Some Mechanical Properties of Concrete by using Manufactured Blended Cement with Grinded Local Rocks

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ABSTRACT

The use of blended cement in concrete provides economic, energy savings, and ecological benefits, and also provides. Improvement in the properties of materials incorporating blended cements. The major aim of this investigation is to develop blended cement technology using grinded local rocks . The research includes information on constituent materials, manufacturing processes and performance characteristics of blended cements made with replacement (10 and 20) % of grinded local rocks (limestone, quartzite and porcelinite) from cement.

The main conclusion of this study was that all types of manufactured blended cement conformed to the specification according to ASTM C595-12 (chemical and physical requirements). The percentage of the compressive strength for blended cement with 10% replacement are (20, 11 and 5) % , (2 , 12 and, 13) % and (18, 15 and 16) % for limestone , quartzite and porcelinite respectively at (7,28 and 90)days for each compare to the reference mix, while blended cement with 20% replacement are (-3, -5 and -11) ,(6, -4% and -5) and (6, 4 and 6) % for limestone , quartzite and porcelinite respectively at (7, 28 and 90)days compare to the reference mix .The other mechanical properties (flexural tensile strength and splitting tensile strength) are the same phenomena of increase and decrease in compressive strength. The results indicated that the manufacture Portland-limestone cement, Portland-quartzite cement and Portland-porcelinite cement with 10% replacement of cement with improvable mechanical properties while the manufacture Portland-porcelinite cement with 20% replacement of cement with slight improvable mechanical properties and more economical cost.

Key words: blended cement, limestone, quartzite, porcelinite.

بعض الخواص الميكانيكية للخرسانة الحاوية على سمنت مخلوط مع مطحون صخور محلية

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الخلاصة

استخدام السمنت المخلوط في الخرسانة يوفر اقتصاديا, حفظ للطاقة , الفوائد البيئية و كذلك يوفر تحسنا في خواص المواد التي يستخدم فيها السمنت مخلوط. الهدف الرئيسي من هذا البحث هو تطوير سمنت مخلوط من مطحون الصخور المحلية , البحث يتضمن معلومات عن عملية الخلط والتصنيع وخصائص الاداء مع نسب الاستبدال (10 و20)% من مطحون الصخور المحلية (الحجر الجيري , الكوارتزايت و البورسلينايت) من السمنت .

الاستنتاج الرئيسي من هذه الدراسة هو ان جميع انواع السمنت المخلوط المصنع مطابق للمواصفة الامريكية **ASTM C595-12** للمتطلبات الفيزيائية والكيميائية الخاصة بالسمنت المخلوط .نسبة نتائج فحص مقاومة الانضغاط للخرسانة الحاوية على 10 % استبدال من السمنت هي كالاتي (5,11,20)% , (13,12,2)% و (16,15,18)% للحجر الجيري , الكوارتزايت والبورسلينايت على التوالي في (90,28,7) يوم لكل نوع مقارنه بالخلطه المرجعيه , في حين ان الاستبدال مع 20 % من السمنت هي كالاتي (-3,-5,-11)% ,(6,-4,-5)% و(6,4,6) للحجر الجيري , الكوارتزايت والبورسلينايت على التوالي في (90,28,7)

يوم. اما الخواص الاخرى (فحص قوة الانثناء ,فحص قوة الانشطار) فمن خلال النتائج يتبين ان الزيادة والنقصان هي في الاتجاه ذاته في فحص مقاومة الانضغاط. النتائج توضح ان افضل نسبة استبدال من السمنت من مطحون (الحجر الجيري , الكوارتزايت و البورسلينايت) هي نسبة 10% مع تحسن جيد بينما يمكن أستخدام 20% لمطحون البورسلينايت مع تحسن طفيف للخواص الميكانية و أقل كلفة .

الكلمات الرئيسية ..السمنت المخلوط , مطحون الحجر الجيري ,مطحون حجر الكوارتزايت , مطحون حجر البورسلينايت

1. INTRODUCTION

The ACI 116, 2000, defined blended cement as a hydraulic cement consisting essentially of an intimate and uniform blend of granulated blast-furnace slag and hydrated lime, or an intimate and uniform blend of Portland cement and granulated blast-furnace slag, Portland cement and pozzolan , or Portland blast-furnace slag cement and pozzolan, produced by intergrading Portland cement clinker with the other materials or by blending Portland cement with the other materials, or a combination of intergrading and blending.

With the extensive use of cement in concrete, there have been some environmental concerns in terms of damage caused by the extraction of raw materials and CO_2 emission during cement manufacture. This has brought pressures to reduce the cement consumption in industry. At the same time, more requirements are needed for the enhancement of concrete durability to sustain the changing environment which is apparently different from old days, **Ishwar**, **2012**.

2. LITERATURE REVIEW

All the cementitious materials have one property in common: they are at least as fine as the particles of Portland cement, and sometimes much finer. Their other features, however, are diverse. This applies to their origin, their chemical composition, and their physical characteristics such as surface texture or specific gravity**.** Some of these materials are cementitious in themselves; some have latent cementitious properties, yet others contribute to the strength of concrete primarily through their physical behavior. It is proposed, therefore, to refer to all these materials cementitious materials, **Neville, 2011.**

Limestone is a sedimentary rock composed primarily of calcium carbonate ($CaCO_3$) in the form of mineral calcite. It is most commonly formed in clear, warm, shallow marine waters. It is usually an organic sedimentary rock that is formed from the accumulation of shell, coral, algal and fecal debris. It can also be a chemical sedimentary rock formed by the precipitation of calcium carbonate from lake or ocean water**.** Most limestone is crushed and used as a construction material. It is used as a crushed stone for road base and railroad ballast. It is used as an aggregate in concrete. It is fired in a kiln with crushed shale to make cement, **Geology, 2014.**

İnan Sezer, 1986, showed that consistency water demand decreases when limestone and clinker are interground together. Studies by **P'era et al., 1999,** suggested an accelerating effect of limestone on the hydration of cement and showed that different hydration products are formed due to the presence of $CaCO_3$. A general observation is that transformation of ettringite into monosulfate is delayed by the calcium carbonate, **Taylor, 1997, Kakali, 2001 and Erdoğdu, 2000,** prepared blended cements with 5, 10, 20, and 30% limestone replacement ratios, and reported that consistency water demand decreases with the increasing limestone replacement.

Al-Taai, 2009, observed that concrete produced from limestone-ordinary Portland cement generally shows enhanced workability properties which are particularly useful in unformed surfaces.

Quartzite is a non-foliated metamorphic rock that is produced by the metamorphism of sandstone. It is composed primarily of quartz. The term quartzite implies not only a high degree of hardening (induration), or “welding,” but also a high content of quartz; similar rocks that contain appreciable quantities of other minerals and rock particles are impure quartzite's, more appropriately called gray wacke, sandstone, or the like, **Britannica.com, 2014**.

Snellings et al., 2013, studied a comparison between the early-age hydration of cements blended with micronized zeolitite and quartzite powders. The Portland cement replacement in the mixes was 30 %, and the effect of introducing a superplasticizer to lower the required water to solid ratio was assessed. The cement pastes were hydrated at 40°C and monitored in situ by time-resolved synchrotron X-ray powder diffraction combined with Riveted quantitative phase analysis.

The quantitative evolution of phase weight fractions showed that the addition of the zeolite tuff accelerated the hydration rate of the main C_3S cement component. Blending with the quartzite powder of similar fineness did not affect the C_3S hydration rate. Reduction of water to solid ratio by introduction of the superplasticiser had a retarding effect on the hydration of the zeolitite-blended cement over the early hydration period up to 3 days and the quartz content in the quartzite blended cement did not present any significant changes over the period of examination. There was no evidence for the pozzolanic reaction between quartz and CH to occur within the experimented time span of 48 h .The researchers explained results of the values for the mean volume weighted crystallite sizes which is 75 ± 2 nm for the clinoptilolite phase in the zeolitite and 410 ±3 nm for quartz as the main component of the quartzite. This effect of crystallinity on the cement hydration was also encountered in a previous study when comparing a well-crystallised chabazite and a typical clinoptilolite tuff of lower clinoptilolite crystallinity **Snellings et al., 2013.**

Porcelanite is one of the important industrial sedimentary rocks in Iraq .it has gone under more than 20 different names, where many are commercial trademarks (e.g. diatomite, diatomaceous earth, kieslelguhr, cellite, filtac .etc), **AL-Jabboory, 1999**.

In 1986, the state company of Geological Survey and Mining discovered Porcelanite rocks in wadi Mallusa in the Iraqi western desert, between Reba, Traibeel and Akashat,.Preliminary studies were made to find its mineral and chemical properties, as well as estimating the reserve of these rocks. Porcelinite rocks are sedimentary deposits associated with clay stone, white to creamy in color and highly cracking.

Al Kassab, 2006, studied the requirements of durability for very severe sulfate attack of ACI 318 – 2005 were tested on local materials. Two sulfate resisting cements having low C_3S (49.4 and 47.5) %, were used with (0, 5, 10 and 15) % porcelinite (natural pozzolana) as addition. Addition of porcelinite to cement increases the 28 days compressive strength of concrete also increases its resistance to sulfate attack at that age. At later ages the compressive strength and sulfate resistance of concrete are the same for both plain cement and cement blended with porcelinite when low C_3S in cement is used (not more than 50%).

3. EXPERIMENTAL PROGRAM

3.1 Materials

3.1.1 Cement

Iraqi ordinary Portland cement manufactured by AL-Mass cement factory (Sulaimaniyah governorate) was used in the investigations the chemical composition and physical properties of the cement are shown in **Tables 1 and 2**. The results conformed to the Iraqi specification **No. 5/1984.**

3.1.2 Fine aggregate

The fine aggregate used throughout this study is brought from AL- Ukhaider region. It re sieved to conform the grading of fine aggregate. The grading and physical properties (specific gravity, absorption, sulfate content and moisture content) are shown in **Table 3**. The used sand is within zone 2 according to the requirements of the Iraqi Standard Specification **No. 45, 1984.**

3.1.3 Coarse aggregate

Crushed gravel of 14 mm nominal size from AL-Soodor district was used. **Table 4** shows the physical properties of coarse aggregate and the grading of coarse aggregate which conforms to the limits of the Iraqi specification **No. 45/1984.**

3.1.4 Water

Tap water was used for mixing and curing of samples.

3.1.5 High range water reducing admixture

Hyperplast PC260 is a high performance super plasticizing type A (Formerly known as Flocrete PC260) admixture based on polycarboxylic polymers with long chains specially designed to enable the water content of the concrete to perform more effectively. **Table 5** shows the technical properties of Hyperplastic PC260

3.2 Raw Material and Grinding Process

The raw material of limestone, quartzite and porcelinite contains rocks being grinded in the Building Research Center/Ministry of construction and, it was crushed, stormed then transformed into a powder finer or equal to fineness of cement for the purpose of getting the most of their effectiveness

3.2.1 Limestone powder

A fine Limestone powder of Iraqi origin (Sulaimaniyah governorate with specific gravity of 2.6 was used. **Table 6** shows the chemical analysis for limestone powder.

3.2.2 Quartzite powder

A fine quartzite powder of Iraqi origin (Al-Anbar governorate) with specific gravity of 2.61 was used. **Table 7** shows the chemical analysis for quartzite powder and it's confirmed to the requirement in, **ASTM 618, 2012.**

3.2.3 Porcelinite powder

A fine porcelinite powder was brought from Akashat district (Al-Anbar governorate) with specific gravity 1.5. **Table 8** shows the chemical analysis for porcelinite powder and it's confirmed to the requirement in, **ASTM 618, 2012.**

3.3 Mortor Mixes and Strength Activity Index of Quartzite and Porcelinite

Mixing of mortar was carried out by a small laboratory mortar mixture according to **ASTMC109/C109 M, 2002, Tables 14, 15 and 16** show the result of mortor mixes for CL, CQ and CP. Control and test mixtures were prepared for strength activity index. The cement or cementations materials (C+ (Q, P) to fine aggregate ratio is 1: 2.75mix proportions according to **ASTM C109**, **2002.** The strength activity index is 84% and 96 % for CQ and CP respectively and CL is equal to 75 % according to **ASTM C311, 2002.**

3.4 Concrete Mixes

In this investigation, the reference concrete mixture was designed to give 28 days as characteristic compressive strength of 35 MPa, according to **ACI 211.1,1991.** The proportion of mix was 1:1.6: 2.0 by weight of cement, sand, coarse aggregate respectively. Cement content was 451 kg/m^3 and the water to cement ratio was 0.47 to give slump of 100 ± 25 mm. The details of the mixes used throughout this investigation are given in **Table 9**. The slump test method was carried out by **ASTM C143, 2005.**

3.5 Mixing of Concrete

Mixing process of concrete was performed according to **ASTM C192, 2006** .Using pan mixes and drill, in case of blended cement. At beginning, the cement was mixed with limestone, quartzite or porcelinite until the blended cement was homogenous. The interior surface of mixer was cleaned and moistened before placing the materials. For the concrete, the dry constituents were placed in the pan mixer; cement was placed with sand and mixed and then gravel was added. The dry materials were firstly mixed together to attain a uniform mix and then the required quantity of SP and tap water were added. The whole mix ingredients were mixed for a period until homogenous concrete was obtained, and then slump tests were measured immediately after mixing. The slump test was done and followed by the casting of concrete in the molds.

3.6 Testing of Hardened Concrete

3-6-1 Compressive strength test

The compressive strength test was made according to **B.S.1881: part 116** using 100 mm cubes. The compressive strength cubes were tested using a standard testing machine with capacity of 200000 LBS (909kN).

3.6.2 Splitting tensile strength test

The splitting tensile strength test was carried out in accordance with **ASTM C496, 2007.** 100x200 mm cylindrical concrete specimens and tests were performed using testing machine at a rate of 1.1 MPa per minute. The average of three cylinders was taken at each test.

3.6.3 Flexural strength test

This test was carried out on (100×100×400) mm prism specimens in accordance with **ASTM C293, 2006** using (TINIUS OLESN) testing machine with capacity of 650 kN ,

3.6.4 Dry density

This test was performed according to **ASTM C642, 2003** on average of two cubic and the dry density was calculated for ages 7, 28 and 90 days.

4. RESULTS AND DISCUSSION

4.1 The Influence of Manufactured Blended Cement on Chemical Composition

Tables 10, 11 and 12 show the chemical analysis for Portland –limestone cement (type IL), Portland-quartzite cement (type IP) and Portland-porcelinite cement (type IP) respectively with replacement proportion (10 and 20) % for each powder. The (L.O.I), SO_3 content as presented are specified with limits for the specification requirements in **ASTM C595, 2012** for each type of cement.

4.2 The Influence of Manufactured Blended Cement on Physical Properties of Concrete

From an examination of the obtained test results shown in **Tables 14, 15 and 16,** they seem that the standard consistency , compressive strength of Mortor , initial and final time are specified to the requirements in **ASTM C595 , 2012.**

4.3 The Influence Limestone Powder (LP), Quartzite Powder (QP) and Porcelinite Powder) (PP) Replacement on the Physical Properties of Concrete.

4.3.1 Compressive strength

Table 16 and **Fig. 1** show the variation of compressive strength with different replacement of LP, it can be seen that 10% (*ML10-1)* of compensation increases the compressive strength by (20, 11 and 5) % at (7, 28 and 90) days respectively and 20% (*ML20-1)* of compensation resulted in (-3 , -5 and 11)% at (7, 28 and 90) days respectively compared with *M ref -1* ; several combined effects may be called upon to explain strength maintenance. In the presence of filler, the solid skeleton may be strengthened to a more homogeneous distribution of smaller C–S–H crystals, finer pore structure, accelerated cement hydration ,**Mossberg and et al., 2003,** Moreover, the bond between cement paste and sand particles may strengthen the reduction of the wall effect provided by the fine particles filling ,**Lawrence, 2003.**

Table 17 and **Fig. 2** also show the variation of compressive strength with different replacement of QP; it can be seen that a 10 % compensating(*MQ10-1*) increases the compressive strength by (2, 12, and 13)% at (7, 28 and, 90) days respectively compared with the reference mix while 20 % compensating(*MQ20-1*) shows a decreasing (-6,-4, and -6)% at (7,28 and 90) days respectively compared to reference mix concrete . Several combined effects may be called upon to explain strength maintenance. In the presence of quartzite powder ,the silicate ions may react with lime produced from the cement hydration to produce additional calcium silicate hydration products(C-S-H).Such increase in compressive strength of QPC is mainly due to presence of high silica and the pozzolanic reaction of QP the presence of high amount of QP (20 % in this study) leads to low value in compressive strength which may be because the cement paste is not able to coat all fine and coarse particles ,so a drop in the reactive cement component results in significant physical modifications of the material.

Table 18 and **Fig.3** show the variation of compressive strength with different replacement of porcelinite powder (PP); it can be seen the compressive strength is increased by (17, 15, and 18) % at (7, 28, 90) days, respectively, and (6, 4 and, 5.5) %, at (7, 28 and 90) days respectively for (10 and 20) % compensation compared with reference mix concrete; several combined effects may be called upon to explain strength maintenance. The increase in compressive strength of concrete may be due to the formation of the secondary C-S-H products from the reaction of the porcelinite with $Ca\,(OH)_2$ and filling the pores of cement paste, reducing the permeability of concrete and increasing the compressive strength. Such increase in compressive strength of PPC is mainly due to presence of high silica and the pozzolanic reaction of PP which depends on the activity of pozzolana , **Matched and et al.,2007 .**

4.3.2 Splitting tensile strength

Table 16 and **Fig. 4** show that the splitting tensile strength at *ML10-1* (10) % replacement is found to be (30, 16.5 and 8.7) % at (7, 28 and, 90) days respectively and at *ML20-1*(20) % replacement is found to be (1, -3 and -6) % at (7, 28 and 90) days respectively compared to reference mix concrete.

Table 17 and **Fig. 5** show the splitting tensile strength ; the results percentage is (7.7 , 18.5 and, 7)% at (7,28 , 90) days respectively for 10% QP as replacement of cement and (-1.3 , -3.3 and -4.3)% at (7,28 and 90) days respectively for (20)% QP as replacement of cement relative to the reference M ref-1. The increase mainly may be due to the pozzolanic reaction of the QP with calcium hydroxide liberated during the hydration of cement. This reaction contributes to the densification of the concrete matrix, thereby strengthening the transition zone and reducing the micro cracking leading to a significant increase in tensile strength, **Naik, 2003**.

Average values of three samples for splitting tensile strength are explained in **Table 18** and **Fig. 6** show the splitting tensile strength , the results percentage is (13.2 , 11.52 and 9.7)% at (7,28 and 90) days, respectively and (0.19 , 3.32 and 3.71)% at (7,28 and 90) days, respectively for (10 and 20)% replacement respectively relative to the reference M ref-1.This increase is mainly due to the pozzolanic reaction of the PP with calcium hydroxide liberated during the hydration of cement. This reaction contributes to the densification of the concrete matrix, thereby strengthening the transition zone and reducing the micro cracking leading to a significant increase in tensile strength, **Naik, 2003.**

4.3.3 Flexural tensile strength

Average values of three samples for flexural tensile strength are explained in **Table 16** and **Fig. 7** show the Flexural tensile strength for 10% replacement of LP, it is (14.4 ,5.0 and 4.2)% at (7,28 and 90) days respectively, while the result percentage of 20% replacement of LP is (2.3,-4.3, and -4.2) % at (7,28 and,90) days respectively. 10 % replacement is the best result and that result agrees with compressive strength behavior.

Table 17 and **Fig. 8** show the Flexural tensile strength for 10% replacement (MQ10-1) is (5.2,5.7 and,7.7) % for (7,28 and 90) days respectively, while 20% replacement (MQ20-1) is (-1,-2 and,-4) % for (7,28 and 90) days, respectively.

Table 18 and **Fig. 9** show the Flexural tensile strength; the results percentage is (3.81,4.63,5.51)% at (7,28 and,90) days, respectively, and (2.8,3.6 and 1.9)% at (7,28 and 90) days respectively for (10 and 20)%replacement respectively.

4.3.4 Dry density

Concrete is a porous material with discrete and interconnected pores of different sizes and shapes; the use of cement replacement materials result in pore size refinement.

Average values of three samples for dry density are explained in **Fig. 10** shows the dry density increase with an increase of LP replacement; the result percentage is (0.83 and, 1) % at (28) days for (10 and 20) % replacement respectively. This is interpreted as filler powder first filling voids around sand grains, up to the optimum, **Mehta 1983, Bédérina, and et al., 2005.** For higher filler amounts of 20% replacement of LP, those voids may be completely filled, Filler powder occupies the place of sand grains and hence it diminishes sand proportion, and consequently the mix density, **Heikal and et al., 2005.**

Fig. 11 shows the dry density decrease with increase of replacement of QP; the result percentage is (0.5 and, -0.4) % at (28) days for (10 and 20) % replacement, respectively.

Fig. 12 shows the dry density decrease with increase of replacement of PP. The results percentage is (0.86 and 0.5) % at (28) days for (10 and 20) % replacement of PP respectively, this is interpreted as PP as light weight and porous material.

5. CONCLUSIONS

The following conclusions can be drawn based on the results of each test:-

1- The manufacture of blended cement using (10 and 20) % replacement of different grinded rocks (limestone, quartzite and porcelinite) confirmed the physical and chemical requirement of the specification in ASTM C595-12.
2- The concrete mixes produced from blended cement (Portland-limestone cement) and (Portland-quartzite cement) showed enhancement in the workability properties while blended cement (Portland-porcelinite cement) diminished the workability properties.

3- The mechanical properties using Portland –limestone cement (10and 20) % replacement of cement compared to reference mix for compressive strength with percentage increases is (20, 11 and 5) % at (7, 28 and, 90) days respectively for 10% replacement and decreases percentage is (-3, -5 and -11) % at (7, 28 and, 90) days respectively for 20% replacement.
4- The mechanical properties using Portland –quartzite cement (10and 20) % replacement of cement were compared to reference mix for compressive strength with percentage increase is (2, 12 and 13) % for (7, 28 and, 90) days respectively for 10% replacement and percentage decrease is (-5.9,-4 and, -5.4) % at (7, 28 and 90) days respectively for 20% replacement.
5- The mechanical properties using Portland –porcelinite cement (10 and 20) % replacement of cement were compared to reference mix for compressive strength with percentage increase is (17.6, 15 and 16.3) % at (7, 28 and 90) days respectively for (10%) replacement and (6, 4 and 6) % at (7, 28 and, 90) days respectively for (20%) replacement.

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Table 1. Chemical composition of cement.

Oxide composition	Abbreviation	Percentage by weight	Limit of Iraqi specification No. 5/1984
Lime	CaO	61	-
Silica	SiO_2	19.84	-
Alumina	Al_2O_3	5.08	-
Iron Oxide	Fe_2O_3	4.8	-
Sulphate	SO_3	2.49	≤ 2.8 % if $C_3A \geq 5$%
Potash	K_2O	0.1	
Soda	Na_2O	0.3	
Equivalent Na_2 O	Na_2O+0.658K_2O	0.36	≤ 0.6%
Magnesia	MgO	2.48	≤ 5.0 %
Loss on ignition	L.O.I.	3.8	≤ 4.0 %
Insoluble residue	I.R.	0.40	≤ 1.5 %
Main Compounds (Bogue′s equations)			
Tri calcium Silicate	C_3S	49.45	-
Di calcium Silicate	C_2S	19.57	-
Tri calcium Aluminate	C_3A	5.34	-
Tetra calcium Aluminate – Ferrite	C_4AF	14.61	-

*chemical tests of cement were made at environmental Laboratory in University of Baghdad

Table 2. Physical properties of cements.

Physical properties	Test results	Limits of Iraqi specification No. 5/1984
Specific surface area (Blaine method) (m2/ kg)	300*	≥ 230
Soundness by Autoclave Method (%)	0.02*	Not more than 0.8
Setting time (Vicat′s method) Initial setting (hrs. : min) Final setting (hrs. : min)	 1 : 40 4: 40	≥ 45 min ≤ 10 hrs.
Compressive strength (MPa) 3 days 7 days	 21 27	 ≥ 15 ≥ 23

* Tests of cement were made at research building center /Ministry of Constructions and Housing
Other tests are carrying out in material Lab. /Civ. Eng. Dep. /University of Baghdad

Table 3. Physicals properties and sulfate content of fine aggregate.

Sieve size (mm)	% passing by weight	Iraqi specifications No.45/1984 (Zone 2)
10	100	100
4.75	94	90-100
2.36	80	75-100
1.18	60	55-90
0.6	44	35-59
0.3	18	8-30
0.15	4	0-10
Material fine than 0.075 mm	2.6	Max. 5
Fineness modulus = 3.0		
Sulfate content (%)*	0.11	Max. 0.5
Specific gravity	2.65	-
Absorption (%)	1.01	-
Moisture Content (%)	6.1	-

* The test was carried out in Building Research Center/ ministry of construction and Housing
Other of tests were carried out in material Lab. /Civ. Eng. Dep. /University of Baghdad

Table 4. Physical properties and sulfate content of coarse aggregate.

Sieve size (mm)	% passing by weight	Iraqi specification No. 45/1984 (5-14)mm
20	100	100
14	91	90-100
10	72	50-85
5	9	0-10
Sulfate content %	*0.01	Max. 0.1
Specific gravity	2.64	-
Absorption %	1	-
Moisture Content %	1.6	-

* The test was carried out in Building Research Center/ ministry of construction and Housing
Other of tests were carried out in material Lab. /Civ. Eng. Dep. /University of Baghdad

Table 5. Typical properties of hyperplast PC260 .

Technical properties @ 250C	
Color:	Light yellow liquid
Freezing point: ≈	-7°C
Specific gravity:	1.1 ± 0.02
Air entrainment:	Typically less than 2% additional air is entrained above control mix at normal

Table 6. Chemical composition for limestone powder*.

Oxide		% Content
Loss on ignition	L.O.I	42.52
Silicon oxides	SiO_2	2.38
Aluminum oxides	Al_2O_3	0.55
Ferric oxides	Fe_2O_3	0.22
Calcium oxides	CaO	51.67
Magnesium oxides	MgO	2.09
Sulphur trioxides	SO_3	0.35

* The test was done in laboratories of state company of Geological Survey.

Table 7. Chemical composition for quartzite powder*.

Oxide		% Content	ASTM C 618-12
Loss on ignition	L.O.I	0.55	Max.10 %
Silicon oxides	SiO_2	98.11	Sum. SiO_2+ Al_2O_3+ Fe_2O_3 not less than 70%
Aluminum oxides	Al_2O_3	0.23	
Ferric oxides	Fe_2O_3	0.3	
Calcium oxides	CaO	0.66	/
Magnesium oxides	MgO	Less than 0.02	/
Sulphur trioxides	SO_3	0.02	Not more than 4%

*The test was done in state company of Geological Survey laboratories.

Table 8. Chemical composition for porcelinite powder*.

Oxide		% Content	ASTM C 618-12
Loss on Ignition	L.O.I	10	Max.10 %
Silicon oxides	SiO_2	67.1	Sum. SiO_2+ Al_2O_3+ Fe_2O_3 not less than 70%
Aluminum oxides	Al_2O_3	4.18	
Ferric oxides	Fe_2O_3	1.24	
Calcium oxides	CaO	11.51	/
Magnesium oxides	MgO	3.39	/
Sulphur trioxides	SO_3	0.03	Not more than 4%

*The test was done in state company of Geological Survey laboratories.

Table 9. Details of the mixes used throughout this investigation.

Symbol of mixes	CEMENT (kg/m^3)	Limestone Powder (kg/m^3)	Quartzite Powder (kg/m^3)	Porcelanite Powder (kg/m^3)	Coarse Aggregate (kg/m^3)	Fine Aggregate (kg/m^3)	Water (ml/m^3)	PC 260 L/100 kg cement.
M ref	451	/	/	/	943	738	119	0.5
ML10	405.9	45.1	/	/	943	738	119	0.5
ML20	360.8	90.2	/	/	943	738	119	0.53
MQ10	405.9	/	45.1	/	943	738	119	0.5
MQ20	360.8	/	90.2	/	943	738	119	0.55
MP10	405.9	/	/	45.1	943	738	119	0.79
MP20	360.8	/	/	90.2	943	738	119	0.97

Table 10. Chemical analysis of Portland-limestone cement.

Requirements	*C (Cement)	**L Limestone Powder	*ML10	*ML20	ASTM C595-12 Type IL
CaO %	61	51.67	60.4	59.1	/
SiO_2 %	19.84	2.38	18.16	17.9	/
Al_2O_3 %	5.08	0.55	4.66	4.2	/
Fe_2O_3 %	4.8	0.22	4.24	3.84	/
MgO %	2.48	2.09	2.45	2.39	/
SO_3 %	2.49	0.35	2.3	2.0	Max. 3
L.O.I %	3.8	42.52	7.4	8.7	Max. 10

*chemical tests of cement were done at enviromentinal Laboratory in University of Baghdad
**The test was done in state Company of Geological Survey Laboratories.

Table 11. Chemical analysis of Portland-quartzite cement.

Requirements	*C (Cement)	**Q Quartzite powder	*MQ10	*MQ20	ASTM C595-12 Type IP
CaO %	61	0.66	57.06	52.11	/
SiO_2 %	19.84	98.11	25.7	33.2	/
Al_2O_3 %	5.08	0.23	4.7	4.27	/
Fe_2O_3 %	4.8	0.3	4.16	3.42	/
MgO %	2.48	0.02	2.33	2.1	Max. 6
SO_3 %	2.49	0.02	2.19	1.9	Max. 4
L.O.I %	3.8	0.55	3.4	2.67	Max. 5

*Chemical tests of cement were done at enviromentinal Laboratory in University of Baghdad
**The test was done in state Company of Geological Survey Laboratories

Table 12. Chemical analysis of Portland -porcelinite cement.

Requirements	*C (Cement)	**P Porcelinite powder	*MP10	*MP20	ASTM C595-12 Type IP
CaO %	61	11.51	56.8	53.18	/
SiO_2 %	19.84	67.1	25.1	28.2	/
Al_2O_3 %	5.08	4.18	5.01	4.9	/
Fe_2O_3 %	4.8	1.24	4.5	4.2	/
MgO %	2.48	3.39	2.61	2.75	Max. 6
SO_3 %	2.49	0.03	1.9	1.7	Max. 4
L.O.I %	3.8	10	4	4.8	Max. 5

*chemical tests of cement were done at enviromentinal Laboratory in University of Baghdad
**The test was done in state Company of Geological Survey Laboratories

Table 13. Physical properties of blended cement (Portland-limestone cement)*.

Requirements	C (Cement)	CL10	CL20	ASTM C595-12 Type IL
Consistency %	28	27	26	-
Initial setting time (min.)	125	115	100	Min 45 mints
Final setting time (hrs.)	4:30	5:09	5:30	Max 7 hrs.
*Fineness (cm^2/g.)	3000	3100	3200	-
Comp. at 3 days (MPa)	25	18	17	13
Comp. at 7days (MPa)	30.9	22	20	20
Comp. at28 days (MPa)	35	30	28	25

*the tests were done at research buildings center /Ministry of housing
**Physical tests of cement were done at material Laboratory in University of Baghdad

Table 14. Physical properties of blended cement (Portland-quartzite cement).

Requirements	C (Cement)	CQ10	CQ20	ASTM C595-12 type IP
Consistency %	28	27	26	/
Initial setting time (min.)	125	162	170	Min 45 mints
Final setting time (hrs.)	4:30	5:19	5:30	Max 7 hrs.
*Fineness (cm^2/g.)	3000	2950	2900	/
Comp. at 3 days (MPa)	25	18	17	Min 13
Comp. at 7days (MPa)	30.9	25	23	Min 20
Comp. at28 days (MPa)	35	31	29	Min 25

*the tests were made at research buildings center /Ministry of housing
Other tests of cement were done at material Laboratory in University of Baghdad

Table 15. Physical properties of blended cement (Portland-porcelinite cement).

Requirements	C (Cement)	CP10	CP20	ASTM C595-12 type IP
Consistency %	28	34	41	/
Initial setting time (min.)	125	170	190	Min 45 mints
Final setting time (hrs.)	4:30	5:20	5:45	Max 7 hrs.
*Fineness (cm^2/g.)	3000	3370	3510	/
Comp. at 3 days (MPa)	25	24	22	Min 13
Comp. at 7days (MPa)	30.9	29	27	Min 20
Comp. at28 days (MPa)	35	34	32	Min 25

*the tests were done at research buildings center /Ministry of Housing
Other tests of cement were done at material Laboratory in University of Baghdad

Table 16. Mechanical properties of concrete (Portland-limestone cement.)

Symbol of mix	**Compressive strength (MPa)**		
	7-days	**28-days**	**90-days**
M ref.	34	45	55
ML10-1	41	50	58
M20-1	33	43	49
Symbol of mix	Splitting strength (MPa)		
	7-days	28-days	90-days
M ref.	2.33	3.0	3.5
ML10-1	3.04	3.5	3.74
M20-1	2.35	2.91	3.3
Symbol of mix	Flexural strength (MPa)		
	7-days	28-days	90-days
M ref.	3.81	4.39	4.7
ML10-1	4.36	4.61	4.9
M20-1	3.9	4.2	4.5
Symbol of mix	Dry density(gm./cm^3)		
	28-days		
M ref.	2.431		
ML10-1	2.451		
M20-1	2.464		

Table 17. Mechanical properties of concrete (Portland-quartzite cement).

Symbol of mix	**Compressive strength (MPa)**		
	7-days	**28-days**	**90-days**
M ref.	34	45	55
MQ10-1	35	48	62
MQ20-1	32	41	52
Symbol of mix	Splitting strength (MPa)		
	7-days	28-days	90-days
M ref.	2.33	3.0	3.5
MQ10-1	2.51	3.56	3.77
MQ20-1	2.3	2.9	3.35
Symbol of mix	Flexural strength (MPa)		
	7-days	28-days	90-days
M ref.	3.81	4.39	4.7
MQ10-1	4.01	4.64	5.06
MQ20-1	3.77	4.29	4.52
Symbol of mix	Dry density(gm./cm^3)		
	28-days		
M ref.	2.431		
MQ10-1	2.443		
MQ20-1	2.421		

Table 18. Mechanical properties of concrete (Portland-porcelinite cement).

Symbol of mix	**Compressive strength (MPa)**		
	7-days	**28-days**	**90-days**
M ref.	34	45	55
MP10-1	40	52	64
MP20-1	36	47	58
Symbol of mix	Splitting strength (MPa)		
	7-days	28-days	90-days
M ref.	2.33	3.0	3.5
MP10-1	2.65	3.35	3.84
MP20-1	2.34	3.1	3.63
Symbol of mix	Flexural strength (MPa)		
	7-days	28-days	90-days
M ref.	3.81	4.39	4.7
MP10-1	4.32	4.63	5.1
MP20-1	4.04	4.53	4.8
Symbol of mix	Dry density(gm./cm3)		
	28-days		
M ref.	2.431		
MP10-1	2.452		
MP20-1	2.443		

NOMENCLATURE

Notation	**Description**
CL10	Blended cement with replacement 10% of limestone powder
CL20	Blended cement with replacement 20% of limestone powder
CQ10	Blended cement with replacement 10% of quartzite powder
CQ20	Blended cement with replacement 20% of quartzite powder
CP10	Blended cement with replacement 10% of porcelinite powder
CP20	Blended cement with replacement 20% of porcelinite powder
LP	Limestone powder
QP	Quartzite powder
PP	Porcelinite powder
PLC	Portland-limestone cement
PQC	Portland-quartzite cement
PPC	Portland-porcelinite cement

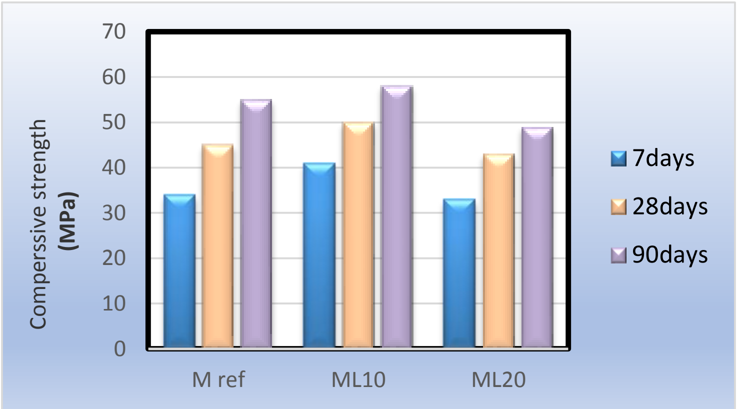

Figure 1. Compressive strength of concrete using Portland-limestone cement.

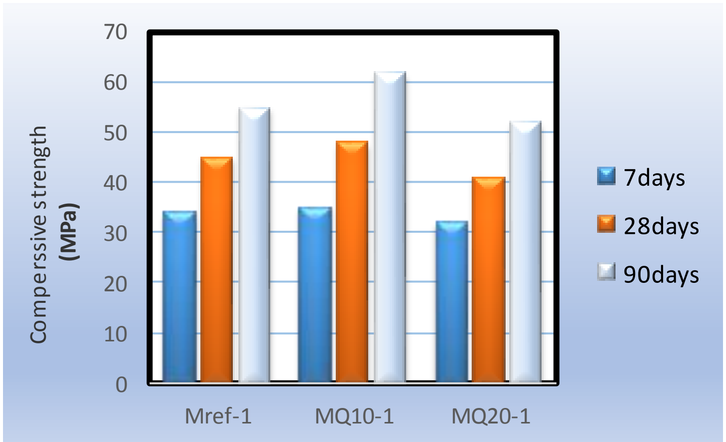

Figure 2. Compressive strength of concrete (Portland-quartzite cement).

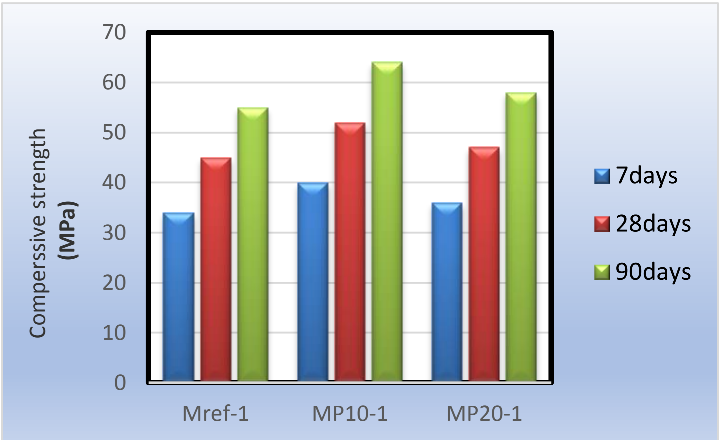

Figure 3. Compressive strength of concrete Portland-porcelinite cement.

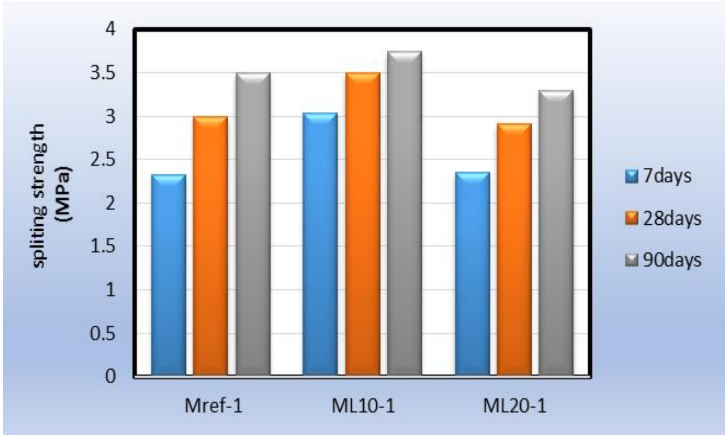

Figure 4. Splitting strength of concrete Portland-limestone cement.

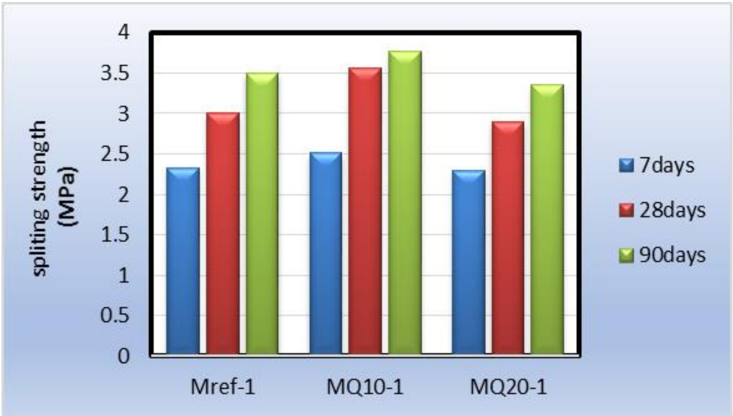

Figure 5. Splitting strength concrete of Portland-quartzite cement.

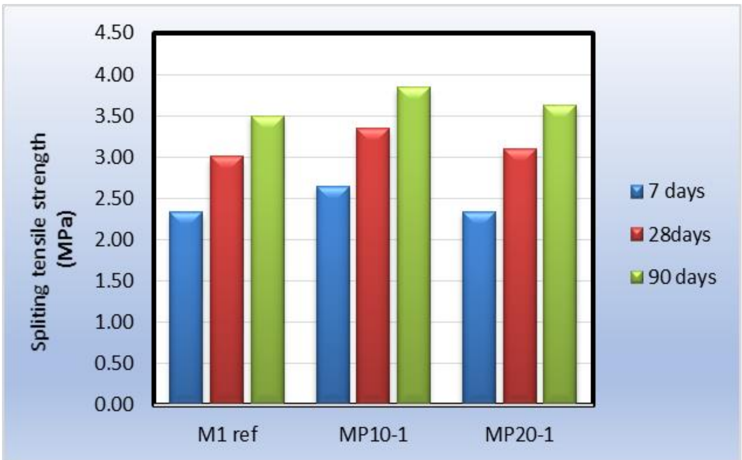

Figure 6. Splitting strength concrete of Portland-porcelinite cement.

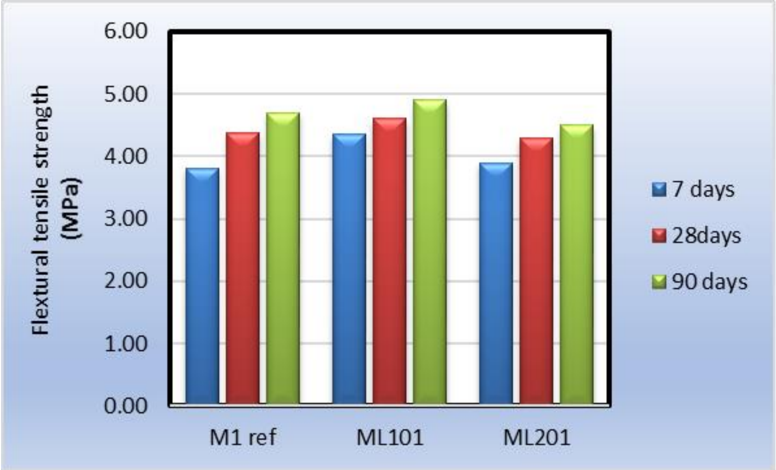

Figure 7. Flexural tensile strength of concrete (Portland-limestone cement.)

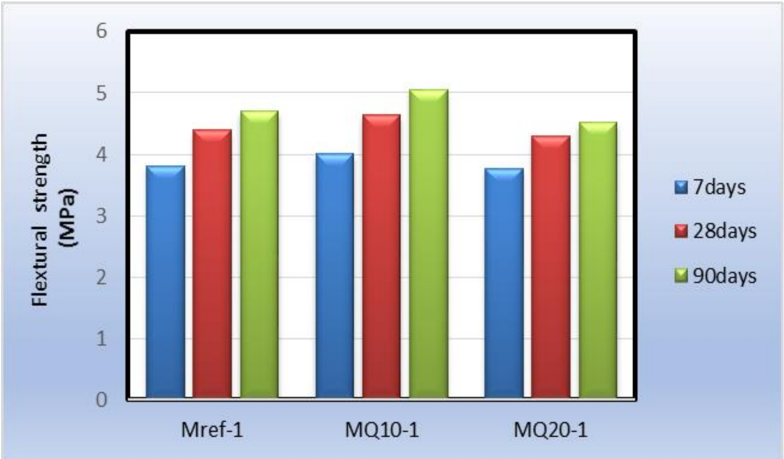

Figure 8. Flexural tensile strength of concrete Portland-quartzite cement.

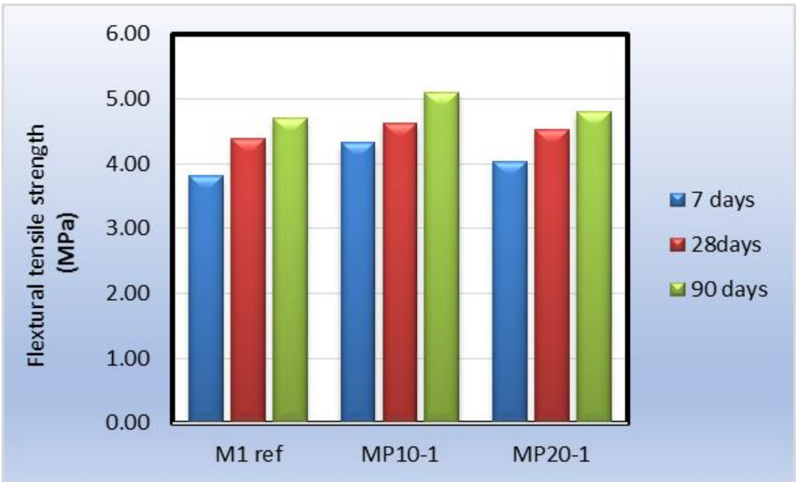

Figure 9. Flexural tensile strength of concrete Portland-porcelinite cement.

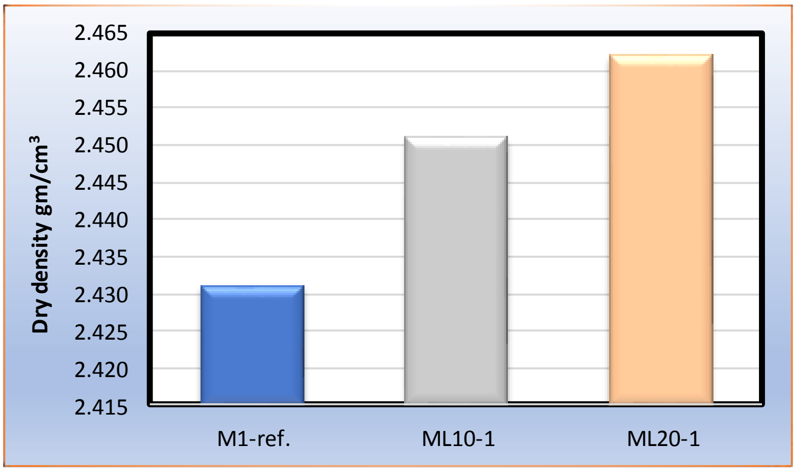

Figure 10. Dry density of concrete Using Portland-limestone cement.

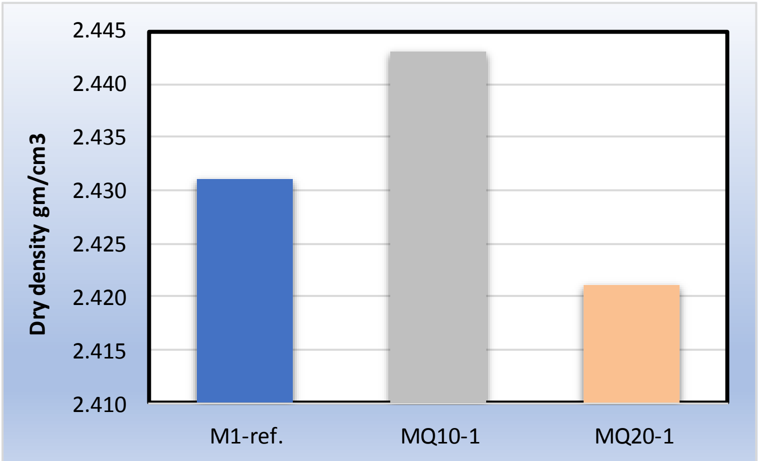

Figure 11. Dry density of concrete Portland-quartzite cement.

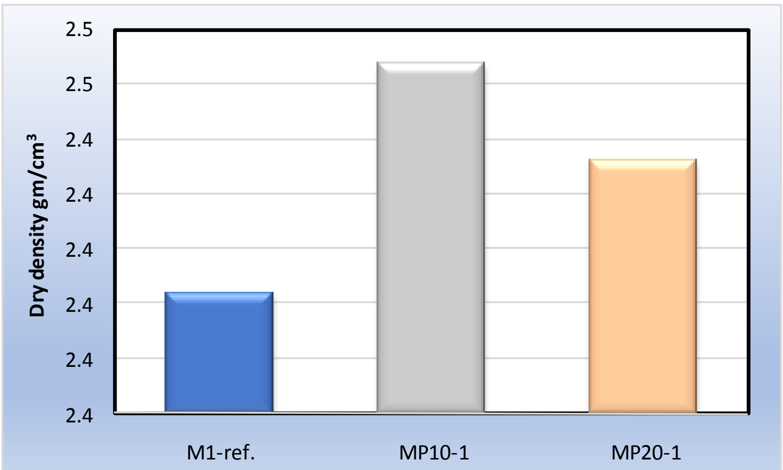

Figure 12. Dry density of concrete Portland-Porcelinite cement.