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Mechanical Properties of Acrylic Mortar

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Abstract

This paper focus on the effect of the acrylic polymer on the performance of cement mortar and cement-lime mortar, through studying; the water –reduction effect of the acrylic in the mortar, and the influence of the acrylic on the density, compressive and tensile strength of the hardened mortar . The effect of sand content on the water demand and mechanical properties of mortars was also studied . The experimental results show that the acrylic is reduce the water in cement mortar by 20% while in cement-lime mortar is 4%.

Also the acrylic increases the compressive strength in cement mortar compared to cement-lime mortar at age of 28 days. In tensile strength the increases was 15.7% and that companied with increase in density due to acrylic in cement mortar while in cement-lime mortar the increase in tensile strength was 13.2% at age of 28 days. While the increasing of the sand content leads to increasing in water demand and reducing of the mechanical properties. The paper shown that cement-lime mortar have excellent workability but low level of mechanical strength.

الخلاصة

يركز هذا البحث على تأثير بوليمر الاكريلك على تصرف مونه السمنت و مونه السمنت-نورة،حيث تم دراسة تاثيره على تقليل كمية الماء ،الكثافة،مقاومة الانضغاط والشد. كما تم أيضا بحث تأثير محتوى الرمل على متطلبات الماء و الخصائص الميكانيكية للمونة.أظهرت النتائج المختبرية بأن الاكريلك قلل ماء مونه السمنت بنسبة 20% في حين كانت 4% لمونة السمنت-نورة. أيضا الاكريلك يقوم بتحسين مقاومة الانضغاط لمونة السمنت مقارنة بمونة سمنت-نورة بعمر 28 يوم.

أما في مقاومة الشد فكانت الزيادة 15.7% لمونة السمنت يصاحبها زيادة في الكثافة بسبب استخدام الاكريلك بينما في مونة السمنت – نورة كانت الزيادة في مقاومة الشد بمقدار 13.2% بعمر 28 يوم. وكذلك بينت النتائج بأن زيادة محتوى الرمل يؤدي الى زيادة كمية الماء و نقصان في الخصائص الميكانيكية. اظهر البحث بأن مونة الاسمنت – نورة تمتلك قابلية تشغيل عالية مع انخفاض المقاومة الميكانيكية.

1-Introduction

The mortar is a material resulting of the intimate mixture of sand grains, binder(lime, cement), and water. The properties and characteristics of the mortars depend mainly on the nature of the binder component.

In general ago mortar which act as constructive element which had a double mission: on one hand to make the link between materials (fundamentally rocks or bricks); and on the other hand to cover and protect the surfaces of columns, walls, facads [(1)]. To modify and /or improve the properties of the mortar, an acrylic polymers may be used as an admixture. It improves adhesion and physical properties such as compressive strength and flexural strength.

One of the most important properties of plastic mortars is its workability .Lime is the primary contributor to workability of cement-lime mortars [(2)].

A lime mortar is a type of mortar composed of lime, an aggregate such as sand and water. Its one of the oldest known types of mortar. Addition of lime to cement mortar makes the mixture thicker and sticker while wet [(3)] .

2- Mortar Ingredients

Mortar specification is covered by the ASTM C-270.

2-1 Portland Cement

Hydraulic cement contributes to durability, high early strength and high compressive strength. Its one of the principle cementations ingredient for mortar. The cement used in this research is Ordinary Portland Cement (O.P.C) Type I which the test result indicated that the cement conformed to the Iraqi Specification No.5/1984.

2-2 Hydrated Lime

Covered by ASTM C-270, contributes to workability, water retentively (preventing water from evaporating too quickly from the mortar) and elasticity. Its also a cementitious ingredient however it takes much longer than Portland cement to develop its strength.

2-3 Sand

Sand acts as a filler, providing the most economical mix and contributing to strength. Natural sand was used in this research of 4.75 mm maximum size conformed to the Iraqi Specification No.45/1984, zone 3 grading limits.

2-4 Water

Water is the mixing vehicle creates plastic workability and initiates the cementing action. Tap water was used in this study .

2-5 Admixtures

An acrylic polymer is a white, milky liquid, normally used to prepare cement/sand mixtures and may be used as a water reduction. The properties of acrylic used in this work are shown below:

Properties of acrylic

--Appearance liquid

--Specific gravity 1.04

--Solid by volume 29%

--Chloride content nil

--Compatibility with cement all types of Portland Cement

--Complies with ASTM C-631. C-932

3- Mortar Mixes

Twelve types of mortar mixes were investigated in this paper. All mortar mixes consist of; 1 part of cement or 1 part of cement-1 part of lime and different parts of sand by volume. Acrylic is added to the mortar with dosage of 7% of the cement volume. The proportion specification for all types of mortar mixes are shown in Table(1).The water/cement or water/cementitious material ratio were adjusted to mention a flow of 110±5 in 25 drops of flow table according to B.S.4721, Table(1). Mortars were mixed by hand, the required quantity of lime was added to cement then the materials were mixed dry by a trowel for a sufficient period to break up the agglomerates of lime-powder particles and dispense them thoroughly the cement particles. Three 50 mm cube specimens were molded from each type of mortar for each age,(3,7&28 day).

Table (1) Mortars Mixed Proportions

Mortar Type	Proportions by volume		Sand by volume	Acrylic %by volume. of cement	W/C or W/Cm
	Portland Cement	Hydraulic Lime			
A0	1		2		0.5
A1	1		3		0.53
A2	1		4		0.6
B0	1	1	2		0.625
B1	1	1	3		0.63
B2	1	1	4		0.675
A0A	1		2	7	0.4
A1A	1		3	7	0.46
A2A	1		4	7	0.57
B0A	1	1	2	7	0.6
B1A	1	1	3	7	0.61
B2A	1	1	4	7	0.65

4- Preparations, Casting, and Curing of the test specimens

The moulds were well cleaned and the internal faces were oiled to avoid adhesion with the mortar after hardening. The casting was carried out in one layer and compaction was performed by means of vibrating table for a sufficient time to reach full compaction. Finally the mortar surfaces were leveled and specimens were warped with nylon sheets for 24 hours prior demolding to prevent moisture evaporation from the surfaces and to avoid plastic shrinkage cracking. After demolding, the specimens were completely immersed in tap water until the time of test.

5- Plastic mortar properties

5-1 Workability (Plasticity)

One of the most important properties of plastic mortar is its workability. Acrylic polymer improves the workability of cement mixes. Lime is the primary contributes to workability of cement-lime mortars. Hedin [(4)] identified one factor, hydrated lime particle shape that can influence workability as measured by plasticity. The hexagonal platelet particle shape of hydrated lime can act like a deck of cards by sliding in one direction, yet remaining in contact with the particle above. This provides lubrication and at the same times a stickiness to the mortar [(5)].

5-2 Water retention

Acrylic admixture are used in mortar mixes to water retentively [(6)]. The fine particle size of hydrated lime particles enhances the ability of plastic mortar to retain water when applied to an absorptive base. Water retention is important, not only to enhance workability (plasticity), but also to extend board life and assure that adequate water is available to hydrate cementitious components of the mortar[(7)].

6- Mortar testing

6-1 Compressive strength test

The compressive strength was measured on 50 mm cube by using a standard testing machine. The test was performed at ages of 3,7,28 days. Each value obtained is an average of three readings measured on three specimens. The test was performed in accordance with B.S EN 1015-11[(8)].

6-2 Tensile strength test

This test covers the determinations of the tensile strength of hydraulic cement mortar employing the briquet specimen. Specimens was measured in according with ASTM C150-58 using standard testing machine. The test was performed at ages of 3,7,28 days.

6-3 Density of hydrated mortar

Its necessary to determined the density of mortar because its related to the air content in mortar. Air content is useful to predict mechanical strength of mortar. The test was performed at ages of 3,7,28 days. The density of hardened mortar was measured on 50 mm cube. Density was determined accordance with B.S.EN 1015-10.

7- Results and discussion

7-1 Compressive strength

The influence of acrylic on the compressive strength for various types of mortar is illustrated in Table (2) and Figs(1&2). Results indicated, that the addition of 7% acrylic by volume of cement (recommended by the company of production) is better. This is mainly due to reaction mechanism of acrylic particles. After adding the water, which includes acrylic, to cement-sand mixture, the acrylic particles gradually start to be deposited on unhydrated cement particles and cement gel, the latter is formed as the hydration product of cement particles, which in turn releases calcium hydroxide into the water phase. Calcium silicate may be formed also as a result of the reaction between calcium hydroxide and the silica found on the surface of aggregate. Acrylic particles start to flocculate due to reaction in the capillary water and form a close-packed layer surrounding the mixture of cement gel and the unhydrated cement particles. Acrylic particles coalesce to a form a continuous polymer film binding the hydrates together through an interpenetrating polymer network[9,10,11]. Fig.(3) shows the compressive strength at 28 days of cement mortar with &without acrylic which is grater than cement-lime mortar with &without acrylic, also it illustrated a drop in compressive strength with increasing sand content. Numerous researches[12,13,2]have found that compressive strength of mortar increase with increases in cement content , but it decreases with an increase of lime, sand and water.

Table (2) Results of compressive strength test

Mortar type	Compressive strength (N/mm^2)		
	3 days	7 days	28 days
A0	24.7	26.1	27.2
A1	14.1	14.7	16.4
A2	9.0	9.6	10.1
B0	6.1	8.3	9.3
B1	5.3	7.8	8.1
B2	3.5	5.0	5.2
A0A	25	26.5	31.1
A1A	17.1	18.8	22.0
A2A	11.7	12.5	15.4
B0A	7.6	8.3	12.5
B1A	6.1	6.8	9.6
B2A	4.1	5.2	6.3

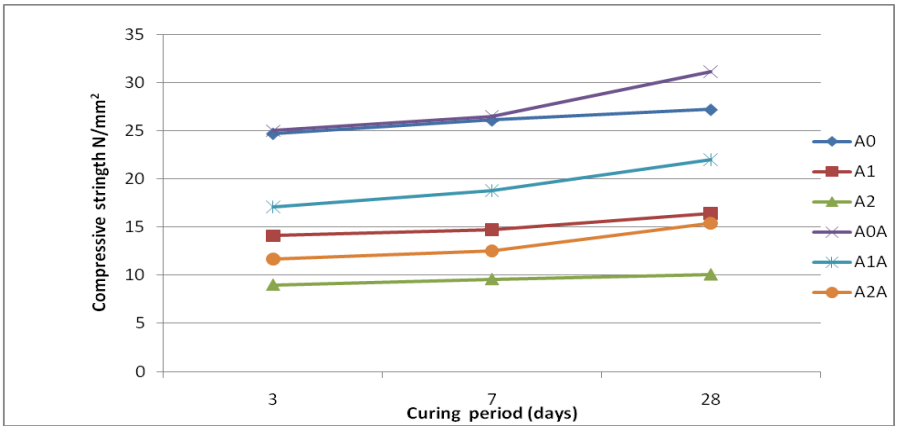


Fig.(1) Compressive strength of cement mortar with& without acrylic

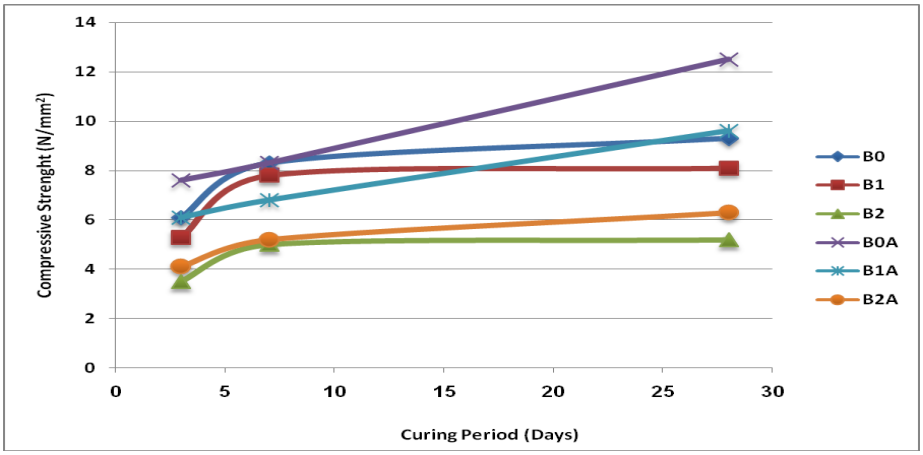


Fig.(2) Compressive strength of cement-lime mortar with& without acrylic

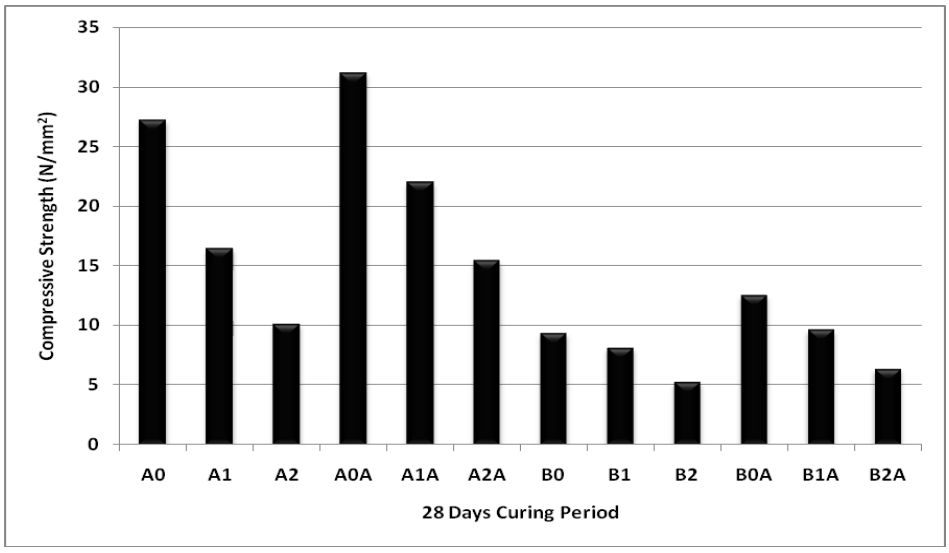


Fig.(3) Comparison of compressive strength for various types of mortar

7-2 Tensile strength

Table (3) and Figs.(4&5) demonstrated superior performance of mortar incorporate with acrylic polymer over those of the control mortar. This behavior is due to mechanism of polymer modification of Portland cement paste which can be schematically describe in three separate steps:

1- Immediately after mixing with water, the cement paste particles start to hydrate .
2- The mixture of cement gel covered unhydrated cement particles is enveloped with a close-packed layer of polymer particles.
3- In the third steps, the removal of water by hydration and evaporation, the closely packed polymer particles start forming polymer films(membranes)[14].

Fig(6) shows the tensile strength at 28 days of cement mortar with and without acrylic is grater than that of cement – lime mortar with and without acrylic, it also illustrated a drop in tensile strength with increasing sand content[15].

Table (3) Results of Tensile strength test

Mortar type	Tensile strength (N/mm^2)		
	3 days	7 days	28 days
A0	1.33	1.97	2.88
A1	1.27	1.7	2.41
A2	0.96	1.12	1.92
B0	0.73	1.0	1.71
B1	0.71	0.98	1.34
B2	0.49	0.65	0.92
A0A	1.96	2.75	3.42
A1A	1.52	1.98	2.96
A2A	0.99	1.72	2.31
B0A	0.96	1.65	1.97
B1A	0.88	1.25	1.74
B2A	0.54	0.75	1.1

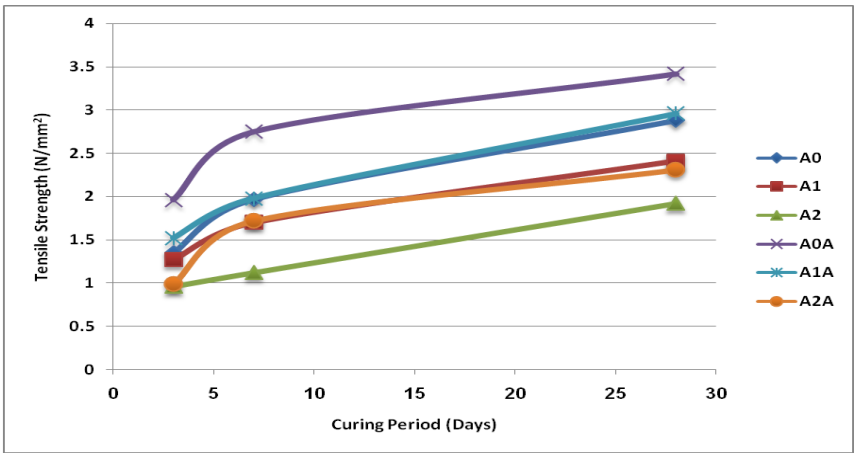


Fig.(4) Tensile strength of cement mortar with& without acrylic

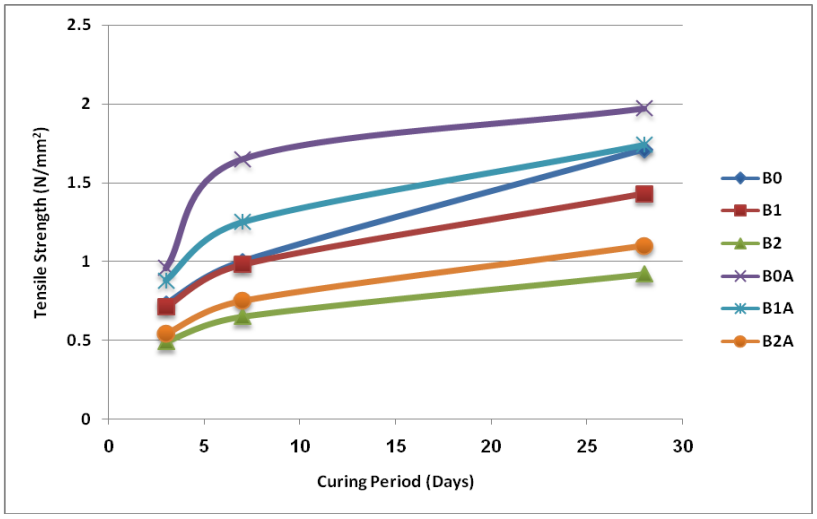


Fig.(5) Tensile strength of cement-lime mortar with& without acrylic

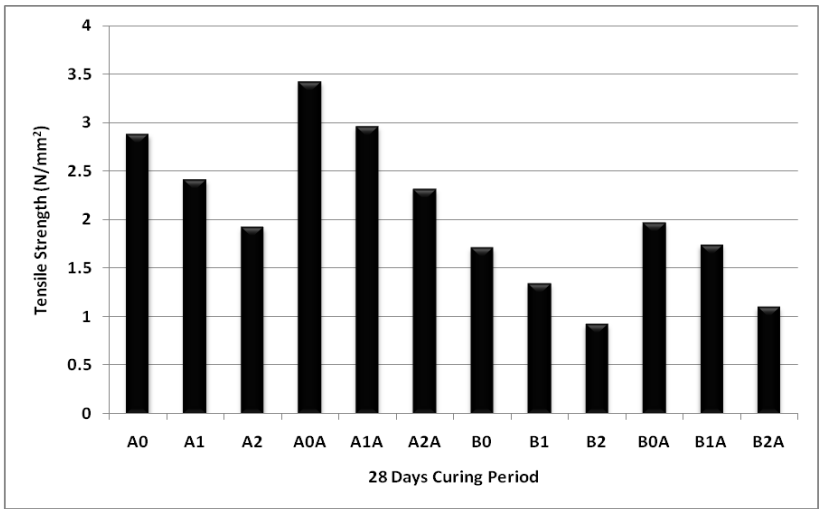


Fig.(6) Comparison of tensile strength for various types of mortar

7-3 Density of hardened mortar

Table (4) and Figs(7&8) illustrated the values of density for various types of mortar. Result generally indicated that a part of density of mortars increase with the addition of acrylic polymer[10].This mainly due to reaction mechanism of acrylic particles[10,11] induced to reducing the porosity of mortar and increased the density.

Fig.(9) shows the density at 28 days of cement mortar with and without acrylic which is grater than cement-lime mortar with and without acrylic and also illustrated a drop in density with increasing sand content. This behavior is strongly related with the increases the water requirement of mortar mix, thereby the porosity increased.

Table (4) Results of Density of hardened mortar test

Mortar type	Density of hardened mortar kN/m^3		
	3 days	7 days	28 days
A0	22.1	22.8	23.6
A1	21.0	21.5	22.8
A2	19.0	19.8	20.1
B0	17.0	18.5	20.0
B1	17.5	19.0	19.6
B2	16.5	18.1	19.0
A0A	22.6	23.0	24.0
A1A	21.7	22.5	23.0
A2A	19.5	20.0	21.8
B0A	17.5	19.0	21.7
B1A	18.0	19.2	20.2
B2A	17.0	18.7	19.6

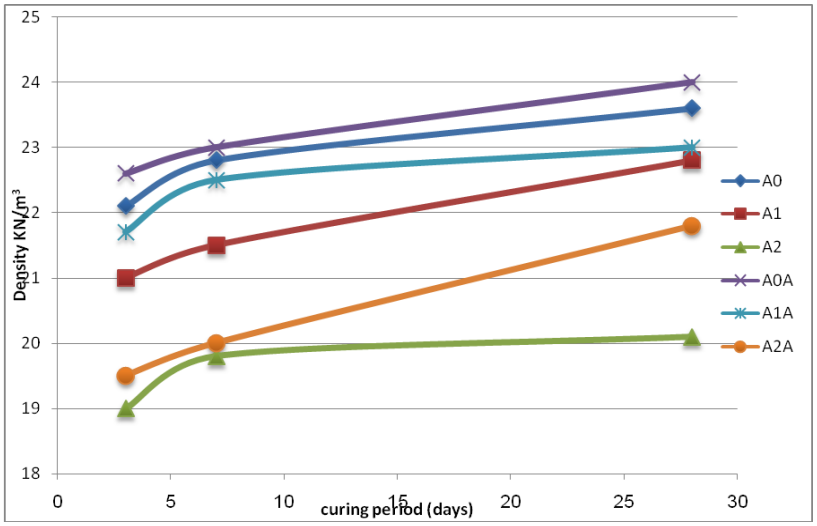


Fig.(7) Density of cement mortar with& without acrylic

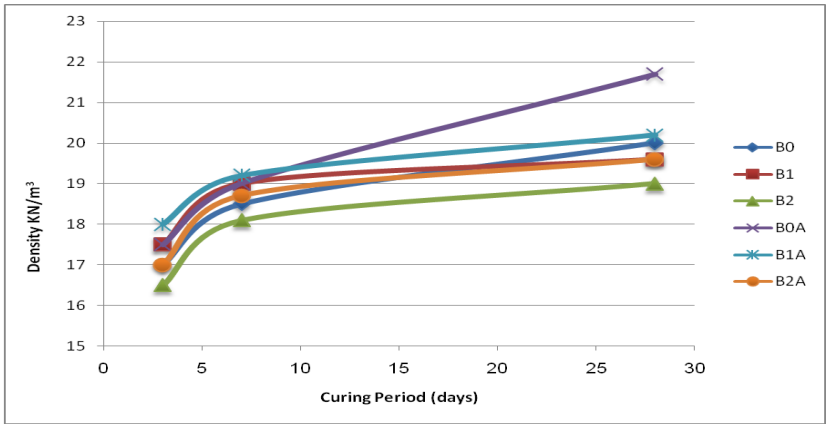


Fig.(8) Density of cement-lime mortar with& without acrylic

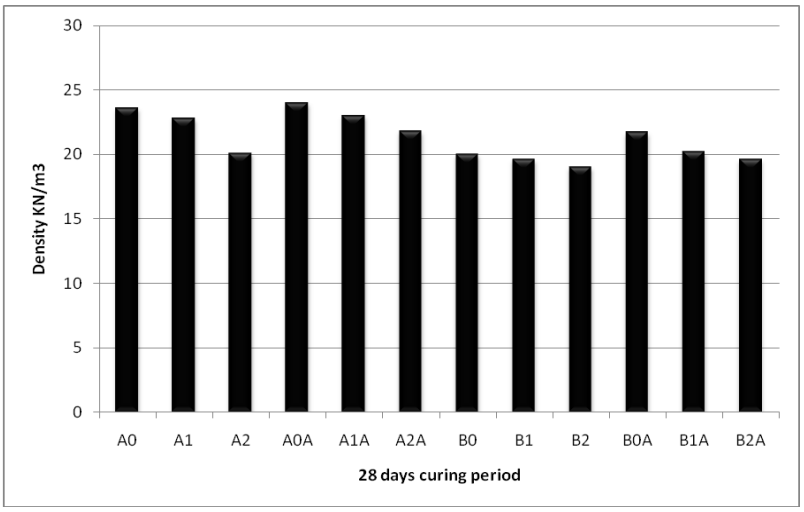


Fig.(9) Comparison of density for various types of mortar

8- Conclusions

Based on the results of this research, the following conclusions may be drawn:

1- The advantages of acrylic which is used with Portland cement mortar are:
- Improves the workability of cement mixes.
- Reduced water demined.
- Enhances tensile and compressive strength.
- Reduced porosity and improves density of hardened mortar.

2- Mortars made with cement-lime mortars can have excellent workability.

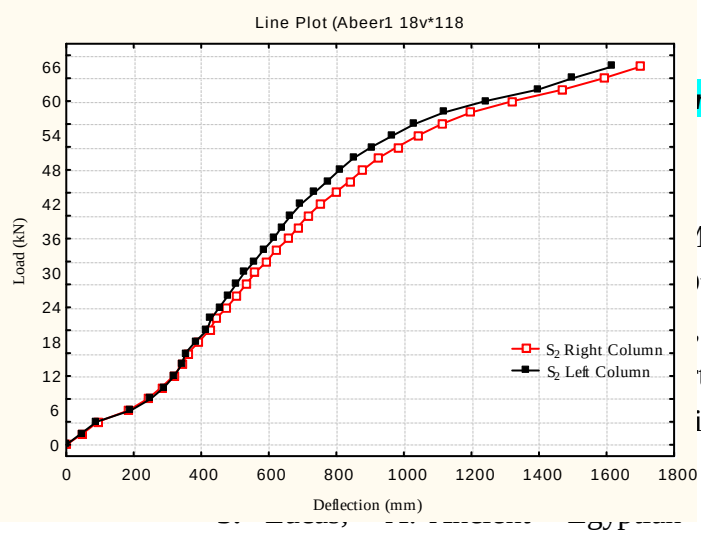
3- Cement-lime mortars required more water than cement mortar.

4- Cement-lime mortars have low level of tensile and compressive strength.

5- Cement-lime mortars have high porosity and low density.

6- Cement mortar with and without acrylic exhibits high levels of water demined, low compressive and tensile strength and reduced density when increased sand content.

7- Mortars made with cement-lime investigated in this work conform to class N of the ASTM C270.



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