International Journal of GEOMATE, Aug. 2023, Vol. 25, Issue 108, pp.172-182
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2023.108.3800
Geotechnique, Construction Materials and Environment

THE EFFECT OF USING LIME, SILICA FUME AND NANO-SILICA ON MORTAR MADE FROM SEA SAND AND SEAWATER

* Antonia Rosalia Indra Tjahjani[1], Jonbi[1], Daral Suraedi[1], Innayyah Nabilla Putri Jun[1] and Risti Bintarti Chandraningtias[1]

[1]Department of Civil Engineering, Faculty of Engineering, Pancasila University, Jagakarsa, South Jakarta, Indonesia

*Corresponding Author, Received: 08 Feb. 2023, Revised: 11 May 2023, Accepted: 28 May 2023

ABSTRACT: The need for natural sand (RS) and freshwater (FW) is not proportional to the existing supply, so substitute materials are needed to meet these needs. Seasand (SS) and seawater (SW) are materials that have the potential as substitute materials which have not been utilized so far. The main obstacle to the use of these materials in mortar and concrete is due to the sodium chloride (NaCl) content which can cause corrosion of the reinforcement. This research is an innovation to overcome the NaCl content mixed with materials: Cement (PC), lime stone (LS), silica fume (SF), nano-silica (NS), and superplasticizer (SP) mixed proportions with a volume ratio, cured with SW and FW. The goal is to produce the optimal composition for the use of SS and SW in mortar. For this reason, tests for water content, organic content, compressive strength, porosity, and X-Ray Fluorescence (XRF) and Metrohm 916 Ti Touch Auto Titrator were carried out. The results showed that the optimal mix proportion was 1 PC : 1 SS : 3.75 LS : 1.125 SF : 0.5625 NS : 0.4 SP achieving a compressive strength of 16 MPa (42.4%) from the control mortar (freshwater curing) and 14 MPa (40.4%) (seawater curing). BL is better than MC the NaCl content decreased from 0.32% to 0.25% and increased porosity by 35%. The benefits of this study show that SS and SW can be used as environmentally friendly construction materials.

Keywords: Seasand, Seawater, Lime, Silica fume, Nano-silica.

1. INTRODUCTION

Concrete is the main material in construction work whose needs continue to increase, one of the component materials of concrete is natural sand, which so far has been the result of mining. Natural sand mining activities in Indonesia have increased sharply, according to data from the Indonesian Central Bureau of Statistics, the production volume of sand minerals until 2021 has reached 240 million m3, this amount indicates that exploration for natural materials is very massive and dangerous for environmental damage [1–3].

The fact is that the production of natural sand mining has not been able to meet the existing needs so getting quality natural sand and freshwater is still very difficult [4,5]. One of the efforts to reduce the impact of mining exploration to meet the needs of natural sand and freshwater is the need for materials that can substitute for seasand and seawater which have not been utilized so far [6-9].

Several researchers have proven that the use of 15% seasand in a mortar mixture can increase 10% permeability and 5% powder from egg shells using seawater increases the compressive strength by 36.4% [10-13].

But unfortunately, the use of seasand and seawater in mortar and concrete is still avoided by construction stakeholders, one of the reasons is due to the content of sodium chloride (NaCl) which can cause corrosion of reinforcement, for that we need an additional material that can reduce NaCl, and several other materials. potential are lime, nano-silica and silica fume. The addition of lime and additives to the mortar mixture can increase the compressive strength by 26%, flexural strength by 25%, and speed up the mortar hydration reaction [14-16].

The addition of nano-silica can increase the compressive strength by 9%, and the durability by 8% [17-19] while the addition of silica fume can increase the compressive strength by more than 30% and decrease the penetration by more than 50% [20-22]

The focus of this research is to obtain the optimal composition for reducing NaCl in seasand and seawater by mixing cement (PC), lime (LS), silica fume (SF), nano-silica (NS), and superplasticizer (SP). The benefit of this research is to maximize the use of seasand and seawater in mortar as an environmentally friendly material.

2. RESEARCH SIGNIFICANCE

This research is an innovation to overcome the disadvantages of using seasand and seawater in concrete and mortar. This research combines the use of seasand and seawater with lime, silica fume, nano-silica and superplasticizer. The significance of this study is that the proportion of the mixture developed by previous researchers was limited to two to three additional materials in mixing, whereas in this study the use of five additional materials was used. This research produced a mortar with high compressive strength, low porosity, and low NaCl content. The benefits of this research scientifically can support the use of seasand and seawater as a substitute for natural sand and freshwater which have not been used optimally so far.

3. MATERIALS AND METHODS

3.1 Materials

In the research, the sand used came from the beach in Sukabumi, West Java, Indonesia. The cement used was portland type I ex PT. Indocement, Lime, silica fume, and superplasticizer (SP) from CV. John Hi-Tech Contrindo, while the nano-silica is used for the brand HDKN20 ex PT. Bratachem. Table 1 shows the particle size and physical properties of cement, lime, silica fume and nano-silica. Table 2 shows the chemical composition of the materials.

The superplasticizers (SP) used are highly effective water-reducing modified Naphthalene Formaldehyde Sulfonate to promote accelerated hardening with high workability. Complies with A.S.T.M. C 494-92 Type F. SP can be used at the dose rate 0.30 % - 2.0 % by total weight of cementitious material depending on requirements concerning workability and strength.

Mix design mortar with MK nomenclature is control mortar, and M1 to M13 is mortar with volume ratio as shown in Table 3. The superplasticizer (SP) used is 0.4% of the existing mixture. For water in the mortar, use seawater with a w/b of 0.35. While the chemical composition of freshwater and seawater used in this study can be seen in Table 4.

Table 1 Particle size and physical properties of cement, lime, silica fume and nano-silica

Material	Particle size	Physical properties
Cement (PC)	1–50 µm	Fineness, soundness, consistency, strength, setting time, heat of hydration, loss of ignition and bulk density
Lime (LS)	1-1.5 µm	Non-flammable, odorless, colorless white crystal or powder.
Silica fume (SF)	0.1-0.3 µm	Composed primarily of pure silica in non-crystalline, very high content of amorphous silicon dioxide and consists of very fine spherical particles.
Nano-silica (NS)	20 nm	Large specific surface area, strong surface adsorption, large surface energy, high chemical purity and good dispersion.

Table 2 Composition of cement, lime, silica fume and nano-silica

Chemical compound	Cement (PC)	Lime (LS)	Silica fume (SF)	Nano-silica (NS)
SiO_2	22.60	7.06	87.74	99.99
Al_2O_3	4.30	2.38	0.72	
Fe_2O_3	2.50	0.06	1.63	
CaO	64.40	84.85	0.520	
MgO	2.10	0.04	1.45	
SO_3	2.30	1.2	0.576	
Na_2O & K_2O	0.60	1.08	3.64	
CuO			0.004	0.01

Table 3 Mix-design mortar (in units of volume ratio)

Code	PC	SS	LS	SF	NS	SW (w/b)	SP (liter)
MK	1	1	-	-	-	0.35	-
M1	1	1	4	1	0.5	0.35	0.40
M2	1	1	4	1.25	0.5	0.35	0.40
M3	1	1	4	1.5	0.5	0.35	0.40
M4	1	1	4	1	0.625	0.35	0.40
M5	1	1	4	1	0.75	0.35	0.40
M6	1	1	3.75	1	0.625	0.35	0.40
M7	1	1	3,5	1	0.75	0.35	0.40
M8	1	1	3.75	1.25	0.5	0.35	0.40
M9	1	1	3,5	1.5	0.5	0.35	0.40
M10	1	1	4	1.125	0.56	0.35	0.40
M11	1	1	4	1.25	0.63	0.35	0.40
M12	1	1	3.75	1.125	0.5625	0.35	0.40
M13	1	1	3,5	1.25	0.625	0.35	0.40

Table 4 Composition of freshwater and seawater [23].

Units	Cl	Ca	Mg	Na	K	Cu	Fe	Mo	Ni	V	Zn
	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Freshwater	124	72	6.5	38.8	2.68	5.42	0.2	6.21	0.52	0.49	23.12
Seawater	22922	539	1673	13396	534	1.2	25.6	12.2	4.7	2.1	9.8

3.2 Methods

Mixing for the manufacture of test specimens with a mix design (Table 3) was carried out using a hand mixer with a mixing time of 3 minutes then put into the mould and opened at 1 day of age. The next curing method is soaking in water, using 2 types of water, namely sea water and freshwater according to ASTM C192 [24]. Testing the compressive strength of mortar measuring 50×50×50 mm according to ASTM C109, tested at ages 3, 7, 28, and 56 days using a compressive strength machine [25]. Then calculated the achievement of compressive strength of the control mortar with the equation:

$$(\%) = \frac{Fc`\ (Result)}{Fc`\ (Control)} \times 100 \quad (1)$$

Where Fc`Result is results of compressive strength for (M1-M13) dan Fc`Control is control compressive strength (MK) Seasand was tested for water content according to ASTM D-2216-98 and tested for organic content according to ASTM C40 [26, 27]. Mortar porosity test at 28 days for samples cured with seawater according to ASTM C642-90 [28].

Testing the Metrohm 916 Ti touch auto titrator using a specific electrode working principle of argentrometry titration to determine the NaCl content and X-Ray Fluorescence (XRF) testing to see the Cl- content in mortar with code MC (control) consisting of cement, seasand and sea water . Then BL is a mixture of cement, seasand, lime, silica fume, nano-silica, and freshwater. BB mix consists of cement, natural sand, lime, silica fume, nano-silica, and freshwater. Furthermore, LL is a mixture of cement, seasand, lime, silica fume, nano-silica, and seawater.

4. RESULTS AND DISCUSSION

4.1 Moisture Content and Organic Content

Examination of the water content is carried out when the sand is in a dry surface state (SSD). The test results obtained an average moisture content of 3.31%, where the fine aggregate water content requirement is 3% - 5%, so the fine aggregate meets the requirements for water content testing.

From the organic content test, it was found that the color of the liquid was appropriate and the sand could be used for normal concrete mixes.

4.2 Compressive Strength

Mortar compressive strength values for each sample are shown in Figure 1 (freshwater curing). In Table 5, shows that MK at 28 days was 33 MPa and 46 MPa at 56 days. With the addition of lime, silica fume, and nano-silica a 28-day compressive strength was achieved for M12 of 42.4% (14 MPa) and M13 of 36.4% (12 MPa). However, at the age of 56 days, only 34.8% (16 MPa) and 30.4% (14 MPa) were achieved, thus there was a decrease of 7.6% and 6%

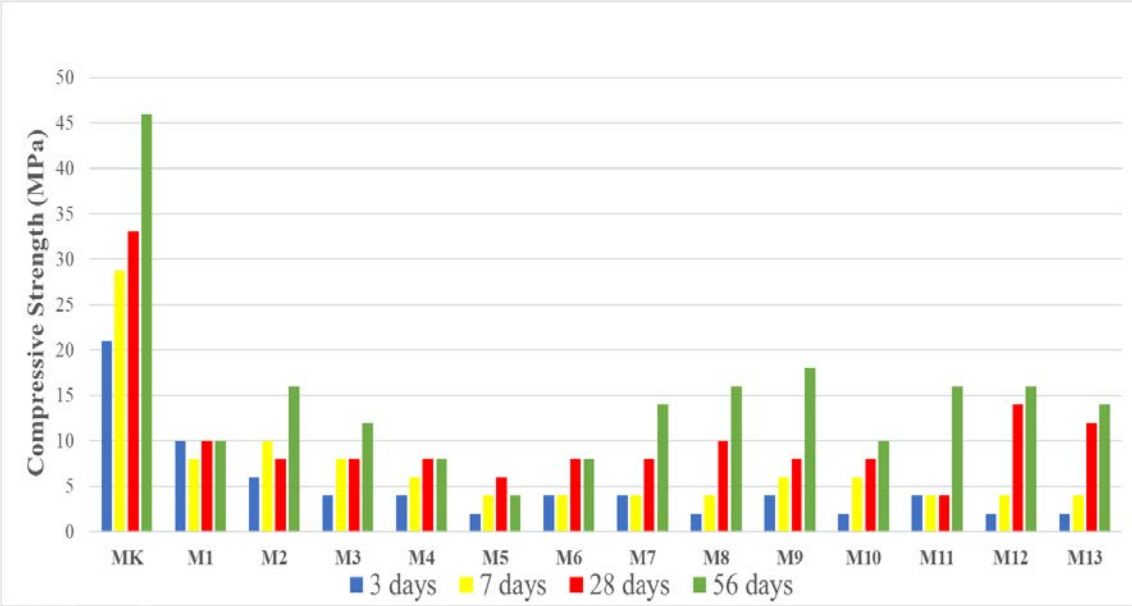


Fig.1 Compressive strength results (curing with freshwater)

In Figure 2 (seawater curing) the MK sample achieved a compressive strength of 29.7 MPa (28 days old) and 41.4 MPa (56 days old). In M12 there was a compressive strength of 40.4% (12 MPa) and in M13 of 47.2% (14 MPa) at 28 days of age. Then at the age of 56 days, there was an achievement of 33.8% (14 MPa) at M12 and 29% (12 MPa) at M13. The decrease in compressive strength occurs due to the salt ion content of SO4 2- [29].

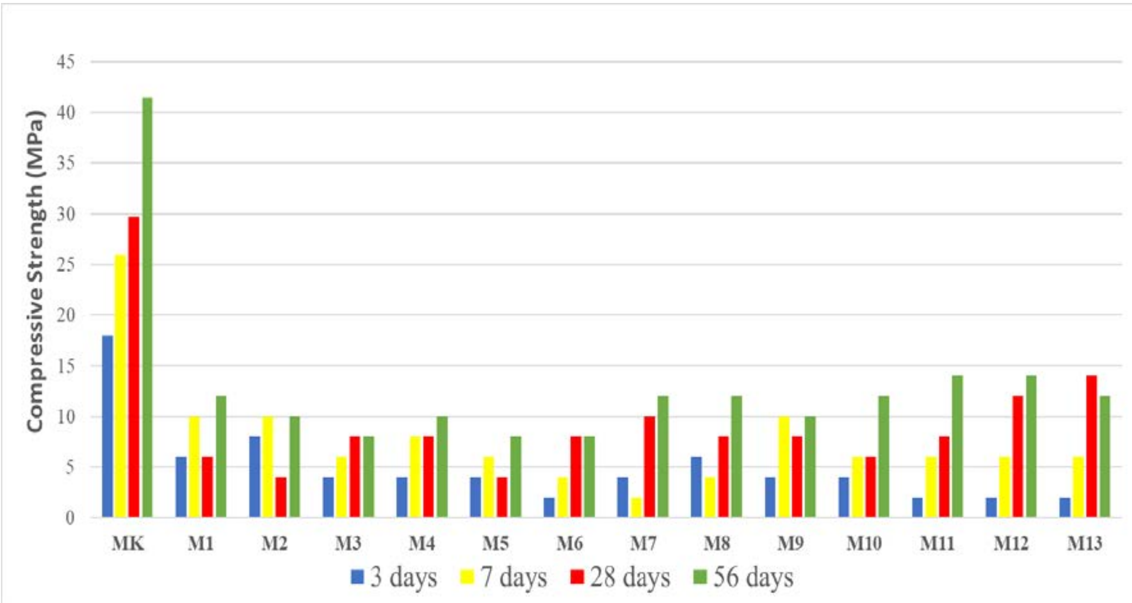


Fig.2 Compressive strength results (curing with seawater)

The compressive strength results show that mortar cured with freshwater is higher than that cured using seawater. While the decrease in compressive strength with age is due to NaCl in seawater reacting with hydrated cement followed by a reduction in calcium chloride [30].

The addition of 25% silica fume can produce a compressive strength of 16 MPa (freshwater curing), while the addition of 50% silica fume increases to 18 MPa (freshwater curing). This is in line with previous studies [31, 32].

With the addition of 25% nano-silica, the compressive strength of M13 is 14 MPa (seawater curing). The addition of 50% to M7 causes a decrease in compressive strength of 12 MPa (Seawater curing). This is due to the agglomeration between silica nanoparticles which affects the decrease in compressive strength [33, 34]. The positive effect of using nano-silica can increase the efficiency of the physical and chemical properties of the Cl- content in seawater due to hydration and chemical reactions that increase the CSH ratio [35, 36].

Table 5 Achievement of compressive strength against control

Code	Compressive strength achievement (%)			
	Seawater curing		Freshwater curing	
	28 Days	56 Days	28 Days	56 Days
MK	100	100	100	100
M1	20.2	29.0	30.3	21.7
M2	13.5	24.2	24.2	34.8
M3	26.9	19.3	24.2	26.1
M4	26.9	24.2	24.2	17.4
M5	13.5	19.3	18.2	8.7
M6	26.9	19.3	24.2	17.4
M7	33.7	29.0	24.2	30.4
M8	26.9	29.0	30.3	34.8
M9	26.9	24.2	24.2	39.1
M10	20.2	29.0	24.2	21.7
M11	26.9	33.8	12.1	34.8
M12	40.4	33.8	42.4	34.8
M13	47.2	29.0	36.4	30.4

At M2 the use of 100% lime achieves a compressive strength of 16 MPa. Reducing the lime content by 25-50% can increase the compressive strength of the mortar as indicated by the M9 sample of 18 MPa (56 days old). The increase in compressive strength along with the reduction in the percentage of lime is due to the smaller filling effect ability [37].

Based on the composition of the stable compressive strength mortar at M12. The effect of using nano-silica and silica fume together can increase the compressive strength of the mortar due to the pozzolanic reaction which can reduce the amount of Ca(OH) to be less, increasing the rate of hydration of cement and mortar to become denser [38,39].

4.3 Porosity

The value of porosity and water absorption can be seen in Figure 3 and 4. The addition of the percentage of nano silica and silica fume can reduce the value of porosity at the age of 7 days obtained the best porosity value of 2.330% in samples M4 and M12 and 28 days of age of 1.294% as in M12 and M13. Porosity will get better with age. This is also due to the increased use of nano silica and silica fume which functions as a filler, has good density, and smaller particle size [40-42].

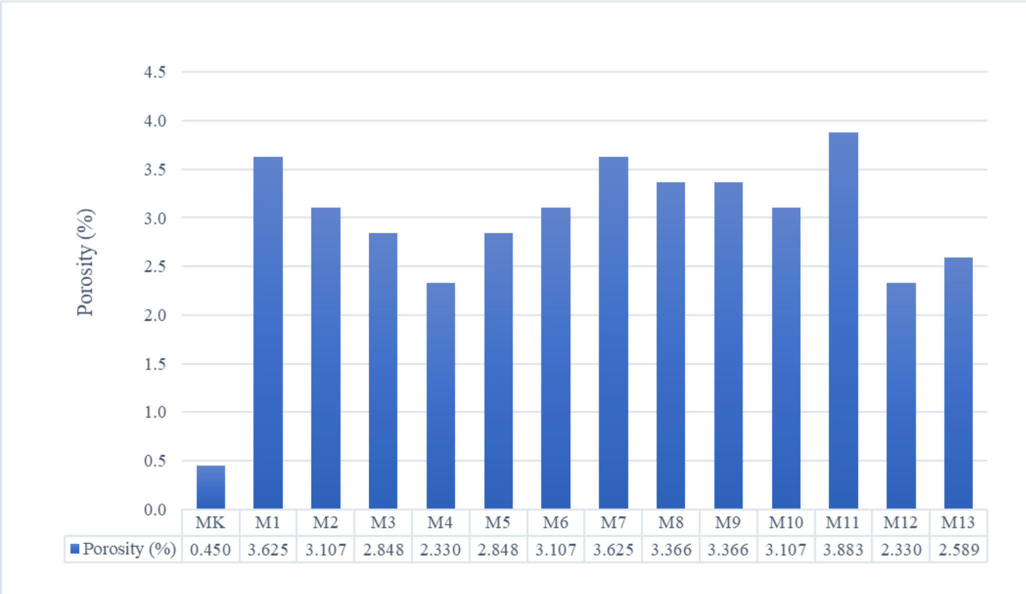


Fig.3 Porosity Results (7 days)

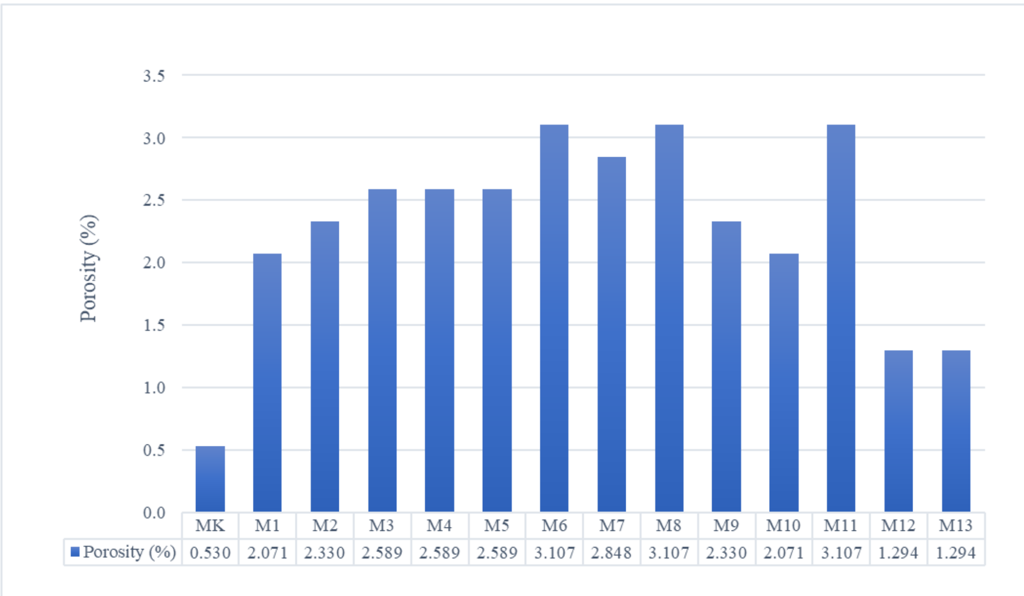


Fig.4 Porosity Results (28 days)

4.4 Testing Metrohm

As shown in Table 6, mortar using seasand and seawater is added with cement (PC), lime (LS), silica fume (SF), nano-silica (NS), and superplasticizer (SP). there was a decrease in the value of NaCl from 0.32% (MC) to 0.25% (BL). This result significantly proves that BL can be used as a mortar. Whereas BB where the NaCl content is close to 0 is a mortar mixture that is commonly used so far.

Whereas in LL, the resulting NaCl is 1.12%, this shows that the resulting mortar is not recommended for use as a construction material.

Table 6. Metrohm test result

Compound	MC	BL	BB	LL	Unit
NaCl	0.32	0.25	0	1.12	%

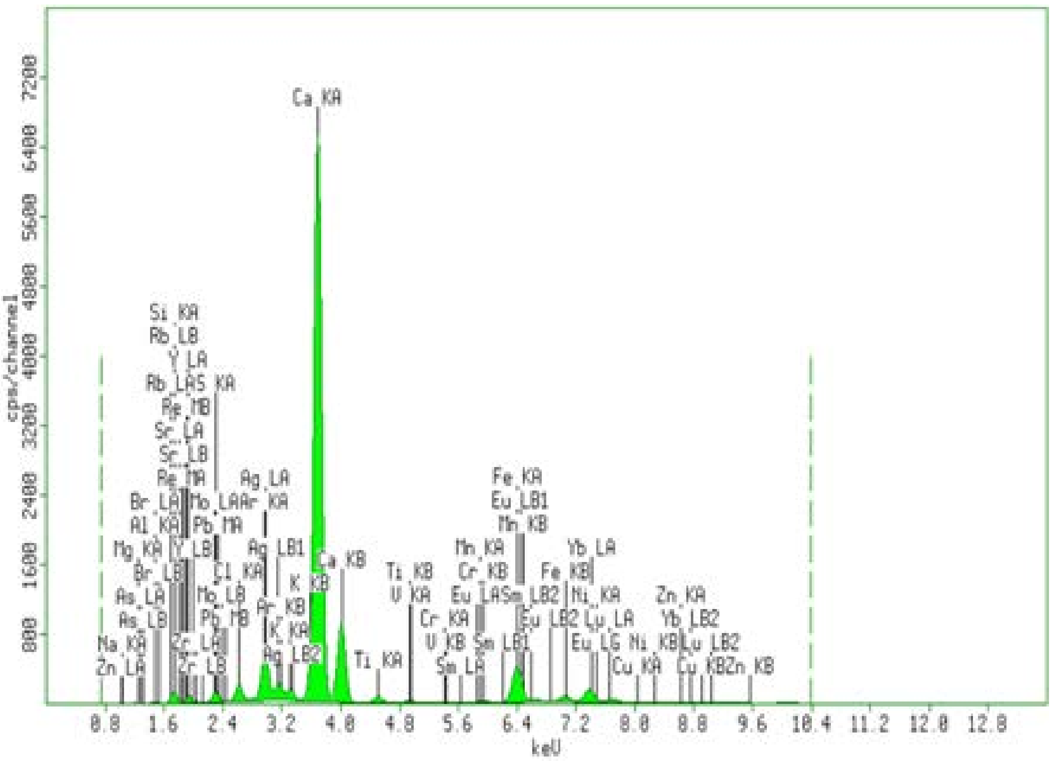
4.5 XRF Testing

Based on the results of the XRF test in Table 7, it can be seen that BL can reduce the Cl-(chloride) content by 70% of the control mortar. on BB can reduce Cl- by 67.37%. While LL there was an increase in Cl- content of 83.6%.

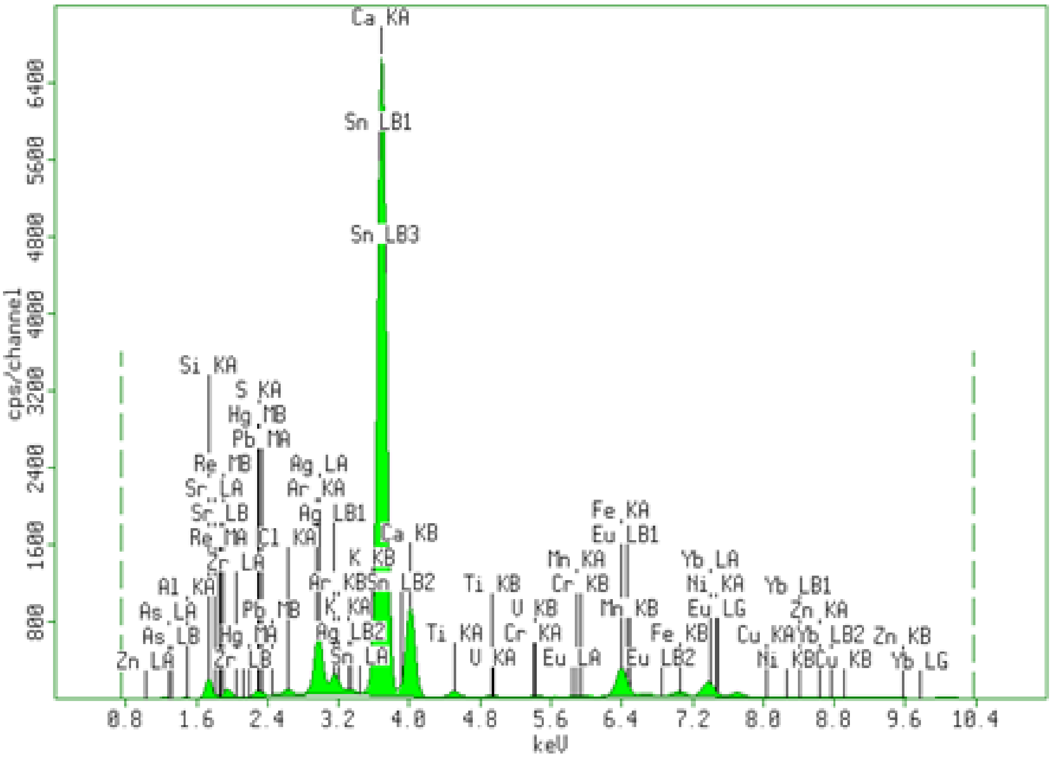
From the two tests above, BL is the proportion of the mortar mixture that consistently lowers NaCl and Cl- levels.

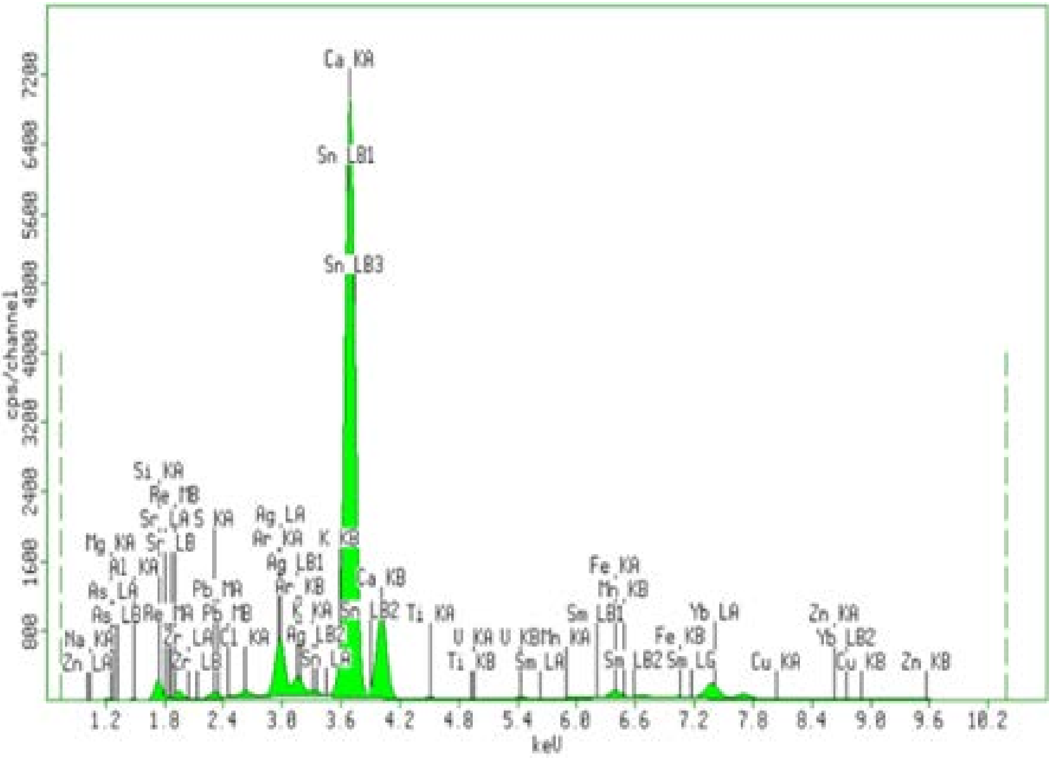
Table 7. XRF test results

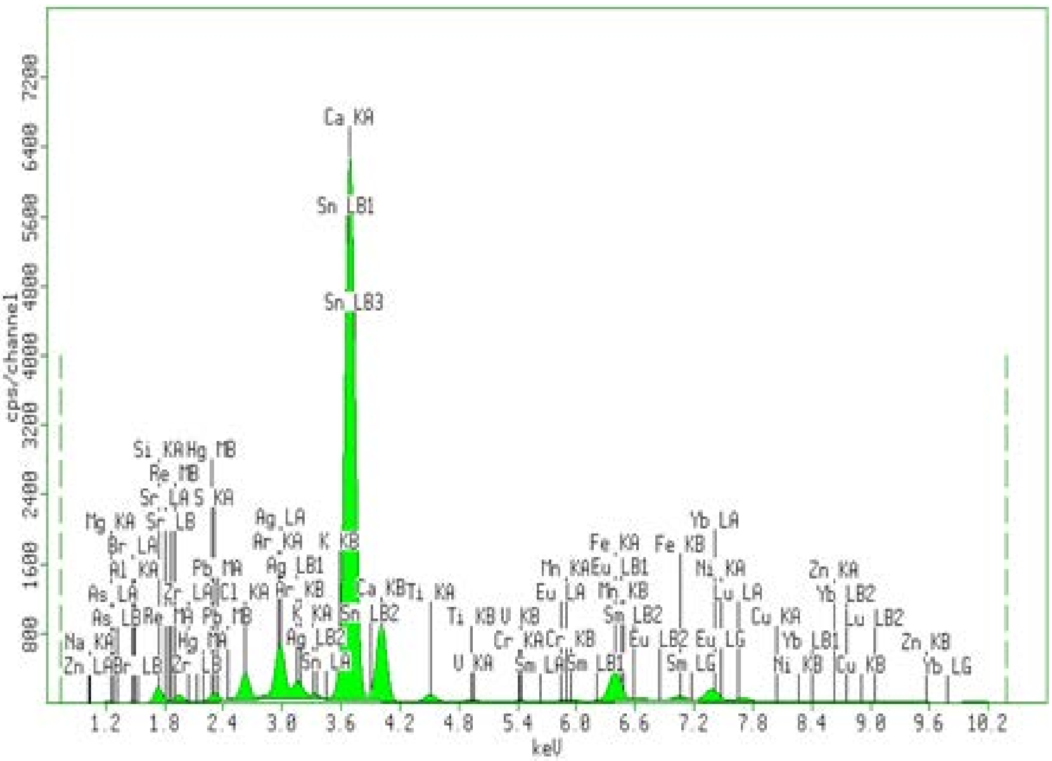
Compound	MC	BL	BB	LL	units
Mg	0.925	1.108	0.916	1,489	%
Al	1275	0.831	0.673	0.788	%
Si	4,768	7,256	7,802	6,521	%
S	0.738	0.389	0.34	0.549	%
cl	0.858	0.257	0.28	1,576	%
K	0913	0.206	0.201	0.207	%
ca	78,049	80,428	87,135	77,857	%
Ti	1,503	1.31	0.214	1,777	%
V	0.052	0.049	0.006	0.054	%
cr	0.01	0.046	0	0.01	%
Mn	0.186	0.172	0.042	0.21	%
Fe	9,983	7.57	2073	8,553	%
Ni	0.014	0.013	0	0.01	%
Cu	0.036	0.019	0.017	0.021	%
Zn	0.075	0.052	0.05	0.047	%
US	0.003	0.005	0.004	0.004	%
Br	0.006	0	0	0.016	%
Rb	0.006	0	0	0	%
Sr	0.518	0.223	0.184	0.215	%
Y	0.006	0	0	0	%
Zr	0.041	0.016	0.015	0.015	%
Mo	0.011	0	0	0	%
sn	0	0.019	0.017	0.015	%
Sm	0	0	0	0.014	%
eu	0	0	0	0.004	%
Yb	0.005	0.004	0.011	0.01	%
Lu	0.009	0.002	0	0.013	%
Re	0.004	0	0	0	%
Pb	0.007	0.022	0.02	0.021	%
Total	100	99,997	100	99,996	%



a)


Ca KA
Sn LB1
Sn LB3
Si KA
S KA
Hg MB
Pb MA
Re MB
Sr LA
Sr LB
Re MA
Zr LA
Al KA
As LA
As LB
Zn LA
Cl KA
Pb MB
Hg MA
Zr LB
Ag LA
Ar KA
Ag LB1
K KB
Ar KB
K KA
Ag LB2
Sn LA
Ca KB
Sn LB2
Ti KA
Ti KB
V KA
V KB
Cr KA
Cr KB
Mn KA
Mn KB
Eu LA
Fe KA
Eu LB1
Eu LB2
Fe KB
Yb LA
Ni KA
Eu LG
Cu KA
Ni KB
Yb LB1
Zn KA
Yb LB2
Cu KB
Zn KB
Yb LG
cps/channel
800
1600
2400
3200
4000
4800
5600
6400
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
7.2
8.0
8.8
9.6
10.4
keV
b)


Ca KA
Sn LB1
Sn LB3
Si KA
Re MB
Sr LA
S KA
Sr LB
Mg KA
Al KA
As LA
As LB
Re MA
Na KA
Zn LA
Pb MA
Pb MB
Zr LA
Zr LB
Cl KA
Ag LA
Ar KA
K KB
Ag LB1
Ar KB
K KA
Ag LB2
Sn LA
Ca KB
Sn LB2
Ti KA
Ti KB
V KA
V KB
Mn KA
Sm LA
Fe KA
Mn KB
Sm LB1
Sm LB2
Fe KB
Sm LG
Yb LA
Cu KA
Zn KA
Yb LB2
Cu KB
Zn KB
cps/channel
800
1600
2400
3200
4000
4800
5600
6400
7200
1.2
1.8
2.4
3.0
3.6
4.2
4.8
5.4
6.0
6.6
7.2
7.8
8.4
9.0
9.6
10.2
keV
c)



d)

Fig.5 Test graph XRF (X-ray fluorescence)

5. CONCLUSION

1. The compressive strength of mortar with freshwater curing is better than seawater curing.
2. Optimal mix proportion by volume ratio = 1 PC : 1 SS : 3.75 LS : 1.125 SF : 0.5625 NS: 0.4 SP produces a compressive strength of 42.4% of the control mortar (freshwater cured) and 40, 4% (seawater curing).
3. The test results with the Metrohm tool show that the BL code is better than the MC. The NaCl content decreased from 0.32% to 0.25%. This decrease was due to the addition of lime, silica fume, and nano silica then mixed with freshwater
4. Reducing the percentage of lime by (25 - 50)% can increase the compressive strength while adding the percentage of silica fume and nano-silica by 25% can increase the compressive strength of mortar.
5. The addition of the percentage of nano-silica and silica fume can reduce the porosity by (20-35)%.
6. This research can be continued by analyzing the long-term effects of NaCl on the compressive strength and durability of concrete.

6. ACKNOWLEDGMENTS

Ministry of education, culture, research and Technology with a superior applied research scheme PTUPT.

No. Contract 309/E4.1/AK.04.PT/2021

7. REFERENCES

[1] Mustikawati R. and Nuryati, Mining Statistics of Indonesian Minerals. Jakarta: BPS RI, 2021.

[2] Rentier ES. and Cammeraat LH., The Environmental Impacts of River Sand Mining. Sci. Total Environ, Vol. 838, 2022, pp. 155877-15583.

[3] Arulmoly B., Konthesingha C., and Nanayakkara A., Performance Evaluation of Cement Mortar Produced with Manufactured Sand and Offshore Sand as Alternatives for River Sand. Constr. builds. Mater, Vol. 297, 2021, pp. 123784-123792.

[4] Gavriletea MD., Environmental impacts of sand exploitation. Anal. Sand Mark, Vol. 1118, 2017, pp 1118-1125.

[5] Xiao J., Qiang C., Nanni A., Zhang K., Use of sea-sand and seawater in concrete construction: Current status and future opportunities. Constr. builds. Mater, Vol. 155, 2017, pp.1101–1111. https://doi.org/10.1016/j.conbuildmat.2017.08.130

[6] Wang C. Su, X., Ding L., Chen Z., Liu S., Wu Z., Experimental study on the seismic behavior of seawater seasand concrete beams reinforced with steel-FRP composite bars. Engineering structures, Vol. 248, 2021, pp.113269. https://doi.org/10.1016/j.engstruct.2021.113269.

[7] Su C., Wang X., Ding L., Wu Z., Effect of carbon nanotubes and silica nanoparticles on the durability of basalt fiber reinforced polymer composites in seawater and seasand concrete environment. Polym. Compos, Vol. 42, 2021, pp. 3427–3444. https://doi.org/10.1002/pc.26069

[8] D. T, R. A, and NS M, Benefits of Using Seasand and Seawater in Concrete: a Comprehensive Review. Aust. J. Struct. Eng, vol. 20, no. 4, 2019, pp. 280-289.

[9] He S., Jiao C., Niu Y., and Li S., Utilizing of Coral/Seasand as Aggregates in Environment-Friendly Marine Mortar: Physical Properties, Carbonation Resistance and Microstructure. Case Stud. Constr. Mater, Vol. 16, 2022, pp. 981-990.

[10] Feng B., Research on Properties and Durability of Desalinated Seasand Cement Modified with Fly Ash. Case Stud. Constr. Mater, Vol. 15, 2021, pp. 675-680.

[11] Moradi S. and Shahnoori S., Eco-friendly Mix for Roller-Compacted Concrete: Effects of Persian-Gulf-Dredged Marine Sand on Durability and Resistance Parameters of Concrete. Constr. builds. Mater, Vol. 281, 2021, pp. 122-135.

[12] Bernardo L., Jacob RB., Philip DS., Jericho MT., and Ken Y., Compressive Strength of Concrete with Seawater and Powdered Eggshells as Partial Replacement for Cement, International. Journal of GEOMATE, Vol. 18, Issue 69, 2020, pp. 52-58.

[13] D. T, R. A, and NS M, Properties and Application of Seasand in Sea-Sand Seawater Concrete. J. Mater. Civ. Eng, Vol. 32, no. 12, 2020, pp. 120-130.

[14] J. R, A. A, ASY, R. E, and L. A, Natural Hydraulic Lime for Blended Cement Mortars: Behavior from Fresh to Hardened States. Cem. Concr. Res, Vol. 120, 2019, pp. 345-356.

[15] García-González J., Faria P., Pereira AS., Lemos PC., and Juan-Valdés A., A Sustainable Production of Natural Hydraulic Lime Mortars Bhrough bio-Amendment. Constr. builds. Mater, Vol. 340, 2022, pp. 127-136.

[16] Yan B., Kouame KJA., Yang W. Lv, P., and Cai M., Modification and in-Place Mechanical Characteristics Research on Cement Mortar with Fly Ash and Lime Compound Admixture in High Chlorine Environment. J. Mater. Res. Technol, Vol. 8, no. 1, 2019, pp. 1451-1460.

[17] Zhu H., Chen J., and Li H., Effect of Ultrafine Pozzolanic Powders on Durability of Fabricated Hydraulic Lime. Case Stud. Constr. Mater, Vol. 17, 2022,pp. 1197-2012.

[18] Liu R., Effects of Nano-SiO2 on the Permeability-Related Properties of Cement-Based Composites with Different Water/Cement Ratios. J. Mater. Sc, Vol. 53, no. 7, 2018, pp. 4974-4986.

[19] Kapeluszna E., Kotwica Ł., and Nocuń-Wczelik W., Comparison of the Effect of Ground Waste Expanded Perlite and Silica Fume on the Hydration of Cements with Various Tricalcium Aluminate Content – Comprehensive Analysis. Constr. builds. Mater, Vol. 303, 2021, pp. 124434-124440.

[20] Abdi Moghadam M. and Izadifard RA., Effects of Zeolite and Silica Fume Substitution on the Microstructure and Mechanical Properties of Mortar at High Temperatures. Constr. builds. Mater, Vol. 253,2020, pp. 150-161.

[21] Ahmad S., Baghabra Al-Amoudi OS., Khan SMS., and Maslehuddin M., Effect of Silica Fume Inclusion on the Strength, Shrinkage and Durability Characteristics of Natural Pozzolan-Based Cement Concrete. Case Stud. Constr. Mater, Vol. 17, 2022, pp. 1255-1269.

[22] ASTM C150/C150M-22, Standard Specification for Portland Cement, vol. 04, no. 1, 2022, pp. 9.

[23] Lardhi M. and Mukhtar F., Radiation shielding performance of seawater-mixed concrete incorporating recycled coarse aggregate and steel slag. J Radiat Res Appl Sci, Vol. 16, no. 1, 2023, pp.100528–100538.

[24] ASTM. C192/C192M-14, Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory, Vol. 04, no. 2, 2015, pp. 8.

[25] ASTM. C109/C109M-20, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens), Vol. 4, no.1, 2020, pp. 11.

[26] ASTM. D2216-19, Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass, Vol. 04, no.8, 2019, pp. 7.

[27] ASTM. C40-04, Standard Test Method for Organic Impurities in Fine Aggregates for Concrete, Vol. 04, no. 2, 2011, pp. 2.

[28] ASTM. C642-21, Standard Test Method for Density, Absorption, and Voids in Hardened Concrete, Vol. 4, no. 2, 2022, pp. 3.

[29] Nguyen-Van D., Nguyen-Tuanand T., Pham-Thanh T., Experimental study on previously cement and pervious geopolymer concrete using seasand and seawater. International Journal of GEOMATE, Vol.23, Issue 99, 2022, pp.63 71, DOI: https://doi.org/10.21660/2022.99.3592

[30] Choi SI., Park JK., Han TH., Pae J., Moon J. and Kim, Early MO., Age Mechanical Properties and Microstructures of Portland Cement Mortars Containing Different Admixtures Exposed to Seawater. Case Stud. Constr. Mater, Vol. 16, 2022, pp.1041–1053.

[31] Simsek O., Aruntas HY., Demir I., Yaprak H. and Yazicioglu S., Investigation of the Effect of Seawater and Sulfate on the Properties of Cementitious Composites Containing Silica Fume. Silicon, vol. 14, no. 2, 2022, pp.663–675.

[32] Zhang Y., Effect of Dosage of Silica Fume on the Macro-Performance and Micro/Nanostructure of Seawater Portland Cement Pastes Prepared with an Ultra-Low Water-to-Binder Ratio. Cem. Concr. Compos, Vol. 133, 2022, pp.104700–104712.

[33] Luo J., Zhou A., Li N., Wang W. and Hu J., Mechanical Properties and Microscopic Characterization of Cement Stabilized Calcareous Sand Modified by Nano SiO2. Case Stud. Constr. Mater, Vol. 17, 2022, pp.1636–1643.

[34] Wei W., Jingjing L., Na L., Lu M., Mechanical properties and micro mechanism of nano-SiO2 modified coastal cement soil at short age[J]. Acta Materiae Compositae Sinica, Vol. 39, no. 4, 2022, pp. 1701-1714.

[35] Tian W., Liu Y. and Wang W., Enhanced Ohmic Heating and Chloride Adsorption Efficiency of Conductive Seawater Cementitious Composite: Effect of Non-Conductive Nano-silica. Compos. Part B Eng, Vol. 236, 2022, pp.109854–109868.

[36] Fulin Q., Wengui L., Kejin W., Vivan T. WY., and Shishun Z., Effects of Seawater and Undesalted Seasand on the Hydration Products, Mechanical Properties and Microstructures of Cement Mortar. Constr. builds. Mater, Vol. 310, 2021, pp.125229–125238.

[37] Qadir W., Ghafor K. and Mohammed A., Evaluation of the Effect of Lime on the Plastic and Hardened Properties of Cement Mortar and Quantified Using the Vipulanandan Model. Open Eng., Vol. 9, 2019, pp.468–480.

[38] Jacob JDS., Mascelani AG., Steinmetz RLR., Costa FAD. and Dalla Costa OA., Use of Silica Fume and Nano-silica in Mortars Attacked by Acids Present in Pig Manure. Procedia Struct. Integr., Vol. 11, 2018, pp. 44–51.

[39] Oh T., Chun B., Lee SK., Lee W.., Banthia N. and Yoo DY., Substitutive Effect of Nano-SiO2 for Silica Fume in Ultra-High-Performance Concrete on Fiber Pull-Out Behavior. J. Mater. Res. Technol., Vol. 20, 2022, pp.1993–2007.

[40] Miao J., Lu L. and Jiang J., Reinforcement of Ultra-Low Dosage of Polycarboxylate Ether (PCE) Grafted Nano-silica Sol to the Mechanical and Durable Properties of Cement Mortar. J. Mater. Res. Technol., Vol. 19, 2022, pp.3646–3657,2022.

[41] Farmani F., Khadiv-Parsi P., Ramezanianpour AA., Bonakdarpour B. and Yazdian F., Dual Eco-Friendly Application of Silica Fume and Scoria in Cement-Based Materials Through the Enhancement of Microbially-Induced Carbonate Precipitation. Case Studs. Constr. Mater., Vol. 17, 2022, pp.1481–1498.

[42] Zhang B., Tan H., Shen W., Xu G., Ma B. and Ji X., Nano-silica and Silica Fume Modified Cement Mortar Used as Surface Protection Material to Enhance the Impermeability. Cem. Concr. Compos., Vol. 92, 2018, pp.**7–17**.