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Properties Of High Performance Concrete Containing Stone Powder As Replacement Of Cement.

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ABSTRACT

The need to produce high performance concrete led the researches to try to exploit the potentialities of natural or artificial materials so as to improve the performance of concrete. White sandstone powder has been used as an alternative of proportion on cement after being processed, since its main oxides are similar to those of cement.

The aim of this research is to study the effect of added (10,15,20,25)% white sandstone powder as replacement of cement, used in concrete mix which it has a mixing proportion of (1:1.6:1.2;w/c=0.28), and it is shown their effect on some of mechanical properties (compressive strength, splitting tensile strength, and flexural strength).

The test results shows clear improvement in some mechanical properties of concrete by using 20% sandstone powder. The increment ratio in compressive strength, splitting tensile strength, and flexural strength were (32, 42.5, 31.6)% respectively for each compared with reference mixture for the same duration.

Keywords: High Performance Concrete (HPC) ; Stone Powder (SP); Mechanical properties.

خصائص خرسانة عالية الاداء المحتوية على طحين الحجارة كنسبة استبدال عن السمنت

الخلاصة

ان الحاجة الى انتاج خرسانة ذات اداء متميز ادت بالباحثين الى محاولة استغلال مواد طبيعية او صناعية لتحسين اداء الخرسانة فقد استعمل مسحوق الحجارة كبديل عن جزء من السمنت لكون أكاسيده الرئيسية مشابهة الى اكاسيد السمنت. ان الهدف الرئيسي للبحث هو دراسة تأثير استبدال مسحوق الحجارة وذلك بإضافته وبنسب وزنية (10, 15, 20, 25)% من وزن السمنت المستعمل في الخلطة الخرسانية ذات النسب الوزنية (1:1.6:1.2) ونسبة الماء الى السمنت(0.28) وبيان مدى تأثيره على بعض خواصه الميكانيكية: مقاومة الانضغاط، مقاومة شد الانفلاق، ومقاومة الانثناء. اظهرت نتائج الفحص تحسنا واضحا في بعض الخواص الميكانيكية للخرسانة باستعمال 20% من مسحوق الحجارة، حيث ازدادت بنسب (32, 42.5, 31.6)% لكل من مقاومة الانضغاط, مقاومة شد الانفلاق، ومقاومة الانثناء على التوالي مقارنة بالخلطة المرجعية ولنفس العمر.

الكلمات الدالة: خرسانة عالية الاداء; مسحوق الحجارة ; الخواص الميكانيكية.

Introduction

High strength concrete is a type of high performance concrete generally with a specified compressive strength of 42 MPa or greater.

In the last few decades, considerable research effort has been spent on the utilization of

industrial by-product (fly ash, blast furnace slag, micro silica, etc.) and natural resources (lime stone, pozzolans, etc.) as replacement of Portland cement. The benefits of addition of supplementary materials to Portland cement are well documented [1,2].

The use of supplementary cementatious material and additives designed to enhance the properties of concrete has grown significantly and it is no longer possible to refer to all concrete as merely "concrete" under generic term, there exist a number of more specific description, as Normal Strength Concrete (NSC) (20 to 42 MPa), High Strength Concrete (HSC) (42 to 80 MPa) and Ultra-High Strength Concrete or Reactive Powder Concrete (RPC) above (100 MPa) [3].

Many researches were examine the possibility of using stone powder, limestone powder as partial replacement of sand and partial replacement of cement. The test results indicate that granite powder of marginal quantity as partial sand replacement has beneficial effect on the mechanical properties such as compressive strength, split tensile strength, modulus of elasticity [4].

M. Hunger and H.J. Brouwers [5] gave the possibility for the direct use of natural sludge of limestone powder or filler cakes, and examine a new grading based design method which is applicable to Self-Compacting Concrete.

It is possible to produce ternary composite cement paste containing relatively high contents of micro silica and limestone powder with no considerable loss in 7-50 days compressive strength compared to plain cement paste [6].

The aim of this research is to study the influence of White Sandstone Powder used as partially replacement of cement on important mechanical properties of hardened concrete.

Experimental Work

Materials

Cement

Ordinary Portland cement from (Sinjar Company) was used in this work. Tables (1) and(2) show the chemical and physical properties of the cement used. The test result indicated that the selected cement conform to the Iraqi specification No.5 [7].

Table 1. physical properties of the used cement

Limit of Iraqi specification	Test results	Physical properties
≥ 230	290	Specific surface by blain method m^2/kg
≥45 minute	2:29	Initial setting (hrs:min)
≤10:00 hours	3:15	Final setting (hrs:min)
≥15 ≥23	22 30	Compressive strength, MPa 3 days 7 days

Table 2. chemical properties of the used cement and sandstone powder

Basic Components% %	Cement	White Sandstone powder
SiO_2	21.2	44.89
Al_2O_3	6.5	0.3
Fe_2O_3	2.5	0.68
CaO	63	18.6
MgO	2.75	2.34
SO_3	3.1	0.39
K_2O	0.45	0.26
Na_2O	0.24	1.06
C_3A	13.6	-

Water

Ordinary tap water was used for all mixtures.

Fine aggregate:

Medium natural sand (zone II) in accordance with British standard B.S.882:1992[8] was used. Its particle size shown in Table (3).

Table.3 Grading of fine aggregate.

Sieve size (mm)	Percentage passing				
	Limits	Percentage passing of the sand used	Grading zone limit		
			Course (zone III)	Medium (zone II)	Fine (zone I)
4.75	89-100	100	-	-	-
2.36	60-100	88	60-100	65-100	80-100
1.18	30-100	69.2	30-90	45-100	70-100
0.6	15-100	46.7	15-54	25-80	55-100
0.3	5-70	14.1	5-40	5-48	5-70
0.15	0-15	3.9	-	-	-

Coarse aggregate

River gravel round shape was used, has maximum aggregate size of 12.5mm, sieve analysis was perform and Table (4) shows the results of the sieve analysis, it is found compatible to the American standard (ASTM C33-93) [9].

Table 4. Grading of course aggregate**.**

Sieve size (mm)	Limits, %	Percentage passing, %
19	100	100
12.5	90-100	93.8
9.5	40-70	59.3
4.75	0-15	0.94
2.36	0-5	0

Sandstone powder

Grinding procedure : white sandstone was washed and dried with a maximum size (45 mm), then the grinding machine shown in Fig.(1) was used to get very fine powder of stone. Productivity of the grinding machine about 3 Kg/h.

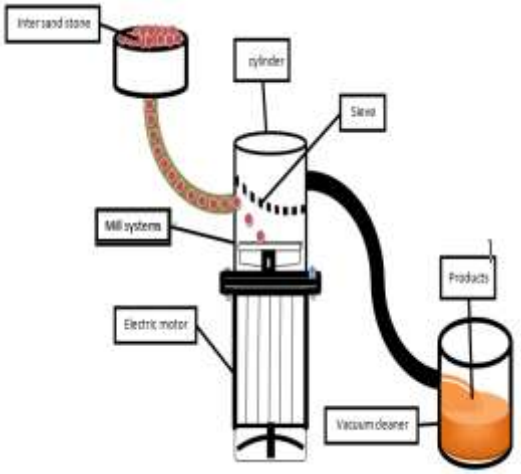

Fig.1 Schematic representation of the manufactured grinding machine.

b. Fig. (2) shows the morphology of the stone powder, after grinding and from this figure, fineness of the stone powder found about 2µm, and more than 50% of the particle was classified as Nano particles. Table (2) shows the chemical composition of the stone powder. Fig.(3) shows the fineness (particle size in nm) for a different additive of concrete and fine aggregate[10].From the figure, it's found that the stone powder used in this work has have more fineness of silica fume.

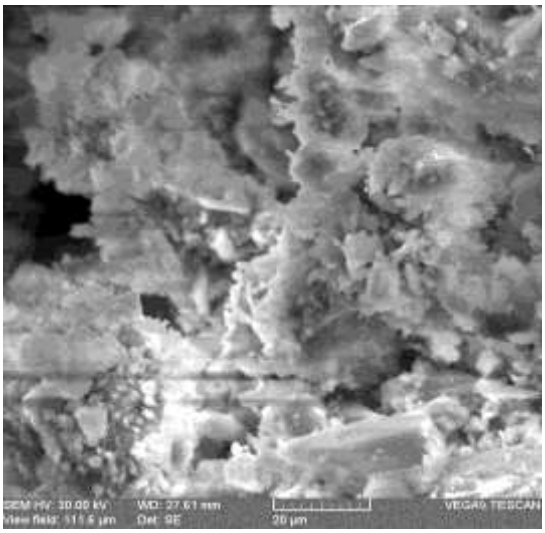

Fig.2 The morphology of the sandstone powder.
*This test was conducted in University of Technology.

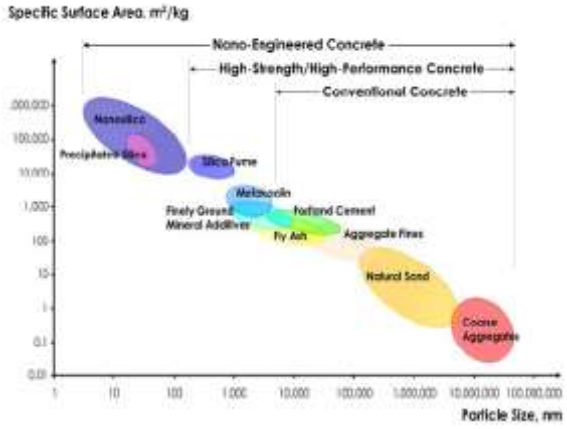

Fig.3 The site of stone powder for other fineness materials [10].

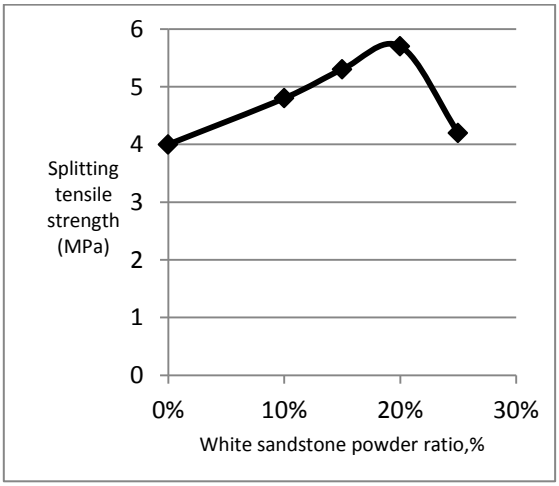

Fig. 4 The relationship between splitting tensile strength and sandstone powder ratio.

Superplasticize

(FFN) high range water reducer was used as superplasticizer, its color was brown and has a density of (1.21-0.02) kg/L.

Activity index

To evaluate the activity of the used sandstone powder, activity index test according to ASTM C311[11] was produced.

The result of strength activity index at 28 day is equal to (137)%.

Mixture Proportions and Testing

A trial mix was used to design the concrete mixtures. Concrete mixtures were included one control mixture with a cementitious materials content of 600 kg/m³. Others concrete mixtures were made with a stone powder content by ratios (10, 15, 20 and 25)% as replacement of the cement. The proportions of the five mixes are summarized in Table (5). The water/cementitious material ratio of the five mixtures was kept equal to 0.28. The batching followed ASTM C192 [12].

The aggregates are mixed with dry cement and stone powder, superplasticizer mixed with water and added to the mixture.

Steel molds (100*100*100) mm. used for compressive strength test. (400*100*100) mm. for flexural test and (200*100) mm. for splitting test, (21) samples were casted for each mix.

After one day the samples were removed from molds and soaked in (23 C˚) water, and kept to the time of test.

Table 5. Composition of mixes

Materials	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Cement kg/m³	600	540	510	480	450
Stone powder kg/m³	-	60	90	120	150
Sand kg/m³	960	960	960	960	960
Gravel kg/m³	720	720	720	720	720
Super plasticizer kg/m³	6	6	6	6	6
w/c (calculated)to give slump (25±5)mm	0.28	0.28	0.28	0.28	0.28

Testing program

Samples were tested for

Compressive strength for (3,7,28,56 and 90) days, according to (BS. 1881:part 116) [13].

Splitting tensile strength, at (28) days of age, according to ASTM C496 [14].

Flexural strength, at (28) days of age, according to ASTM C78 [15].

RESULTS and DISCUSSION

Tables (5 to 8) shows mixture properties and the test results of specimens.

Compressive strength

The compressive strength of the concrete made with and without admixture are given in Table (6).

Table 5. Composition of mixes.

Materials	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Cement kg/m³	600	540	510	480	450
Stone powder kg/m³	-	60	90	120	150
Sand kg/m³	960	960	960	960	960
Gravel kg/m³	720	720	720	720	720
Super plasticizer kg/m³	6	6	6	6	6
w/c (calculated)to give slump (25±5)mm	0.28	0.28	0.28	0.28	0.28

Table 6. Compressive strength in (N/mm^2) .

Mix No.	3 days	7 days	28 days	56 days	90 days
Mix 1	20	33	50	57	59
Mix 2	23	37	56	64	65
Mix 3	25	42	63	72	74
Mix 4	27	44	66	76	77
Mix 5	21	35	52	60	62

A comparison between the compressive strength of mix 1 and other mixes showed that the using of stone powder lead to give the highest increase ratio. The highest value of compressive strength obtained when 20% sandstone powder was used as replacement of the cement. The products of manufactured grinding machine contain high percent of micro and Nano particles, the micro-white sandstone powder works on two levels. The first one is the chemical effect: the pozzolanic reaction of white sandstone powder with calcium hydroxide forms more CSH-gel at final stages. The second function is physical one, because micro-white sandstone powder is about 100 times smaller than cement, micro-white sandstone powder can fill the remaining voids in the young and partially hydrated cement paste, increasing its final density .

Tensile strength

The splitting tensile strength of the concrete specimens made with the different percentages of stone powder and the control mix are given in Table (7) and shown in Fig.(4). From these results, it can be observed that for each group the splitting tensile strength of the modified concrete is higher than that of concrete without admixtures. Mix 4 indicate 42.5% increment in splitting strength than the reference mix. This behavior of the admixture enriched concrete is similar to that observed when investigating the compressive strength of concrete mixes containing stone powder.

Table 7. Splitting tensile strength in (MPa).

Mix No.	Splitting tensile strength
Mix 1	4
Mix 2	4.8
Mix 3	5.3
Mix 4	5.7
Mix 5	4.2

Table 8. Flexural results in (MPa)

Mix No	Flexural strength
Mix 1	6
Mix 2	6.7
Mix 3	7.1
Mix 4	7.9
Mix 5	6.2

Flexural strength

The flexural strength results for the different concrete mixes are shown in Table (8). From the test results it can be seen that for both groups the concrete with partially replacement with stone powder showed higher strength

than those without replacement. A comparison between mix 1 and mix 4 shows that there was an increasing in flexural strength by increasing the stone powder percent (20%), mix 4 gave increment about (31.6 %) compared with the reference mix.

CONCLUSIONS

1. High performance concrete can be produced by using white sandstone powder as partial replacement of cement.
2. At 28 days, the compressive strength of samples containing white sandstone powder still higher than the results for samples without white sandstone powder but both are of acceptable range.
3. The most suitable percentage of sandstone powder as partial replacement of cement was 20%, which gave highest activity index.
4. Splitting and flexural tensile strength were found to increase as the compressive strength increased, therefore the use of admixture (stone powder) has significant improvement to the tensile strength.
5. Replacement of cement by 20% white sandstone powder will have an economic benefits, because white sandstone powder is a local natural material.

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