing strength properties of concrete. Results also show that, the microstructure of MWP-mixes (with and without nS) is more compacted, compared with the other tested mixes.



a) M_0 (M_0+0.0% nS) and M_{13} (M_0+2% nS)



b) M_5(M_5+0.0% nS) and M_{15}(M_5+2% nS) **c)** M_2(M_2+0.0% nS) and M_{14}(M_2+2% nS)

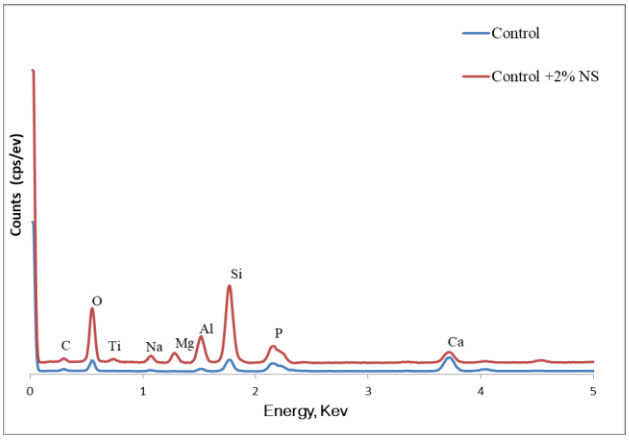


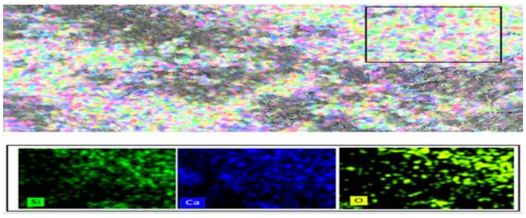
d) M_{11}(M_{11}+0.0% nS) and M_{17}(M_{11}+2% nS) **e)** M_8(M_8+0.0% nS) and M_{16}(M_8+2% nS)

Fig. 10: SEM photos control and cement composites

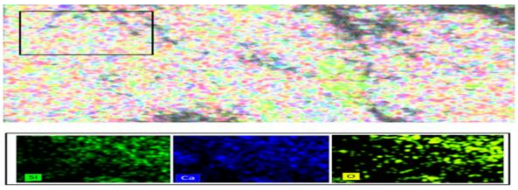
3.3.2 EDX-curves

Figs. (11-15) illustrates EDS mapping shows the elemental distribution map of concrete mixes. In general, the distribution of different elements within concrete samples was identified by color designation. Ca, Si, Ti, O, Mg, Fe, Al and C are the main elements within hardened samples. Regardless of waste type, nS-particles are homogenously distributed in concrete mixtures. The overlapping of Si (green color), O (bright green color), and Ca (blue color) is the main feature of the EDS mapping analysis. This result confirms that, CSH-phase is the dominant hydration product. SEM/EDS and EDS mapping observations are in a good accordance with compressive strength and XRD-results.



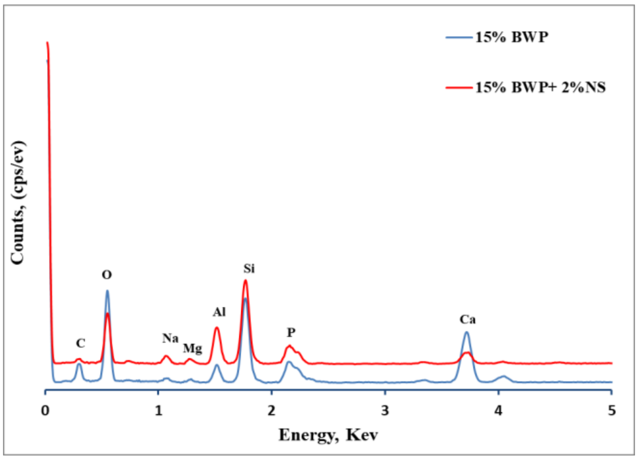


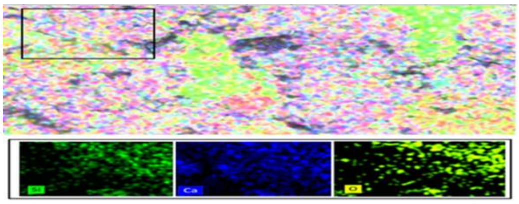
b) EDS-images of control concrete cubes



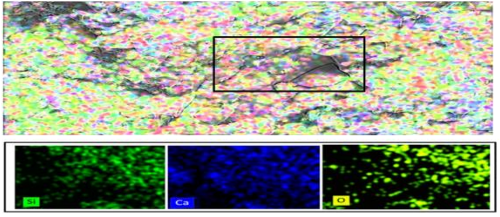
a) EDS-curves of control concrete cubes with and without Ns c) EDS-images of control concrete cubes with nS

Fig. 11: EDS of control concrete cubes with and without Ns



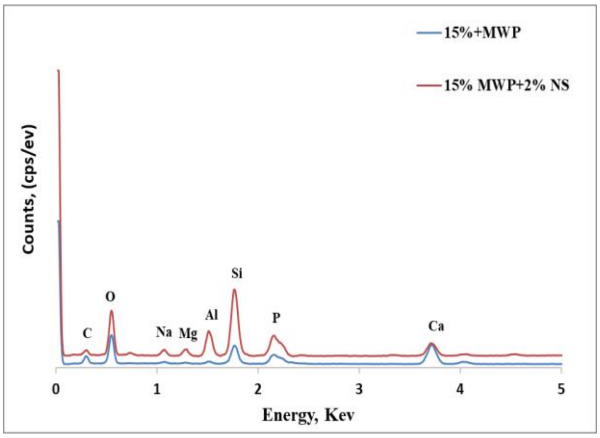


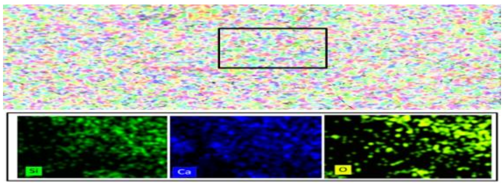
b) EDS-images of BWP cubes



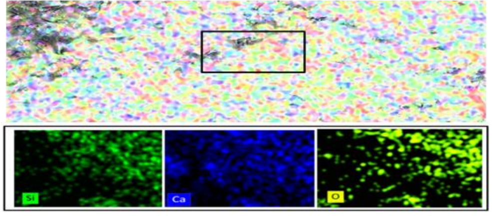
a) EDS-curves of BWP cubes with and without Ns c) EDS-images of BWP cubes with nS

Fig. 12: EDS of BWP cubes with and without Ns



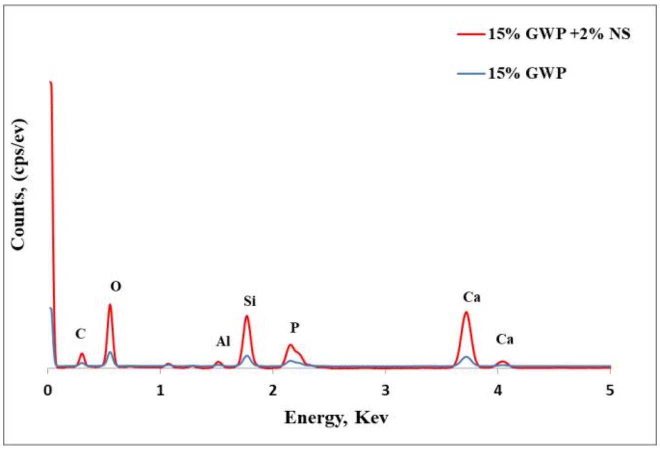


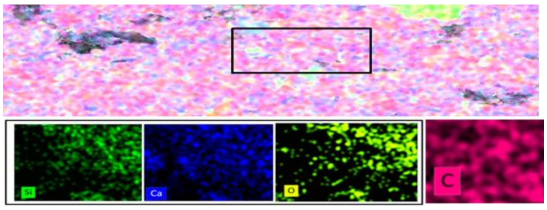
b) EDS-images of MWP cubes



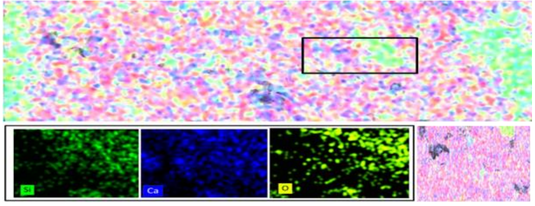
a) EDS-curves of MWP cubes with and without Ns c) EDS-images of MWP cubes with nS

Fig. 13: EDS of MWP cubes with and without Ns





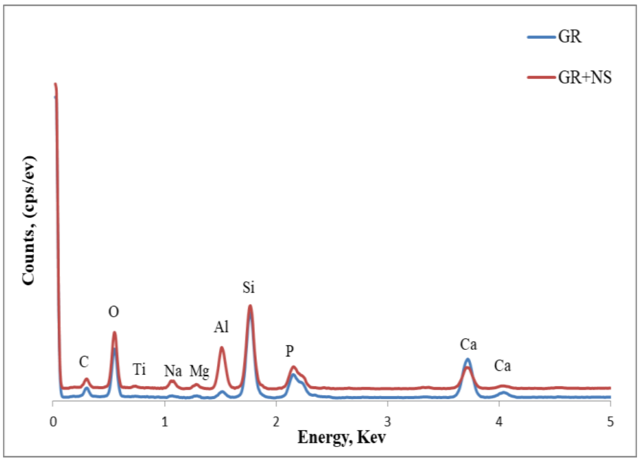
b) EDS-images of GWP cubes

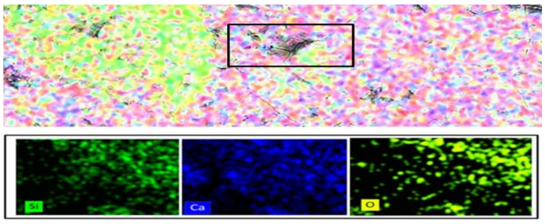


a) EDS-curves of GWP cubes with and without Ns

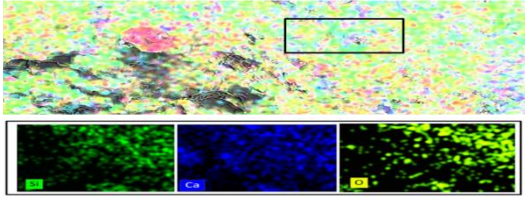
c) EDS-images of GWP cubes with nS

Fig. 14: EDS of GWP cubes with and without Ns





b) EDS-images of GrWP cubes



a) EDS-curves of GrWP cubes with and without Ns

c) EDS-images of GrWP cubes with nS

Fig. 15: EDS of G_rWP cubes with and without Ns

IV. Conclusions

The following conclusions could be drawn from the current study:

- Encapsulation of industrial wastes (MWP, G_rWP, BWP and GWP) in concrete is a good solution to overcome the environmental pollution.
- The optimum cement replacement level with industrial wastes (MWP, G_rWP, BWP and GWP), producing cement concrete mixtures with desirable mechanical properties (compressive and tensile) is 15% Wt.
- The compressive strength of concrete at 28 days increased by 8.6% of control value with 15% MWP cement replacement.
- The compressive strength is decreased by 10.3%, 16.6% and 5.96 % of reference value due to GrWP, BWP and GWP cement replacement of 15%.
- The splitting tensile strength of concrete mixture containing 15% of GWP is more than that of the control concrete mixture at 28 days with 4.26 %.
- The splitting tensile strength of concrete mixtures containing 15% of MWP, G_rWP, and GWP is lower than that of the control concrete mixture with 8.32, 2.99 and 0.64 %, respectively.
- All concrete mixtures containing 15% of industrial wastes (MWP, G_rWP, BWP and GWP) and 2% of nS exhibits higher mechanical performance comparing with the concrete mixtures containing only industrial wastes (G_rWP, MWP, and GWP) without nS.
- The compressive strength at 28-days of hardened concrete mixtures incorporating 15% of individual industrial wastes (MWP, G_rWP, BWP and GWP) and 2% nS is higher with 2.9, 2.2, 9.6 and 17.7%, respectively than that of the corresponding value of the same concrete mixtures without nS.
- The splitting tensile strength at 28-days of hardened concrete mixtures incorporating 15% of individual

industrial wastes (MWP, G_rWP, BWP and GWP) and 2% nS is higher with 2.27, 1.72, 1.48, and 10.02%, respectively than that of the corresponding value of the same concrete mixtures without nS.

- The SEM images shows regardless of waste type, concrete cubes microstructure becomes denser and more homogeneous and compacted with nS addition.
- EDS shows Regardless of waste type, nS-particles are homogenously distributed in concrete mixtures. The overlapping of Si (green color), O (bright green color), and Ca (blue color) is the main feature of the EDS mapping analysis. This result confirms that, CSH-phase is the dominant hydration product.

References

[1]. G. M. Sadiqul Islam, M.H. Rahma, Nayem Kazi, (Waste glass powder as partial replacement of cement for sustainable concrete practice), Int. J. Sustain. Built Environ. 6(2017), pp. 37-44.

[2]. Ali A. Aliabdo, Abd Elmoaty M. Abd Elmoaty, Ahmed Y. Aboshama, (Utilization of waste glass powder in the production of cement and concrete), Constr. Build. Mater. 124 (2016) 866-877.

[3]. M. Dobiszewska, A. Beycioğlu, (Investigating the Influence of Waste Basalt Powder on Selected Properties of Cement Paste and Mortar), IOP Conf. Series: Materials Science and Engineering, 245, 022027, (2017) doi:10.1088/1757-899X/245/2/022027.

[4]. M. Majeed, A. Khitab, W. Anwer, R. Bilal Nasar Khan, A. Jalil, Z. Tariq (Evaluation of Concrete with Partial Replacement of Cement by Waste Marble Powder), Vol. 7, No. 01, January, (2021), E-ISSN: 2476-3055; ISSN: 2676-6957, Civil Engineering Journal.

[5]. N. T. Seghir, O. Benaimeche, K. Krzywinski and L. Sadowski, (Ultrasonic Evaluation of Cement-Based Building Materials Modified Using Marble Powder Sourced from Industrial Wastes), Buildings (2020), 10, 38; doi:10.3390/buildings10030038.

[6]. S.Sengottaiyan, M.Muthumurugan, Mrs. U.Nandhini, (Study on Strength Characteristics of Concrete with Partial Replacement of Cement by Granite Powder and Fine Aggregate by Quarry Dust), International Conference on Latest Innovations in Applied Science, Engineering and Technology (ICLIASET 2017), March (2017).

[7]. Y.Yaswanth Kumar1, C.M. Vivek Vardhan1, A.Anitha, (Use of Granite Waste as Partial Substitute to Cement in Concrete), ISSN: 2248-9622, Vol. 5, Issue 4, (Part -6) April (2015), pp.25-31.

[8]. S. Unčík, V. Kmecov, (The Effect of Basalt Powder on the Properties of Cement Composites), Procedia Engineering 65 (2013), pp. 51 – 56, doi:10.1016/j.proeng.2013.09.010.

[9]. W. Kurdowski, (Cement and Concrete Chemistry), Springer, (2014).

[10]. E. A. Al Majeed, (Influence of Waste Glass Powder on Compressive Strength of Sulfate Resistance Portland Cement), Al Majeed, Ind Eng Manage (2018), S:3 doi: 10.4172/2169-0316.S3-003.

[11]. S. Rao. Hunchate, S. Chandupalle, V. G. Ghorpode and V. Reddy.T.C, (Mix Design of High Performance Concrete Using Silica Fume and Superplasticizer), (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 3, March (2014).

[12]. J. J. Gaitero, I. Campillo, P. Mondal and S. P. Shah, (2010), “Small Changes Can Make a Great Difference” In Transportation Researsh Record, Journal of the Transportation. Volume: 2141, issue: 1, pages: 1-5.

[13]. P. Ganesh, A. R. Murthy, S. S. Kumar, M. M. S. Reheman, N. R. Iyer, (Effect of nanosilica on durability and mechanical properties of high-strength concrete), aper 1400338 Received 17/10/2014; revised 16/09/2015; accepted 21/09/2015 ICE Publishing: All rights reserved, Article in Magazine of Concrete Research · November (2015) doi: 10.1680/jmacr.14.00338.

[14]. S. Kinaekar, (Design of High Strength Concrete with Addition of Mineral and Chemical Admixtures), International Journal of Innovative Research in Science, Engineering and Technology.Vol. 7, Issue 4, April (2018).

[15]. Liu M, Tan H, He X. (Effects of nano-SiO_2 on early strength and microstructure of steam-cured high volume fly ash cement system). Constr Build Mater 2019;194:350–9. doi:10.1016/j.conbuildmat.2018.10.214.

[16]. ACI 363.2R-98, (Guide to Quality Control and Testing of High-Strength Concrete).

Khaled M. Osman, et. al. "Effect of Marble and Glass Industrial Wastes on the Properties of High Strength Concrete Containing nano-Silica.” *International Journal of Engineering Science Invention (IJESI)*, Vol. 12(5), 2023, PP 53-66. Journal DOI- 10.35629/6734