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Properties of Lightweight Cement Mortar Containing Treated Pumice and Limestone

Hesham Alsharie, Talal Masoud, Aziz Ibrahim Abdulla and Aseel Ghanem
Department of Civil Engineering, Faculty of Engineering, Jerash University, Jerash, Jordan

Abstract: This study aims to investigate the ability of improving the properties of lightweight cement mortar containing limestone and pumice stone treated with sodium hypochlorite (NaOCL). Treated limestone and treated pumice were used as fine aggregate in cement mortar mixtures. Control cement mortar using untreated limestone and untreated pumice were also prepared for comparison purpose. The effect of sodium hypochlorite on some physical and mechanical properties of limestone and pumice were also investigated. Compressive strength of cement mortar was examined at ages of 3, 7 and 28 days. Results demonstrated that the treated limestone and treated pumice increased cement mortar strength significantly. The cement mortar containing treated pumice showed high strength as compared with cement mortar containing treated limestone. The results also indicated that sodium hypochlorite improve limestone and pumice stone characteristics as a mean of specific gravity, absorption, abrasion resistance and compressive strength.

Key words: Lightweight cement, pumice and limestone, sodium hypochlorite, NaOCL, gravity

INTRODUCTION

Recently, in construction sector attention attended towards using Lightweight Concrete (LWC) rather than Normal Strength Concrete (NSC) since the development of high rise buildings, larger sized and long span concrete structures requires better concrete performance these requirement includes high strength and lightweight concrete (Gao *et al*., 1997). Using of lightweight concrete in structures has many advantages that contributed in making it a quite competitive since it's reduce structures dead load which lead to minimize structures cross section and decrease steel reinforcement. In addition, lightweight concrete reduces the risk of earthquake damages to a structure since, the earthquake forces are proportional to the mass of those structures (Wasserman and Bentur, 1997). LWC derive its vital properties from the use of low density aggregates a large body of researches has been concerned with using the limestone and pumice as aggregate to produce lightweight concrete (Kayali *et al*., 2003).

Limestone is sedimentary rocks composed essentially of calcium carbonate. Generally, limestone ($CaCO_3$) is obtained from the calcareous remains of marine or fresh water organisms embedded in calcareous mud. They change from the soft chalks to hard crystalline rocks. Pumice is a natural material of volcanic origin produced by the release of gases during the solidification of lava (Khandakar and Hossain, 2004). The challenge is to use pumice and limestone aggregate to produce lightweight concrete with higher strength so the world-wide trend towards improving the properties of lightweight concrete by different method such as adding super plasticizer and silica fume (Abdulla *et al*., 2012).

Binici (2007) studied the effect of using crushed ceramic and basaltic pumice as fine aggregates on concrete mortars properties. Results indicated that ceramic wastes and basaltic pumice concretes had good workability. In addition to that it was found that abrasion resistance is increased as the rate of fine crushed ceramic and crushed basaltic pumice was increased. Fine crushed ceramic concrete had 30% lower abrasion than crushed basaltic pumice concrete. The compressive strength of concrete increased with fine crushed ceramic content. Finally, results of this study showed that fine crushed ceramic and crushed basaltic pumice could be very conveniently used in concrete to achieve high abrasion resistance and high compressive strength.

Nevruz and Ugur investigated experimentally the effect of pumice aggregate on some properties of mortars. Three different originated pumice aggregates (one was acidic whereas the other two were basaltic specimens) were used to prepare mortar specimens. Control mortars were also prepared using limestone for comparison purpose. Results showed that the rodded and loose bulk density, specific gravity and strength for pumice aggregate are lesser than the limestone aggregate. For water absorption pumiced aggregate showed higher value compared with limestone aggregate. Degirmenci and Yilmaz (2011) examined the viability of using pumice

Corresponding Author: Hesham Alsharie, Department of Civil Engineering, Faculty of Engineering, Jerash University, Jerash, Jordan

aggregate as fine aggregate to produce lightweight cement mortar. The results showed that the using of weak pumice aggregate type as sand in mortar decreased strength of mortar due to the replacement of strong standard sand by relatively weak pumice aggregate. The dry unit of mortar containing pumice aggregate also decreases about 50%. Water absorption of pumice aggregate is higher four times than that of control samples. The result also indicated that the pumice aggregate mortar has higher frost resistance.

This study presents the results of an experimental investigation on the effect of using treated limestone and treated pumice stone as a fine aggregate on lightweight mortar properties. In addition, the mechanical and physical properties of treated limestone and treated pumice stone were studied. The experimental program was conducted on 50×50×50 mm^3 which used to compute compressive strength of cement mortar at 3, 7 and 28 days. Prisms of 40×40×160 mm were used to compute modulus of rupture of cement mortar. Additionally, 100×100×100 mm cubes of limestone and pumice stone were used to determine limestone and pumice properties.

MATERIALS AND METHODS

Cement: Ordinary Portland Cement (Type 1produced by Lafarge company) was used to prepare mortar mixes (ASTM C-150Type 1).

Limestone: Limestone rocks were obtained from Ajloun Region in North of Jordan. Limestone rocks were cut to cubes with approximately (100×100×100 mm) size. Limestone cubes were then crushed to be used as fine aggregate to prepare control and treated limestone cement mortar. Limestone characteristics are summarized in Table 1.

Pumice: Pumice rocks were obtained from Al-Swafie Region in West of Jordan. Pumice cubes were cut to cubes with approximately 100 mm cross sectional dimension. Pumice cubes were also crushed to be used as fine aggregate to prepare control and treated pumice cement mortar. Table 1 shows the characteristics of pumice rocks. Table 2 shows the sieve analysis test result for both limestone and pumice.

Alkaline solution: Sodium hypochlorite (NaOCL) 1 M pH = 12 were used to treat pumice and limestone cubes.

Treatment and mixing

Treatment: The 6 cubes of both limestone and pumice were immersed in alkaline solution NaOCL (sodium hypochlorite) for 24 h then washed very well and dried in oven to remove the effect of alkaline solution which could affect the cement mortar after that the compressive strength of the stone cubes were tested. Table 1 shows characteristics of treated pumice and treated limestone.

The specific gravity and absorption for fine aggregate were obtained according to ASTMC128-88 whereas sieve analysis and abrasion obtained according to ASTMC131-84a (ASTM C136, 2006) and ASTM C131-88, respectively. Figure 1 shows treated pumice and limestone cubes before crushing. Figure 1 shows treated

Table 1: Characteristics of pumice and limestone rocks before and after treating

Physical properties	Untreated limestone	Untreated pumice	Treated limestone	Treated pumice
Color	Yellow	Dark grey	Dark yellow	Black
Compressive strength (MPa)	18.25	19.4	24.88	30.49
Density (kg/m^3)	1313.3	1096.5	1388	1174.5
Specific gravity	2.3	1.66	2.35	1.7
Absorption (%)	10.2	8	10.5	6
Abrasion (%)	55	29	45	26

Table 2: Sieve analysis test result for pumice and limestone

Sieve size	Passing percent for pumice aggregate	Passing percent for limestone aggregate
10.00 mm	97	95
5.00 mm	93	90
2.36 mm	77	78
1.18 mm	40	43
600 Mm	33	35
300 Mm	15	12
150 Mm	11	10

Fig. 1: Limestone and pumice cubes after treating: a) treated limestone cubes and b) treated pumice cubes

pumice and limestone cubes. Figure 2 shows the shows treated pumice and treated limestone cubes after crushing.

Mixing: The mixing ratio is 1:2.75 (cement:sand). Pumice and limestone treated with NaOCL were used as 100% replacement of fine aggregate. Mortar cubes of 50×50×50 mm size and prisms of 40×40×160 mm were casted and cured according toASTM C109 and ASTM C348.

Fig. 2: Treated pumice and limestone cubes after crushing

RESULTS AND DISCUSSION

Color: Limestone rocks color become darker after treating with NaOCL whereas pumice rocks color changed from dark grey to black.

Density: Results showed that the NaOCL solution has a small effect on limestone and pumice density. NaOCL increased limestone density about 6% and increased pumice stone density about 7% as shown in Table 3-6.

Specific gravity: NaOCL solution increased slightly limestone and pumice specific gravity. Specific gravity of treated limestone and treated pumice is approximately, 2 and 2.4% higher than untreated limestone and untreated pumice, respectively. The increasing in the limestone aggregate specific gravity was very high as compared with pumice aggregate specific gravity as shown in Table 1.

Table 3: Compressive strength of untreated pumice cubes

Cube No.	Cube cross sectional area (mm^2)	Sample volume (mm^3)	Sample weight (g)	Sample density (kg/m^3)	Compressive strength (N/mm^2)
1	96303	956697	1103	1152	21.8
2	10506	1071612	1198	1118	20.06
3	10100	99990	1075	1075	20.2
4	9120	866400	1032	1191	19.2
5	10815	1146390	1141	995	20.16
6	11128	1179568	1236	1048	15.2
Sum	147972	5320657	6785	6579	116.62
Av.	33273.5	1614103	2077.833	2001	35.24

Table 4: Compressive strength of treated pumice cubes

Cube No.	Cube cross sectional area (mm^2)	Sample volume (mm^3)	Sample weight (g)	Sample density (kg/m^3)	Compressive strength (N/mm^2)
1	8648	769672	1013	1310	26.50
2	9408	921984	1075	1166	27.28
3	11448	119592	1136	954	36.06
4	10710	1145970	1162	1014	35.30
5	8930	866210	1126	1230	28.60
6	8740	795522	1092	1373	29.20
Sum	57884	4618950	6604	7047	182.94
Av.	17853.33	1411371	2032.5	2130.667	56.56

Table 5: Compressive strength of untreated limestone cubes

Cube No.	Cube cross sectional area (mm^2)	Sample volume (mm^3)	Sample weight (g)	Sample density (kg/m^3)	Compressive strength (N/mm^2)
1	9603	95069	1227	1290	18.2
2	10100	103200	1325	1299	18.8
3	9120	893760	1242	1389	18.6
4	10200	105668	1347	1282	15.7
5	9408	903168	1197	1325	19.1
6	9702	97990	1269	1295	19.1
Sum	58133	2198855	7607	7880	109.5
Av.	17777.17	717106.8	2331.167	2411.667	33.5

Table 6: Compressive strength of treated limestone cubes

Cube No.	Cube cross sectional area (mm^2)	Sample volume (mm^3)	Sample weight (g)	Sample density (kg/m^3)	Compressive strength (N/mm^2)
1	9310	803070	1217	1347	23.6
2	8742	839232	1208	1439	25.8
3	8745	839250	1230	1500	22.6
4	9702	960448	1186	1235	23.7
5	9702	960448	1286	1339	25.9
6	8832	871376	1205	1467	27.7
Sum	55033	5273824	7332	8327	149.3
Av.	16792.67	1624096	2241.167	2551.167	45.8

Absorption: Results showed that the treated limestone absorption is higher than untreated limestone. Absorption percent of treated limestone increase by a ratio of 3% whereas that the NaOCL solution decrease pumices aggregate absorption percent by a ratio of 25% as shown in Table 1.

Abrasion: Treating by NaOCL solution increase limestone and pumice abrasion resistance since, the treating by NaOCL solution decrease limestone and pumice abrasion ratio about 14 and 3.85%, respectively. Pumice show high resistance to abrasion as compared with limestone as shown in Table 1.

Compressive strength of limestone and pumice stone cubes: The results for compressive strength of untreated pumice, treated pumice, untreated limestone and treated limestone are summarized in Table 3-6. Results clearly showed that the compressive strength of treated cubes is higher than untreated cubes for both limestone and pumice since the average compressive strength treated limestone cubes is 26% higher than the average compressive strength of untreated limestone cubes. For pumice samples the average compressive strength increased about 36% after treating. Treaded pumice cubes showed higher compressive strength more than treated limestone cubes by a ratio of 38.5%. Figure 3 shows the compressive strength of treated limestone and treated pumice.

Compressive strength of cement mortar: Table 7-10 show the results of compressive strength of cement mortar specimens at an age of 3, 7 and 28 days. Results showed that the treated limestone increased the compressive strength of cement mortar by a ratio of 1.28, 1.44 and 1.25% at an age of 3, 7 and 28 days, respectively. The compressive strength of cement mortar with treated pumice at an age of 3, 7 and 28 days increased by a ratio of 1.49, 1.31 and 1.44%, respectively compared with cement mortar with untreated pumice cement mortar. Untreated pumice aggregate increased the mortar strength by a ratio of 1.31, 1.26 and 1.34% at an age of 3, 7 and 28 days, respectively as compared with untreated limestone whereas treated pumice aggregate increased the cement mortar strength by a ratio of 1.52, 1.15 and 1.59% at an age of 3, 7 and 28 days, respectively as compared with treated limestone cement mortar. Figure 4-7 summarize the results graphically.

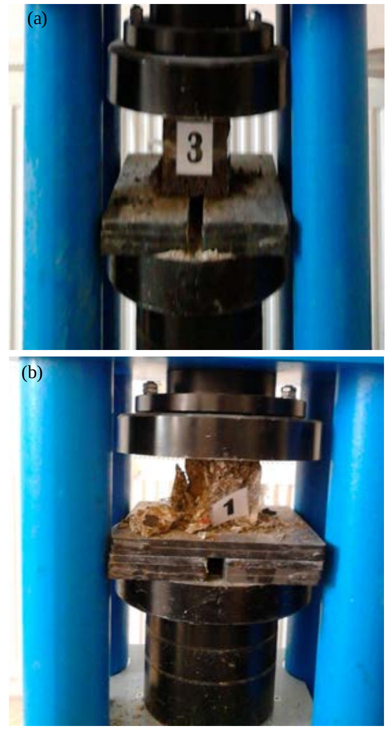

Fig. 3: Compressive strength of: a) treated pumice and b) treated limestone

Table 7: Average compressive strength of cement mortar with untreated limestone and untreated pumice

Age (days)	Untreated limestone (MPa)	Untreated pumice (MPa)	Increment (%)
3	13.70	17.95	1.31
7	26.60	33.50	1.26
28	35.92	48.00	1.34

Table 8: Average compressive strength of cement mortar with treated limestone and treated pumice

Age (days)	Treated limestone (MPa)	Treated pumice (MPa)	Increment (%)
3	17.53	26.70	15.20
7	38.30	44.17	1.15
28	44.90	69.20	1.59

Table 9: Average compressive strength of cement mortar with untreated limestone and treated limestone

Age (days)	Untreated limestone (MPa)	Treated limestone (MPa)	Increment (%)
3	13.70	17.53	1.28
7	26.60	38.30	1.44
28	35.92	44.90	1.25

Flexural strength: Figure 8 shows that the flexural strength of treated limestone and treated pumice cement mortar increased about 6 and 10%, respectively as compared with untreated limestone and untreated pumice cement mortar as shown in Table 11.

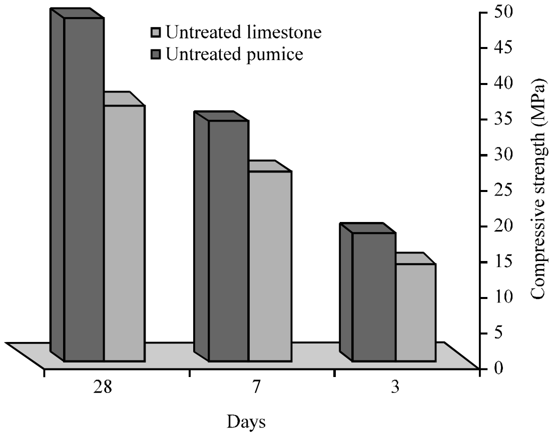

Fig. 4: Average compressive strength of mortar with untreated limestone and untreated pumice

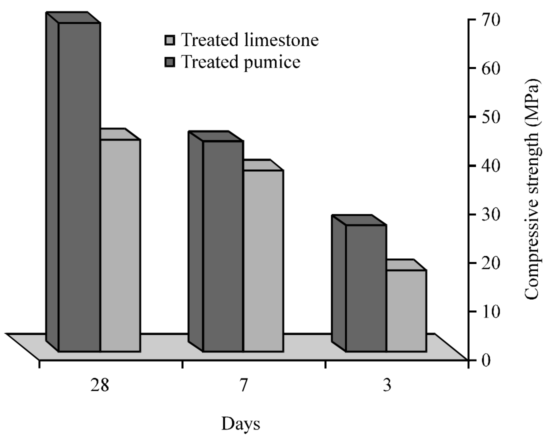

Fig. 5: Average compressive strength of mortar with treated limestone and treated pumice

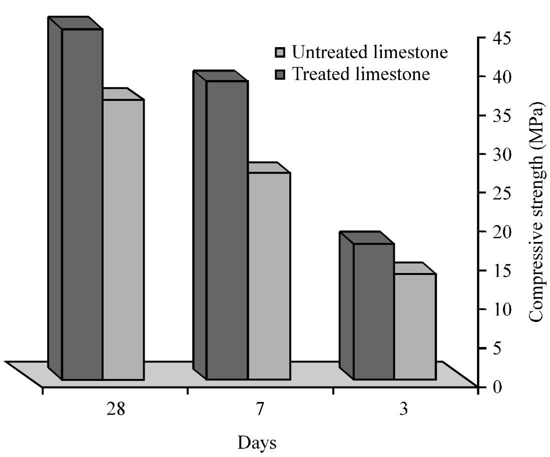

Fig. 6: Average compressive strength of mortar with untreated limestone and treated limestone

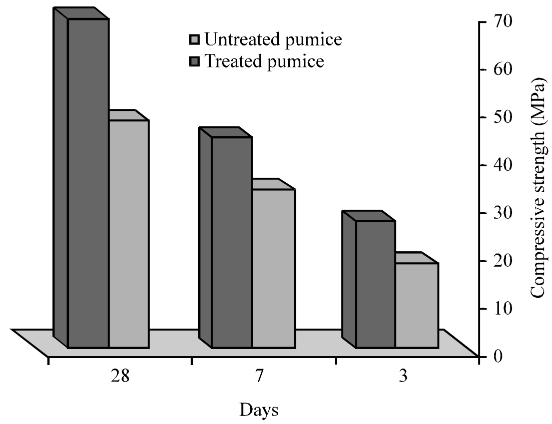

Fig. 7: Average compressive strength of mortar with untreated pumice and treated pumice

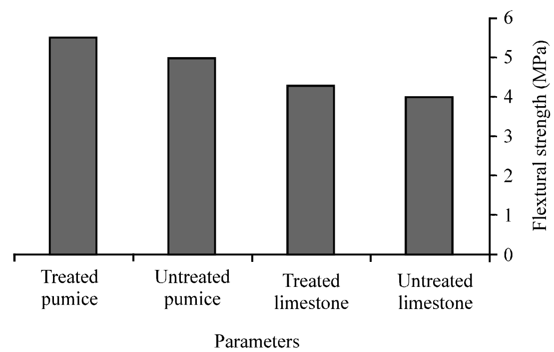

Fig. 8: Average compressive strength of mortar with untreated pumice and treated pumice

Table 10: Average compressive strengthof cement mortar with untreated pumice and treated pumice

Age (days)	Untreated pumice (MPa)	Treated pumice (MPa)	Increment (%)
3	17.95	26.70	1.49
7	33.50	44.17	1.31
28	48.00	69.20	1.44

Table 11: Flexural strength of cement mortar

Age	Untreated limestone (MPa)	Treated limestone (MPa)	Untreatedp pumice (MPa)	Treated pumice (MPa)
28 days	4	4.3	5	5.5

CONCLUSION

NaOCL solution improve limestone and pumice properties and the following remarks can be shown from the experimental studied.

- NaOCL increase limestone stone density, specific gravity, absorption about 6, 2, 3%, respectively
- Limestone abrasion resistance is increased after treating where the abrasion ratio decrease by a ratio of 14%

- The treated limestone cubes compressive strength increased about 26% as compared with untreated limestone cubes
- NaOCL solution affected pumice density and specific gravity slightly. NaOCL increase pumice density and specific gravity about 7 and 2.4%, respectively
- NaOCL affects pumice abrasion resistance since, the abrasion ratio decrease about 3.85%
- NaOCL adversely affected pumice absorption
- The compressive strength of treated pumice cubes is 36% higher than untreated pumice cubes
- The compressive strength of treated pumice cube is 38% higher as compared with treated limestone compressive strength
- Using treated limestone and treated pumice increased significantly cement mortar compressive strength and flexure strength
- Cement mortar containing treated pumice show high strength as compared with cement mortar containing treated limestone

RECOMMENDATIONS

- SEM (Scanning Electronic Microscope) tests for pumice and limestone stone treated with NaOCL solution
- Physco-Chemical tests on pumice and limestone stone treated with NaOCL solution

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