Using of Porcelinite as Coarse Aggregate in Concrete

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Abstract

In this research the ability of using porcelinite as coarse aggregate to produce light weight concrete was investigated. The experimental program consists of preparing and testing a mixes to investigate mechanical properties of concrete, with a total of 15 cubes (100×100×100) mm, 30 cylinders (100×200) mm. The tests include compressive strength, splitting tensile strength, fresh and hardened density of light weight concrete for different porcelinite percentages ranged between(0% to 100%) of the coarse aggregate weight. The obtained results for tested specimens were compared to control one. Test results indicated that using of porcelinite in concrete mix reduces the strength of concrete Porcelinite aggregate represents a reduction in density ranging between (10%-36%) of normal weight concrete, therefore there is an advantage using this type of light weight aggregate in this country where soil bearing capacity is low in most construction sites.

Keywords: Coarse aggregate, Light weight concrete, Porcelinite

استخدام البورسلينات كركام خشن في الخرسانة

الخلاصة

تم في هذا البحث دراسة امكانية استخدام البورسلينايت كركام خشن لإنتاج خرسانة خفيفة الوزن.يتضمن البرنامج العملي إنتاج وفحص نماذج خرسانية لدراسة الخواص الميكانيكية حيث تم اعداد 15 مكعب بأبعاد (100×100) ملم، 30 اسطوانة بأبعاد (100×200)ملم.قد اجريت فحوصات مقاومة الانضغاط ،مقاومة الانشطار والكثافة للخرسانة الطرية والمتصلبة ولنسب مختلفة من البورسلينايت تتراوح ما بين(0%–100%) من وزن الركام الخشن.وتم مقارنة النتائج المستحصلة من الفحوصات المذكورة مع مثيلتها للخلطة الخرسانية المرجعية وقد بينت النتائج ان استخدام البورسلينايت في الخلطة الخرسانية يقلل من مقاومة انضغاط الخرسانة. ان استحدام البورسلينايت ادى الى خفض كثافة الكونكريت بنسبة تتراوح بين (10%–36%) مقارنة بالخلطة المرجعية، وتعتبر هذه ميزة لقطرنا الذي تمتاز تربته بقابلية تحمل ضعيفة في اغلب نواحيه.

الكلمات الدالة: ركام خشن، خرسانة خفيفة الوزن، البورسلينايت

Notations

d : diameter of cylinder.
l : length of cylinder.
P : maximum applied load.
p_c: density of concrete.
$f't$: Uniaxial tensile strength of concrete.
f'_c : Uniaxial compressive strength of concrete (cylinder test).

Introduction

Light Weight Concrete (LWC) is a concrete which has been made lighter than normal concrete. (LWC) is not just one item, it is a spectrum of different concretes with a variety of characteristics and it fills a number of needs. It is produced by including large quantities of air in the aggregate or in matrix or between the aggregate particles **[1].**

Lightweight concrete is considered as having a density not exceeding 1850 kg / m^3, while normal density concrete is considered to have the usual density ranging from 2300 to 2400 kg/m^3[2]. Lightweight concrete with compressive strength ranging from 17.25 to 27.6 MPa is defined as Low-Strength Concrete (LSC). For compressive strength ranging from 27.6 to 41.4 MPa lightweight concrete is classified as Medium-Strength Concrete (MSC). However, for compressive strength greater than 41.4 MPa the lightweight concrete is classified as High- Strength Concrete (HSC) [3,4].

Light Weight Aggregate Concrete in Iraq

For a long time investigators in this country had shown great interest in heat insulating lightweight materials. They experimented on many materials such as rice husks and hay with clay or gypsum, as binding material, to lighten dead loads of roofs [5]. The use of lightweight concrete in Iraq is limited to very few buildings, and the aggregate used in most cases was imported. For example, the lightweight aggregate of the expanded clay type was used in the dome of the Martyr monument as well as in the flooring of telephone Exchanges in Baghdad [6]. Polystyrene aggregate was used in making lightweight concrete for the penthouse walls in the University of Baghdad in 1980, which is still in good condition [5]. Also it has been used in the false ceilings of Conference Center Building, another type of imported aggregate commercially known as lytag was used. During the seventies of the last century there had been an attempt by the Building Research Center to produce such aggregate from clay found in the middle and southern parts of Iraq[7] .

Also Munir Engineers produced in the seventies of the last century lightweight aggregate. This experiment took place in one of the clay bricks factories (in the 7th Nissan district in Baghdad). But this remained within research context [8].

Most of aggregate which is used is quarried from rocks discovered in the Iraqi Western Desert. It is called porcelinite. Since the production of manufactured light weight aggregate (from clay, shale …etc.) is more costly [9]. Porcilinite rock is one of the important industrial sedimentary rocks[10].

The porosity of these porcilinites ranges from 46.2 to 55.6% and the bulk density ranges between 1.01 and 1.22 gm/cm^3. Two grades of porcilinites were identified according to their silica contents; grade I ($SiO_2 \geq 70\%$) and grade II (SiO_2 = 60-69%) [9].

Structural Light Weight Aggregate Concrete

Al-Hadad in 2001[11]investigated the durability of porcelinite concrete with High Range of Water Reducing Agent (HRWRA) and Slag (SL) against sulfate and chloride solution, 10% of Iraqi slag was used as a partial replacement by weight of cement. The results of AL-Dhaher in 2001[10] led to the fact that the

use of porcelinite aggregates gives concrete having density between 1400-1960 kg/m^3 and 28 day compressive strength between 13.0 and 22.4 MPa.

Al-Ani in 2002[12]studied the corrosion process of steel reinforcement in LWC using porcelinite aggregate. Results indicated that the mixture containing High Range Water Agent (HRWRA) exhibited higher 28 day compressive strength of 38.5 Mpa with an air dry density of 1970 kg/m^3. Kadhi in 2002[13]studied the effect of steel fibers content and High Range of Water Reducing Agent(HRWRA) with Rice Husk Ash (RHA) as partial replacement by weight of cement on the engineering properties of high performance LWC. He found that the LWA concrete reinforced with 2, 2.5 and 3% steel fibers by volume of the mix exhibited significant improvement in all engineering properties at all ages of curing compared with reference LWA concrete without steel fibers.

Al-Wahab in 2003[14]studied the fire resistance properties of porcelinite light weight concrete, it is reached to the density and compressive strength ranging between 1850-1920 kg/m^3 and 22.27-29.60 MPa at 28 day respectively. Sarsam and other in 2009[15]studied the behavior of reinforced porcelinite concrete column subjected to concentrated loads. From this study it was found that the porcelinite aggregate is good structural material to produce lightweight concrete columns. Al-Mashhadani and other in 2009[16] studied the properties of light weight concrete containing carbon fiber. The test results indicated that the inclusion of carbon fiber to the light weight concrete mix did not affect the compressive strength significantly, while the splitting tensile strength and the modulus of rupture were improved significantly.

Khaleel and other in 2010[17] studied mechanical properties of high strength light weight aggregate fine grain concrete. The results indicated that the structural light weight aggregate concrete produced from local porcelinite aggregate is suitable to use as a structural concrete.

The present work includes the use of porcelinite aggregate in concrete with ratios of 25, 50,75and 100% by weight of the coarse aggregate. Cubes (100×100) mm are used to compute the compressive strength at 28-days, and cylinders (100×200mm) are used to compute the compressive strength and splitting tensile strength .

Experimental Program

Materials

1.Cement: Ordinary Portland Cement was used. The specific gravity of the cement used was 3.15.

2.Fine aggregate: Normal weight natural sand from AL-Tuz region was used as fine aggregate. The grading of the requirement of Iraqi specification No.45/1984, grading area (3).

3. Coarse aggregate

3.1 Natural gravel

The grading was within the limits of gravel by British Standard (B.S..882:1973)[18]as shown in table (1).

3.2 Porcelinite aggregate

Local natural (LWA) of porcelinite stone was used as coarse aggregate. The quarry of this stone is located in Trefawi area in Rutba at the Western Desert in Al-Anbar governorate. The jaw of machine crusher was set up to give a finished product of about 20 maximum aggregate

sizes. The grading was made in a manner similar to the grading of the natural gravel aggregate.

Mixture Proportions

Concrete mixes

The concrete mix ratio was kept constant for all types of concrete using the mix proportioning ratio by weight (cement: sand: aggregate) of 1:2:4. Five values of porcelinite aggregate (0%, 25%, 50%, 75, 100%) were used. Concrete mixes were cast in (100×100×100 mm) cubes and in (100×200mm) cylindrical steel moulds.

Curing

After casting, the specimens were stripped and kept in the water bath for a curing period of 28 days to ensure that the hydration process was completely carried out under laboratory temperature.

Testing of Hardened Concrete

Compressive strength test

The test program consisted of a total of 30 specimens (15 cylinders and 15 cubes). For compressive strength tests (100×100×100mm), concrete cubes were tested according to B.S. 1881, part (116) [19]. A compressive machine (Wecabe) of 2000 kN capacity was used to perform this test. Three cubes specimens were used to determine the average of compressive strength at 28 days curing age.This test was done in the laboratory of civil engineering department/ Tikrit University.

Splitting tensile strength test

The splitting strength was conducted on cylinders of (100mm diameter and 200mm height). The test program consisted of 15 spesimens for tensile strength test.The average of three test specimens was taken. The splitting tensile strength test was carried out according to ATSM C496-90 [20].The splitting tensile strength was calculated as follows:

$$f't = 2p / \pi dl \quad \text{.....(1)}$$

where:

$f't$ = splitting tensile strength (N/mm^2).

P = maximum applied load, (N).

l = length, (mm).

d = diameter, (mm).

Results and Discussions

Dry density

Figs. (1) and (2) shows the densities for all specimens. It is noticed that the density decreases by replacing natural gravel by porcelinite. Also this light weight aggregate (LWA) presents a reduction in density from normal weight concrete ranging between 6% and 30.5% for cubic specimens and between 8% and 23% for cylindrical specimens.

Wet density

Figs. (3) and (4) show the wet density ranged from 2248kg/m^3 to 1600kg/m^3. Here a reduction in density from normal weight concrete ranging between 10% and 31% and 10% to36% for cubic and cylindrical specimens, respectively.

Water- cement ratio

Because the crushed porcelinite aggregate is lighter than the natural gravel, the volume of the crushed porcelinite aggregate is larger than that of the natural gravel when the weight is kept constant. Due to this fact a higher water-cement ratio was chosen for concrete mixes with crushed porcelinite aggregate. Fig. (5) shows the effect of using the porcelinite aggregate on water- cement ratio.

Compressive and tensile strengths

Results of compression tests are shown in Fig(6) and Fig(7) for cylinders and cubes, respectively. The results reported are the average of 3 specimens of cylinders and 3cubes at age of 28 days. Results of the splitting tensile strength for various types of concrete cylindrical (100×200) mm are demonstrated in Fig (8). The ration of the compressive strength and splitting tensile strength depended on general level of strength of concrete. In other words, for higher compressive strength concrete it shows higher splitting tensile strength. From these figures it is clear that the use of crushed porcelinite in concrete reduces its strength in compression (for cylinders and cube) and in tension. The reduction in strength may be attributed to two reasons

1- Crushed porcelinite failed to develop proper adequate bond with concrete and cement matrix.
2- Because the high porosity of the surfaces of crushed porcelinite, the mixture needed more water to get the required slump.

Figure (9) shows the best curve, the best equation ® (correlation factor) between the splitting tensile strength and compressive strengths of cylinders. Based on test, figure (10) shows the relationship between the compressive strength (cylinder specimen) and hardened concrete density at age 28 days. The empirical formula is suggested for this work:

$$f'_c = 0.1299e^{0.0019p_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

R^2=0.9821 (Coefficient of determination)

where:

f'_c = compressive strength, (N/mm^2).

p_c= density of concrete, kg/m^3 (density of concrete, 28 day age).

Conclusions

On the basis of the result of this work, the following conclusions may be deducted:-

1-The use of crushed porcelinite as a coarse aggregate in concrete increases the water cement ratio.

2-Compressive strength decreases with increase partial replacement of natural gravel by porcelinite gravel.

3- The use of porcelinite gravel decreases the splitting tensile strength.

4-From tests carried out in this work a relationship between compressive strength (cylinder specimen) and dry density of concrete is suggested as an empirical formula

$$f'_c = 0.1299e^{0.0019p_c} \quad (N/mm^2)$$

5- Increase in poecelinite aggregate shows reduction in the density.

6-Porcelinite aggregate presents a reduction in density ranging between 10% and 36% of normal weight concrete, therefore there is an advantage in this country where soil bearing capacity is low in most construction sites.

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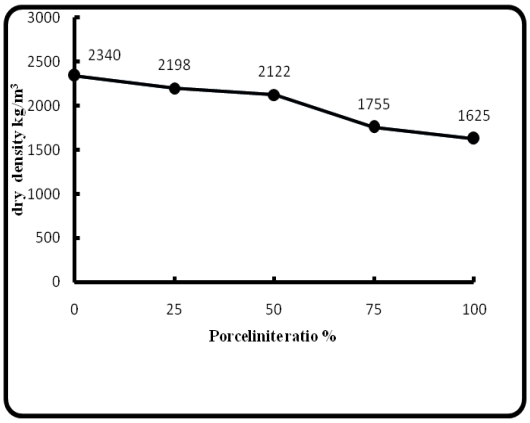


Figure(1).Influence of porcelinite ratio on density(cubic specimens)

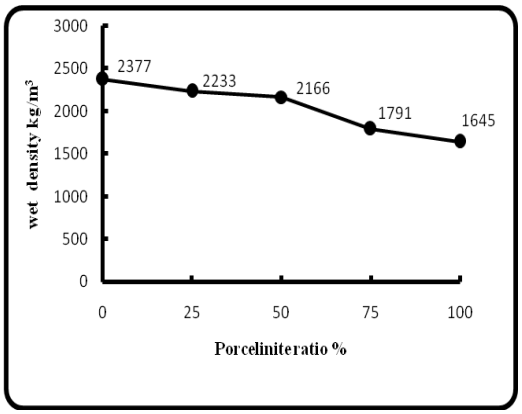


Figure (4): Influence of porcelinite ratio on wet density(cylindrical specimens)

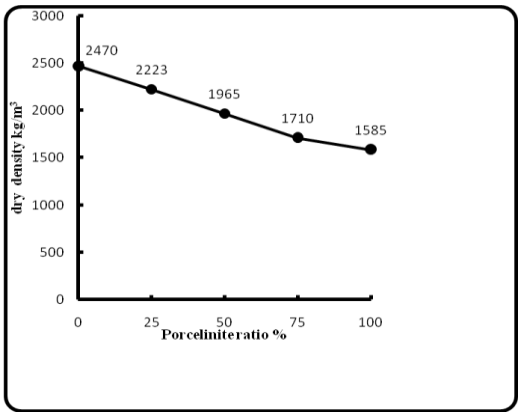


Figure (2): Influence of porcelinite ratio on dry density (cylindrical specimens).

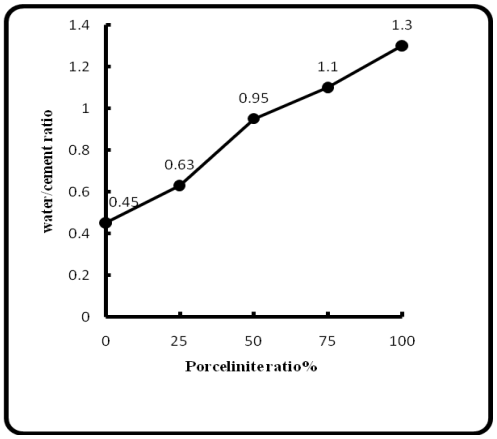


Figure (5): Influence of using porcelinite on water/cement ratio.

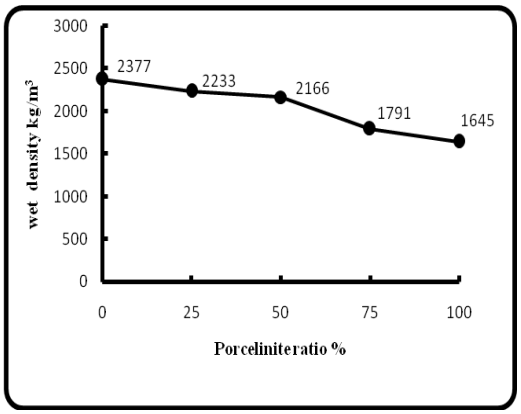


Figure (3): Influence of porcelinite ratio on wet density (cubic specimens)

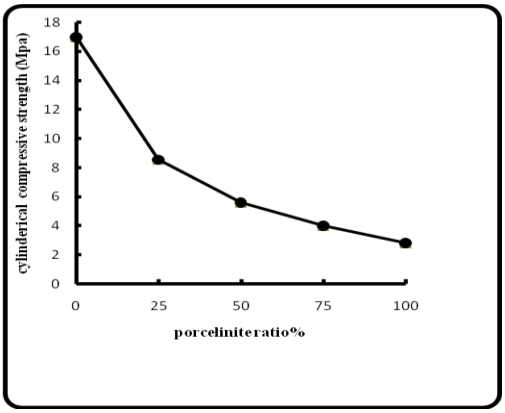
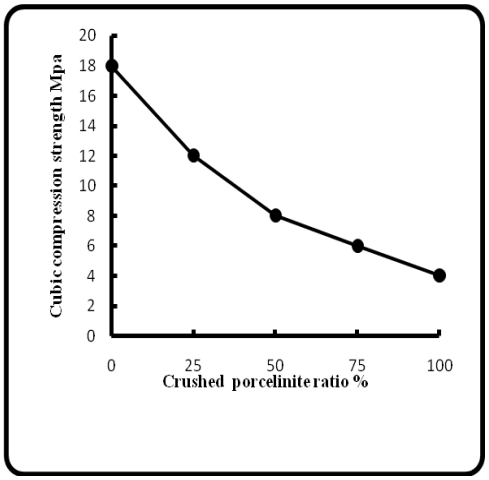
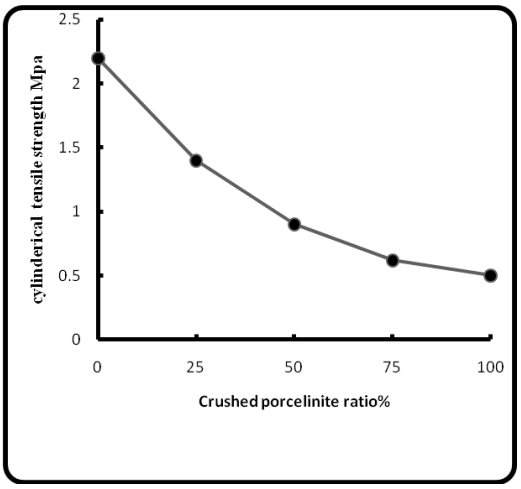


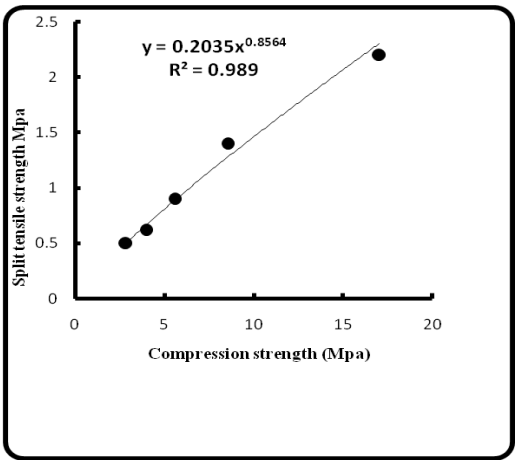
Figure (6): Effect of porcelinite on cylindrical compressive strength.



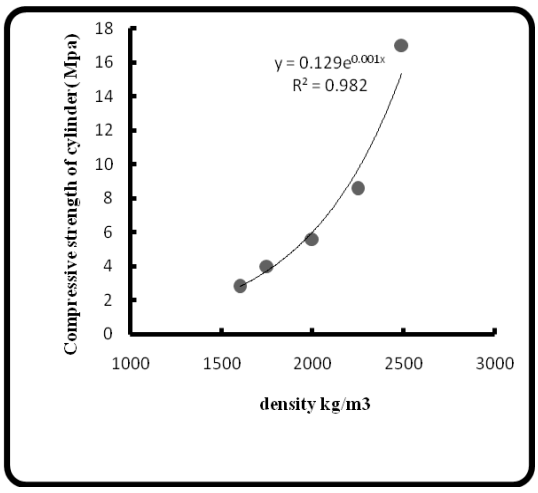
Figure(7):Effect porcelinite on compressive strength of cubes.



Figure(8): Effect of porcelinite on splitting tensile strength



Figure(9):Relationship between compressive and split tensile strength (best curve).



Figure(10) :Relationship between density and compressive strength

Table(1) Grading for gravel

Sieve size mm	Natural gravel passing %	Passing range according to B.S.882:1973%
20	85	85-100
9.5	15	0-25
4.75	0	0-5
0.150	0	0