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THE MECHANICAL PROPERTIES OF LIME CONCRETE

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Abstract: Lime concrete shall be prepared by mixing coarse aggregate and lime mortar in the specified proportions with required quantity of water. Lime has been used as a cementing material since times immemorial. The influence of hydrated lime $Ca(OH)_2$ on the 7, 28 and 56 days compressive and splitting tensile strength also 28 day density tests were investigated. Results indicated that all mixes specimens exhibited continuous strength gain. The defects in lime concrete, particularly its slow setting compared with that of cement concrete could be got rid of by adding to it a definite proportion of cement. Result showed that the 28 – day compressive strength of lime concert mix was 4.8mpa, while the 28 day compressive strength of cement concert mix was 28.7mpa with the same mix proportion. At 28days of curing, the Percentage increase in compressive strength of lime- cement concert mix relative to lime concert mix was 70%. Lime concrete have some advantageous properties e.g. good workability and plasticity, lime is cheaper too and is locally available.

الخواص الميكانيكية لخرسانة النورة

الخلاصة: يتم تحضير الخرسانة المصنوعة من النورة وذلك بخلط الركام الخشن مع مونة النورة وبنسب معينة وبإضافة كمية مناسبة من الماء. ان استعمال النورة كمادة اسمنتية كان منذ فترات زمنية سحيقة. أن تأثير هيدروكسيد الكالسيوم $Ca(OH)_2$ على مقامة الانضغاط والشد بالأعمار 7 ,28 ,56 يوم وكذلك على كثافة الخرسانة بعمر 28 يوم تم التحقق منهُ في هذا البحث. لقد بينت النتائج بأن جميع الخلطات الخرسانية ابدت تقدماً في نمو المقاومة مع الزمن. أن أهم عيب في النورة هو بطأ عملية التصلب مقارنة مع الخلطات التي تم استعمال السمنت فيها، لكن من الممكن زيادة سرعة التصلب وذلك بإضافة كمية مناسبة من الاسمنت. لقد بنيت النتائج بان مقاومة الانضغاط لامر 28 يوم لخرسانه النورة كانت بمقدار 4.8 Mpa بينما كانت مقاومة الانضغاط بعمر 28 يوم لخرسانه السمنت بمقدار 28.7 Mpa لنفس نسب الخلط، بينما كانت نسبة الزيادة في مقاومة الانضغاط بعمر 28 يوم 70% لخرسانة النورة والسمنت. ان مميزات الخرسانة المصنوعة من النورة هي ذات قابلية تشغيل عالية وكذلك ذات مرونة عالية وتعتبر النورة مادة رخيصة الثمن مقارنة مع السمنت ومتوفر محلياً.

1. Introduction

A concrete made from a mixture of lime, sand and gravel is said to be as lime concrete. It was widely used before the lime was replaced by Portland cement. Concrete made with lime cement is well known form more than 5000 years old. It was widely used in all over the world. Sign of its usage can be found easily after surveying different archaeological sites.

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Lime is one of the most versatile chemical in the world. There are two types of lime produced, quicklime and hydrated lime. Quicklime is formed during the calcination of limestone. Hydrated lime results from subsequent hydration of quicklime where required.

Lime has been innovatively rediscovered to be a more environmentally sustainable product aiding in the implementation of new cleaner systems. The uses of lime have evolved steadily over time; this is thought to be due to its ease of acquisition affordable price and unique versatile properties [1].

The manufacture of Portland cement is an energy and carbon intensive process and it's responsible for 5 to 8 percent of the total global carbon emissions. Thus, today, the world's yearly output of 1.5 billion tons of cement, account for nearly 7 percent of global CO_2 emissions[2].

The manufactures of lime is not dissimilar form the manufacture of cement, as both are produced by burning limestone. The environmental benefits of lime – based building material lime in potential process energy and carbon savings, associated with lime production[3]. Lime is formed at a significantly lower temperature than cement. This means that its production requires less fuel and energy than other conventional Portland cement types, which offers a clear environmental benefits[4].

2. Properties of lime concrete

Lime concrete provides good bases to bear the sufficient loads and also provide certain degree of flexibility. It adjusts very well when it is in contact with surface. Lime concrete also exhibits certain degree of water proofing property and thus prevents subsoil dampness in floors and walls. Lime concrete also exhibits volumetric stability. It can be made easily and can be available at much cheaper rates. It also resists weathering effects and very durable. On the other hand, the use of lime concrete has not been continued due to their important disadvantage including long setting time along with low early – age strength[5].

3. Proportioning

The proportions of aggregate to lime mortar shall be done by volume. Generally, lime concrete is Prepared by mixing 1 or 3 parts of coarse aggregate and 1 or 2 parts of sand to 1 part of hydrated lime.

4. Mixing

Concrete shall be mixed in a mechanical mixer. The mixer shall be flushed clean with water. Mixing shall be done by pouring measured quantity of coarse aggregate and mortar for one batch in the drum of the mixer. The water shall be added gradually up to the required quaintly and the wet mixing of batch shall be continued for at least two minutes in the drum till concrete of uniform color uniformly distributed materials and consistency is obtained. The consistency of the concrete shall be such that the mortar does not tend to separate from the coarse aggregate.

5. Materials

5.1.1 Hydrated limes

Hydrated limes are prepared from quicklimes by the addition of a limited amount of water during the manufacturing processes. Calcium hydroxide is called hydrated lime, because it contains water that is chemically combined with calcium oxide[6]. Hydrated lime was develop so that greater control could be exercised over the slaking operation by having it carried out during manufacture rather than on the construction job.

After the hydration process ceases to evolve heat, a fine, dry powder is left as the resulting product. Hydrated lime can be used in the field in the same manner as quicklime, as a putty or paste, but it does not require along seasoning period. It can also be mixed with sand while dry, before water is added. Hydrated lime can be handled more easily than quicklime because it is not so sensitive to moisture. The plasticity of mortars made with hydrated limes, although better than that obtained with most cement, is not nearly so high as that of mortars made with an equivalent amount of quicklime putt[7].

The x- ray diffraction analysis Fig. (1) of lime used in this work indicated that the material consists essentially of calcium hydroxide $Ca(OH)_2$ and very little of calcium carbonate $CaCO_3$. Table (1) shows the chemical and physical properties of the hydrated lime.

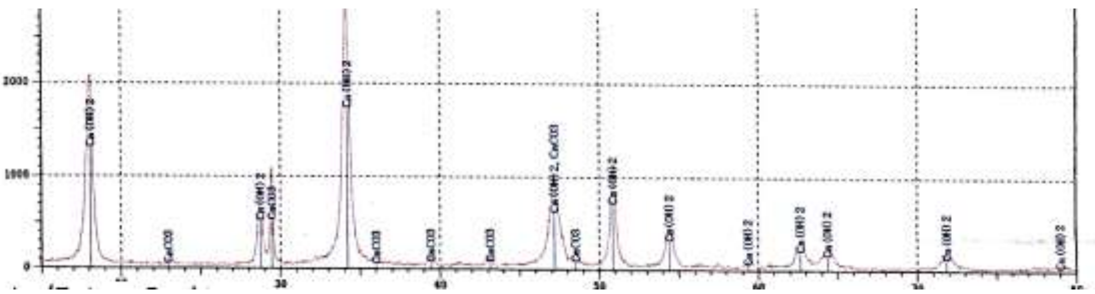

Fig. (1): x-ray diffraction analysis of hydrated lime

Table (1) chemical and physical properties of hydrated lime.

Chemical composition	*Content (percent)*
AL_2O_3 %	0.1
Fe_2O_3 %	0.035
CaO %	0.15
MgO %	0.1
$Ca(OH)_2$ %	98.00
$CaCO_3$	0.25
$Blain\ Method(m^2/kg)$	1150
Specific gravity	2.55

5.1.2 Carbonation of lime

When exposed to air, lime mortar hardens by reabsorbing carbon dioxide to become calcium carbonate again. This is called carbonation[8].

The hardening property of lime results from its ability to react with atmospheric carbon dioxide to form calcium carbonate - the raw material used in making lime. Thus, the chemical reaction of lime with carbon dioxide returns lime to its original material, limestone which is hard and strong.

5.2 Cement

Ordinary Portland Cement is used in this work. The chemical composition and physical properties of cement are shown in table(2) and (3) respectively. Test results indicate that the adopted cement conform to the Iraqi specification No. 5/ 1984[9].

Table (2) Chemical composition and main compounds of cement.

Oxides composition	Content%	Limits of (I.O.S) No.5/1984
CaO	62.52	-
SiO_2	18.57	-
Al_2O_3	7.10	-
Fe_2O_3	4	-
MgO	1.23	< 5.00
SO_3	2.69	< 2.80
L.O.I	2.31	< 4.00
Insoluble residue	0.8	< 1.5
Lime Saturation Factor, L.S.F.	0.79	0.66- 1.02
Main compounds (Bogu's equations)		
C_3S	57.2	-
C_2S	14.68	-
C_3A	10.9	-
C_4AF	8.7	-

Table (3) physical properties of cement

Physical Properties	Test results	Limits of (I.O.S.) No.5/ 1984
Specific surface area (Blaine method), m^2/ kg	244	≥ 230
Setting time (Vicate apparatus),		
Initial setting, h:min	2:15	≥ 00:45
Final setting, h:mim	8:15	≤ 10:00
Compressive strength, MPa		
3 days	23.3	≥ 15.00
7 days	32.76	≥ 23.00
Soundness (Le-Chateler) method, mm	1.0	≤ 1.0

5.3 Sand

Natural sand was used as a fine aggregate Table (4) and Fig. (2) illustrate the sieve analysis of sand used in this work.

Table (5) illustrated the chemical and physical properties of the sand used.

Results indicate that the sand grading and the sulfate content are within the requirements of the Iraqi specification No. 45/1984[10]

Table (4) Grading of sand

Sieve size (mm)	Cumulative passing%	Cumulative passing % Limits of (I.O.S)No.45/ 1984 Zone (3)
4.75	100	90-100
2.36	92.0	85-100
1.18	82.3	75-100
0.60	66.1	60-79
0.3	29.8	12-40
0.15	8.3	0-10

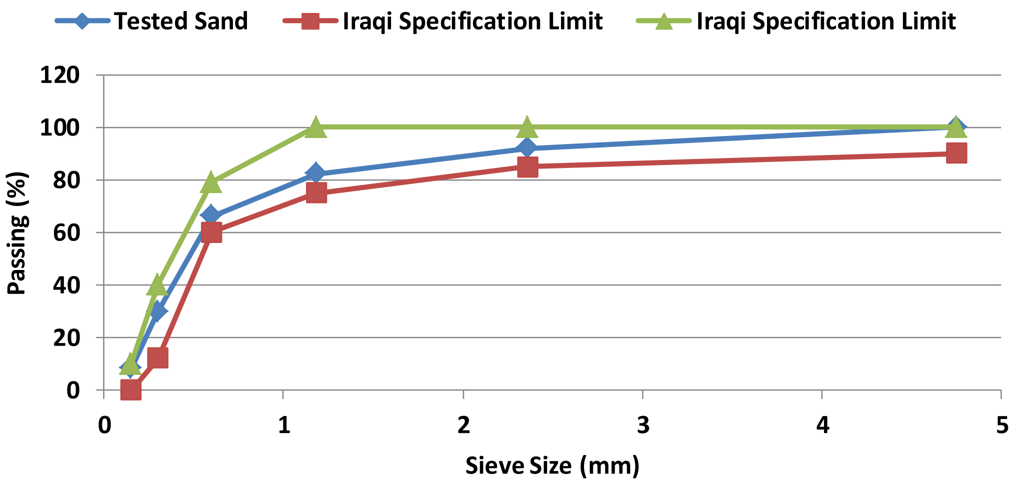

Fig. (2): Grading curve for natural sand.

Table (5) Chemical and physical properties of sand

Properties	Test results	Limit of Specification
Specific gravity	2.63	-
Absorption %	0.72	-
Dry loose-unit weight Kg/m^3	1590	-
Sulfate content as So_3 %	0.09	≤ 0.5
Materials finer than 75μm%	1.2	≤ 3.0

5.4 Course aggregate

The coarse aggregate was natural gravel of 12.5mm maximum size. The grading of coarse aggregate are illustrated in table (6) and in Fig. (3). Table (7) showed the sulphate and chloride content of course aggregate.

Result indicate that the coarse aggregate grading and the sulfate content are within the requirements of the Iraqi specification No.45/ 1984[10].

Table (6) grading and physical properties of Coarse aggregate

Sieve size	Cumulative passing%	Limits Iraqi specification No.45/ 1984
14mm	100	90-100
10 mm	64	50-85
5mm	5	0-10
2.36m	-	

Specific gravity =2.63

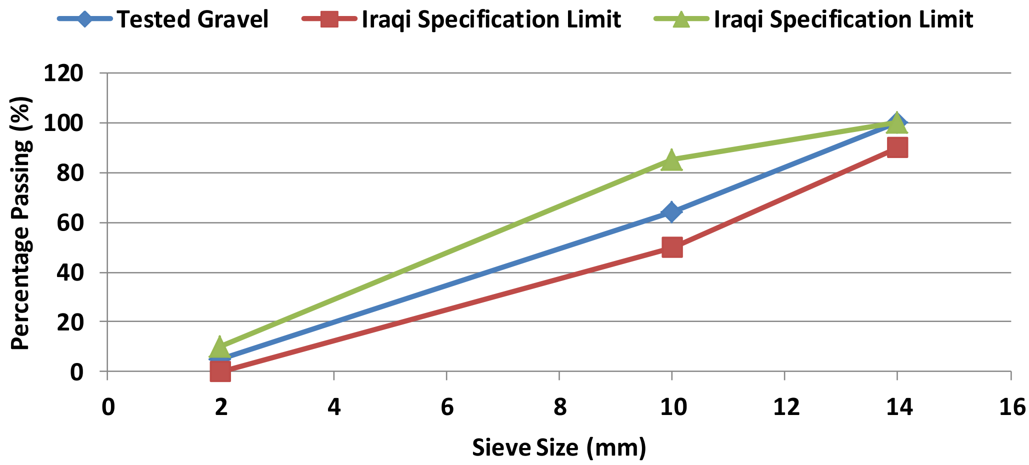

Fig. (3): Grading curve for coarse aggregate

Table (7) sulphate and chloride content of the coarse aggregate

Coarse aggregate	Sulphate content % by weight of aggregate	Chloride content % by weight of aggregate
	0.09	0.019

5.5 Water

Tap water that is suitable for making ordinary and lime concrete should be used.

6. Workability and Plasticity

The term workability is used with reference to concrete, mortar, and plaster mixes. With concrete, it is some what quantified by the slump measure. With mortar and plaster mixes (lime concrete), there is no such quantification of workability. However, a good mason can judge workability while spreading the mortar or plaster mix with a trowel.

Basically, a workable mortar or plaster will spread more easily-a difference similar to spreading a creamy peanut butter on a piece of toast [6].

7. Concrete Mixes

Four types of concrete mixes were investigated, three types with lime and one without lime. The proportion of concrete mixtures and some properties of fresh and hardened concrete are shown in Table (8).

Table (8) Concrete mixes

lndex	Proportion of mix by volume				Water/binder ratio	Density at 28 days kg/m^3
	Lime	cement	sand	gravel		
A	1	---	2	3	0.75	2296
B	1	---	1	1	0.85	2214
C	0.5	0.5	2	3	0.6	2300
D	---	1	2	3	0.45	2410

8. Placing, Compaction and Curing of the test specimens

Concrete shall be laid (and not thrown) in layers while it is quite fresh. Each layer shall be thoroughly rammed and consolidated before succeeding layer is placed.

After the lime concrete has begun to harden i.e about 24 hours after its placing and compaction the curing shall be done by keeping the lime concrete specimens in air because the hydrated lime - water paste set and herders due to the chemical reaction of the carbon dioxide in air with lime.

The cement concrete specimens were wrapped with nylon sheets for 24 hours prior to demolding to prevent moisture evaporation from the surface and to avoid plastic shrinkage cracking. After demolding, the specimens were completely immersed in tap water at temperature of 22±1°C and a relative humidity of about 95% for a period of testing.

9. Hardened Concrete Testing

9.1 Compressive Strength test

The concrete compressive strength measured on 100mm cube by using a standard testing machine with a capacity of 2000 kN. The test was performed at ages 7,28,56 days. Each value obtained is an average of three readings measured on three specimens. Load was applied at the rate of $15mN/m^2$/min. in accordance with B.S. 1881 part4:1970.

9.2 Tensile strength test

The splitting tensile strength of 100×200mm cylindrical concrete specimens was measured in accordance with the ASTM C 496-86 using a standard testing machine of capacity 2000kN. The test was performed at ages of 7, 28, 56 days. The splitting tensile strength of the specimen was calculated by the following equation:

$T=2p/\pi ld$

Where T = splitting tensile strength (N/mm^2)

P = maximum applied load indicated by the testing machine (N)
I = length, (mm) and
d = diameter, (mm).
Each value obtained is an average of three readings measured on three specimens.

9.3 Density test

The concrete density was measured on 100mm cube in accordance with ASTM C 642-06 standard. The test was performed at 28 days age. The value obtained is an average of the three readings measured on three specimens.

10. Result and discussion

10.1 Compressive strength

Table (9) and Fig. (4) show the result of compressive strength development for all mixes. Result indicated that, all mixes exhibit continuous increase in compressive strength with increasing age. This increase is due to the nature of the hydrated phases formed during the hydration process. As a result, the total porosity decreases and the compressive strength increase[11].

The hardening of lime is due to the conversion of hydroxides to carbonates, also the strength of concrete lime depend upon mix proportion[12].

Lime concrete mix showed improvements in compressive strength with the addition of Portland cement because Portland cement is a much better hydraulic cement. Fig (4) shows the slow reaction of lime concrete as compared with cement concrete. This is mainly due to a hardening property of lime result from its ability to react with atmospheric carbon dioxide to form calcium carbonate. The slow setting is also due to the fact that only a small fraction (less than 0.04%) of air is carbon dioxide[6]. Kadum, N., M.[13] and Velosa, Anal, Cachim, Paulo B. [14] have showed slow reaction of lime with water.

Table (9) Result of compressive strength test

Index	water/ binder ratio	Compressive strength N/ mm^2		
		7 days	28 days	56 days
A	0.75	1.8	4.8	5.1
B	0.85	1.9	5.7	5.9
C	0.6	9.7	16.1	16.9
D	0.45	13	28.7	29.1

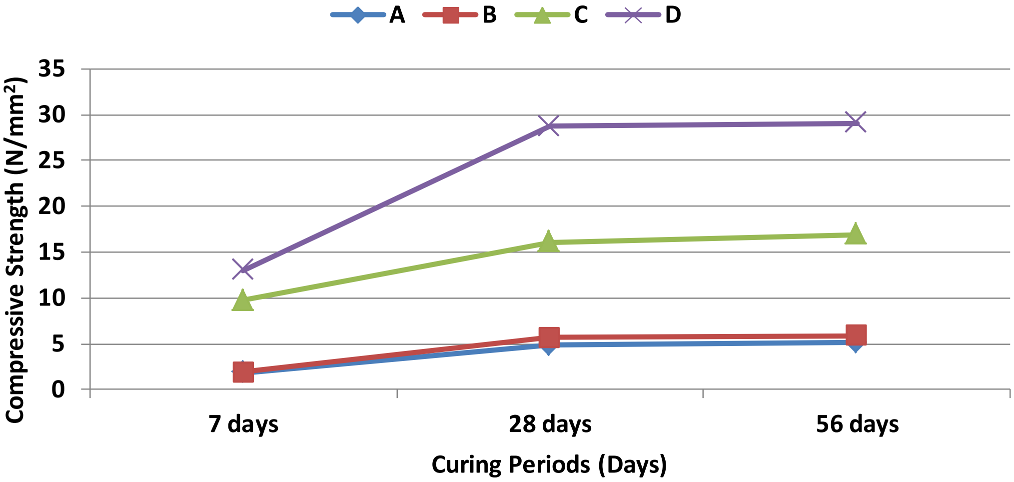

Fig (4) compressive strength of different concrete mixes

10.2 Tensile strength

The splitting tensile strength of all the tested specimens are presented in table (10) and Fig. (5). Result showed that lime concrete and cement concrete exhibited continuous strength gain with different rates. The rates are dependent to the water/ Binder ratio and lime/ aggregate ratio. The increase in water/ Binder ratio, would cause a reduction in strength gain. This is because the increase in volume of hydrated products will not be able to occupy the space already filled with water. Hence, porosity increases and strength decreases(15).

Also the increase in aggregate/ lime ratio, especially the coarse aggregate would reduce the binder volume which makes the hydration process slower (16). The addition of Portland cement showed further improvement in tensile strength over those of the lime only. This is because their cement was hydraulic[6].

Table (10) Result of tensile strength test

Index	Proportion of mix by volume				Water/ Binder ratio	Tensile strength N/mm^2		
	Lime	cement	Sand	gravel		7 days	28 days	56 days
A	1	--	2	3	0.75	0.4	0.95	0.99
B	1	--	1	1	0.85	0.41	1.3	1.33
C	0.5	0.5	2	3	0.6	0.87	1.7	1.9
D	--	1	2	3	0.45	1.6	2.5	2.99

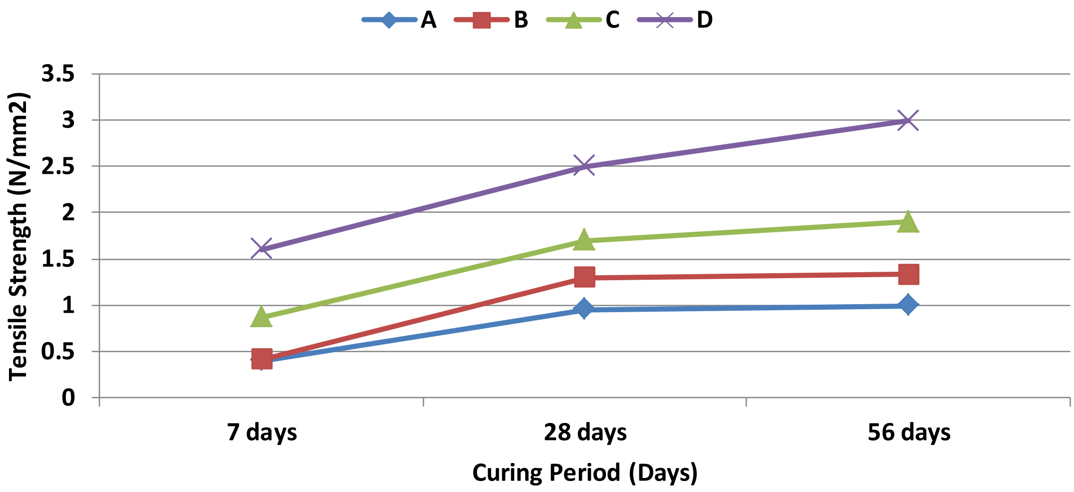

Fig (5) Tensile strength of different concrete mixes

10.3 Density of hardened concrete

The density for all types of concrete are presented in table (8) and Fig. (6). The density of lime concrete is always lower than that for cement concrete. This decrease can be explained by the lower specific gravity of hydrated lime than cement. The density values for lime concrete also show a significant increase when aggregate content increase. This increase in density can be attributed to the high density of aggregate comparatively with the binder[17].

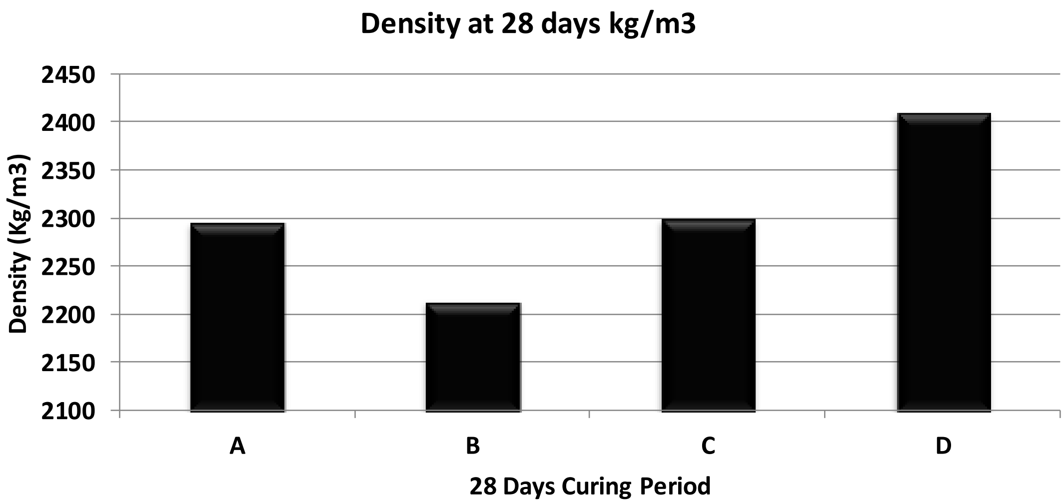

Fig (6) comparison of density for various types of concrete mixes

11. Conclusions

Based on the result of this investigation, the following conclusions may be drawn:

1. Hydrated lime could be considered as a sustainable binder due to lower production energy needs, lower CO_2 emission during production and CO_2 absorption by carbonation.
2. Hydrated lime has greater workability and plasticity.
3. Hydrated lime- water paste sets and hardens due to the chemical reaction of the carbon dioxide in air with lime.
4. Hydrated lime usually gains strength in time greater than the time in which cement concrete gains same value of strength.
5. Lime concrete takes a long time to cure, and while the ancient world had lots of time, today time is money.
6. Lime concrete does not harden in water but stays soft. So there are situations where it cannot be used.
7. The density of lime concrete is lower than that for cement concrete.

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