VOL. 15, NO. 15, AUGUST 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

UTILIZING LOCAL NATURAL POZZOLAN AS PARTIAL REPLACEMENT FOR CEMENT AND SAND IN CEMENT MORTAR CUBES WITH SILICA FUME

Hany A. Dahish[1,3], Saud Almutairi[1], Ahmed F. Elragi[2,3] and Sherif M. Elkholy[2]
[1]Civil Engineering Department, College of Engineering, Qassim University, Unaizah, Saudi Arabia
[2]Civil Engineering Department, College of Engineering, Qassim University, Buraydah, Saudi Arabia
[3]Civil Engineering Department, Faculty of Engineering, Fayoum University, Fayoum, Egypt
E-Mail: had00@fayoum.edu.eg

ABSTRACT

The concrete is considered as one of the most important building materials. Ordinary Portland cement is used as binding material in concrete production. The manufacturing process of cement is accompanied with carbon dioxide emission. The use of green concrete as environmentally friendly material is very important. The local natural pozzolan (LNP) found in volcanic areas in Almadinah Almunawara in Saudi Arabia may be used as partial replacement of cement and sand to produce lightweight, environmental friendly concrete with special properties and improved mechanical properties. The main objective of this study is to investigate the effect of partial replacement of cement by weight with local natural pozzolan powder in cement mortar cubes to reduce carbon gas emissions and energy in the manufacturing process of cement. The study also includes the effect of partial substitution for sand used in cement mortars with (LNP) and with partial substitution for cement with silica fume on its mechanical properties. The use of pozzolan with special type of cement is recommended by the Saudi Building Code in case of concrete exposed to sulfate and / or chloride with severe exposure. The experimental work was carried out on 84 cement mortar cubes (50 mm in size). The specimens comprised two groups: cement replacement by weight with (LNP) powder at levels ranged from 10% to 40% and sand replacement by volume with (LNP) at levels ranged from 10% to 40% in addition to cement replacement by weight with silica fume at levels ranged from 0% to 10%. The specimens were tested at 28 and 180 days. The utilization of (LNP) and silica fume showed a marked influence on the mechanical properties of cement mortar especially in the case of sand replacement with (LNP).

Keywords: cement, sand replacement, local natural pozzolan, silica fume, mortar, mechanical properties.

1. INTRODUCTION

The natural pozzolan is locally available in volcanic areas in Al-Madinah Al-Munawarah, KSA. It contains siliceous and aluminous materials. It can be used in blended cement manufacturing because of its availability [1]. It can be used as mineral admixtures for concrete production and it was beneficial to use it in hot climate regions as a result of the reduction of hydration rate of cement due to its use as cement partial replacement [2]. The use of natural pozzolan as cement partial replacement in high performance concrete had no bad effect on its performance [3]. The utilization of natural pozzolan and ferronickel slag in blended cement gave a reduction in the rate of hydration at early ages [4]. Al-Chaar *et al*. [5] used the (NP) as cement replacement in concrete. The use of natural pozzolan decreased the hydration rate which is good for concrete exposed to sulfate attack.

S. Ahmad *et al*. [6] utilized various mineral admixtures as a substitution for sand and silica fume in concrete. The addition of mineral admixtures as fly ash or blast furnace slag decreased the required quantity of cement and silica fume [7]. Many studies investigated the use of supplementary cementing materials as partial replacement of cement in concrete [8 to 11].

Many researchers have been investigated the possibility of using various materials as partial substitution for sand in concrete to improve its mechanical properties. Ghasan *et al*. [12] replaced quantity of sand in mortar with spent garnets in addition to fly ash and they concluded that the replacement of sand with spent garnets up to 25% did not affect the strength. The 40% replacement of sand with spent garnet contributed thermal stability for high strength concrete [13].

The utilization of plastic waste as a replacement for sand in concrete had been conducted by many researches. The replacement of 10% of sand with plastic waste saved 820 million tons of natural sand yearly [14]. The use of plastic waste as partial replacement of sand in concrete improved energy absorption for concrete under impact loading [15].

The utilization of waste foundry sand in concrete reduced the consistency and compressive strength of it while the performance of mortar with calcined foundry sand was the same as of natural sand [16]. Cheah *et al*. [17] studied the possibility of sand replacement with granite quarry. The level of replacement up to 60% improved both compressive strength and flexural strength. The substitution for 5% of cement and 15% of sand with limestone fines improved the compressive strength of concrete [18].

The replacement of sand with raw vermiculite decreased the strength of cement mortars when exposed to high temperatures [19]. The partial substitution for sand with copper slag was recommended at level up to 50% to produce environmentally friendly concrete [20].

In this research, the possibility of utilizing local natural pozzolan as partial replacement for both cement and sand in cement mortar cubes with the presence of silica fume to improve the mechanical properties of environmental friendly concrete was investigated.

2. MATERIALS

The used materials are natural sand, local natural pozzolan, silica fume and cement. The properties of mortar ingredients are as follows.

2.1 Natural Sand and Local Natural Pozzolan (LNP)

Table-1 shows the properties of natural sand and local natural pozzolan.

Table-1. Natural sand and (LNP) properties.

	Natural Sand	(LNP)	
Bulk density	1670	1100	kg/m^3
Specific gravity	2.60	2.51	
Moisture content	0.10	1.33	%
Absorption	0.21	5.23	%

The (LNP) is the ground form found in volcanic areas located in Almadinah Almunawara, KSA. The gradation for the used natural sand and local natural pozzolan as a partial substitution for sand is shown in Figure-1. The chemical composition of (LNP) is shown in Table-2. Parts of the (LNP) were ground to powder to achieve a fineness of 2000 to 3000 cm^2/g.

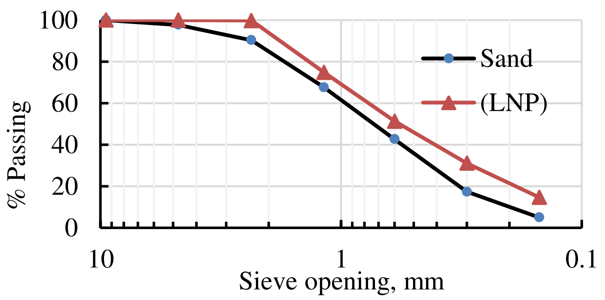

Figure-1. Gradation for natural sand and (LNP).

Table-2. Chemical compositions of (LNP).

Oxides	SiO_2	Al_2O_3	Fe_2O_3	Ca O
Weight, %	41.12	15.44	17.35	11.21
Oxides	**Mg O**	**SO_3**	**K_2O**	**Na_2O**
Weight, %	4.47	0.18	1.05	0.25
Loss on ignition		2.2		

2.2 Ordinary Portland Cement

Table-3 shows the chemical properties of used ordinary Portland cement.

Table-3. Chemical properties of cement.

Oxides	SiO_2	Al_2O_3	Fe_2O_3	Ca O
Weight, %	19.97	5.85	3.43	64.13
Oxides	**Mg O**	**SO_3**	**LOI (%)**	
Weight, %	0.6	2.8	1.6	
Fineness-Blaine (cm^2/g)			3148	

2.3 Silica Fume

Table-4 shows the chemical properties of used silica fume.

Table-4. Chemical properties of silica fume.

Oxides	SiO_2	Al_2O_3	Fe_2O_3
Weight, %	92	1.0	1.0
Oxides	**Ca O**	**Mg O**	**SO_3**
Weight, %	0.3	0.6	0.3
Fineness-Blaine (cm^2/g)		150000-200000	

3. EXPERIMENTAL PROGRAM

The experimental work comprises two parts according to the type of replacement of cement or sand with (LNP). The first part was the effect of partial substitution for cement in mortars with (LNP) powder and the second part was the effect of partial substitution for sand in mortars with (LNP) in addition to partial substitution for cement by weight with silica fume on the mechanical properties of cement mortar cubes.

Eighty-four cement mortar cubes of 50x50x50 mm were prepared. Six cubes as control specimens, 24 cubes of cement replacement by weight with (LNP) powder at percentages of 10%, 20%, 30% and 40%, 24 cubes of sand replacement by volume with (LNP) at percentages of 10%, 20%, 30% and 40% without silica fume, 15 cubes with sand replacement by volume with (LNP) at replacement levels of 0%, 10%, 20%, 30% and 40% and with 5% substitution for cement by weight with silica fume, and 15 cubes with sand replacement by volume with (LNP) at replacement levels of 0%, 10%, 20%, 30% and 40% and with 10% replacement of cement by weight with silica fume). Figure-2 shows the flowchart of the experimental work. The prepared specimens were in accordance with ASTM C 109. The specimens were covered with polyethylene sheets for 1 day after casting process. The specimens were demolded after 24 hours and were immersed in water storage tanks at a temperature of 22 ± 2 °C. The specimens were tested after 28 and 180 days of curing.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

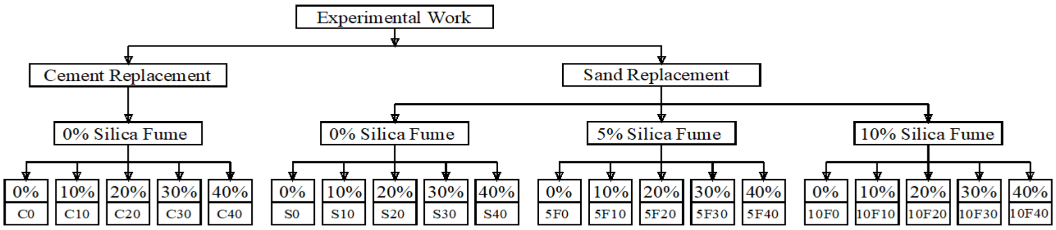

Figure-2. Experimental work.

3.1 Test Procedures

The ratio of water/cement (w/c) was 0.49 for all specimens. Tables-5 shows the quantities of used materials for both cases of cement and sand replacement.

Table-5. Constituent materials used to prepare specimens.

Specimen	% of cement repl.by weight with (LNP)	% of sand repl. by volume with (LNP)	Natural Sand (gm)	NP as cement (gm)	NP as sand repl. (gm)	Silica (gm)	Cement (gm)	Water (gm)	w/c ratio
C0, S0	0%	--	1356	0.0	--	--	490	239	0.49
C10	10%	--	1356	49	--	--	441	239	0.49
C20	20%	--	1356	98	--	--	392	239	0.49
C30	30%	--	1356	147	--	--	343	239	0.49
C40	40%	--	1356	196	--	--	294	239	0.49
S10	--	10%	1220	--	90	--	490	239	0.49
S20	--	20%	1084	--	180	--	490	239	0.49
S30	--	30%	949	--	270	--	490	239	0.49
S40	--	40%	814	--	360	--	490	239	0.49
5F0	--	0%	1356	--	0	24.5	465.5	239	0.49
5F10	--	10%	1220	--	90	24.5	465.5	239	0.49
5F20	--	20%	1084	--	180	24.5	465.5	239	0.49
5F30	--	30%	949	--	270	24.5	465.5	239	0.49
5F40	--	40%	814	--	360	24.5	465.5	239	0.49
10F0	--	0%	1356	--	0	49.0	441	239	0.49
10F10	--	10%	1220	--	90	49.0	441	239	0.49
10F20	--	20%	1084	--	180	49.0	441	239	0.49
10F30	--	30%	949	--	270	49.0	441	239	0.49
10F40	--	40%	814	--	360	49.0	441	239	0.49

Mixing was done in an electrically driven mechanical mixer of the epicyclic type conforming ASTM C305. The percentages of cement replacement by weight with (LNP) powder were 10%, 20%, 30% and 40%, the percentages of partial replacement of sand by volume with (LNP) were 10%, 20%, 30% and 40% and the percentages of cement replacement by weight with silica fume were 0%, 5% and 10%. Figure-3 shows part of specimens after molding and before curing.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

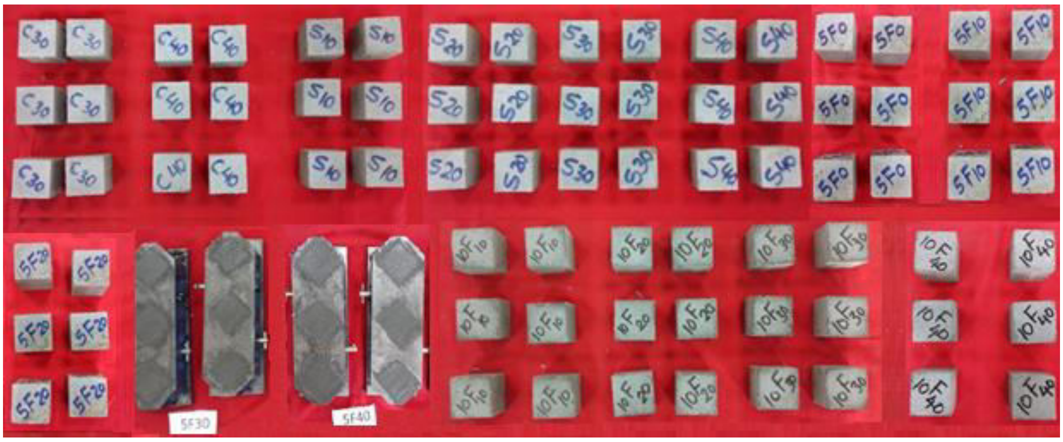

Figure-3. Mortar Specimens (cement and sand replacement).

4. METHODS

4.1 Compressive Strength

Compressive strengths were measured using 50 mm cube specimens after periods of 28 and 180 days of curing for both cases of cement and sand replacement in cement mortars without silica fume. The sand replacement specimens with (LNP) in addition to cement replacement by weight with silica fume were tested after 28 days of curing. The reported value was the average of three specimens tested under compression at each curing period.

4.2 Ultrasonic Pulse Velocity (UPV).

The ultrasonic pulse velocity gives an indication to how dense is the hardened concrete and its density. The speed of the wave increases when the concrete is denser and the strength also increases. The ultrasonic pulse velocities were measured for tested specimens after 28 days of curing.

5. RESULTS AND DISCUSSIONS

5.1 Compressive Strength

Table-6 shows the compressive strengths of all tested cement mortar cubes after 28 days of curing.

Table-6. Compressive strength of mortar cubes.

Cement Replacement (0 % silica fume)			Sand Replacement (0 % silica fume)			Sand Replacement (5 % silica fume)			Sand Replacement (10 % silica fume)		
Specimen	$\sigma_{comp.}$, 28 days, MPa	% σ_{comp} to that one without LNP	Specimen	$\sigma_{comp.}$, 28 days, MPa	% σ_{comp} to that one without LNP	Specimen	$\sigma_{comp.}$, 28 days, MPa	% σ_{comp} to that one without LNP	Specimen	$\sigma_{comp.}$, 28 days, MPa	% σ_{comp} to that one without LNP
C0	45.91	100.0	S0	45.91	100.0	5F0	60.52	131.8	10F0	62.62	136.4
C10	39.60	86.24	S10	48.67	106.0	5F10	56.06	122.1	10F10	58.82	128.1
C20	37.46	81.58	S20	47.33	103.09	5F20	54.84	119.4	10F20	54.68	119.1
C30	26.66	58.08	S30	44.56	97.05	5F30	46.43	101.1	10F30	51.99	113.2
C40	20.80	45.30	S40	38.25	83.31	5F40	42.81	93.25	10F40	47.56	103.6

5.1.1 Effect of cement partial replacement by weight with (LNP) powder

The effect of the cement substitution with (LNP) powder on the compressive strength of cement mortars after 28 days of curing is shown in Figure-4. The compressive strength of cement mortars C0, C10, C20, C30 and C40 with cement replacement by weight with (LNP) powder at replacement levels of 0%, 10%, 20%, 30% and 40% are 45.91, 39.60, 37.46, 26.66 and 20.80 MPa, respectively. The effects of percentage of cement replacement of 10%, 20%, 30% and 40% on strength reduction were 13.74%, 18.41%, 41.93% and 54.69%, respectively. It was noticed that the compressive strength of cement mortar with more than 20% of cement replacement with (LNP) powder showed severe reduction in compressive strength when compared to those with less than 20 % of cement replacement after 28 curing days.

VOL. 15, NO. 15, AUGUST 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

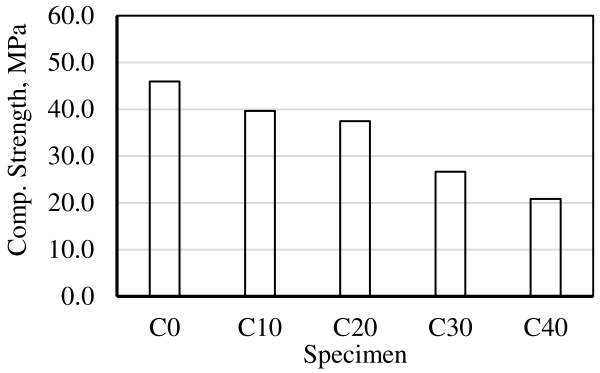

Figure-4. Compressive strength of mortar cubes (Cement replacement).

5.1.2 Effect of sand replacement by volume with (LNP) without silica fume

The effect of sand replacement with (LNP) on the compressive strength of cement mortars after 28 days of curing is shown in Figure-5. The compressive strength of cement mortars S0, S10, S20, S30 and S40 with sand replacement by volume with (LNP) at replacement levels of 0%, 10%, 20%, 30% and 40% are 45.91, 48.67, 47.33, 44.56 and 38.25 MPa, respectively. The compressive strength increased by 6% and 3.1% for sand replacement levels of 10% and 20%, respectively compared with control specimen and decreased by 3% and 16.7% for sand replacement levels of 30% and 40%, respectively. It can be noticed that the compressive strength of cement mortar with more than 20% of sand replacement with (LNP) showed low compressive strength when compared to those with less than 20 % of sand replacement by volume with (LNP) at 28 days of curing.

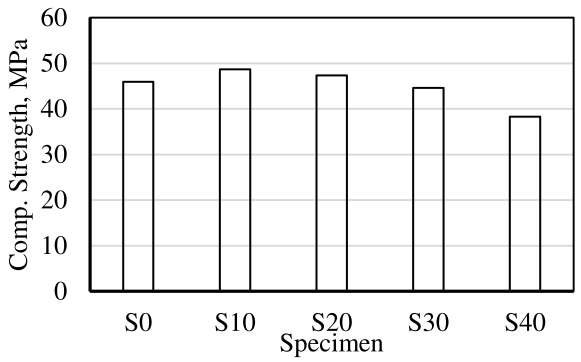

Figure-5. Compressive strength of mortar cubes (Sand replacement and 0% silica fume).

5.1.3 Effect of sand replacement by volume with (LNP) with 5% cement replacement by weight with silica fume

The effect of sand replacement by volume with (LNP) and 5% cement replacement by weight with silica fume on the compressive strength of cement mortars after 28 days of curing is shown in Figure-6. The compressive strength of cement mortars 5F0, 5F10, 5F20, 5F30 and 5F40 with sand replacement by volume with (LNP) at replacement levels of 0%, 10%, 20%, 30% and 40% are 60.52, 56.06, 54.84, 46.43 and 42.81 MPa, respectively. The compressive strength increased by 31.80%, 22.10%, 19.45% and 1.10% for sand replacement levels of 0%, 10%, 20% and 30%, respectively compared with control specimen. It can be noticed that the compressive strength of cement mortars with more than 30% of sand replacement with (LNP) showed low compressive strength when compared to those with less than 30 % of sand replacement by volume with (LNP) and 5% cement replacement by weight with silica fume.

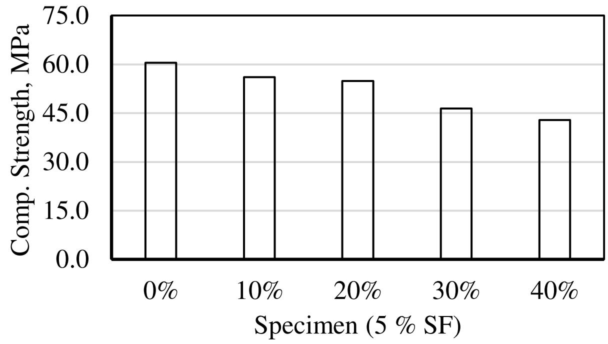

Figure-6. Compressive strength of mortar cubes (Sand replacement and 5% silica fume).

5.1.4 Effect of sand replacement by volume with (LNP) with 10% cement replacement by weight with silica fume

The effect of sand replacement by volume with (LNP) and 10% cement replacement by weight with silica fume on the compressive strength of cement mortars after 28 days is shown in Figure-7. The compressive strength of specimens 10F0, 10F10, 10F20, 10F30 and 10F40 with sand replacement levels of 0%, 10%, 20%, 30% and 40% are 62.62, 58.82, 54.68, 51.99 and 47.56 MPa, respectively. The compressive strength increased by 36.40%, 28.10%, 19.10%, 13.20% and 3.60% for sand replacement levels of 0%, 10%, 20%, 30% and 40%, respectively compared with control specimen. It can be noticed that the compressive strength of cement mortar with up to 40% of sand replacement with (LNP) and 10% cement replacement by weight with silica fume showed increase in compressive strength when compared with control specimen.

Figure-7. Compressive strength of mortar cubes (Sand replacement and 10 % silica fume).

VOL. 15, NO. 15, AUGUST 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

5.1.5 Cement and sand replacement effect without silica fume on compressive strengths

Figure-8 shows the compressive strengths of mortar cubes for both cases of cement replacement by weight and sand replacement by volume with (LNP) after 28 days of curing. It can be seen that the partial substitution for sand by volume with (LNP) of 10% improved the compressive strength by 23% when compared to cement mortar with partial cement replacement by weight with 10% (LNP) powder and by 6% increase in case of specimen without replacement with (LNP).

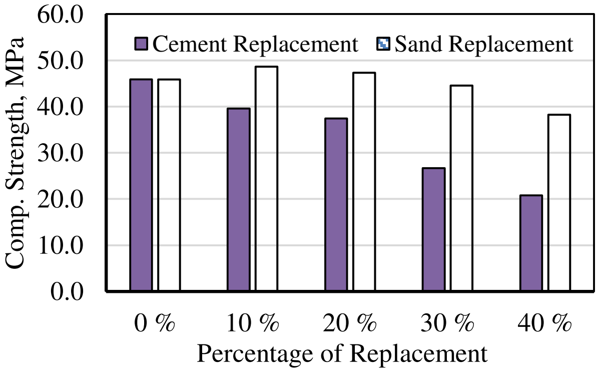

Figure-8. Compressive strength of mortar cubes (Cement and Sand replacement without silica fume).

5.1.6 Silica fume effect on compressive strength

The compressive strengths of mortar cubes for various levels of sand replacement were measured at 28 days. Figure-9 shows the compressive strengths of three groups of specimens at different levels of sand replacement with (LNP) in addition to cement replacement by weight with silica fume at percentages of 0%, 5% and 10%.

The compressive strength increased by 6% for sand replacement levels of 10% and by 3.1% for replacement level of 20% compared with control specimen without sand replacement.

The compressive strength increased by 31.80% for specimen without replacement of sand and with 5% cement substitution with silica fume. The compressive strength of specimens with 5% cement replacement with silica fume increased by 22.10%, 19.40% and 1.10% for sand replacement with (LNP) at levels of 10%, 20% and 30%, respectively compared with control specimen.

The compressive strength increased by 36.40% for specimen without replacement of sand and with 10% cement replacement with silica fume. The compressive strength of specimens with 10% cement replacement with silica fume increased by 28.10%, 19.10%, 13.20% and 3.60% for sand replacement with (LNP) at levels of 10%, 20%, 30% and 40%, respectively compared with control specimen.

The results showed that the partial replacement of sand with (LNP) up to 20% increased the compressive strength for specimens without silica fume. It can be noticed that the presence of 5% cement replacement with silica fume increased the compressive strength for cases of sand replacement by volume with (LNP) up to 30%. The presence of 10% cement replacement by weight with silica fume increased the compressive strength for cases of sand replacement by volume with (LNP) up to 40%.

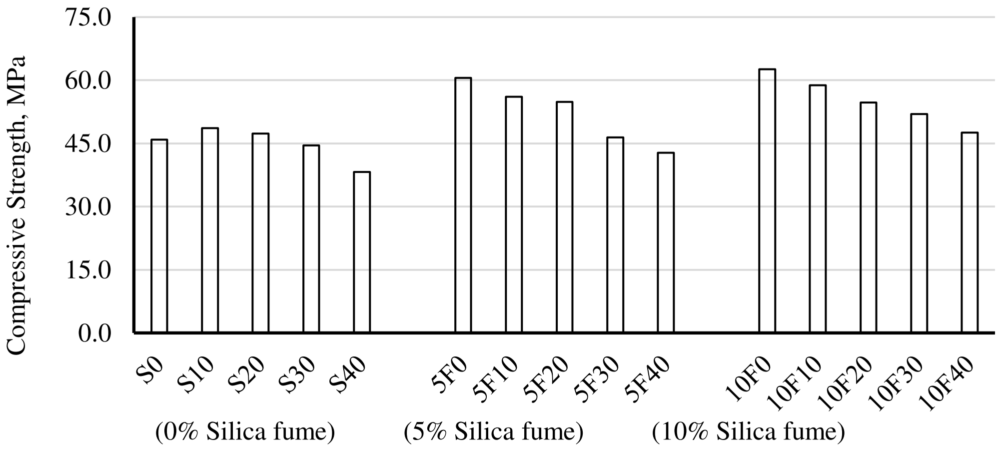

Figure-9. Compressive strength of mortar cubes at 28 days (0%, 5% and 10% SF).

5.2 Ultrasonic Pulse Velocity (UPV)

Ultrasonic pulse velocities at 28 days of all cement mortars for both cases of cement replacement by weight with (LNP) powder and specimens with sand replacement by volume with (LNP) were recorded and shown in Table-7 and Figure-10. The pulse velocity for control specimen was 3498 m/s.

The pulse velocities for specimens C0, C10, C20, C30 and C40 with cement replacement by weight of (LNP) powder with percentages 0, 10, 20, 30 and 40% were 3498, 3472, 3350, 3297 and 3261 m/s. The ultrasonic pulse velocities of specimens S0, S10, S20, S30 and S40 were 3498, 3320, 3450, 3440 and 3400 m/s, respectively. The ultrasonic pulse velocities of specimens 5F0, 5F10,

VOL. 15, NO. 15, AUGUST 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

5F20, 5F30 and 5F40 were 3828, 3613, 3515, 3425 and 3372 m/s, respectively. The ultrasonic pulse velocities of specimens 10F0, 10F10, 10F20, 10F30 and 10F40 were 4012, 3885, 3801, 3709 and 3522 m/s, respectively.

It can be noticed that the increase in the level of replacement with (LNP) decreased the speed of ultrasonic pulse in all cases without and with cement replacement by weight with silica fume. Figure-11 shows the relationship between compressive strength of mortar cubes after 28 days and ultrasonic pulse velocities. The results showed matching between compressive strengths and the ultrasonic pulse velocities.

Table-7. Ultrasonic pulse velocities.

Specimen (0% SF)	Velocities, m/s	Specimen (0% SF)	Velocities, m/s	Specimen (5% SF)	Velocities, m/s	Specimen (10% SF)	Velocities, m/s
C0	3498	S0	3498	5F0	3828	10F0	4012
C10	3472	S10	3320	5F10	3613	10F10	3885
C20	3350	S20	3450	5F20	3515	10F20	3801
C30	3297	S30	3440	5F30	3425	10F30	3709
C40	3261	S40	3400	5F40	3372	10F40	3522

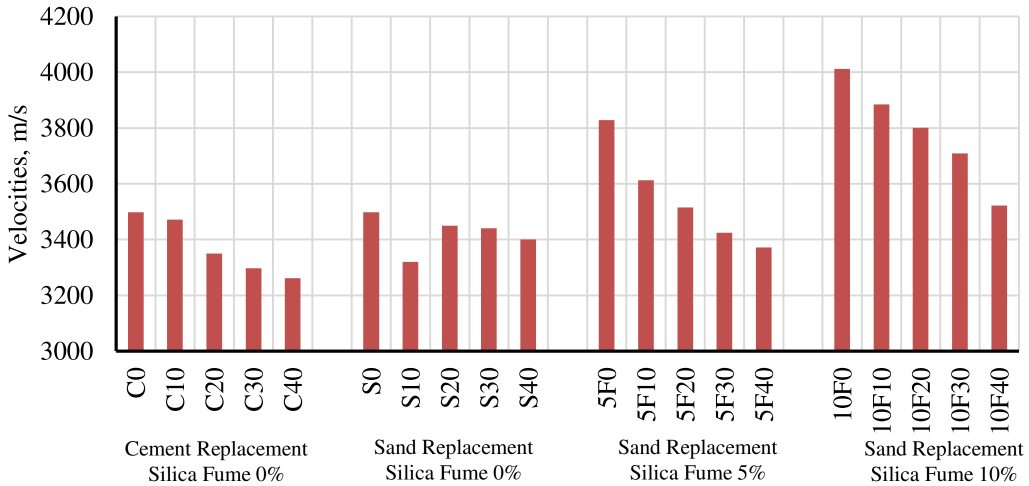

Figure-10. Ultrasonic pulse velocities.

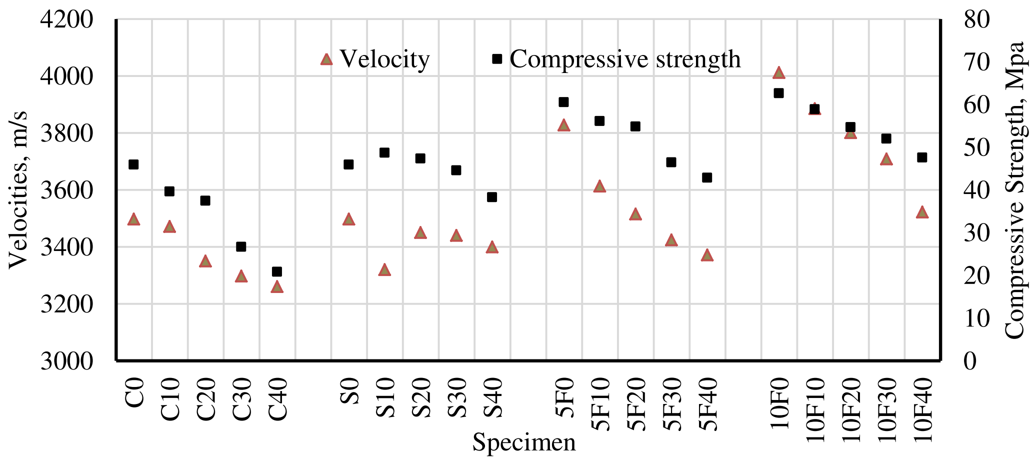

Figure-11. Relationship between compressive strength of mortar cubes after 28 days and ultrasonic pulse velocities.

5.3 Effect of Curing Duration

The compressive strengths of cement mortars for both cases of cement and sand replacement were measured at 28 days and at 180 days. Table-8 and Figure-12 show the compressive strength of mortar cubes after 28 and 180 days for both cases of cement replacement by weight with (LNP) powder and sand replacement by volume with (LNP) without silica fume.

The compressive strength of mortar cubes with cement replacement levels of 10%, 20%, 30% and 40% at 180 days are 48.03, 42.08, 34.22 and 27.42 Mpa, respectively. The results illustrated that the 10% cement replacement by weight with (LNP) powder after 180 days gave a compressive strength greater than that of specimen without cement replacement at 28 days.

The compressive strength of mortar cubes with sand substitution specimens with (LNP) at levels of 10%, 20%, 30% and 40% at 180 days are 50.38, 53.58, 48.22 and 39.90 Mpa, respectively. The results illustrated that the 30% sand replacement by volume with (LNP) after 180 days gave a compressive strength greater than that of specimen without sand replacement at 28 days. The increase in the compressive strengths were 9.7%, 16.7% and 5% for specimens with sand replacement with (LNP) at levels of 10%, 20% and 30%, respectively.

Table-8. Compressive strength of mortar cubes at different ages (Cement & Sand replacement).

Type	Specimen	Compressive strength at 28 days, MPa	Compressive strength at 180 days, MPa
Cement Replacement	C10	39.60	48.03
	C20	37.46	42.08
	C30	26.66	34.22
	C40	20.80	27.42
Sand Replacement	S10	48.67	50.38
	S20	47.33	53.58
	S30	44.56	48.22
	S40	38.25	39.90

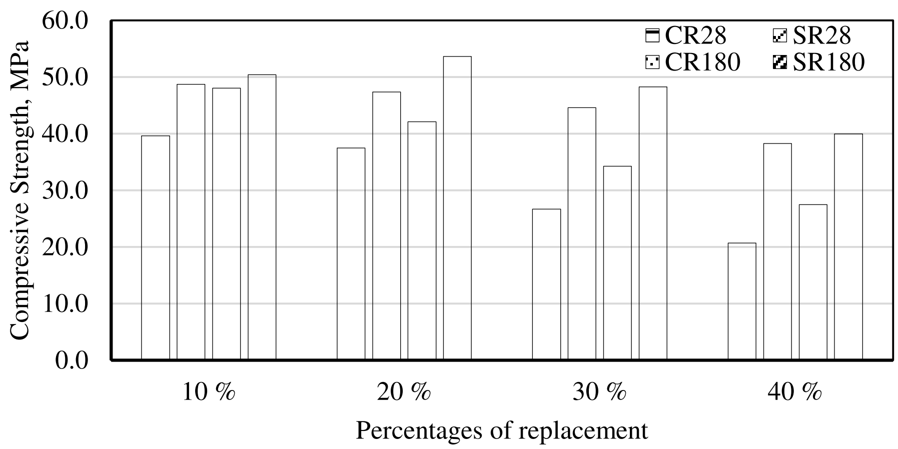

Figure-12. Compressive strength of mortar cubes after 28 and 180 days (Cement and Sand Replacement without SF).

6. CONCLUSIONS

The objective of this research is to study the effect of using local natural pozzolan powder as a partial substitution for cement by weight and the effect of using (LNP) as a partial replacement of sand by volume in addition to the presence of silica fume in cement mortar cubes on its mechanical properties. The mechanical properties of cement mortar cubes were measured at 28 days and at 180 days of curing. The ultrasonic pulse velocities were measured for specimens with both cement and sand replacement at 28 days.

Based on test results, the following conclusions have been obtained:

a) The utilization of (LNP) powder as partial substitution for cement decreased the compressive strength of mortar cubes with the increase of replacement level. It might be due to the need of (LNP) powder to be activated.
b) The utilization of (LNP) as partial substitution for sand by volume increased the compressive strength of cement mortars for replacement level up to 20%

without utilization of silica fume. It might be considered as a result of the reactivity of (LNP).

c) The utilization of (LNP) as a partial substitution for sand by volume increased the compressive strength of mortars for replacement level up to 30% in case of 5% of partial replacement of cement by weight with silica fume because silica fume affects the pore-size distribution of mortars by reacting with calcium hydroxide formed around the sand and LNP grains and also with that dispersed throughout the cement paste.
d) The utilization of (LNP) as partial replacement of sand by volume increased the compressive strength of cement mortar for replacement level up to 40% in case of 10% of partial substitution for cement with silica fume.
e) The compressive strength of cement mortar with cement substitution by weight with (LNP) powder of 10% at 180 days gave a value higher than control specimen at 28 days by 4.6%, while the compressive strength of cement mortar with sand substitution by volume of (LNP) with 10%, 20% and 30% at 180 days gave values higher than control specimen at 28 days by 9.7%, 16.7%, 5%, respectively.
f) The partial replacement of both cement and sand helped in gaining more strength at long ages due to cementitious effect of pozzolan.
g) The results of ultrasonic pulse velocity test on cement mortar cubes in both cases of cement and sand replacement at 28 days were matched with compressive strengths at the same age. The utilization of (LNP) as partial substitution for sand by volume decreased the ultrasonic pulse speed which may help in using it as isolations.

ACKNOWLEDGMENTS

The authors appreciate the support received from Deanship for Scientific Research at Qassim University (QU), Saudi Arabia, for supporting this project under the Standard Research Grants funding - Research Centre for Applied Sciences (Project no. 5112-enuc-2018-1-14-S).

REFERENCES

[1] M. Kemal Ardoga, Sinan T. Erdogan and Mustafa Tokyay. 2019. Effect of particle size on early heat evolution of interground natural pozzolan blended cements. Construction and Building Materials. 206: 210-218.

[2] K. Ezziane, A. Bougara, A. Kadri, H. Khelafi, E. Kadri. 2007. Compressive strength of mortar containing natural pozzolan under various curing temperature. Cement & Concrete Composites. 29: 587-593.

[3] S. Ahmad, K. Own Mohaisen, S. Kolawole Adekunle, S. U. Al-Dulaijan, Mohammed Maslehuddin. 2019. Influence of admixing natural pozzolan as partial replacement of cement and microsilica in UHPC mixtures. Construction and Building Materials. 198: 437-444.

[4] N. Lemonis, P. E. Tsakiridis, N. S. Katsiotis, S. Antiohos, D. Papageorgiou, M.S. Katsiotis, M. Beazi-Katsioti. 2015. Hydration study of ternary blended cements containing ferronickel slag and natural pozzolan. Construction and Building Materials. 81: 130-139.

[5] G. K. Al-Chaar, M. Alkadi and P. G. Asteris. 2013. Natural pozzolan as a partial substitute for cement in concrete. Open Construction and Building Technology Journal. 7: 33-42.

[6] S. Ahmad, I. Hakeem, and M. Maslehuddin. Development of UHPC Mixtures Utilizing Natural and Industrial Waste Materials as Partial Replacements of Silica Fume and Sand. Scientific World Journal, Volume 2014, Article ID 713531.

[7] Halit Yazıcı, H. Yigˇiter, A. S. Karabulut and B. Baradan. 2008. Utilization of fly ash and ground granulated blast furnace slag as an alternative silica source in reactive powder concrete. Fuel. 87(12): 2401-2407.

[8] K. Yang, Y. Jung, M. Cho, S. Tae. 2015. Effect of supplementary cementitious materials on reduction of CO2 emissions from concrete. J. Clean. Prod. 103(15): 774-783.

[9] B. Lothenbach, K. Scrivener, D. Hooton. 2011. Supplementary cementitious materials. Cem. Concr. Res. 41(12): 1244-1256.

[10] H. Owaid, B. Roszilah, M. Taha. 2012. A review of sustainable supplementary cementitious materials as an alternative to all-portland cement mortar and concrete. Aust. J. Basic Appl. Sci. 6(9): 2887-303.

[11] G.K. Al-Chaar, M. Al-Kadi, P. G. Asteris. 2013. Natural pozzolan as a partial substitute for cement in concrete. Open Constr. Technol. J. 7: 33-42.

[12] Ghasan Fahim Huseien, Abdul Rahman Mohd Sam, Kwok Wei Shah, A. M. A. Budiea, and Jahangir Mirza. 2019. Utilizing spend garnets as sand replacement in alkali-activated mortars containing fly ash and GBFS. Construction and Building Materials Journal. 225: 132-145.

[13] Mariyana Aida Ab Kadir, Mohammad Iqbal Khiyon, Abdul Rahman Mohd. Sam, Ahmad Beng Hong Kueh, Nor Hasanah Abdul Shukor Lim, Muhammad Najmi Mohamad Ali Mastor, Nurizaty Zuhan, Roslli Noor Mohamed. 2019. Performance of spent garnet as a sand replacement in high-strength concrete exposed to high temperature. Journal of Structural Fire Engineering. 10(4): 468-481.

[14] J. Thorneycroft, J. Orr, P. Savoikar, R. J. Ball. 2018. Performance of structural concrete with recycled plastic waste as a partial replacement for sand. Construction and Building Materials Journal. 161: 63-69.

[15] Maher Al-Tayeb Mustafa, Ismail Hanafi, Rade Mahmoud, B. A. Tayeh. 2019. Effect of partial replacement of sand by plastic waste on impact resistance of concrete: experiment and simulation. Structures Journal. 20: 519-526.

[16] Paulo Ricardo de Matos, Matheus Felipe Marcon, Rudiele Aparecida Schankoski, Luiz Roberto Prudêncio Jr. 2019. Novel applications of waste foundry sand in conventional and dry-mix concretes. Journal of Environmental Management. 244: 294-303.

[17] Cheah Chee Ban, Lim Jay Sern, Mahyuddin B. Ramli. 2019. The mechanical strength and durability properties of ternary blended cementitious composites containing granite quarry dust (GQD) as natural sand replacement. Construction and Building Materials Journal. 197: 291-306.

[18] Zakaria Skender, Abderrahim Bali & Ratiba Kettab. 2019. Self-compacting concrete (SCC) behaviour incorporating limestone fines as cement and sand replacement. European Journal of Environmental and Civil Engineering.

[19] Mehmet Karatas, Ahmet Benli, Hasan Anil Toprak. 2019. Effect of incorporation of raw vermiculite as partial sand replacement on the properties of self-compacting mortars at elevated temperature. Construction and Building Materials Journal. 221: 163-176.

[20] Aysegul Petek Gursel and Claudia Ostertag. Life-Cycle Assessment of High-Strength Concrete Mixtures with Copper Slag as Sand Replacement. Advances in Civil Engineering. Volume 2019, Article ID 6815348.