BILINGUAL PUBLISHING CO.
Pioneer of Global Academics Since 1984

Journal of Building Material Science
https://ojs.bilpublishing.com/index.php/jbms

ARTICLE

Effect of Quartz Particle Size and Cement Replacement on Portland Limestone Cement Properties

Kachallah Bukar Gubio   Muhammad Mukhtar Ismail   Olubajo Olumide Olu*

Chemical Engineering Department, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, 740102, Nigeria

ARTICLE INFO

Article history
Received: 23 September 2022
Revised: 9 November 2022
Accepted: 14 November 2022
Published Online: 17 November 2022

Keywords:
Quartz powder
Particle size
Consistence
Setting times
Mortar compressive strength

ABSTRACT

This research focuses on investigating the effect of quartz particle size and cement replacement on their physicomechnical properties. Portland limestone cement (PLC) was employed and replaced with quartz powder (QP) at various particle sizes (1.19 mm, 425 μm, 300 μm, 212 μm, <212 μm) and cement replacement between 2.5 wt.% ~ 15 wt.% at interval of 2.5 wt.% to study their impact on the cement properties. The PLC chemical composition revealed a relatively low lime and high silica content compared to the conventional cement. QP revealed a high silica, lime and sulphur contents compared to natural sand. A high consistence, elongated setting times and lower strengths and specific gravities were observed as cement was replaced with QP at a given particle size respectively. The effect of replacing cement with QP content between 2.5 wt.% and 15 wt.% at various particle sizes resulted in average increments by 45.32%, 23.13% and 36.06% for initial setting time, final setting time and water demand respectively. This increase could be related with clinker diminution coupled with enhanced QP surface area and clinker diminution. Similarly, an increase in the QP surface area at a given cement replacement led to higher water consistence, retarded setting times and lower strength. The effect of enhancing the QP' surface area between 1.19 mm and below 212 μm at a given cement replacement resulted in average increments by 26.27%, 8.61% and 7.49% for initial and final setting times and water demand respectively. The strength gain of the QP cement blend diminished significantly above 30% up to 15 wt.% cement replacement especially beyond 3 days. The low strength could be due to the high-water consistence linked with silica content resulting in setting time retardation. The optimal QP content was determined at 5 wt.% owing to the fact that the physicomechnical properties did not significantly deviate from the properties of control.

1. Introduction

Quartz powder is considered a natural and industrial byproduct obtained from mining activities such as sawing stones which can be employed as filler [1]; fine aggregate replacement and possess high void filling capacity which produces enhanced strength due to its high silicon content [2]. The QP is employed in the manufacture of both high and

---

*Corresponding Author:
Olubajo Olumide Olu,
Chemical Engineering Department, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, 740102, Nigeria;
Email: ooolubajo@atbu.edu.ng

DOI: https://doi.org/10.30564/jbms.v4i2.5091

ultra-high-performance concrete and can be considered as chemically inert at room temperature, whereas at high temperature and pH [3,4]. They also possess relatively low hydraulic effect on cement [5]. The high purity quartzes are relevant in high technological industries such as semiconductors, high temperature lamp tubing, tele-communications, optics, microelectronics and solar silicon applications [6,7]. It is the second most abundant mineral on the earth surface after Feldspar and possesses a hardness of 7, white in color with a specific gravity between 2.6 and 2.7 [8]. It is a widely distributed mineral of many varieties which consist mainly of silica and other minor constituents including lithium, sodium, potassium and titanium having many applications ranging from glass manufacturing, ceramics, refractory materials. Crushed quartz could be used as an abrasive material for sand paper, etc. [9]. The decline in the natural resources encountered by the fast industrialization and urbanization of developing countries such as Nigeria coupled with the enormous demand for cement and sand in the construction sector, since is a serious concern. The increase in mining activities, enormous byproducts such as quartz resulting in waste generation. Thus, there is need to recycle these materials as cement replacement materials considered a promising prospect and could drive sustainability in the construction sector [10]. One solution to this menace is the use of these materials as either cement or fine aggregate replacement materials [11].

Finely ground quartz and limestone are mostly referred to as non-pozzolanic inorganic materials and may be considered a pozzolan despite exhibiting filler effect. The filler effect works on the principle of filling the voids in the cement matrix, thereby densifying the cement matrix resulting in acceleration of the early age hydration rate [12-18]. The provision of nucleation sites is responsible for the growth of more CSH and hydrates [19-20]. The use of finely ground quartz particle may either possess pozzolanic activity or filler effect is dependent on the particle size and surface area [21]. According to Yao *et al.* [22], investigated the effect of prolonged grinding (particle size) on the pozzolanic activity and hydration properties of quartz and suggested that the prolonged grinding led to a higher pozzolanic activity index, higher percentage alkaline dissolution in solution and lower crystallinity. Kadri *et al.* [23] observed that quartz with diameter between 20 μm and 25 μm did not exhibit pozzolanic activity and was considered a filler. The inclusion of fillers as one of the drivers for sustainability in the cement industry could provide economic, ecological and technical benefits as a result formation of more CSH despite clinker diminution [24-28].

Nikdel [52] investigated the effect of replacing cement with silica fume and observed its impact on the fresh and hardened states of concretes and was considered as an additive which could be employed as a cement replacement material. It was also believed that Portland cement mortars possesses a lot of voids, thus resulting in high permeability and low durability whereas if Portland cement was blended with QP, could fill up the voids and provide an enhanced permeability. Soumya & Karthiga [2] investigated the influence of replacing cement with silica fumes and fine aggregate with quartz on the concrete strength and found the optimal replacement to be 15%, 15% and 60% for concrete compressive, tensile and flexural strengths increments of 19.16%, 7.2% and 6.64% in comparison with 28 days control strengths respectively. Lin *et al.* [5] also studied the effect of water-binder ratio and quartz content on the properties of quartz-cement paste ranging from 0.2 and 0.5 and cement replacement ranging from 0%, 10% and 20% respectively. Results indicated that QP produced a dilution effect as well as a crystal nucleation effect on cement hydration which did not affect the hydration products monitored using XRF, XRD and SEM and TG techniques. Research findings suggested QP as chemically inert at room temperature whereas at elevated temperature and high pH, may not be inert [52]. It is also knowledge that inert fillers could enhance the degree of cement hydration by production of more nucleation site for C-S-H despite the fact that it could results in cement dilution [13]. There is a need to utilize the enormous waste materials being generated as a cement replacement has been tremendously employed owing to environmental, economic and technical benefits [29-31]. Arroudi *et al.* [32] investigated the effect of replacing cement with fine quartz from 15% to 25% on the fresh and mortar properties and observed that the presence of quartz did not influence the initial setting time but delayed the final setting time. The diminution of the clinker content by replacement of quartz results in decrease in the temperature rise leading to production of more CSH due to secondary hydration. The crystal structure of quartz is a significant factor in its pozzolanicity.

Tikkanen [33] investigated the effect of replacing cement between 10% and 40% at interval of 10% with quartz and it was observed that its concrete' compressive strength experienced increments beyond 7 and 28 days as well as the hydration kinetics were influenced. Popek & Sadowski [34,35] and Popek *et al.* [36] made attempts on several replacement materials such as quartz and quartz-feldspar mixture and basalts obtained from mining sites and concluded that the cement replacement with these materials significantly affect the mechanical properties owing to factors ranging from its quality to the amount of cement replaced. According to Ahmed *et al.* [37] observed that a high compressive strength was obtained at 20 wt.% crushed QP as a partial replacement of fine sand and its strength gain was attributed to quartz being a good filler material whereas beyond 20 wt.% resulted in a reduction in its strength. Similarly, Galiska & Czarnecki [38] investigated beyond 30% cement replacement i.e., 40%-60% with quartz and quartz-feldspar powders affected the mechanical properties like tensile and compressive strength and was shown that the concrete compressive strength diminished by 6%-93% and 40%-65% of 7 days control compressive and tensile strength and diminished by 10%-85% and 17%-58% of the 28 days control compressive and tensile strength respectively as quartz content was increased. In conclusion, the strength of cement replaced with greater than 40% quartz-feldspar and quartz diminished significantly while the tensile strength was not negatively affected in comparison with control concrete for 7 and 28 days.

QP inclusion improved the concrete properties by physically acting as a filler and densifying and homogenizing the paste due to its fine particles, while surface chemical effect, is if the particle enhances hydration by acting as a part of the paste and increase in its surface area. The chemical effect by acting as a pozzolan to produce CSH [39]. Similarly, its inclusion in cement could also lead to Alkali Silica Reaction which is a major menace in many structures which occurs between silica and alkalis present in cement pastes in water saturated environment to produce amorphous silica gel that reacts with water and could result in expansion due to reaction, thus, deterioration of concrete's surface. Another unwanted phenomenon is carbonation in which calcium hydroxide produced from cement hydration reacts with CO_2 and affects the surface of concrete resulting in cracks for which one solution to this problem is the use of pozzolans. Thus, this paper tries to investigate the effect of replacing PLC with QP on the physico-mechanical properties such as consistence, initial and final setting time, soundness and mortar compressive strength as well as the effect of particle size on the cement properties.

2. Materials and Method

The quartz samples were collected at quarry site in Yelwa, Bauchi state and then sorted to remove unwanted materials, followed by size reduction into four main classes namely < 212 μm sieve, between 212 μm ~ 300 μm, between 300 μm ~ 425 μm and > 425 μm respectively. The particles that do not pass the sieve were recycled by grinding before being re-sieved. The QP sample required to obtain the chemical composition was ground to 75 μm and PLC CEM II A-L 42.5R were characterized via X-ray fluorescence spectrometer to obtain their chemical compositions.

The standard consistence and setting time tests were conducted and placed in a mold according to IS 4031 part 4 and 5 [40,41]/ASTM C 191 [42]. The experimental mix for the consistence and setting time of the various cement blends and control are presented in Table 1. The consistence and setting times of QP cement blends as well as PLC (control) were determined using a Vicat apparatus. This is achieved by addition of water at various percentage level until the paste indicates resistance to penetration. The penetration of the plunger into the paste should be between 5 mm ~ 7 mm above the bottom of the mould according to ASTM C 187 [43]. The consistence was recorded and obtained by arithmetic mean of three repetition and used in determining the setting times. The period elapsed between the time when the water was added to the cement and the time at which the needle ceased to descend beyond 4 mm from the bottom of the test block was noted as the initial setting time. In the case of the final setting time, the needle used for the initial setting time was replaced by a needle with annular attachment. The values of the initial and final setting times were determined by averaging three tests.

The mortar compressive strength of cement blend was conducted according to ASTM C 109 standard [44]. After proper mixing the mortar, the mix was transferred into the 50 mm cube moulds and compacted using a standard jolting apparatus and kept in a cabinet for 24 hours. The moulds were then demoulded and placed in curing tank containing water until the strength testing for 3, 7, 28 and 60 days. The experimental matrix for the determination of the physical and mechanical properties of PLC and QP cement blends are presented in Table 1.

Table 1. Experimental matrix for QP cement blend physicomechnical properties

S/No	Cement Blends	PLC %	QP %
1	PLC	100	0.0
2	2.5QP	97.5	2.5
3	5QP	95.0	5.0
4	7.5QP	92.5	7.5
5	10QP	90.0	10.0
6	12.5QP	87.5	12.5
7	15QP	85.0	15.0

3. Results and Discussion

The characterization of the QP, sand and PLC CEM II A-L 42.5R were carried out in Ashaka cement Plc to determine the compositional analysis via X-ray Fluorescence spectrometer and presented in Table 2. Table 2 presents the chemical composition of PLC, QP and sand via X-ray Fluorescence analysis. Chemical analysis revealed that QP and sand contained about 89.30 and 85.4 wt.% of SiO_2

respectively. The summation of alumina, silica and ferric oxide in QP was 91.10 wt.% hence the material satisfy to possess pozzolanic activity according to ASTM C 618 [45]. QP had a higher loss on ignition of 6.18 wt.% compared with sand' LOI of 0.27 wt.%. This could possibly be due to the presence of carbonates especially calcium carbonate evident from the chemical composition of QP. The high LOI of QP could be linked with the presence of carbonates. The lime content of 7.74 wt.% present in the QP composition met class F with CaO content < 10 wt.%. The sand' chemical composition indicated significant Fe_2O_3, Al_2O_3 and K_2O contents compared to QP, whereas the lime, sulphur contents and LOI were higher in QP compared with sand.

Table 3 indicates the effect of QP content and particle size on the water demand, initial and final setting times of cement blends whereas the effect of QP particle size and content on the water requirement at standard consistence for QP cement blends was illustrated in Figure 1.

An increase in the water consistence of the PLC blended with QP was observed as QP content was gradually replaced between 2.55 wt.% to 15 wt.% at various particle sizes. Similarly, particle size between 300 µm ~ 425 µm produced higher water consistence in comparison with other particle sizes. As the QP particle size was gradually decreased from the first fraction (1.19 mm ~ 2.0 mm) to the third fraction (300 µm ~ 425 µm) experienced increased water consistence whereas beyond sieve fraction of 300 µm ~ 425 µm resulted in a reduction in the water consistence at various cement replacements.

Table 2. Chemical composition of PLC, QP and Sand

Components	PLC wt.%	QP wt.%	Sand wt.%
SiO_2	12.39	89.30	85.42
Al_2O_3	4.20	1.72	9.15
Fe_2O_3	1.95	0.38	2.05
CaO	43.14	7.74	0.41
MgO	0.74	0.09	0.05
SO_3	1.03	0.50	0.08
K_2O	0.63	0.06	1.96
Na_2O	0.09	0.14	0.48
P_2O_5	0.18	0.01	-
Mn_2O_3	0.10	0.00	-
TiO_2	0.19	0.08	-
C_3S	50.42		
C_2S	–2.51		
C_3A	7.83		
C_4AF	5.93		
Silica Ratio	2.01	42.39	-
Alumina Ratio	2.16	4.49	-
Calcium Carbonate	79.00	16.75	-
L.O. I	34.67	6.18	0.27

Table 3. Effect of QP particle size and content on the setting times, normal consistence and water demand of PLC blends

QP Particle size	Properties	2.5 wt.%	5 wt.%	7.5 wt.%	10 wt.%	12.5 wt.%	15 wt.%
1.19 mm -2 mm	IST mins	96	103	108	122	130	143
	FST mins	210	221	233	245	257	268
	Consistency %	29	29	31	33	36	40
	Water demand mm	87	87	93	99	108	120
425 µm -1.19 mm	IST mins	106	112	118	133	147	165
	FST mins	232	245	256	268	281	301
	Consistency %	30.0	30.0	33.0	33.0	40.0	44.0
	Water demand mm	90	90	99	99	120	132
300 µm- 425 µm	IST mins	107	112	120	135	137	157
	FST mins	232	247	259	263	275	297
	Consistency %	32	33	36	41	45	46
	Water demand mm	96	99	108	123	135	138
212 µm- 300 µm	IST mins	118	128	140	148	161	160
	FST mins	236	241	250	263	273	268
	Consistency %	30.5	30	36	35	37	36.5
	Water demand mm	91.5	90	108	105	111	109.5
Below 212 µm	IST mins	121	130	144	153	167	169
	FST mins	239	245	253	261	277	279
	Consistency %	31	31.5	33	37	39	41
	Water demand mm	93	94.5	99	111	117	123

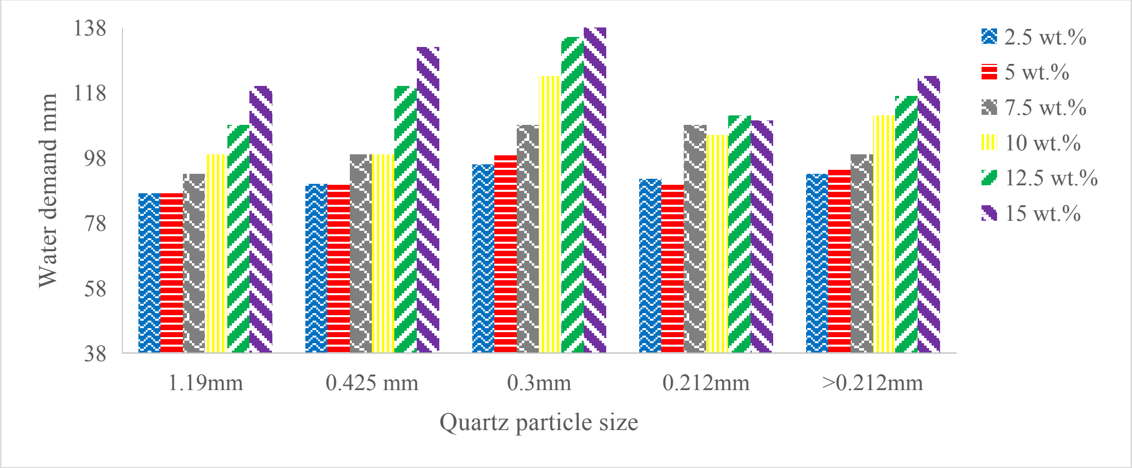

Figure 1. Effect of QP content on the water demand of PLC blend at various particle sizes.

Most of the QP-cement blend required more water demand for normal consistence especially beyond 5 wt.% of the various fractions. From Figure 1 it could also be seen that an increase in QP content resulted in an increase in the normal consistence for Q-PLC paste at various particle size. The water consistence of Q-PLC experienced an increase from 87 mm to 120 mm; 90 mm to 132 mm; 96 mm to 138 mm; 91.5 mm to 109.5 mm; 93 mm to 123 mm as QP content increased from 2.5 wt.% to 15 wt.%. Most of the cement blended with QP required more water for consistence compared to PLC as control. The QP possesses significantly high silica content with a low LOI of 6.18%. Excess of the silica could increase the water requirement for normal consistence according to Olubajo *et al*. [25].

This increased water requirement for normal consistence of the cement blended with QP compared with the control could be due to the high surface area of the QP [27,46] as well as the diminution of the clinker content by cement replacement according to Waziri and Olubajo [46]. Other reasons for increased water demand include excess silica content in the cement matrix [24] and formation of nucleation sites for CSH precipitation [47].

The initial and final setting time of PLC was 190 and 295 minutes respectively while the water consistence was 31% (93 mL). The inclusion of QP into the cement matrix resulted in an acceleration in the initial and final setting time values in comparison with PLC whereas as the cement was gradually replaced with QP from 2.5 wt.% ~ 15 wt.% resulted in a retardation at the various particle size. The quality of cement could be ascertained owing to the varying proportion of ingredients that comprises the cement blend. This decrease in the setting time (acceleration) in comparison with PLC as control could be attributed to the lower lime content requirement. The diminution of the clinker by replacement of cement with QP is responsible for the retardation in the setting time as the cement replacement was increased. The excess silica present in the cement blend leads to increase in the setting time (retarda-

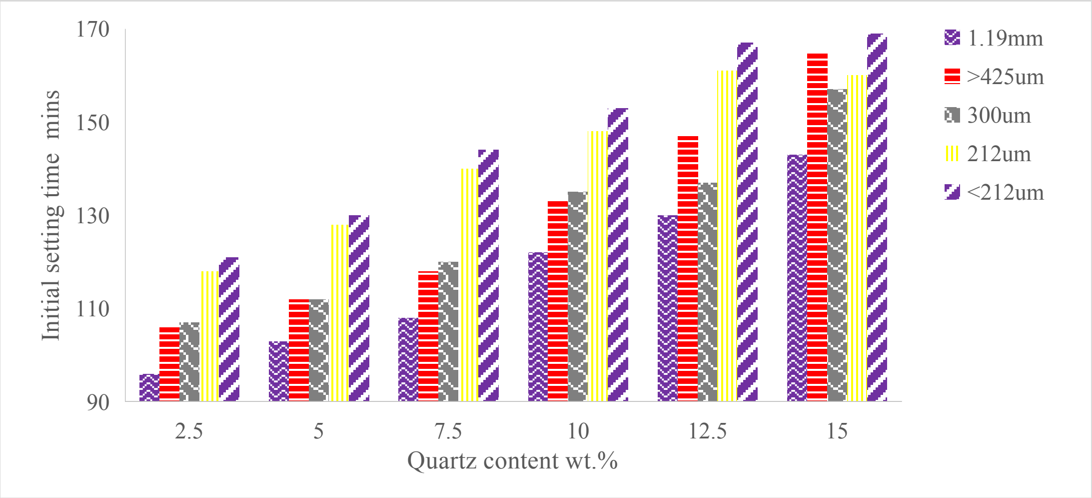

Figure 2. Effect of cement replacement on the initial setting time of PLC blends of various QP particle size

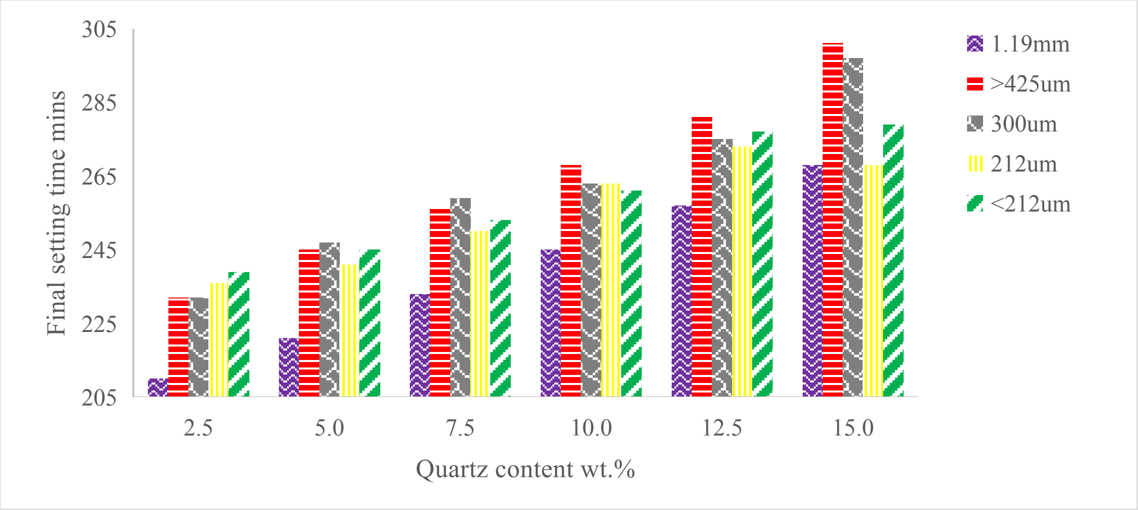

Figure 3. Effect of cement replacement on the Final setting time of PLC blends of various QP particle size

tion). Another reason for the elongated initial and final setting time could be linked with an increase in silica content which agrees with Zhu *et al.* [16] in which increase in the silica fume content led to a significantly elongation in its initial setting time results. Similar trend was observed for various particle sizes between: 1.19 mm ~ 2 mm, 425 µm ~ 1.19 mm, 300 µm ~ 425 µm, 212 µm ~ 300 µm and less than 212 µm respectively. It could also be observed that as the cement replacement level was increased from 2.5 wt.% ~ 15 wt.% at intervals of 2.5 wt.%, the initial setting time retarded from 96 ~ 143, 103 ~ 130, 108 ~ 144, 122 ~ 153, 130 ~ 167, 143 ~ 169 minutes respectively. It could be observed that as the cement replacement level with QP was gradually increased from 2.5 wt.% ~ 12.5 wt.% resulted in a gradual retardation in its setting time at various particle sizes.

Table 4 presents the effect of replacing PLC with QP at 0 wt.% ~ 15 wt.% at 2.5 wt.% interval. Results indicated that the specific gravity of cement blended with QP was lower than PLC employed as control. The decrease in the QP cement blends could be due to the lower specific gravity of the QP which agrees with Friedman *et al.* [8] resulting in lower specific gravity at higher cement replacement level. Since the specific gravity of the PLC is higher than QP.

Table 5 presents the effect of QP content on the mortar compressive strength of cement blends along with the mortar strengths of QP-cement blend expressed as a percentage rate of PLC at the same curing age. A reduction in the mortar compressive strength of PLC blended with QP was experienced as QP content was gradually increased between 2.5 wt.% ~ 15 wt.% at 2.5 wt.% interval. As the cement replacement level with QP content was increased from 0 ~ 15 wt.% resulted in a reduction in the 3-, 7-, 28- and 60-days strength by 85.1%, 67.5%, 63.9% and 70.8% respectively. This diminution in strength could be linked with the decrease in clinker content which is in agreement with Olubajo *et al.* [24] and Olubajo *et al.* [25] resulting in lower 28- and 60-days mortar compressive strength (63.9% and 70.8%) respectively.

Table 4. Variation of QP content on the Specific gravity of the various cement blends

QP wt.%	Specific gravity
0	3.07
2.5	3.05
5.0	3.04
7.5	3.03
10.0	3.02
12.5	3.01
15.0	3.00

Figure 3 indicates the effect of replacing PLC with QP on the mortar compressive strength as curing days progressed. From the compressive strength results, it could be deduced that most of the cement blends produced lower strengths in comparison with control except for 2.5 wt.% QP at curing age of 3 days which was 104.8% of the control strength at 3 days. This strength loss could be attributed to the diminution of the clinker content which is responsible for the formation of calcium silicate hydrate CSH, thus if the C_2S and C_3S content decreased resulting in lower strength which agrees with Waziri and Olubajo [46], Hossain *et al.* [48], Celik et al. [49], Kejela [50]. Similarly, as the curing age progressed from 3 to 60 days, the mortar compressive strength of cement blends as well as the control experienced increments of 53.36%, 32.52%, 50.82%, 20.43%, 43.02%, 43.68% and 27.63%. The increase in the

Table 5. Effect of QP content on the mortar compressive strength at various cement replacements

QP content wt.%	3 days (N/mm^2)	% Gain vs control gain	7 days (N/mm^2)	% Gain vs control gain	28 days (N/mm^2)	% Gain vs control gain	60 days (N/mm^2)	% Gain vs control gain
0	27.32	-	37.05	-	41.30	-	41.90	-
2.5	28.63	104.8	33.48	90.4	35.92	87.0	37.94	90.5
5	26.25	96.1	33.96	91.7	34.3	83.1	39.59	94.5
7.5	27.6	101.0	30.33	81.9	30.98	75.0	33.24	79.3
10	22.99	84.2	24.21	65.3	30.28	73.3	32.88	78.5
12.5	22.3	81.6	23.19	62.6	27.4	66.3	32.04	76.5
15	23.24	85.1	25.01	67.5	26.41	63.9	29.66	70.8

mortar compressive strength as curing age progress can be as a result of formation of more CSH as hydration of the cement matrix. Similar trends have been observed by Olubajo *et al.* [24], Olubajo *et al.* [25], Olubajo *et al.* [26], Waziri and Olubajo [46] and Olubajo *et al.* [51].

Another reason for lower strengths could be due to the high-water demand compared to control. At 28 days compressive strength for 2.5 wt.% and 5 wt.% QP, the cement blends attain 87% and 83.1% of the mortar compressive strength of the control. Thus, the optimal cement replacement with QP should not exceed 5 wt.%. considering early age of 3 days, the strength gain of between 2.5 wt.% (104.8%) and 7.5 wt.% (101.0%) produced significantly better strengths compared to control. Whereas beyond cement replacement of 7.5 wt.% resulted in significant strength loss.

At 2.5 wt.% QP-cement blend for curing ages of 3, 7, 28 and 60 days produced percentage compressive strength approximately 105%, 90%, 87% and 91% of the control' compressive strength respectively. The percentage mortar strength of 5 wt.% QP-cement blend in comparison with PLC at 3, 7, 28 and 60 curing ages were 96%, 92%, 83% and 95% respectively. For 7.5% QP-cement blend produced percentage compressive strength to control of 102%, 82%, 75% and 79% for 3, 7, 28 and 60 days respectively. For 10 wt.% QP-cement blend produced percentage compressive strength to control of 84%, 65%, 73% and 79% for 3, 7, 28 and 60 days respectively whereas for 12.5 wt.% QP-cement blend produced percentage compressive strength to control of 82%, 63%, 66% and 77%; for 15 wt.% QP-cement blend produced percentage compressive strength to control of 85%, 68%, 64% and 71% for 3, 7, 28 and 60 days respectively.

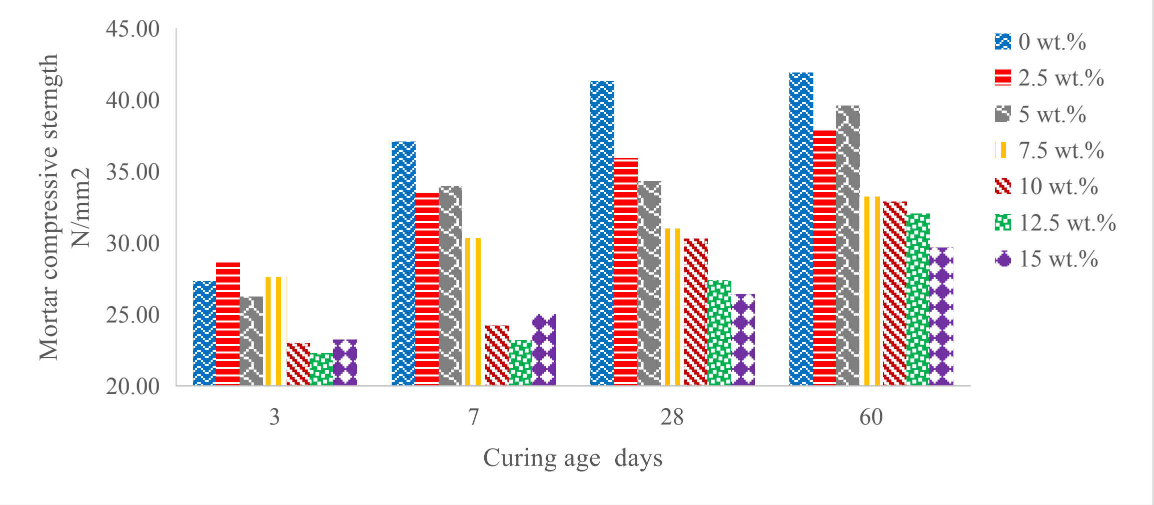

Figure 4. Effect of Curing age and QP content on the mortar compressive strength of cement blends

4. Conclusions

The following conclusions on the investigation of the effect of QP particle size and content on the cement properties are as follows: First of all, the QP chemical composition via X-ray fluorescence spectrometer indicated a significantly high silica content of 89.3 wt.%, alumina of 1.72 wt.% and Ferric oxide of 0.38 wt.% $SiO_2 + Al_2O_3 + Fe_2O_3$ (91.10 wt.%) which suggests that might possess pozzolanic properties according to with CaO content less than 10% at 7.74 wt.% which met Class F according to ASTM C618. Secondly, an increase in cement replacement with QP between 2.5 wt.% to 15 wt.% resulted in a reduction in its specific gravity. An increase in water consistence of QP-PLC blend occurred as cement was gradually replaced with QP at a given particle size. An increase in the QP surface area from 1.19 mm to 300 μm produced an increase in the water consistence of the cement blends ranging from 10.35 wt.% ~ 25 wt.% at a given cement replacement. Whereas for particle size below 300 μm produced higher water consistence in comparison with QP particle size of 1.19 mm. An increase in the water consistence of QP-PLC was experienced as the surface area of QP was enhanced at a given cement replacement. Thirdly, an elongation in the initial and final setting time was experienced as the particle size was enhanced (increased surface area), whereas an increase in cement replacement with QP content at given particle size resulted in a retardation in both setting times. This elongation in the setting time could be attributed to either clinker diminution or presence of silica. Finally, the mortar compressive strength of QP-cement blend experienced an increase as the curing age progressed at various cement replacements whereas, as the cement replacement level with QP content was gradually increased, resulted in a diminution in the strength in comparison with control. This could be linked with high water demand resulting in lower strengths coupled with diminution of the clinker content. The optimal QP content was determined at 5 wt.% owing to the fact that the physicomechnical properties did not significantly deviate from those of PLC as control. All the QP-cement blends fell within ASTM standards based on the cement properties.

Conflict of Interest

The authors declared that they have no conflict of interest.

Acknowledgments

The authors wish to thank Ashaka Cement Plc Nigeria and the departments of Chemical and Civil Engineering of Abubakar Tafawa Balewa University, Bauchi Nigeria for providing infrastructure, facilities and their support to this research work.

References

[1] Khan, M.N.N., Jamil, M., Karim, M.R., et al., 2017. Filler effect of pozzolanic materials on the strength and microstructure development of mortar. KSCE Journal of Civil Engineering. 21(1), 274-284.

[2] Soumya, G., Karthiga, S., 2018. Study on mechanical properties of concrete using silica fume and quartz sand as replacements. International Journal of Pure and Applied Mathematics. 119(14), 151-157.

[3] Zhang, H., Ji, T., Lin, X., 2019. Pullout behavior of steel fibers with different shapes from ultra-high-performance concrete (UHPC) prepared with granite powder under different curing conditions. Construction and Building Materials. 211, 688-702.

[4] Du, J., Meng, W., Khayat, K.H., et al., 2021. New development of ultra-high-performance concrete (UHPC). Composites Part B: Engineering. 224, 109220.

[5] Lin, R.S., Wang, X.Y., Zhang, G.Y., 2018. Effects of Quartz Powder on the Microstructure and Key Properties of Cement Paste. Sustainability. 10(3369), 1-16.

[6] Zuo, R.F., Du, G.X., Yang, W.G., et al., 2016. Mineralogical and chemical characteristics of a powder and purified quartz from Yunnan Province. Open Geosci. 8, 606-611.

[7] Afahnwie, N., Kedia, A., Suh, C., et al., 2022. The Potential of Quartzitic Veins in SW Cameroon for High-Purity Quartz. International Journal of Geosciences. 13, 281-302.

[8] Friedman, H., Koegel, D., Gilden, M., et al., 2014. Retrieved from http://www.minerals.net/GeneralInfromation.aspx.

[9] Obot, M.U., Yawas, D.S., Aku, S.Y., et al., 2016. An assessment on the production of abrasive sandpaper from locally sourced materials. Tribology in Industry. 38(2), 176.

[10] Collivignarelli, M.C., Ricciardi, G.C.P., Miino, M.C., et al., 2020. The production of sustainable concrete with the use of alternative aggregates: A review. Sustainability. 12, 7903.

[11] Dash, M.K., Patro, S.K., Rath, A.K., 2016. Sustainable use of industrial-waste as partial replacement of fine aggregate for preparation of concrete – A review. International Journal of Sustainable Built Environment. 5(2), 484-516.

[12] Li, C., Jiang, L., 2020. Utilization of limestone powder as an activator for early-age strength improve-

ment of slag concrete. Construction and Building Materials. 253, 119257.

[13] Moon, G.D., Oh, S., Jung, S.H., et al., 2017. Effects of the fineness of limestone powder and cement on the hydration and strength development of PLC concrete. Construction and Building Materials. 135, 129-136.

[14] Celik, K., Hay, R., Hargis, C.W., et al., 2019. Effect of volcanic ash pozzolan or limestone replacement on hydration of Portland cement. Construction and Building Materials. 197, 803-812.

[15] He, W., Liao, G., 2021. Effects of nano-CSH seed crystal on early-age hydration process of Portland cement. Fullerenes, Nanotubes and Carbon Nanostructures. 1-8.

[16] Zhu, J., Zhang, R., Zhang, Y., et al., 2019. The fractal characteristics of pore size distribution in cement-based materials and its effect on gas permeability. Scientific Reports. 9, 1-12.

[17] Lin, R.S., Wang, X.Y., 2021. Effects of cement types and addition of quartz and limestone on the normal and carbonation curing of cement paste. Construction and Building Materials. 305, 124799.

[18] Bezerra, A.C.S., Saraiva, S.L.C., Lara, L.F.S., et al., 2017. Effect of partial replacement with thermally processed sugar cane bagasse on the properties of mortars. Review of Materials. 22, 20.
DOI: https://doi.org/10.1590/s1517-707620170 001.0117

[19] John, E., Matschei, T., Stephan, D., 2018. Nucleation seeding with calcium silicate hydrate–A review. Cement and Concrete Research. 113, 74-85.

[20] Bai, S., Guan, X., Li, G., 2022. Early-age hydration heat evolution and kinetics of Portland cement containing nano-silica at different temperatures. Construction and Building Materials. 334, 127363.

[21] Menezes, R.M.R.O., da Silva, R.M., Figueiredo, E.P., et al., 2018. Hydraulic binder obtained from recycled cement and sand powder. Revista IBRACON de Estruturas e Materiais. 11, 1178-1185.

[22] Yao, G., Cui, T., Zhang, J., et al., 2020. Effects of mechanical grinding on pozzolanic activity and hydration properties of quartz. Advanced Powder Technology. 31(11), 4500-4509.

[23] Kadri, E.H., Aggoun, S., De Schutter, G., et al., 2010. Combined effect of chemical nature and fineness of mineral powders on Portland cement hydration. Materials and Structures. 43, 665-673.

[24] Olubajo, O.O., Nuuman, A., Likita, N.S., 2020. The Effect of sugarcane bagasse ash on the properties of Portland limestone cement. American Journal of Construction and Building Materials. 4(2), 77-87.

[25] Olubajo, O.O., Isa, Y.M., Ayeni, S., et al., 2020. A Study on Ordinary Portland cement blended with Rice Husk Ash and Metakaolin. Path of Science. 6(1), 3001-3019. Available on website link: http://www.pos.org.

[26] Olubajo, O.O., Abubakar, J., Osha, O.A., 2020. The effect of eggshell ash and locust bean pod ash on the compressive strength of ternary cement. Path of Science. 6(3), 4001-4016. Available on website link: http://www.pos.org.

[27] Tavares, L.R.C., Junior, J.F.T., Costa, L.M., et al., 2020. Influence of quartz powder and silica fume on the performance of Portland cement. Scientific Reports.

[28] Tchamo, L.C.C., Libessart, L., Djelal, C., et al., 2020. Pozzolanic activity of kaolin containing aluminum hydroxide. Scientific Reports. 10, 2-13.

[29] Maljaee, H., Madadi, R., Paiva, H., et al., 2021. Incorporation of biochar in cementitious materials: A roadmap of biochar selection. Construction and Building Materials. 283, 122757.

[30] Saedi, A., Jamshidi-Zanjani, A., Darban, A.K., 2020. A review on different methods of activating tailings to improve their cementitious property as cemented paste and reusability. Journal of Environmental Management. 270, 110881.

[31] Olubajo, O.O., Osha, O.A., El-Natafty, U.A., et al., 2017. A study on Coal bottom ash and limestone effects on the hydration and physico-mechanical properties of ternary cement blends. Ph.D. Thesis. Abubakar Tafawa Balewa University, Bauchi, Nigeria. 1-305.

[32] Arroudj, K., Lanez, M., Oudjit, M.N., 2015. Characterization of cement mortar based on fine quartz, World Academy of Science Engineering and Technology. International Journal of Structural and Construction Engineering. 9(9), 1278-1281.

[33] Tikkanen, J., 2014. Effects of mineral powders on hydration process and hydration products in normal strength concrete. Construction and Building Materials. 72, 7-14.

[34] Popek, M., Sadowski, L., 2017. Selected physical properties of concrete modified using mineral powders. Procedia Engineering. 172, 891-896.

[35] Popek, M., Sadowski, L., 2017. Effect of selected mineral admixtures on mechanical properties of concrete. Key Engineering Materials. 728, 367-372.

[36] Popek, M., Sadowski, L., Szymanowski, J., 2016. Abrasion resistance of concrete containing selected mineral powders. Procedia Engineering. 153, 617-622.

[37] Ahmed, H.A.R., Mohamed, M., Mashaly, A.A., 2018. Mechanical and fracture mechanics properties of ultra-high-performance concrete. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE). 15(5), 33-39.

[38] Galiska, A., Czarnecki, S., 2017. The effect of mineral powders derived from industrial wastes on selected mechanical properties of concrete. IOP Conference Series: Materials Science and Engineering. 245, 1-7.

[39] Borges, A.L., Soares, S.M., Taís Freitas, T.O.G., et al., 2021. Evaluation of the pozzolanic activity of glass powder in three maximum grain sizes. Materials Research. 24(4), 1-11.

[40] IS:4031(Part 4):1988-Methods of physical tests for hydraulic cement (Determination of normal consistence).

[41] IS:4031(Part 5):1988-Methods of physical tests for hydraulic cement (Determination of initial and final setting times).

[42] ASTM C 191, 2008. Standard test method for time of setting of hydraulic cement by vicat needle. Annual Book of ASTM Standards.

[43] ASTM C 187, 2010. Standard test method for normal consistency of hydraulic cement. Annual Book of ASTM Standards.

[44] ASTM C 109, 2008. Standard test method for compressive strength of hydraulic cement mortars. Annual Book of ASTM Standards.

[45] ASTM C 618, 2008. Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. Annual Book of ASTM Standards.

[46] Olubajo, O., Waziri, H., 2022. Potentials of Balanite Endocarp Pod ash as a cement replacement material. Journal of Building Material Science. 4(1), 44-53. DOI: https://doi.org/10.30564/jbms.v4i1.4800

[47] Kumar, A., Oey, T., Falzone, G., et al., 2017. The filler effect: The influence of filler content and type on the hydration rate of tricalcium silicate. Journal of the American Ceramic Society. 100(7), 3316-3328.

[48] Hossain, M.M., Karim, M.R., Hasan, M., et al., 2016. Durability of mortar and concrete made up of pozzolans as a partial replacement of cement: A review. Construction and Building Materials. 116, 128-140.

[49] Celik, K., Hay, R., Hargis, C.W., et al., 2019. Effect of volcanic ash pozzolan or limestone replacement on hydration of Portland cement. Construction and Building Materials. 197, 803-812.

[50] Kejela, B.M., 2020. Waste paper ash as partial replacement of cement in concrete. American Journal of Construction and Building Materials. 4(1), 8-13.

[51] Olubajo, O.O., 2020. The Effect of Eggshell Powder and Saw Dust Ash on the physico-mechanical properties of blended cement. American Journal of Construction and Building Materials. 4(2), 78-88.

[52] Suraneni, P., Weiss, J., 2017. Examining the pozzolanicity of supplementary cementitious materials using isothermal calorimetry and thermogravimetric analysis. Cement & Concrete Composites. 83, 273-278.