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The Central Organization of
Standardization and Quality Control

Behavior of Concrete Containing Ceramic Waste as Sand

سلوك الخرسانة المحتوية على مخلفات السيراميك كالرمل

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Abstract.

The demand of concrete has been increases on a daily bases which consume a lot of natural resource such as sand and gravel, there is an immediate need for finding suitable alternative which can be replace sand partially with other materials or at high proportion. Many researches study the effect of several waste products such as ceramic tiles, glass, crushed rock flour, building demolition waste in the partial replacement of sand. Ceramic waste is one of the strong research areas that include the activity of replacement in all the sides of construction materials. It is main to improve the performance of concrete using ceramic waste. This paper studies the mechanical properties to the concrete with partial replacement of sand by using waste porcelain. For analysis the mechanical properties such as compressive strength, split tensile and flexural strength, the specimen were Foundry with 10% ,20% ,30% ,40%, and 50% replacement of sand using waste porcelain and curing with different time under water for 7 days , 28 days , 60 days . The optimum considering the mechanical properties of concrete, the amount of ceramic waste added was analyzed.

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Objective of study

To protect the natural resources of the environment as well as reduce the solid waste (porcelain waste), therefore improve the mechanical properties of concrete by using porcelain waste as sand.

Chapter One: Introduction

1.1 Introduction

Concrete is a composite of cement (binder), sand (fine aggregate) and gravel or broken stone (coarse aggregate) [1]. It has been used for more than a century in all construction work [1-2]. In recent years, a variety of new materials in the field of concrete technology have been developed, with the continuous demand of the construction industry to meet the functionality, strength, economy and durability demand . India's ceramic production is 100 million tons per year. India ranks as the world largest tile producer [3]. During production 2011- 2012 about 600 million square meters [4-5]. This huge ceramic production is due to the prosperity of the housing sector, coupled with government policies to promote the strong growth of the real estate industry [6]. In the ceramic industry, about 15% to 30% of total waste is generated from all production [7]. Although the reuse of ceramic waste has been implemented, the amount of waste recycled in this way is still negligible [4-8]. Therefore, its application needs in other industries have become absolutely important. The construction industry can become the end user of all ceramic waste, and in this way can help solve this environmental problem [9-10].

This research aims replace sand with waste porcelain in the produce of concrete materials. However, the mechanical properties have been study ensure the composites is promising for concrete production.

Chapter Two: Materials and Experimental Method

2.1 Material

Materials used in this study include cement, sand, coarse aggregate, fine aggregate, waste porcelain and water.

2.2 Experimental Method

The research method of this work mainly involves investigating the potential use of waste ceramic (waste porcelain) and concrete mixes. At present, as with other solid wastes, ceramic waste generated from recycled materials is also thrown into the dump. Waste is usually produced by dismantling the building's containers, but also different buildings and rebuilt and waste. In addition, the study also used ceramic waste as sand and ceramic waste as a partial replacement for sand. Mix the ceramics into the fresh concrete and study the effect of the ceramics on the properties of the concrete. Porcelain, can be used to replace natural aggregates by replacing some natural materials with recycled materials that produce the same functions, the possible benefits are as follows: Many ceramic wastes are now being through into the environment. The current experimental procedure is to explore the effect of the use of powdered spent ceramic parts in the ASTM test procedure specification as a ceramic in a normal concrete mixture on the compression properties for the hardened concrete.

All the materials used in research study locally exist. In this study, Portland cement will be used as ceramic waste. Sand with a size of 4.75 mm will replace 0%, 10% and 20% 30%, 40% and 50% ceramics. Figure 1 shown that the experimental work includes a description of the materials used, mixed design, mixing procedures, placement, curing, fresh and mechanical, thermal characterization procedures.

2.3 Cement

The Iraqi ordinary cement was used throughout the survey and was based on the standard specification ASTM C150-02 Portland cement [2]. Store it in a dry place (air-tight plastic container) to reduce the effects of humidity and temperature. Tables (2) and (3) show the chemical and physical properties for the X-RAY diffraction of the cement used in this paper respectively.

Table 1: The oxide composition of ordinary PC

Common name	oxide	Abbreviation	Approximate composition limits (%)
Lime	CaO	C	60-66
Silica	SiO_2	S	19-25
Alumina	Al_2O_3	A	3-8
Iron oxide	Fe_2O_3	F	1-5
Magnesia	MgO	M	0-5
Alkalis-soda	Na_2O	N	0.5-1
Polassa	K_2O	K	0.5-1
Sulfurtnoxide	SO_3	P	1-3

Table 2: Chemical composition and main compounds of the cement used in this investigation

Abbreviation of Oxide	**% by weight**	**Limits of Iraqi Specification**
SiO_2	19.90	-
CaO	60.80	-
MgO	1.50	≤5.0
Fe_2O_3	3.00	-
Al_2O_3	5.69	-
SO_3	2.30	≤ 2.8
Loss on Ignition	1.50	≤ 4.0
Insoluble residue	1.10	≤1.5
Lime saturation factor	0.85	0.66-1.02
Main Compounds (Bogue's equation)		
C_3S	47.14	-
C_2S	21.57	-
C_3A	10.00	-
C_4AF	9.12	-

Table 3: physical properties of the cement used in this study

Physical property	Test Results	Limits of Iraqi Specification No.5/1984
Specific surface area (Blaine method), m^2/kg	318	≥ 230
Setting time (vicat's method) Initial :by minutes Final, by minutes	 121 230	 ≥ 1 hr ≤10.00 hrs
Compressive strength (70.7mm cube) (N/mm^2) 3days 7days	 19.20 28.50	 ≥15 ≥23
Soundness (autoclave method) %	0.22	≤0.8%

2.4 Fine Aggregate

The term "sand" used in the construction and construction industry is synonymous with fine-grained material having a particle size of less than 5 mm. Sand is located in the construction industry all over the world and is an important raw material for providing infrastructure and housing. The main purpose of sand is to make concrete and concrete products, such as ready-mixed concrete block products, columns, stumps, manholes, pipes, plates, beams, walls, roof tiles and various other products. Standards require sand to have physical and chemical characteristics such as particle size distribution limitations, hardness, inertness, water absorption limit, density, mineral type, durability, and no harmful substances [10].

Figure 1: Natural sand

Table (4) shows the sieve analysis of the used natural sand, it is observed that the sand falls within zone three according to the requirement of the Iraqi specification. The chemical and physical properties of natural sand are illustrated in Table (5).

Table 4: grinding of fine aggregate

Sieve Size (mm	**% Passing**	**% Passing according to limits of I.O.S No. 45/1984**
4.75	95	90-100
2.36	90	85-100
1.18	85	75-100
0.60	70	60-79
0.30	25	12-40
0.15	5	0-10
Fineness Modulus = 2.15		

Table 5: physical and chemical properties of sand

Property	**Specification**	**Result**	**Iraqi Specification**
Specific gravity	ASTM C128-88(14)	2.63	-
Absorption, %	ASTM C128-88(14)	0.75	-
Dry loose- unit weight, kg/m^3	ASTM C29-89(43)	1592	-
Sulphate content as SO_3 ,%	I.O.S No.45/1984(42)	0.08	≤ 0.5
Material finer than 75µm sieve , %	I.O.S No.45/1984(42)	3.8	≤ 5

2.5 Coarse Aggregate

Aggregates are minimized, the cement requirement to fill the voids can be reduced to maintain the workability and strength of the concrete [10]. Polymers have been classified into two types, such as coarse aggregates having a size in excess of 2.36 mm to 12.5 mm. The coarse aggregates typically have the maximum permissible dimensions for gravel and crushed stone with 2.36 to

12.5 mm size for the coarse aggregate left on the screen. The function of course Aggregate is to serve as the main load-bearing component of concrete.

Figure 2: Coarse Aggregate

Figure 2 Natural coarse aggregate concrete samples. In this study, ceramic waste was proposed as a substitute for coarse aggregate because it helps to increase the productivity of concrete production. Partially substituted ceramics help reduce roughness. Integrated use of natural resources.

Table 6: Sieve analysis of coarse aggregate

Sieve analysis (mm)	% passing	% passing ASTM C330-87
12.5	95	90-100
9.5	70	40-80
4.75	15	0-20
2.36	5	0-10

2.6 Water

Water is an important part of concrete because it actually participates in the chemical reaction with cement. Because it helps to power cement gels, the amount and quality of water need to be carefully studied.

2.7 Porcelain Waste

Waste porcelain is available a large amount especially in medal east countries, some of Arab countries such as Iraq they don’t manufacturing the porcelain, they import it [2]. Thus, during transportation some of them damage and therefore the landfill site becoming overcrowding. We got the waste porcelain free from landfill site and crushed in crusher machine to make the sand [8]. Thus, the using this system to crush waste porcelain is possible to obtain fine aggregate and porcelain powder that after sieving (4.75-0.15) mm can be used without extra work and the cost is minimal.

Table 7: Percentages of concrete mix proportion fine aggregate (sand) partially replacement (porcelain).

Materials / S.N	Cement in kg/ m3	W/C Ratio	Coarse aggregate	sand in kg	Waste porcelain as sand Replacement %	Water in lit
1	100%	0.5	100%	100%	0	100%
2	100%	0.5	100%	90%	10%	100%
3	100%	0.5	100%	80%	20%	100%
4	100%	0.5	100%	70%	30%	100%
5	100%	0.5	100%	60%	40%	100%
6	100%	0.5	100%	50%	50%	100%

For the table 7 the materials for the first mixing ratio experiment will be OPC Type 1, coarse sand aggregates and waste ceramic tiles, which have selected porcelain as a substitute for natural aggregates. The cement, sand, and water materials will be constant, while the crushed porcelain will partially change for 0%, 10%, 20%, 30%, 40%, and 50% aggregates.

Table 8: Concrete mix ratio for recycle (porcelain) replaced with sand.

Materials / S.N	Cement in kg/ m3	W/C Ratio	Sand in kg	Waste porcelain as sand Replacement %	Coarse aggregate (Kg)	Water in lit
1	180	0.5	270	0	540	90
2	180	0.5	243	27	540	90
3	180	0.5	216	54	540	90
4	180	0.5	189	81	540	90
5	180	0.5	162	108	540	90
6	180	0.5	135	135	540	90

Table 8 shows the actual number of materials that determine the replacement of porcelain into fine aggregate substitutes, from 0%, 10%, 20%, 30%, 40%, 50% respectively, and then from the best results Research was conducted to measure and test the mechanical properties of concrete microphones and ceramic tiles to determine the best point with high compressive strength and tensile strength as well as to perform the addition of polymer polyester types to the mixture.

2.8 Mix Design

-Mix proportioning for a concrete of M30 is as follows:

a. Grade designation : M30
b. Type of cement : OPC Iraqi cement
c. Maximum nominal size of aggregate : 12.5 mm
d. Maximum water-cement ratio :0.5
e. Workability (slump) : 100mm
f. Exposure condition : severe
g. Method of concrete placing : pumping
h. Degree of supervision :Good
i. Type of aggregate : crushed angular aggregate

-Mix proportion

Cement	= 180 kg/m^3
Water	= 90 kg/m^3
Fine aggregate	= 270 kg/m^3
Coarse aggregate	= 540 kg/m^3

Chapter Three: Testing and Discussion

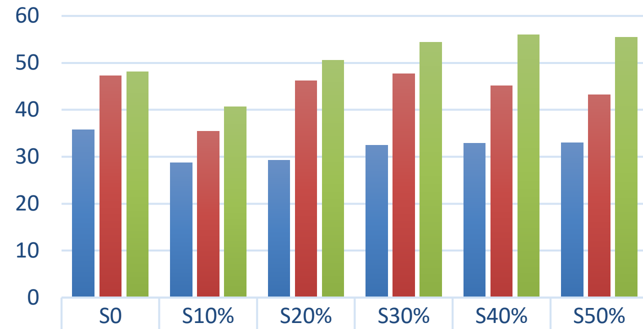
3.1 Compressive Strength (MPa)

Compressive strength test is the most common test conducted on concrete, because it is the desirable characteristic properties of concrete are quantitatively related to its compressive strength [12-13]. Compressive strength was determined by using Compression Testing Machine (CTM) of 2000 kN capacity. The compressive strength of concrete was tested using 100 mm x 100 mm x 100 mm cube specimens. The test was carried out by placing a specimen between the loading surfaces of a Compression Testing Machine (CTM) and the load was applied until the specimen fails. Three test specimens were cast for each proportion and used to measure the compressive strength for each test conditions and average value was considered. The average value of compressive strength of 3 specimens for each category at the age of 7 days, 28 days and 60 days are shown below.

Fig (3) Compressive strength machine test

Table 9: compressive strength for the cubes

Sample No	Compressive strength (MPa) 7 days	Compressive strength (MPa) 28 days	Compressive strength (MPa) 60 days
S0	35.7	47.3	48.1
S10%	28.7	35.4	40.7
S20%	29.3	46.2	50.6
S30%	32.5	47.7	54.4
S40%	32.9	45.1	56
S50%	33	43.2	55.5



	S0	S10%	S20%	S30%	S40%	S50%
Compressive strength (MPa) 7 days	35.7	28.7	29.3	32.5	32.9	33
Compressive strength (MPa) 28 days	47.3	35.4	46.2	47.7	45.1	43.2
Compressive strength (MPa) 60 days	48.1	40.7	50.6	54.4	56	55.5

Figure 4: compressive strength (MPa)

Figure 4 illustrates the comparison for compressive strength of a concrete that has been constructed within 7 days, 28 days and 60 days. As it can be seen from figure 4 that the compressive strength for the control has been constructed and tested after 7 days tend to be nearly equal to the conventional concrete at approximately 50%. On other hand, there is a modesty increase for the concrete after 28 days at 30% compare to the conventional concrete with 47.7 MPa and 47.3MPa respectively while in 60 days the result increase to 55.5 for the 50% and 56 for the replacement of 40%. In addition, it is clear that using porcelain as a replacement of the sand has good effect on the compressive strength development.

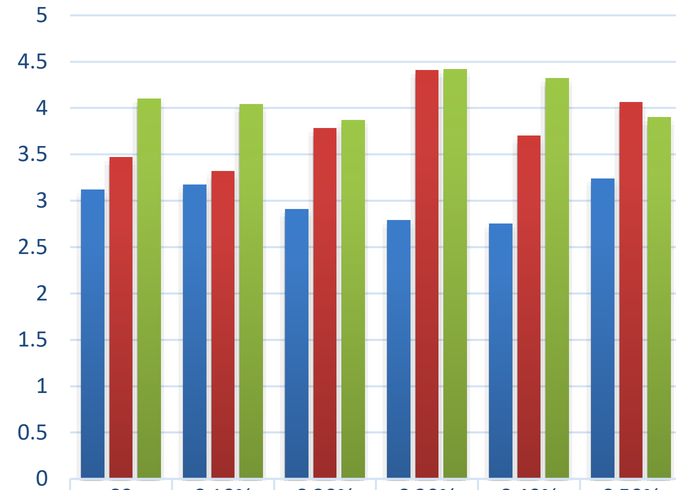
3.2 Splitting Strength (MPa) for the Cylinder

Comprehend of splitting strength of concrete is a very important sector to obtain the best results. Splitting strength was determined using Compression Testing Machine (CTM) of 2000 kN capacity. The split tensile strength of concrete was tested using 100 mm x 200 mm cylinder specimens and carried out by placing a specimen between the loading surfaces of a CTM and the load was applied until the failure of the specimen. Three test specimens were cast for each proportion and used to measure the splitting strength for each test conditions and average value was considered. The average values of 3 specimens for each category at the ages of 7 days, 28 days and 60 days are shown in the Figure 5.

Fig (5) Splitting tensile machine test

Table 10: Splitting Strength (MPa) for the Cylinder

Sample No	**Splitting strength (MPa) 7 days**	**Splitting strength (MPa) 28 days**	**Splitting strength (MPa) 60 days**
S0	3.12	3.47	4.1
S 10%	3.17	3.32	4.04
S 20%	2.91	3.78	3.87
S 30%	2.79	4.41	4.42
S 40%	2.75	3.7	4.32
S 50%	3.24	4.06	3.9



	S0	S 10%	S 20%	S 30%	S 40%	S 50%
Splitting strength (MPa) 7 days	3.12	3.17	2.91	2.79	2.75	3.24
Splitting strength (MPa) 28 days	3.47	3.32	3.78	4.41	3.7	4.06
Splitting strength (MPa) 60 days	4.1	4.04	3.87	4.42	4.32	3.9

Figure (6) Splitting Strength (MPa) for the Cylinder

Figure 6 shows the comparison for splitting strength of a concrete that has been constructed within 7 days a, 28 days and 60 days. As it can be seen from figure **5** that the splitting strength for the control sample has been constructed and tested after 7 days achieved a high strength at 50% compared to the concrete with replacement of porcelain over the sand at a small scale as in the 7 days 3.12 MPa and in the 50% increased to 3.24 and for the 60 days the control were 4.1 MPa while for the highest achieved on the 30% which is 4.42 MPa that approve that the porcelain replacement can increase from the splitting of the concrete which not good by the incensement of porcelain percentage . On other hand, there is a remarkable increase for the concrete after 28 days at 30% compare to the conventional concrete with 4.41 MPa and 3.47 MPa respectively.

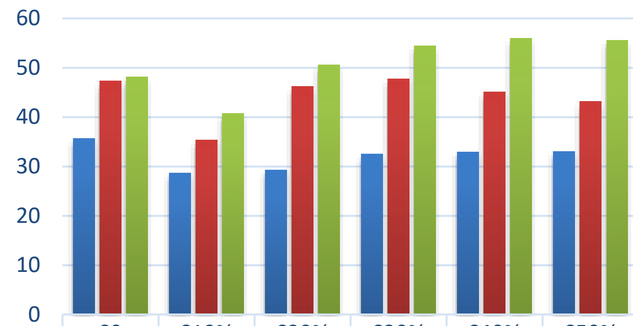
3.3 Flexural Strength (MPa) for the Beam

Flexural strength is a measurement that indicates the resistance of a material to deformation when placed under a load. The values needed to calculate flexural strength are measured by experimentation, with rectangular samples of the material placed under load in a 2 point loading testing setup. The strength of a material in bending, expressed as the stress on the outermost fibres of a bent test specimen, at the instant of failure. Prism specimens were tested for flexural strength. The tests were carried out confirming to IS: 516-1959 (8). The specimens are tested under two-point loading. The average value of two specimens for each category at the age of 7 days, 28 days and 60 days is shown in Figure. 7.

Fig (7) Flexural strength test

Table 11: Flexural strength (MPa) for the beam

Sample No	**Flexural strength (MPa) 7 days**	**Flexural strength (MPa) 28 days**	**Flexural strength (MPa) 60 days**
S0	4.58	9.25	13.89
S 10%	3.18	7.37	9.34
S 20%	2.83	7.65	10.33
S 30%	3.163	8.73	12.76
S 40%	3.24	8.89	12.32
S 50%	3.37	8.05	12.63



	S0	S10%	S20%	S30%	S40%	S50%
Compressive strength (MPa) 7 days	35.7	28.7	29.3	32.5	32.9	33
Compressive strength (MPa) 28 days	47.3	35.4	46.2	47.7	45.1	43.2
Compressive strength (MPa) 60 days	48.1	40.7	50.6	54.4	56	55.5

Figure 8: Flexural strength (MPa) for the beam

Figure 8 shows the flexural strength of a concrete that has been constructed within 7 days, 28 days and 60 days. As it can be seen from figure that the flexural strength for the conventional concrete that has been constructed and tested after 7 days achieved a high strength at 50% compared to the conventional concrete. While for the 28 and 60 days the flexural had increment to 9.25 MPa and 13.89 MPa for the control sample respectively, while for the additive of porcelain replacement the achieved result were 12.76 for the 30% of replacement to the specimen On other hand, there is a remarkable increase for the concrete after 28 days at 30% compare to the conventional concrete with 4.41 MPa and 3.47 MPa respectively.

Chapter four: Conclusion and Recommendation

4.1 Conclusion

The modern approaches of porcelain replacement are being adopted by the construction industry in order to produce sustainable concrete particularly in developing countries like Malaysia and others were taken such much more discussed subject of using new materials for the concrete with efficient and good effect to the improvement of the mechanical and physical properties of concrete. A number of the issues associated to the demotions waste of building and solid waste has been addressed by various researchers. However, the development of concrete elements by substitute it's materials such sand aggregate can be replaced by ceramic waste such porcelain with high performance encasing the mechanical and physical properties to the concrete in general. This is why this study was undertaken to investigate the characteristics of porcelain as partially replacement to the sand with 10%, 20%, 30%, 30%, 40%, and 50% to the sand. An extensive experimental was chalked out and conducted by addressing a large number cubes, beams and cylinder formed molding. The discussions are already made which can be summarized as under.

- A remarkable enhancement in compressive strength was obtained due to the encasement all percentage of replacement porcelain to the mixture of concrete.
- Compressive strength of the all samples had conducted with the control that have no porcelain to compare the result with the replacement of waste porcelain crushed as small particles and curing period of 7 days , 28 days and 60 days as a significant effect diminished with the further addition of porcelain replacement . This led to the conclusion that the in terms of compressive strength have good result by the replacement of porcelain.
- The construction industry can use end contribute to the green building practices on porcelains as a partial replacement to the sand for concrete production prevention of environmental pollution and considers the elements of sustainable in construction projects, especially material usage. Despites this industry brings a lot of advantages to the country such as creating more job opportunity and brings positive economic growth, but there are some issues that need attention from the public as well.

- Ceramics have been used since the earliest civilization. The field of ceramic materials has its roots in more traditional aspects of the subject like tiles as most advanced technological applications have attracted considerable amount of attention while the ceramics can be defined as solid compounds that are formed by the application of heat, and sometimes heat and pressure in construction industry has generated the greatest waste fraction in its availability.
- Over the years, there has been increasing in the volume of waste from the construction industry used as filling material or illegally dumped in vacant lots, which has in one way or the other increasing the lack of landfill or has led to high dumping cost at landfills areas, especially in the urban areas. The land has now become a dumping yard and highly increased dumping cost at landfill site Therefore, one of the new waste materials used in the concrete industry is a recycled of ceramic waste as a solving for the disposal of a large number of ceramic waste materials which reused of ceramic in the concrete industry considered as the most feasible application. Also, to promote recycling, the incentive should be given to demolition contractors and construct a thermal material concrete.

4.2 Recommendation

1- using glass waste as sand in concrete.

2- using solid waste materials in concrete.

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الخلاصة

يزداد الطلب على الخرسانة بشكل يومي والتي تستهلك الكثير من الموارد الطبيعية مثل الرمل والحصى ، وهناك حاجة فورية لإيجاد بديل مناسب يمكن أن يستبدل الرمل جزئيًا بمواد أخرى أو بنسب عالية. تدرس العديد من الأبحاث تأثير العديد من منتجات النفايات مثل بلاط السيراميك والزجاج ودقيق الصخور المسحوقة ومخلفات هدم المباني في الاستبدال الجزئي للرمل . تعتبر نفايات السيراميك من مجالات البحث القوية التي تشمل نشاط الاستبدال في جميع جوانب مواد البناء. من الضروري تحسين أداء الخرسانة باستخدام نفايات السيراميك. يدرس هذا البحث الخصائص الميكانيكية للخرسانة مع الاستبدال الجزئي للرمل باستخدام نفايات البورسلين (الخزف). لتحليل الخواص الميكانيكية مثل مقاومة الانضغاط وقوة الشد والانحناء ، كانت العينة مسبوكة مع استبدال ١٠٪ ، ٢٠٪ ، ٣٠٪ ، ٤٠٪ ، و ٥٠٪ من الرمل باستخدام نفايات الخزف والمغمورة بأوقات مختلفة تحت الماء من أجل ٧ أيام ، ٢٨ يومًا ، ٦٠ يومًا. تم تحليل كمية النفايات الخزفية المضافة بالنظر إلى الخواص الميكانيكية للخرسانة .