Some Durability Test of No-Fine Concrete

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ABSTRACT

In this study, two types of mixes were adopted by using two grading of coarse aggregate. The practical side of this study was to produce no-fine aggregate concrete by using crushed clay brick aggregates. The durability of the produced concrete and internal sulfate attack was studied. For durability assessment, it is found that the no-fine concrete made with crushed brick aggregate lost about (15-25) % of its compressive strength after being subjected to 60 cycles of wetting and drying with age 120 days. The curing condition showed that the water curing improved the compressive strength with a rate higher than that when sealed or air dry curing were used. The crushed brick no-fine concrete deteriorated in compressive strength after exposure to internal sulfate attack for 60 cycles; the percentage decrease was about (23.33-25) and (25-27.5) % for 0.57 and 0.83sulfate content respectively.

Keywords: compressive strength, durability, internal sulfate attack.

بعض فحوصات ديمومة الخرسانه الخاليه من الركام الناعم

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الخلاصة

تم خلال هذه الدراسه استخدام نوعين من الخلطات الخرسانيه الخفيفه الوزن حاويه على تدرجين من الركام الخشن. تضمن الجانب العملي من البحث انتاج خرسانه خاليه من الركام الناعم باستخدام الركام الاعتيادي ومكسر الطابوق. وتم دراسة ديمومة الخرسانه الخفيفه في البحث. لتقيم الديمومه وجد ان مقاومه الانضغاط للخرسانه الخاليه من الركام الناعم تنخفض من (15-25) % بعد تعرضها الى 60 دورة ترطيب وتجفيف بعمر يعادل 120 يوم. كما وجد ان مقاومه لانضغاط عند انضاج النماذج في الماء افضل مقارنا مع انضاجها في الهواء الجاف او المغلفه باستخدام النايلون. كما دلت النتائج على تدهور الخرسانه الخاليه من الركام الناعم بعد تعرضها الى 60 دوره ترطيب وتجفيف كما وجد ان معدل النقصان في مقاومه الانضغاط يصل الى (25-27.5) % عندما يكون محتوى الاملاح 0.57 و 0.83 على التوالي.

الكلمات الرئيسيه: مقاومه الانضغاط, الديمومه, مقاومه الاملاح الداخليه.

1. INTRODUCTION

No-fine concrete, sometimes referred to as porous or open textured concrete, is a concrete consisting of cement, water, and coarse aggregate (size ranges 19.0- 9.5mm) only without fine aggregate. Thus it contains voids throughout the concrete matrix. [1] When fine aggregate is omitted a lightweight concrete is formed. It is an agglomeration of coarse aggregate particles surrounded by a coat of cement past up to about 1.3mm thick. Thus, large pores exist through the body of concrete and these pores are important factor for low strength, low thermal conductivity and its lightweight nature. The large sizes of these pores do not allow water to transit by capillary characteristics through concrete matrix. [2] No-fine concrete is commonly used in the manufacture of precast concrete and in the manufacture of interior and exterior walls of building units (bearing and non-bearing). It is also used in partition construction and insulations. Britain used no-fine concrete for commercial purposes in 1924. During World War II, studies and research on no-fine concrete started to rise and develop and resulted in about 130000 building that used this type of concrete in Britain between ,**1945and1961.**

Desai [3] studied the effect of the size of aggregates and proportions of cement, admixture, and water on the porosity of no fine concrete. His concluded that the samples in which aggregates above 20mm were used were not porous from the base because of the large voids in the cement slurry settled down. Also in all those cubes in which compaction was done, the cement slurry settled down and thus made a flat bottom surface. So the final conclusion was to use a maximum size of aggregates 10-19mm and not to compact it while filling. Also the density of this concrete was less than the normal concrete because fine aggregate were not used, and the strength was lower than that of normal concrete.

The high porosity of brick particles contributes to higher permeability; the porosity of the particles has also shown to provide enhanced durability performance in freeze-thaw testing. Most studies in this area have been performed on very small brick particles used as a partial replacement for fine aggregate. Litvan and Sereda added brick particles of approximately 0.5 mm in size to mortar and concrete mixtures in order to assess whether the porosity of the brick would enhance freeze-thaw durability. Testing was performed in accordance with ASTM C666, and ASTM C456 procedures to characterize the air void parameters including spacing factor. They concluded that incorporation of small particles (0.4 mm to 0.8 mm) with high porosity improved the freeze-thaw resistance of the mixtures.

Arulrajah et al. investigated the use of recycled crushed brick as pavement subbase material in Australia. The experiments included water absorption, Los Angeles abrasion loss. The Los Angeles abrasion loss value obtained was just above the maximum limits specified for pavement subbase material. At higher moisture ratio level, sheer strength of crushed brick was found to be reduced beyond the acceptable limits. The geotechnical testing results indicated that crushed brick may have to be blended with other durable recycled aggregate to improve its durability and to enhance its performance in pavement subbase applications.

2. MATERIALS USED IN THIS STUDY

2.1 Cement

Ordinary Portland cement (OPC) manufactured in Iraq with a commercial name of (Al-Mass) was used in no-fine concrete mixes throughout the present work. **Tables 1** and **2** show the chemical analysis and physical properties of the cement used respectively. Results indicate that the cement is conformed to the Iraqi Standard Specification (I.S.Q) **No.5/1984** .

Aggregate

A waste crush clay brick was used as coarse aggregate with single size (10mm and 20mm). It was brought from a project near the university and used as recycled materials. The aggregate grading conformed to Iraqi specification ,**No.45/1984.** as shown in **Tables 3** and **4. Table 5** illustrates the specific gravity; bulk density (S.S.D), absorption, and sulfate content of coarse aggregate used.

2.2 Water

Ordinary, tap water was used for washing, mixing and curing throughout this study.

2.3 Super Plasticizer

The super plasticizer used in this work is considering high range water reducing admixture. It is commercially know as SP603. **Table 6** shows its typical properties. This admixture complies with the requirement of the **ASTM C494-03**.

3. CONCRETE MIXES

Two concrete mixes with different grading of coarse aggregate were selected. The design of mixes was performed in accordance with ,**Shetty.** cannot be done due to very little cohesion between particles, experienced visual examination and trial and error method were used for deciding optimum water/cement ratio. In this study the water/cement ratio chosen was (0.3) for all mixes and after many trials and errors, the super plasticizer (0.8%) by weight of cement was used.

4. CASTINGAND CURING OF CONCRETE

According to **ASTM C192-88** .concrete casting was carried out in two layers each layer was compacted by simple Roding (25 blows). Mechanical compaction or vibratory method may cause the cement paste to run off the aggregate. All specimens were covered with plastic sheet to minimize water losses for 24±2 Hrs. After that, they were demoded and immersed in water tank up to age 28, 90, and 180 days except drying and wetting and sulfate attack were exposed to cycling at laboratory temperature of about (23±2 ºC).

5. TESTING PROGRAM

5.1 Exposure Durability Test

To assess the durability of no-fine concrete in this study, specimens were exposed to different environmental conditions. The no-fine concrete specimens were divided into four groups. In group one specimen were immersed in water up to 6 months. In group two specimens were exposed to air laboratory temperature up to 6 month. While in group three specimens were kept cover with nylon sheet (sealed) for the same period. And group four included two parts. In part one, the specimens were exposed to wetting and drying for 60 cycles (each cycle included one day of wetting and one day of drying). And in part two, specimens were exposed to wetting and drying for 20 cycles (each cycle included immersion in water for three days and then air drying for three days).

5.2 Effect of Internal Sulfate Attack

To determine the effect of internal sulfate attack on the physical properties of no-fine concrete The specimens were exposed to internal sulfate content by using crushed brick with sulfate content of 0.57 and 0.83 to study the effect of using crushed brick with high SO_3 % on the compressive strength of produced no-fine concrete.

Total SO3 obtained by following equations:

$Y/Y * C + P/Y * S + X/Y * A$

Where:

C: amount of SO3 in cement.

S: amount of SO3 in sand.

A: amount of SO3 in coarse aggregate.

Y/Y: ratio of cement to cement per kg/m^3.

P/Y: ratio of sand to cement per kg/m^3.

X/Y: ratio of coarse aggregate to cement per kg/m^3.

For example:

$SO3= 1* 2.49 + 0+ 6*0.08= 2.97$

$SO3= 1*2.49+ 0+ 6*0.57 = 5.91$

$SO3= 1* 2.49 + 0+ 6*0.83= 7.47$

6. RESULTS AND DISSUSTION

Figs. 1 and 2 show the variation of compressive strength with number of wetting and drying cycles (short and long interval) respectively. These results indicated that the compressive strength of no-fine concrete specimens decreased with the increase number of drying and wetting cycles. This is attributed to a reduction in the rate of hydration process after each drying period. Also it was found that the compressive strength of no-fine concrete made of large size aggregate particles was relatively less than that of no-fine concrete made of small size aggregate particles before and after subjecting the specimens to the cycles of wetting and drying. For example, the percentage decrease of compressive strength of Mb20 after 60 cycles of short interval and 20 cycles of long interval wetting and drying cycles was (20-25) % from Mb10.

Figs. 3 and 4 show the test results of air dry density for short and long intervals of wetting and drying cycles for all no-fine concrete specimens. These results indicated that the air dry density after subjecting the concrete to the long intervals of wetting and drying cycles was higher than the air dry density of no-fine concrete after being subjected to short intervals of wetting and drying cycles. This is attributed to erosion of materials for no-fine concrete due to the water evaporation from voids and pores which are more than those in short intervals of wetting and drying cycles.

Figs. 5, 6 and 7 show the data result of compressive strength of no-fine concrete specimens exposed to different types of curing (immersed in water, sealed, and exposed to laboratory environmental) for 28, 90, and 180 days. These results indicated that the no-fine concrete specimens cured in water improved the compressive strength as compared with the compressive strength of no-fine concrete specimens sealed in Nylon sheet and exposed to air. This is attributed to the development of hydration process more than no-fine concrete subjected to sealed and exposed to air. **Fig. 8** also indicates that the density of no-fine concrete specimens exposed to air or sealed with Nylon sheet was relatively less than the density of no-fine concrete specimens that were cured in water.

Fig. 9 shows the data results of compressive strength for crushed brick no-fine concrete specimens subjected to internal sulfate attack. These results indicated that the compressive strength of crushed brick no-fine concrete decreased when the cycles of wetting and drying increased. This is attributed to the chemical reaction of sulfate with the cement gel (hydration product) producing solid materials (calcium sulfoalominate) with larger volume that cause stresses and cracking of the matrix. **Fig. 10** shows the air dry density of no-fine concrete specimens after wetting and drying cycles.

7. CONCLUSION

1. The effect of long term interval of wetting and drying was higher than the effect of short term interval of wetting and drying on the density and compressive strength by about (0.8-1.36) % and (2.54-3.22) %, respectively.
2. The immersion of no-fine concrete in water improved the compressive strength with a rate (5.51-17.32) % at 28 days higher than that when sealed or air dry curing were used.
3. It is found that the increases of internal sulfate content increased the reduction of density and compressive strength of no-fine concrete. Maximum reduction (4.5) % and (27.5) % was found at sulfate content 0.83% for crushed brick no-fine concrete for density and compressive, strength respectively.

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Acronyms

ASTM = American Society for Testing and Materials.

IQS = Iraqi Standard Organization

Mb10 = crushed brick no-fine concrete made with maximum size 10.

Mb20 = crushed brick no-fine concrete made with maximum size 20.

Table1. Chemical composition and main compounds of cement.

Oxide Composition	Abbreviation	Content (%)	Limits of Iraqi Specification No.5/1984
Lime	CaO	61	-
Silica	SiO_2	19.84	-
Alumina	Al_2O_3	5.28	-
Iron Oxide	Fe_2O_3	4.2	-
Magnesia	MgO	2.48	≤5.0%
Sulfate	SO_3	2.49	≤2.8%
Loss on Ignition	L. O. I.	3.8	≤4.0%
Insoluble residue	I. R.	1.13	≤1.5%
Lime saturated factor	L.S.F	0.92	0.66-1.02
Main Compounds (Bogue's equations)			
Tricalcium Silicate	C_3S	48.90	-
Dicalcium Silicate	C_2S	20.27	-

Tricalcium Aluminate	C_3A	6.89	-
Tetracalcium alumino-Ferrite	C_4AF	12.76	-

Table2. Physical properties of cement used throughout this work.

Physical Properties	Test Results	Limits of Iraqi Specification No.5/1984
Setting time (Vicat's apparatus) Initial hrs. : min. Final hrs. : min.	 1:40 4:00	 ≥ 45 min ≤ 10 hrs
Compressive strength of mortar 3days, MPa 7days, MPa	 21 27	 ≥ 15 ≥ 23

Table3. Grading of crushed brick aggregate single size 10mm.

Sieve Size (mm)	Percent passing	
	% Passing	Limits of Iraqi Specification No.45/1984
14	100	100
10	92.5	85-100
5	12.5	0-25
2.36	2.5	0-5

Table4. Grading of crushed brick aggregate single size 20mm.

Sieve size mm	**Percent Passing**	
	% Passing	**Limits of Iraqi specification No.45/1984**
37.5	100	100
20	92.5	85-100
10	12.5	0-25
5	2.5	0-5

Table5. Properties of crushed brick aggregate.

Property	**Test Result Grading 10mm**	**Test Result Grading 20mm**
Specific gravity	2.15	2.11
Bulk density (S.S.D)	1130	1131
Sulfate content	0.08	0.08
Absorption	27	26

Table 6. Typical Properties of super plasticizers type F.

From	Black Liquid
Color	Dark Brown
Specific gravity	1.21@ 25±2ºC
Chloride content	Nil
Flash point	N/A

Table7. Compressive strength of no-fine concrete mixes subjected to (short and long) intervals of wetting and drying.

Type of mix.	Compressive Strength MPa				
	No. Cycle (28days)	Short Interval		Long Interval	
		30 cycle	60 cycle	10 cycle	20 cycle
Mb10	8	7.6	6.8	7	6.4
Mb20	6	5.5	4.8	5	4.5

Table8. Air dry density of no-fine concrete mixes subjected to (short and long) intervals of wetting and drying.

Type of mix.	Air Dry Density kg/m^3				
	No. cycle (28days)	Short Interval		Long Interval	
		30 cycle	60 cycle	10 cycle	20 cycle
Mb10	1507	1485	1458	1457	1424
Mb20	1438	1410	1378	1398	1353

Table9. Compressive strength of no-fine concrete specimens under different types of curing with age.

Type of mix.	Compressive Strength Mpa								
	Cured in Water			Sealed in Nylon sheet			Exposed to Air		
	28 days	90 days	180 days	28 days	90 days	180 days	28 days	90 days	180 days
Mb10	8	9.6	10.2	7	6.4	6.1	5.9	5.3	4.9
Mb20	6	7	7.8	4.6	3.5	2.9	3.4	2.8	2.3

Table10. Fresh, 28-days (air dry and sealed), and surface saturated dry density.

Type of mixes.	Air Dry Density kg/m^3	Sealed Density kg/m^3	Surface Saturated Dry Density
Mb10	1507	1520	1530
Mb20	1438	1455	1465

Table11. Average test result of compressive strength of internal sulfate attack test.

Type of mixes.	` Reference Specimen 28 Days	Compressive Strength (Mpa) after Cyclic Wetting And Drying into Water					
		Sulfate content in crushed brick aggregate					
		0.08 sulfate content		0.57sulfate content		0.83 sulfate content	
		30 cycles	60 cycles	30 cycles	60 cycles	30 cycles	60 cycles
Mb10	8	7.6	6.8	7	6	6.6	5.8
Mb20	6	5.5	4.8	5.3	4.6	5.1	4.5

Table12. Air dry density of internal sulfate attack test for no-fine concrete.

Type of mixes.	Air Dry Density						
	At 28 days	0.08 sulfate content		0.57sulfate content		0.83 sulfate content	
		30 cycles	60 cycles	30 cycles	60 cycles	30 cycles	60 cycles
Mb10	1507	1485	1458	1473	1445	1468	1438
Mb20	1438	1410	1378	1402	1365	1395	1352

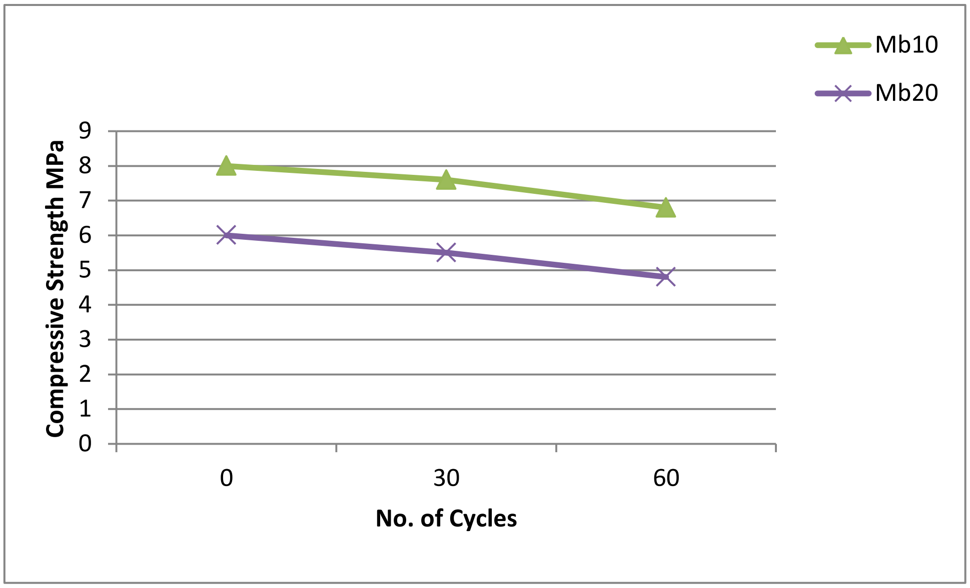

Figure1. Variations of compressive strength with no. of wetting and drying cycle (short intervals).

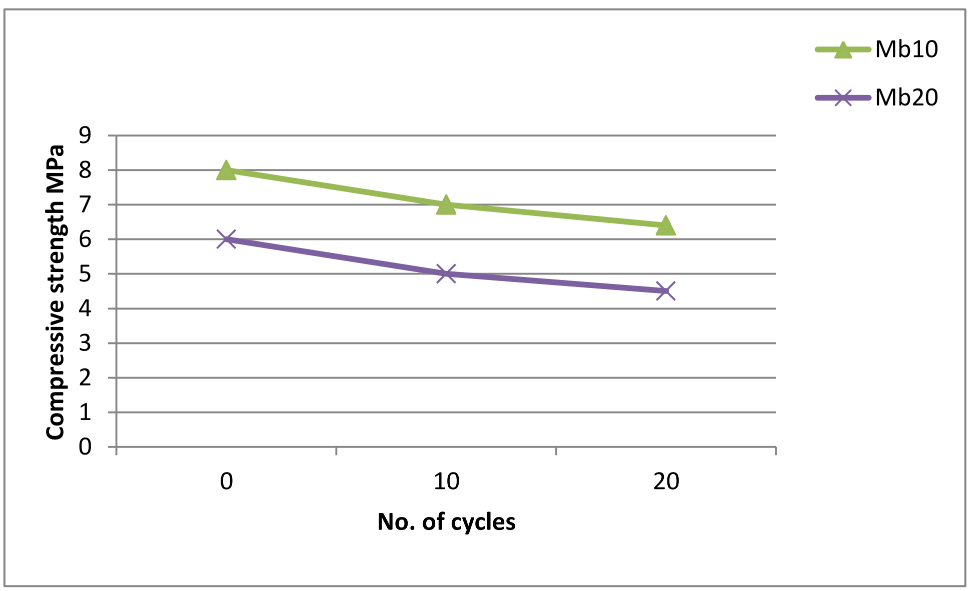

Figure2. Variations of compressive strength with no. of wetting and drying cycle (long intervals).

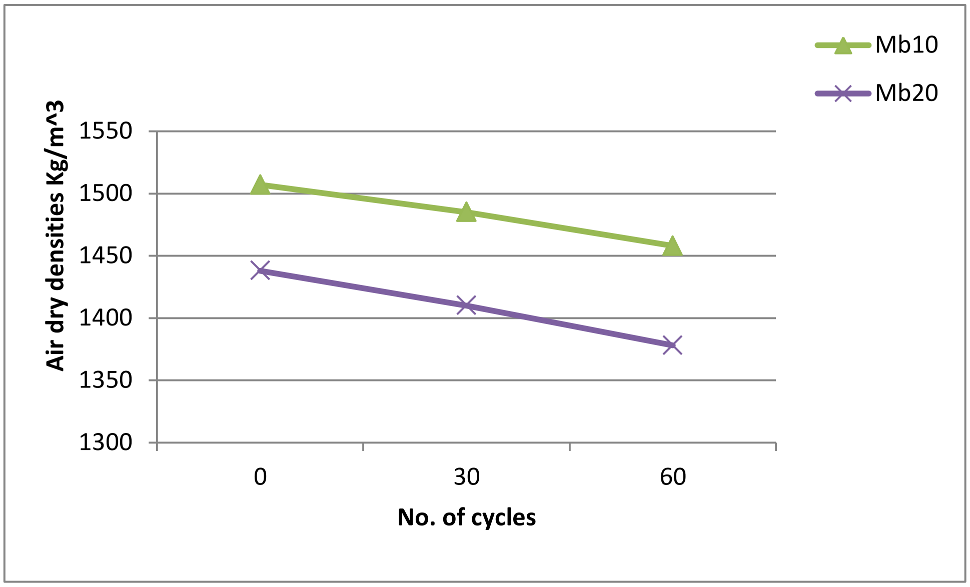

Figure3. Variation of air dry density of no-fine concrete with no. of wetting and drying cycle (short intervals).

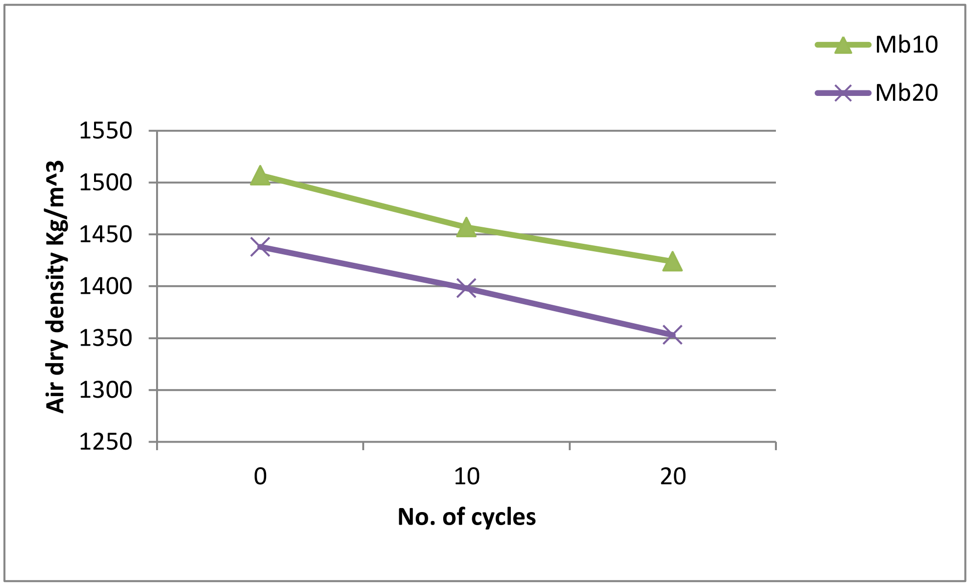

Figure4. Variation of air dry density of no-fine concrete with no. of wetting and drying cycle (long intervals).

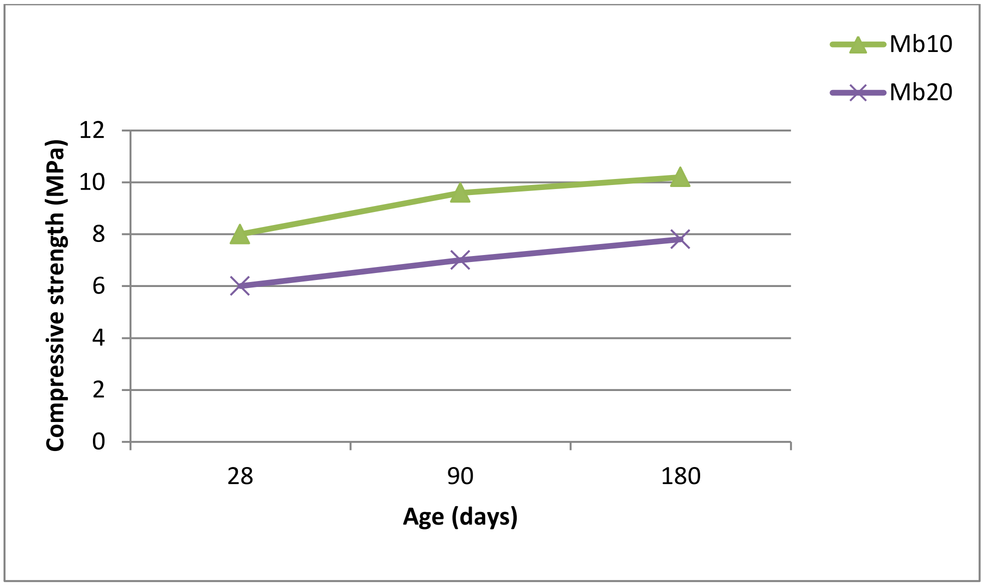

Figure5. Compressive strength of no-fine concrete with different age.

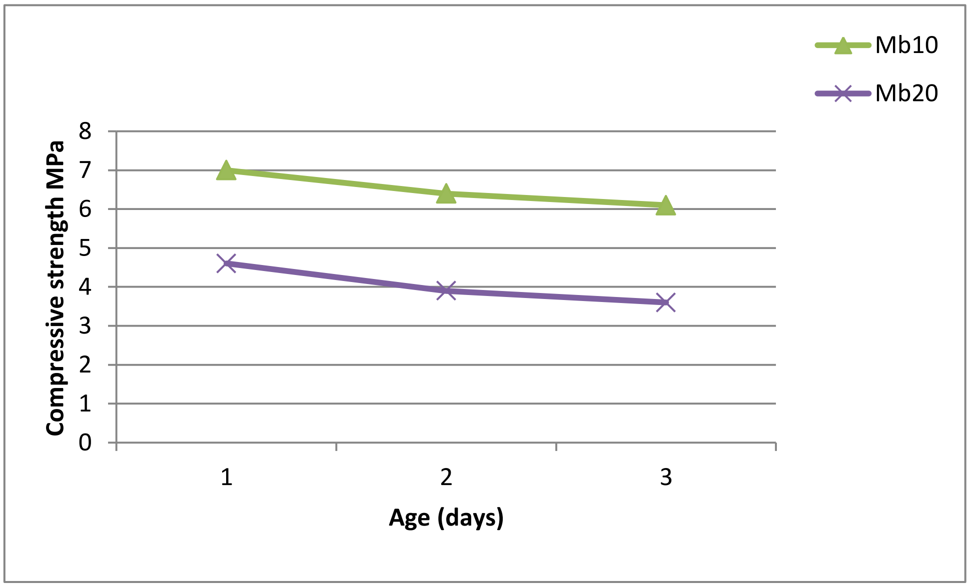

Figure6. Compressive strength with age for no-fine concrete specimens under sealed curing.

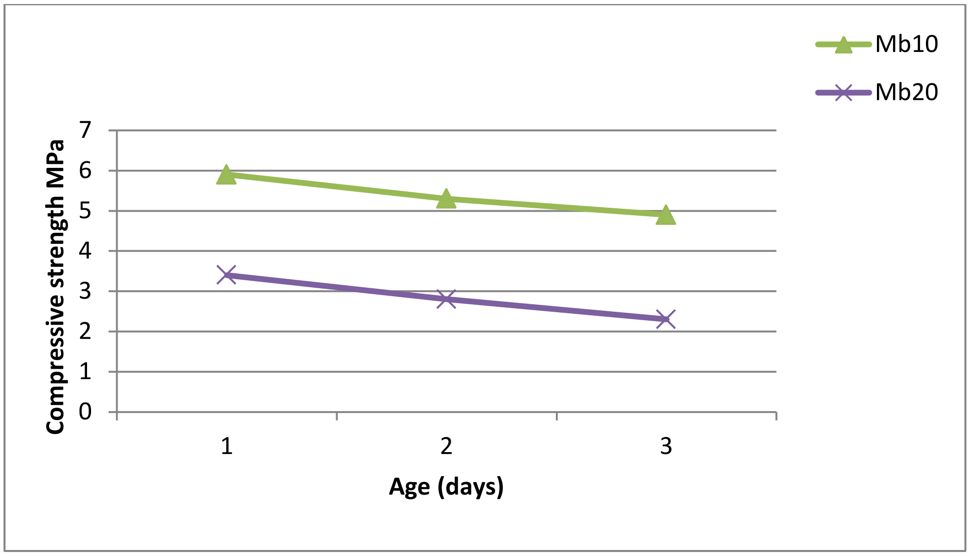

Figure7. Compressive strength with age for no-fine concrete specimens under air curing.

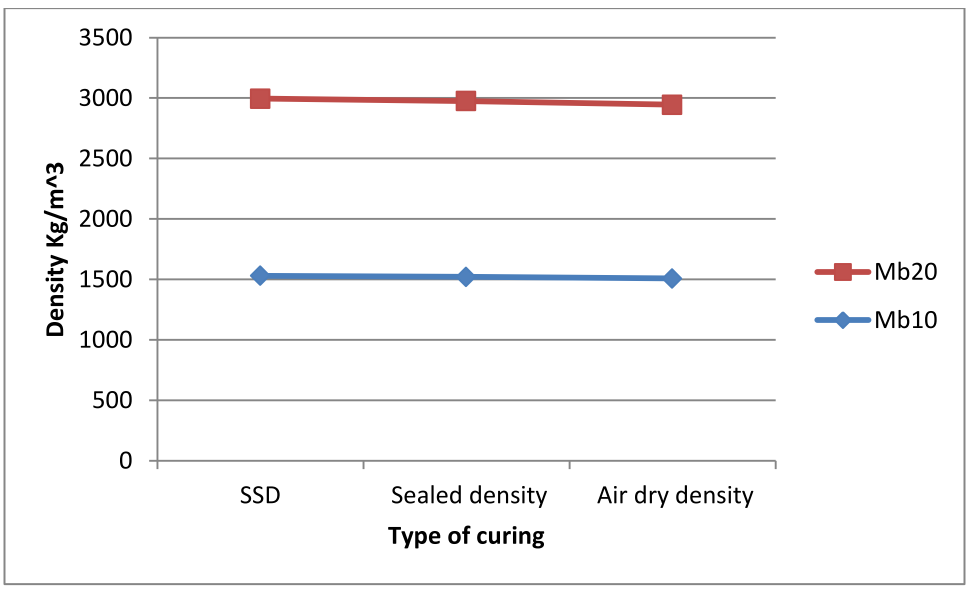

Figure8. Density at 28 days with type of curing.

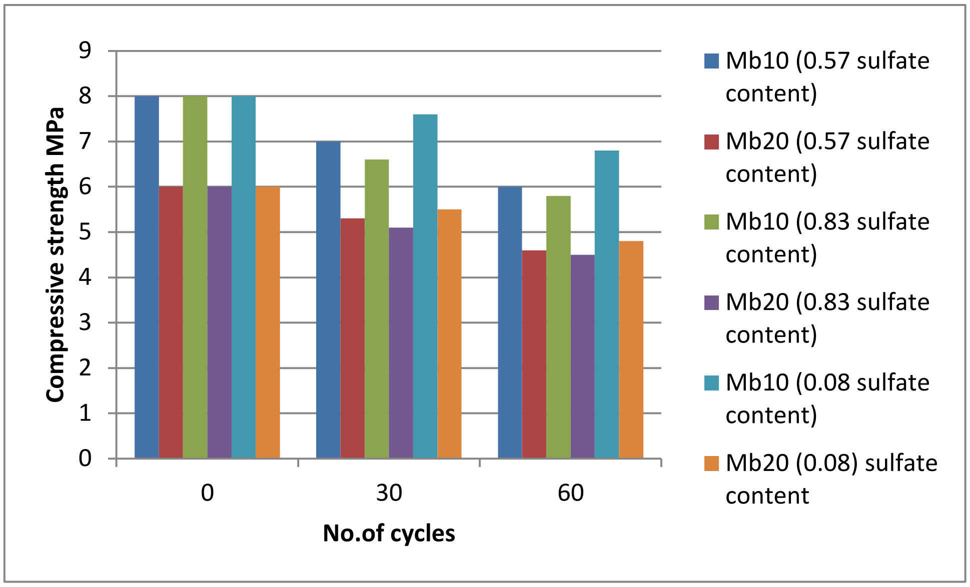

Figure9. Compressive strength with No. of cycles of wetting and drying for no-fine concrete specimens.

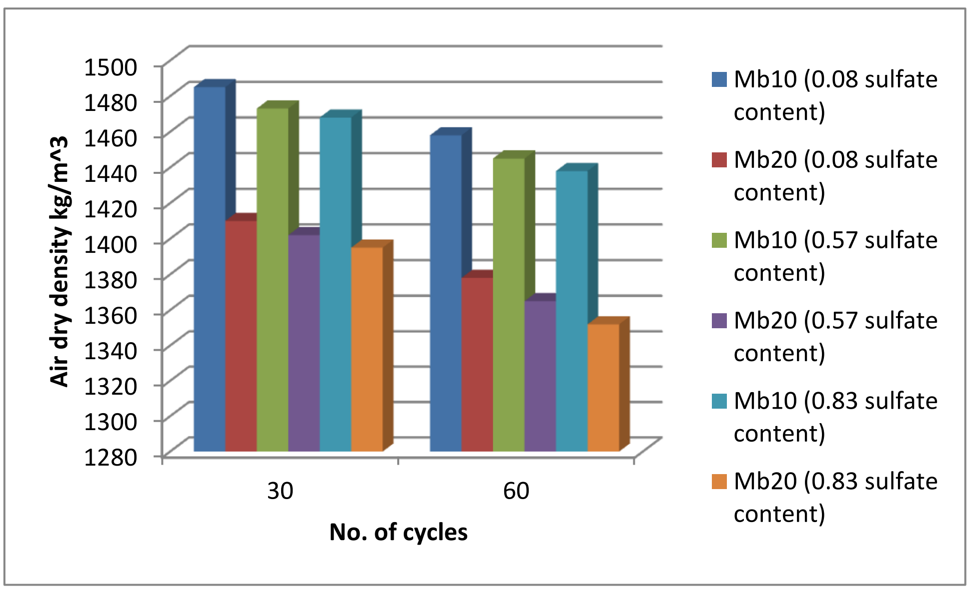

Figure10. Bulk density with No. of cycles of sulfate attack test for no-fine concrete specimens.