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Mechanical Properties of Sustainable Concrete Containing Red Clay Brick Waste

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ABSTRACT : One of the important solid. waste in the world is the construction and demolition wastes. The main purpose of this research is to study the effect of replacement of waste red clay brick powder (RCBP) on the behavior of cement mortar and concrete (C25) at both conditions; fresh and hardened on the mechanical properties of concrete through using of different partial replacement of powdered brick with cement until 100 percent by weight (0% , 5% , 10% , 15% , 20% , 25% , 50% and 100%) to produce concrete and to reduce the impact on environment by consuming the material generally considered as waste product. The Red clay brick was crushed and grinded manually and also sieve through 75µm sieve size in order to be fineness as cement. Cubes, 150mm x 150mm x 150mm, Cylinders ,300mm x 150mm, and prisms, 100mm x 100mm x 500mm, were casted and tested, different ratios of waste CBP have been used to study its effect on the workability (slump flow), compressive strength and splitting tensile strength for 7days, 14days and 28days; and modulus of rupture for 28days. A comparison was performed between the tested specimens with respect to reference specimens in term. of the mechanical properties of concrete.. The importance of the research in the use of waste from the bricks in the production of ordinary concrete, which contributes to securing the environment of these wastes as well as reducing the amounts of cement used in the concrete industry, which also reduces the emissions of CO_2 gas from the manufacture of cement. The addition was the use of waste as an alternative to cement and up to 15% with a slight decrease in the properties of concrete compared with ordinary concrete
***KEYWORDS:** Brick Dust, Waste clay bricks, Replacement, Construction and Demolition, Workability, Mechanical Strength.*

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I. INTRODUCTION

In the middle and last decades of the last century, the scientifics start to take a benefits from waste material for many reasons; reduce to some extent the waste.

The sustainability is one of the major solution to get rid from the waste in addition to get abenefit for manufacturing the concrete [1-3]. The Portland cement clinker produce alarge consummation of energy about 850 kcal per kg of clinker, in addition to severe impact on environmental[4]. So, using the construction waste such as brick wastes reduce to large extent the energy consumption that needed in manufacturing of concrete consistent.

There are several ways to create aclay bricks waste materials; mistake the process of production, waste create through transportation and distribution of clay brick pieces and brick waste by demolishing of buildings.

In literature, there are several researches interested in studying the production of concrete by using clay brick waste. The durability of concrete was studied by Swaroop. et.al.[5]; in this investigation, brick powder (BP) and quarry dust (QD) was developed in the concrete instead of cement powder. Partially (BP) may be used in new concrete. On the other hand, QD was used instead of sand due to its chemical composition and physical properties such that fineness, resistance to sulphate attack and Alkali-Silica reaction (ASR). In their investigation, different mixes of concrete were adopted; normal aggregate concrete, replacing 10% of cement by brick powder, replacing 10% of brick powder and 10% of quarry dust by cement and sand respectively, replacing 10% of brick powder and 15% of quarry dust by 10% cement and 15% sand respectively, replacing 10% of brick powder and 20% of quarry dust by 10% cement and 20% sand respectively, replacing 15% of cement with 15% of brick powder, replacing 15% of cement and 10% of sand by 15% of brick powder and 10% of quarry dust, replacing 15% of cement and 20% of sand by 15% of brick powder and 20% of quarry dust, and replacing 15% of cement and 30% of sand by 15% of brick powder and 30% of quarry dust. The results indicated that all above mixes achieved increase in the strength of concrete after 7days, 28days and 120days of curing.

In the study of Usha Rani, et al[6]; the mechanical properties of concrete were studied by replacing the normal coarse aggregate by crushed brick brought from masonry demolishing. In the experiments, the amount of coarse aggregates were replaced; 15%,20% and 25% by the same amount of crushed brick in addition to partial replacing of sand. The results is accepted by replacing 15% of coarse aggregates by crushed brick.

The efficiency pozzalanic waste bricks powder as alternative to cement was discussed by Naceria, et al.[7].

This paper presents, the experimental work consists replacing cement powder by (5-100)% bricks powder. In addition to variation in mechanical properties of the concrete, it ensured the reduction of hazard on environment.

II. EXPERIMENTAL PROGRAM

2.1. MATERIALS USED

2.1.1 CEMENT

Ordinary Portland cement (OPC) type (I) manufactured at northern cement factory Bazin, Al-Sulaimaniya / Iraq with the trademark of (Al-mass) has been used in this investigation.
It was tested by National Center for Construction Laboratories (NCCL) / Central Baghdad Laboratory. Tables (1) and (2) show the chemical.composition.and.main.compounds, and physical.properties.of the cement used throughout this.work.respectively. The test results show that the used cement conforms to the requirements of the Iraqi Specification (I.O.S No.5/1984-Type I)[8].

Table (1) Chemical Composition and main compounds of Al-mass ordinary Portland cement used throughout this work

Oxide Composition	*% by weight*	*Limits of Iraqi specification No.5:1984[8]*
Silica Dioxide (SiO_2)	21.61	-
Lime (CaO)	64.23	-
Magnesia Oxide (MgO)	2.28	<5.0
Iron Oxide (Fe_2O_3)	3.30	-
Alumina Trioxide (Al_2O_3)	4.97	-
Sulphate (SO_3)	2.65	<2.8
Loss on ignition (L.O.I)	1.90	<4.0
Insoluble residue (I.R)	0.85	<1.5
Time saturation factor (L.S.F)	0.909	0.66 – 1.02
Main Compounds (Bogue´s equation) %by weight of cement		
Tricalcium Silicate (C_3S)	51.510	-
Dicalcium Silicate (C_2S)	23.182	-
Tricalcium Aluminate (C_3A)	7.593	-
Tetracalcium Alumino-Ferrite (C_4AF)	10.032	-

Table (2) Physical Properties of Al-mass Ordinary Portland Cement used throughout this work

Physical Properties	*Test result*	*Limits of Iraqi specification No.5:1984[8]*
Fineness (m2/kg) by Blaine method	335	≥ 230
Setting time (Vicat´s method)		
Initial setting (min)	*150*	*≥ 45 min*
Final setting (hrs.)	*4:40*	*≤ 10 hrs*
Compressive strength for cement mortar cube (70.7)mm at, MN/m2		
3 days	30.0	> 15
7 days	39.5	> 23
Soundness using Auto clave%	*0.03*	*< 0.8*

2.1.2 CLAY BRICK POWDER

The waste clay bricks (WCBs) used in the investigation were taken from the demolished building. The WCBs were converted into the same size of aggregates, then, the products were placed inside the impact crusher, after that, ground and softening the products to different average particle size were converted into fine powder. After grinding, which has been sieved and grains passing through 75micron was the primary material used, plate

(1 & 2). The waste clay bricks types used derived from a variety of sources in Iraq, and are referred to as Red Clay Brick (RCB). The chemical compositions of red clay brick powder (RCBP) was analyzed and results obtained are reported in Table 3.

Plate 1. Step's of crushing and grounding the WCBs

Plate 2. Step's of sieving and grains passing through 75µm

Table (3): The chemical composition of CBP* (wt.%)

Composition	***RCBP***
SiO_2	*50.70 %*
Al_2O_3	*16.92 %*
Fe_2O_3	*6.18 %*
CaO	*14.12 %*
Na_2O	*0.95 %*
K_2O	*2.17 %*
MgO	*4.20 %*
TiO_2	*0.72 %*
P_2O_5	*0.16 %*
SO_3	*1.11 %*
L.O.I	*3.0 %*

* The chemical composition tests made by the Central Laboratories Department for Iraq Geological Survey

2.1.3 Fine Aggregate

From Al-Ukhaider region, Karbalaa-Iraq, natural sand is used in this study, which has fineness modulus of (3.18) and specific gravity (2.63). The grading of the fine aggregate was checked according to Iraqi Standard Specification (No.45: 1984)[9]. Table (4) show the sieve analysis and the grading curve of fine aggregate. Table (5) shows the physical properties of the fine aggregate that are performed by National Center for Construction Laboratories (NCCL) / Central Baghdad Laboratory

Table (4) Sieve analysis of fine aggregate (Zone 2)

Sieve size mm (I.S.S No.23)[10]	*% passing by weight*	*Limits of Iraqi standard specification No. 45:1984*[9] *(Zone 2)*
10	100	*100*
4.75	92	*90-100*
2.36	75	*75-100*
1.18	56	*55-90*
0.6	38	*35-59*
0.3	16	*8-30*
0.15	5	*0-10*
Pan	0	-

Table (5) Physical properties of fine aggregate

Physical properties	*Test result*	*Limit of Iraqi specification No.45:1984*[9]
Specific gravity	2.63	-
Sulphate content as SO_3	0.194%	0.5% (max)
Fineness modulus	3.18	
Fine materials passing from sieve (75μm)	2.2%	5% (max)
Dry rodded density kg/m^3	1715	-
Absorption	2%	
Moisture content	1.4	

2.1.4 Coarse Aggregate

Natural crushed coarse aggregate of maximum size 10 mm was used in this research. It was brought from AL–Badrah.region. The gradation, specific gravity, density and sulphate content were tested. The properties of natural coarse aggregate used are show in Tables (6,7). The results demonstrate that the grading and sulphate content of the coarse aggregate conform to the requirements of Iraqi Standard No. 45/1984[9] and it was tested by National Center for Construction Laboratories (NCCL) / Central Baghdad Laboratory.

Table (6) Sieve analysis of natural coarse aggregate

Sieve size mm	*% passing by weight*	*Limits of Iraqi standard specification No. 45:1984*[9]
20	100	*100*
14	99	*90-100*
10	86	*50-85*
5	4.1	*0-10*
2.36	-	-

Table (7) Physical properties of natural coarse aggregate

Physical properties	*Test result*	*Limit of Iraqi specification No.45:1984[9]*
Specific gravity	2.65	-
Sulphate content as SO_3	0.034%	≤ 0.1%
Fine materials passing from sieve (75μm)	0.4	-
Compacted bulk density kg/m^3	1575	-
Absorption	0.7%	-

2.1.5 Water

The water used in the mix preparation and curing the specimens of concrete for 7,14 and 28 days was potable water (tap water).

2.2. Concrete Mix Design:

A reference mix was made with ordinary Portland cement (a concrete without waste brick powder material), and proportioned according to the ACI 211.1-91[11] . The specified minimum compressive strength at 28 days for this mix was 25 MPa. (M25). Many trail mixes were adopted to check the required properties and accurate amount of W/B ratio. In order to achieve the scope of this study, eight types of Green binding concrete mixes were used in the present research as listed in Table (8). The variables used in these mixes were type of pozzolana material. At the beginning of the mixture design, binder content 400 kg/m3, fine aggregate weight was 600kg each cubic meter, coarse aggregate weight was 1200kg each cubic meter and water to cement ratio was 0.5. were chosen as constant. Concrete mixes were made with waste bricks powder replacing 5, 10 , 15 , 20 , 25 , 50 and 100 percent by weight of the cement as pozzolana and the amount of aggregates and water were kept constant. The value of cement and waste bricks powder is shown in Table 8.

Table (8) Samples name and composition

Abbreviation	*Cementitious materials percent*		*Cementitious materials weight (kg/m^3)*	
	Cement	Pozzolana	Cement	Pozzolana
C	100	0	400	0
RCBP5	95	5	380	20
RCBP10	90	10	360	40
RCBP15	85	15	340	60
RCBP20	80	20	320	80
RCBP25	75	25	300	100
RCBP50	50	50	200	200
RCBP100	0	100	0	400

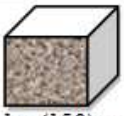
The mixtures were performed accordance to ASTM C192, the workability of the concrete was measured by slump cone test according to ASTM C143[12]. Before starting, the mixer was cleaned with water then thecoarse aggregate and sand were mixed to gather.

With each mix, control specimens are prepared to determine the mechanical.properties of the hardened concrete at 7,14 and 28 days. Control specimens involve 9 cubes (150)mm for compressive strength measurement, 18 cylinders (150×300)mm for compressive strength measurement, splitting tensile strength, and 1 prism (100×100×500)mm for flexural strength (modulus of rupture) at age 28day.

Plate (3) and table (9) shows specimens, number of specimens and types of test used for these specimens in order to determine the properties of the hardened concrete.

Plate 3. Control Specimens

Table (9) Specimen and Type of Testing

Specimen	*Total Number of specimen for each test*	*Test*	*Standards of Test*
 *Cube:(150)mm*	72	Cube Compression Strength	B.S: 1881: part 116[13]
 *Cylinder:(150×300)mm*	72	Splitting Tensile Strength	ASTM C496-04[14]
 *Prism:(100×100×500)mm*	8	Modulus of Rupture	ASTM C78- 02[15]

III. FRESH AND HARDENED PROPERTIES TESTS OF SC-RCBP:

The different tests were conducted in the laboratories as shown in below. It consists of mixing of concrete by partial and fully replacing cement with proportions (by weight) of waste red clay brick powder (RCBP) added to concrete mixtures were as follows: 0% (for the control mix), 5%, 10%, 15%, 20%, 25%, 50% and 100% Concrete samples are tested, to evaluate the concrete fresh and harden properties like Workability, Compressive strength, Split tensile strength and Flexural strength requirements.

3.1 WORKABILITY OF CONCRETE (SLUMP TEST):

Slump cone tests were performed according to ASTM C143/ C143M[12] immediately after completing the mixing of concrete as shown in table (10)

Table (10) Measured values of Concrete Workability

Mix	% of RCBP replacement	Slump value (cm)
NC-OPC	0	11.1
SC-RCBP5	5	10.4
SC-RCBP10	10	9.7
SC-RCBP15	15	9.0
SC-RCBP20	20	8.1
SC-RCBP25	25	6.9
SC-RCBP50	50	4.9
SC-RCBP100	100	3.8

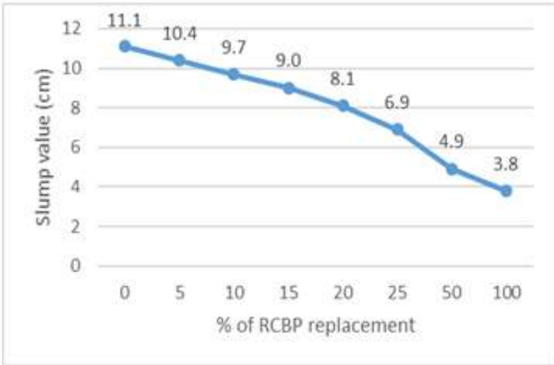


Figure 1 Slump value with %of RCBP replacement

Figure 1, shows the relationship between the waste red clay brick powder and the slump test value of the Green concrete mix. According to the results obtained, replacing (5%, 10%, 15%, 20%, 25%, 50% and 100%) from the cement weight in the Green concrete with RCBP causes to decrease its workability of fresh concrete about (6.31%, 12.61%, 18.92%, 27.03%, 37.84%, 55.85%, 65.76%) respectively.

3.2 COMPRESSIVE STRENGTH TEST:

The concrete compressive strength was measured experimentally using standard cube (150) millimeter according to (B.S 1881 [13]), the tests results are shown in table 11 and figure 2

Table (11) Average compressive strength in ages 7,14 and 28 days

	Compressive strength (MPa)		
% of RCBP replacement	7 days	14 days	28 days
0	20.5	24.26	30.11
5	18.9	23.13	29.78
10	17.81	22.3	28.79
15	16.87	21.45	27.1
20	15.1	20.2	26.19
25	13.81	18.9	25.06
50	10.9	15.87	19.42
100	5.58	7.02	8.87

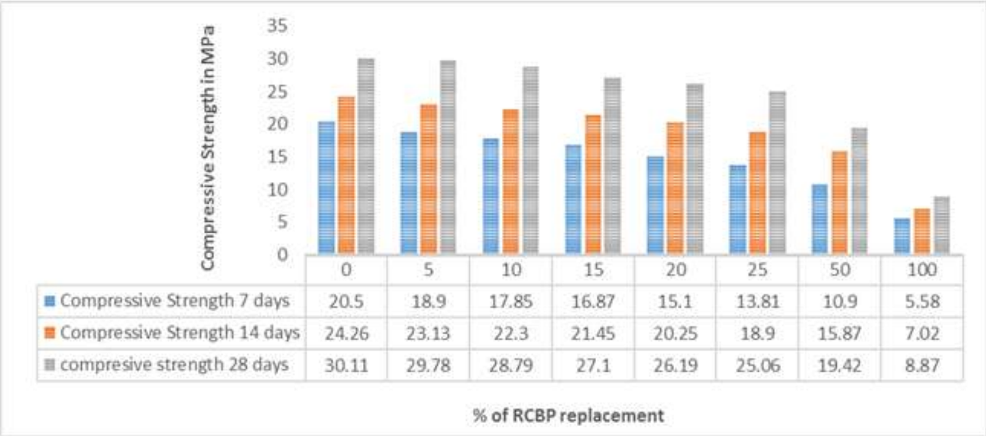


Figure 2 Average compressive strength with % of RCBP replacement

Figure 2, shows the.relationship.between compressive strength for OPC-NC (reference mix) and the weight replacement ratio of OPC by waste red clay brick powder.

According to the results obtained, the.results.show, that the average of compressive strength of samples decrease (7.8, 13.17, 17.7, 26.34, 32.63, 46.83 and 72.78) percent in 7 days curing, but this rate has drop to (1.09, 4.38, 9.99, 13.02, 16.77, 35.50 and 70.54) percent in 28 days curing respectively for replacing (5%, 10%, 15%, 20%, 25%, 50% and 100%) from the cement weight in the concrete mix by RCBP.

3.3 SPLITTING TENSILE STRENGTH TEST:

The concrete splitting tensile strength was measured experimentally using standard cylinder with the dimensions of d=150mm, h=300mm according.to ASTM C496/C496M[14]. the tests results are shown in figure (6).Three cylinders were tested for each batch at the age of 7days, 14days and 28days, and an average value of the splitting tensile strength was obtained, as shown in table (12).

Table (12) Average splitting tensile strength in ages 7,14 and 28 days

% of RCBP replacement	*Splitting tensile strength (MPa)* 7 days	14 days	28 days
0	2.197	2.83	3.28
5	2.02	2.67	3.11
10	1.88	2.26	2.85
15	1.69	2.03	2.58
20	1.39	1.86	2.32
25	1.13	1.68	1.95
50	0.89	1.25	1.43
100	0.67	0.81	1.05

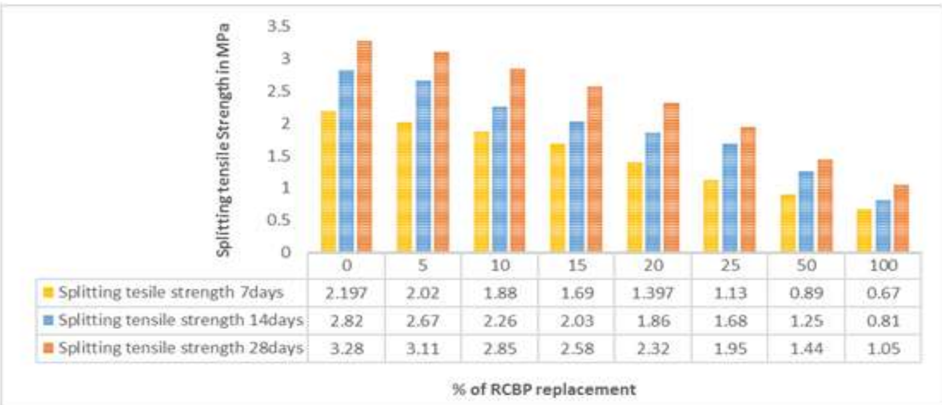


Figure 3 Average splitting tensile strength with % of RCBP

From table 12 and figure 3, the reduction of splitting tensile strength with presence of RCBP due.to the effect of bond strength.between.the cement and RCBP in.the.concrete matrix and the weakness of res clay brick which entirely made up of concrete.

3.4 MODULUS OF RUPTURE TEST:

The concrete modulus of rupture was measured experimentally using standard prismatic with the dimensions of b=100mm, d=100mm, h=500mm according.to ASTM C78-02[15], the results as shown in table 13 and figure 4.

Table (13): Modulus of Rupture value in MPa

% of RCBP replacement	*Modulus of Rupture MPa*
0	**4.635**
5	**4.5**
10	**5.13**
15	**4.86**
20	**4.12**
25	**3.87**
50	**3.51**
100	**2.34**

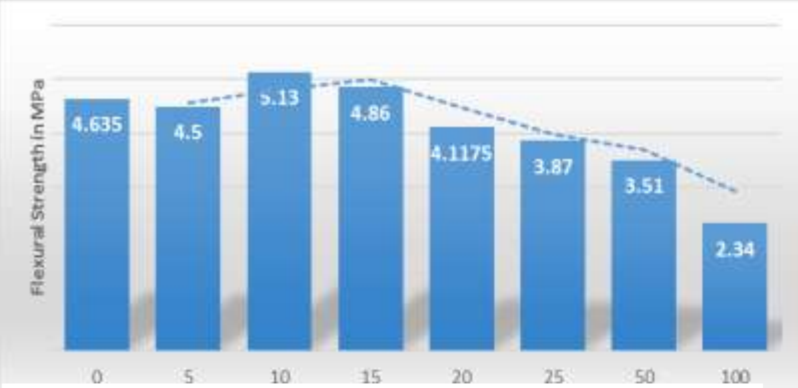


Figure 4 Modulus of rupture with % of RCBP replacement

Table 13 and figure 4, shows a comparison of the modulus of rupture for normal concrete mix and the type of concrete included red clay brick powder mixes. The comparison between flexural strength values for sustainable concrete with RCBP with a combination of normal concrete, shows that the flexural strength of the RCBP concrete specimen is more decreased. This is attributed to the lower tensile strength of RCBP and the weaker bond between RCBP and cement matrix.

IV. CONCLUSION

From experimental work results, for normal and sustainable concrete with (RCBP), in this study that waste bricks can be used until 100 percent as a replacement of cement in concrete, besides to their corresponding cubes, cylinders and prisms specimens, the conclusions can be illustrated below:

1. Replacing (5%, 10%, 15%, 20%, 25%, 50% and 100%) from the cement weight in the sustainable concrete with Red powder of the waste of clay bricks (RCBP) causes a decrease in its workability of fresh concrete about (6.31%, 12.61%, 18.91%, 27.02%, 37.83%, 55.85%, 65.76%) respectively as compared with reference mix.
2. the average of compressive strength of samples decrease (7.8, 13.17, 17.7, 26.34, 32.63, 46.83 and 63.02) percent in 7 days curing, but this rate has drop to (1.09, 4.38, 9.99, 13.02, 16.77, 32.18 and 57.25) percent in 28 days curing respectively for replacing (5%, 10%, 15%, 20%, 25%, 50% and 100%) from the cement weight in the concrete mix by RCBP. The results shows that there is slight.decrease.in compressive strength of the mixes (5%, 10% and 15%) as compared with reference mix.
3. Replacing (5%, 10%, 15%, 20%, 25%, 50% and 100%) from the cement weight in the mortar with the waste red clay brick powder (RCBP), the average of splitting tensile strength of samples decrease (8.05, 14.43,

23.07, 36.41, 48.56, 59.49 and 66.77) percent in 7 days curing, but this rate has drop to (5.18, 13.11, 21.43, 27.13, 37.5, 56.09 and 67.98) percent in 28 days curing respectively. The results also shows the same trend as mentioned above in point (2) especially in samples tested at 28days.

4. It is observed that the flexural strength values of the concrete decrease about (2.91%) when replacing 5% of waste clay brick powder (RCBP) but that strength increase about (10.67% and 4.85%) when replacing 10% and 15% respectively when it is compared with reference concrete, and returned drop to (11.16, 16.5, 24.27 and 49.51) percent in 28 days curing respectively for replacing (20%, 25%, 50% and 100%) from the cement weight in the concrete mix by RCBP.
5. The concrete can be produce by using the 10% replacement of cement, which is giving the same mechanical properties of.reference.concrete.
6. The resultant deterioration is a result of the decrease of the fast kinetics of hydration of the mineral C3S (tricalcium silicate) and C2S (dicalcium silicate) These are the two principal minerals which ensure the development of the resistances Thus, the weakness of strengths to short term can be compensated by the pozzolanic activity of the waste clay brick. This could be attributed to the slow pozzolanic reaction of RCBP.

V.THE OBJECTIVE OF THE RESEARCH :

1. This research aims to investigate the mechanical properties of concrete containing one type of waste (RCBP) and compared the obtained results with that of reference concrete as well as this study will be helped to get rid of the waste.
2. The importance of the study in the use of waste from the bricks in the production of ordinary concrete, which contributes to securing the environment of these wastes as well as reducing the amounts of cement used in the concrete industry, which also reduces the emissions of CO_2 gas from the manufacture of cement.
3. That is consider as one of the opinion of sustainability.

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