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EFFECT OF USING CONSTRUCTIONAL WASTE ON STRENGTH PROPERTIES OF NORMAL CONCRETE

***[1]Mohammed M. Salman and [2]Mohammad Z. Al-Rawas**

[1]Prof., Civil Engineering Department, College of Engineering, Mustansiriayah University, Baghdad, Iraq
[2]Lecture, Civil Engineering Department, College of Engineering, Mustansiriayah University, Baghdad, Iraq

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ABSTRACT

The main solid waste production in the world is the construction and demolition waste constituents. Thispaper discuss the effect of replacement of waste Red Clay Brick Powder (RCBP) on the mechanical properties of concrete (C25) at both conditions; fresh and hardened concrete through using of different partial replacement of powdered brick with cement until 50 percent by weight (0% , 5% , 10% , 15% , 20% , 25% and 50%) andreplacing10% of microsilica fume (MSF) by weight replacement of cement to produce concrete and to reduce theimpact on environment by consuming the material generally considered as waste product. Crushed red clay brick and sieved through 75µm sieve size to achieve fineness as in cement. Cubes of size 150mm, Cylinders of size 300mm x 150mm and prisms of size 100mm x 100mm x 500mm were casted and tested.Workability (slump flow), compressive strength and splitting tensile strength for 7, 14 and 28 days; and the modulus of rupture and the modulus of elasticity for 28 days, were investigation. The results were compared with the referencespecimen that casted with normal concrete only.The addition was the use of waste as an alternative to cement and up to 20% with a slight decrease in the properties of concrete compared with ordinary concrete.

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INTRODUCTION

The new development in construction material industry passed through depending on availing from the waste material and industrial waste such as pozzolanic materials. According to some authors the best way for the construction. Industry to become a more sustainable one is by using wastes from other industries as building.materials (Kae, 2010; Mehta, 2001 and Meyer, 2009). About 850kg of CO_2 are emitted per ton of clinker production (Gartner, 2004). Environment protection from the pollution is the main benefit of using the construction and industrial waste. Different resources are usually used as brick waste; some of them are from mistake the industry process and other are from demolition or reconstruction of structures. Millions tons of waste are the amount of waste material were disposed from the environment. 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.* (2015); in this investigation, brick powder (BP) and quarry. dust (QD) was developed in the concrete instead of cement powder. Secondary cementing materials like Brick Powder can be used to partially replace cement because of pozzolanic nature. Materials like quarry dust best suites to sand due to its physical and chemical properties, fineness etc. Also these materials are known to increase durability, 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, 28

****Corresponding author:*** **Mohammed M. Salman,**
Prof., Civil Engineering Department, College of Engineering, Mustansiriayah University, Baghdad, Iraq

days and 120days of curing. Heidari and Hasanpour (2013), investigated the feasibility of using waste bricks powder in concrete. Cement is replaced by waste bricks powder in different proportions until 40 percent by weight. pozzolanic properties of bricks powder and compressive strength of concrete were investigated. Results show that concrete with partial cement replacement by waste bricks powder has minor strength loss. The results of the investigation confirmed the potential use of this bricks powder material to produce pozzolanic concrete. Pradhan and Dutta (Debabrata Pradhan, 2013), determined the compressive strength of concrete in which cement was partially replaced with silica fume (0%, 5%, 10%, 15%, and 20%). The compressive strength test was conducted on age of 24 hours, 7 days and 28 days for 100mm and 150mm cubes. The results indicated that the compressive strength of concrete increased with additional of silica fume Up to 10% replaced by weight of cement. This paper presents, the experimental work consists replacingcementby (5-50)% bricks powder in addition to variation in mechanicalproperties of the concrete at different ages, it ensured the reduction of hazard on environment.

EXPERIMENTAL PROGRAM

Materials Used

Cement: Ordinary Portland Cement (OPC) type (I) manufactured at northern cement factory Bazian, Al-Sulaimaniya / Iraq with the trademark of (Al-mass) has been used in this investigation. Tables (1) and (2) show the chemical. composition and main. compounds, and. physical. properties of the cement used throughout this work respectively.

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 (m^2/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/m^2		
3 days	30.0	> 15
7 days	39.5	> 23
Soundness using Auto clave%	0.03	< 0.8

Clay brick powder: The waste clay bricks (WCBs) used in the investigation were taken from the 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, plates (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 RCBP was analyzed and results obtained are reported in Table (3).

Plate 1. Sep's of crushing 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 %*

Micro Silica Fume (MSF): Micro Silica Fume (MSF) has been used as an artificial pozzolanic admixture that is effective in improving the mechanical properties significantly (2000). Silicafumeor microsilica (very fine amorphoussilicap articles < 1µm) used throughout this research is commercially known as partial replacement of cement weight. Tables (4&5) illustrate the composition and properties of microsilica fume according to manufacture reditions and the chemical composition test.

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) (Iraqi Specification, 1984). Table (6) shows the sieve analysis of fine aggregate. Table (7) shows the physical properties of the fine aggregate.

Coarse Aggregate: Natural crushed coarse aggregate of maximum size 10 mm was used in this research.

Table 4. Physical properties and requirements of microsilica fume

Physical properties	Results	Limit of Specification Requirement (ASTM C1240)[10]
Colour	Grey to medium grey	
Specific surface area (m^2/kg)	22000	≥ 15000
Strength active Index with Portland cement at 7 days, min. percent of control	122	≥ 105
Percent retained on 45µm (No.325), max,%	8	≤ 10

Table 5. Chemical properties of microsilica fume

Oxides composition	Abbreviation	Oxide Content (%)	Limit of Specification Requirement (ASTM C1240)[10]
Silica	SiO_2	93.03	85.0 (min)
Alumina	Al_2O_3	< 0.04	-
Iron oxide	Fe_2O_3	0.05	-
Lime	CaO	1.38	-
Sodium oxide	Na_2O	0.21	
Magnesia	MgO	0.35	-
Titanium dioxide	TiO_2	< 0.01	
Sulfate	SO_3	0.55	-
Phosphorus pentoxide	P_2O_5	0.19	
Potassium oxide	K_2O	1.09	-
Loss on ignition	L.O.I.	3.37	6.0(max)

Table 6. Sieve analysis of fine aggregate (Zone 2)

Sieve size mm	% passing by weight	Limits of Iraqi standard specification No. 45:1984[11] (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 7. Physical properties of fine aggregate

Physical properties	Test result	Limit of Iraqi specification No.45:1984[11]
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	

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 (8,9).

Water: The water used in the. mix. Preparation and curing the specimens of concrete for 7,14 and 28 days was potable water from the water-supply network system (tap water).

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[12]. The specified minimum compressive strength at 28 days for this mix was 25 MPa. Many trial mixes were adopted to check the required properties and accurate amount of W/B ratio. In order to achieve the scope of this study, six types of sustainable concretemixes were used in the present research as listed in Table (10). At the beginning of the mixture design, binder content 400 kg/m^3, fine aggregate content was 600 kg/m^3, coarseaggregatecontentwas1200 kg/m^3 and w/c ratio is (0.5) were chosen as constant. Concretemixes were made with waste bricks powder replacing 5, 10, 15, 20, 25 and 50 percent with replacing 10% MSF by weight of the cement and with the same amount of aggregates and water as in the reference. The concrete mixtures were mixed in accordance with ASTM C192/C192M (ASTM, 2002). The work ability of the concrete was measured by slump cone test according to ASTM C143/C143M (ASTM, 2012). The interior of the drum was initially washed with water to prevent absorption. The coarse and fine aggregate were mixed first, followed by addition of the cement and RCBP with 10% MSF and water containing required amount. 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, 21 cylinders (150×300)mm for compressive strength measurement, splitting tensile strength and modulus of elasticity and 1 prism (100×100×500)mm for flexural strength (modulus of rupture). Plate (3) and table (11) shows specimens, number of specimens and types of test used for these specimens in order to determine the properties of the hardened concrete.

Fresh and hardened properties tests of RCBPSF concrete: It consists of mixing of concrete by partial replacing cement with proportions (by weight) of waste red clay brick powder

Table 8. Sieve analysis of natural coarse aggregate

Sieve size mm	*% passing by weight*	*Limits of Iraqi standard specification No. 45:1984*[11]
20	100	***100***
14	99	***90-100***
10	86	***50-85***
5	4.1	***0-10***
2.36	-	***-***

Table 9. Physical properties of natural coarse aggregate

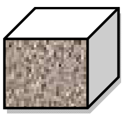
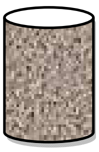
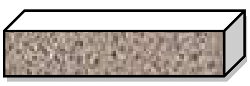
Physical properties	Test result	Limit of Iraqi specification No.45:1984[11]
Specific gravity	2.65	-
Sulphate content as SO_3	0.034%	$\leq$ 0.1%
Fine materials passing from sieve (75µm)	0.4	-
Compacted bulk density kg/m^3	1575	-
Absorption	0.7%	-

Table 10. Samples name and composition

Abbreviation	Cementitious materials percent			Cementitious materials weight (kg/m^3)		
	Cement	Pozzolana RCBP	MSF	Cement	Pozzolana RCBP	MSF
OPC-NC	100	0	0	400	0	0
RCBP5SF10	85	5	10	340	20	40
RCBP10SF10	80	10	10	320	40	40
RCBP15SF10	75	15	10	300	60	40
RCBP20SF10	70	20	10	280	80	40
RCBP25SF10	65	25	10	260	100	40
RCBP50SF10	40	50	10	160	200	40

Plate 3. Control Specimens

Table 11. Specimen and Type of Testing

Specimen	*Total Number of specimen for each test*	*Test*	*Standards of Test*
 *Cube:(150)mm*	*63*	*Cube Compression Strength*	*B.S: 1881: part 116*[15]
 *Cylinder:(150□300)mm*	*63* *21*	*Splitting Tensile Strength* *Modulus of Elasticity*	*ASTM C496/C496M*[16] *ASTM C469*[17]
 *Prism:(100□100□500)mm*	*8*	*Modulus of Rupture*	*ASTM C78/C78M*[18]

(RCBP) added to concrete mixtures were as follows: 0% (for the control mix), 5%, 10%, 15%, 20%, 25% and 50% with replacing 10% MSF concrete samples are tested, to evaluate the concrete fresh and harden properties like Workability, Compressive strength, Split tensile strength, Modulus of elasticity and Flexural strength requirements.

Workability of Concrete (Slump Test): The workability of all concrete mixes was measured immediately after mixing in accordance with test method of ASTM C143/ C143M (ASTM, 2012). Figure 1, shows the relationship between the waste redclay brick powder and the slump test value of the sustainable concrete mix with replacing 10% MSF. According to the results obtained, when replacing 10% of MSF from the cement weight in the sustainable concrete mix with RCBP replacement, the results show, from table (12), the workability of sustainable concrete at fresh state are decrease about (27.92%, 34.23%, 40.54%, 48.64%, 56.75% and67.56%) respectively when replacing (5%, 10%, 15%, 20%, 25% and 50%) of RCBP from the cement weight.

3.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 (14). From table 14 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 mix and the weakness of red clay brick which entirely made up of concrete.

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/C78 (ASTM, 2015), the results as shown in table 15 and Figure 4. Table 15 and figure 4, shows a comparison of the flexural tensile strength for normal concrete mix and the type of concrete included RCBP with 10% MSF 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 when replacement 50%

Table 12. Measured values of Concrete Workability

MIx	% of RCBP replacement	Slump value (cm)
NC-OPC	0	11.1
RCBP5SF10	5	8.0
RCBP10SF10	10	7.3
RCBP15SF10	15	6.6
RCBP20SF10	20	5.7
RCBP25SF10	25	4.8
RCBP50SF10	50	3.6

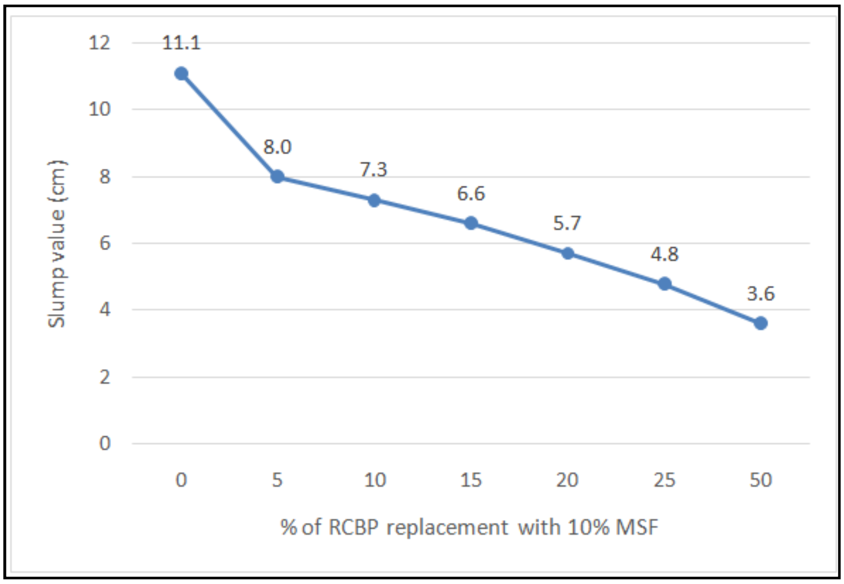


Figure 1. Slump value with % RCBP with 10% MCF replacement

Compressive Strength Test: Standard cubes (150mm) are used according to (B.S 1881: part116, are casting and testing to determine the compressive strength at 7, 14 and 28 days. The machine used in the test is hydraulic compression machine of 2000 kN capacity. The average of three specimens at age of 7, 14 and 28 days is used to determine the compressive strength for the NC as well as the partial replacement mixes, as shown in Figure (2).

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[16]. The tests results are shown in figure

RCBP from the cement weight. This is attributed to the lower tensile strength of RCBP and the weaker bond between RCBP and cement matrix.

Static Modulus of Elasticity Test: It is one of the most important elastic properties of concrete. The concrete static modulus of elasticity was measured experimentally using standard cylinder with the dimensions of d=150mm, h=300mm according to ASTM C469/C469M. The tests results are shown in Figure 4.Three cylinders were tested for each batch at the age of 28days, and an average value of the static modulus of elasticity was obtained, as shown in Table (16).

Table 13. Average compressive strength in ages 7, 14 and 28 days

		Compressive strength (MPa)		
Mix	*% of RCBP replacement*	*7 days*	*14 days*	*28 days*
NC-OPC	0	20.5	24.26	30.11
RCBP5SF10	5	23.92	26.80	35.67
RCBP10SF10	10	22.86	26.05	32.65
RCBP15SF10	15	20.80	24.30	28.05
RCBP20SF10	20	18.30	21.87	26.69
RCBP25SF10	25	16.84	19.65	23.41
RCBP50SF10	50	12.93	15.86	17.28

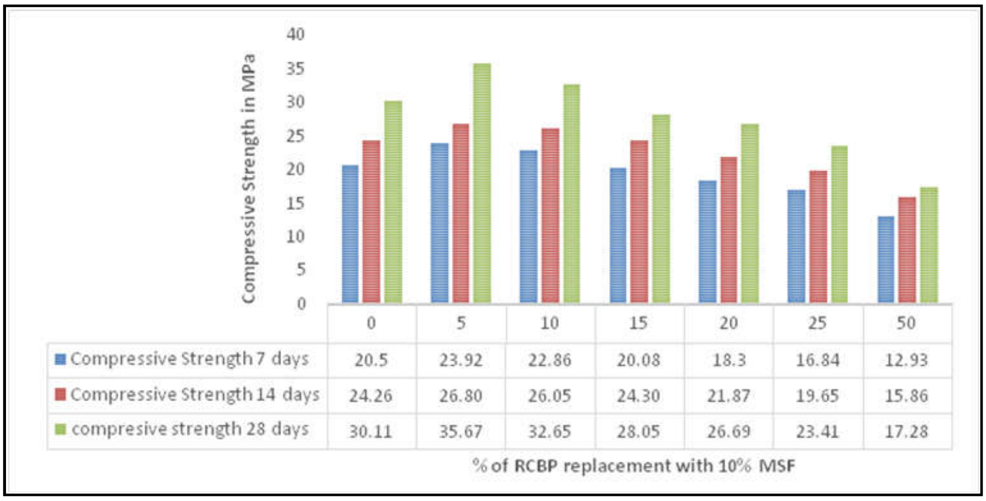


Figure2. Average compressive strength with % of RCBP replacement

Table 14. Average splitting tensile strength in ages 7, 14 and 28 days

		Splitting tensile strength (MPa)		
Mix	*% of RCBP replacement*	*7 days*	*14 days*	*28 days*
NC-OPC	0	2.197	2.82	3.28
RCBP5SF10	5	2.36	2.927	3.38
RCBP10SF10	10	2.166	2.645	3.225
RCBP15SF10	15	1.924	2.292	2.94
RCBP20SF10	20	1.605	2.06	2.73
RCBP25SF10	25	1.414	1.697	2.433
RCBP50SF10	50	0.93	1.08	1.39

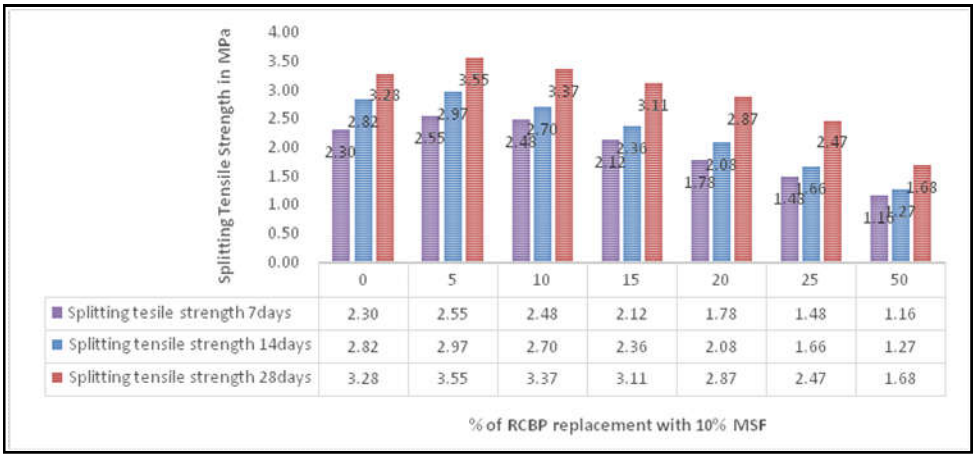


Figure 3. Average splitting tensile strength with % of RCBP replacement

Table 15. Modulus of Rupture value in MPa

% of RCBP replacement	Modulus of Rupture MPa
0	4.64
5	5.22
10	5.07
15	4.50
20	4.10
25	3.71
50	2.47

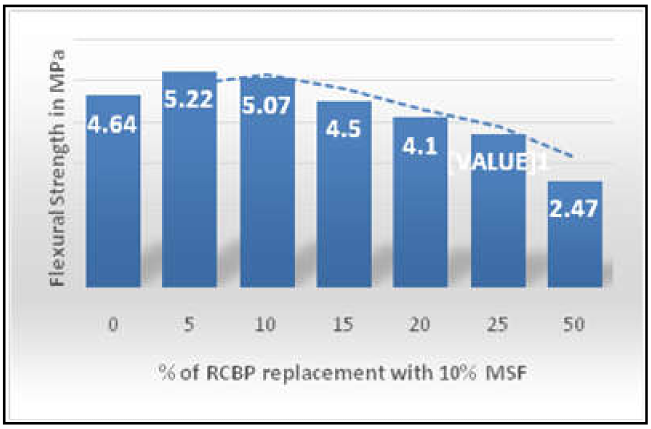


Figure 4. Modulus of rupture with % of RCBP replacement

Table 16. Static Modulus of Elasticity value in GPa

MIx	% of RCBP replacement	Static Modulus of Elasticity (GPa)
NC-OPC	0	27.58
RCBP5SF10	5	32.17
RCBP10SF10	10	29.53
RCBP15SF10	15	26.88
RCBP20SF10	20	22.45
RCBP25SF10	25	18.87
RCBP50SF10	50	13.83

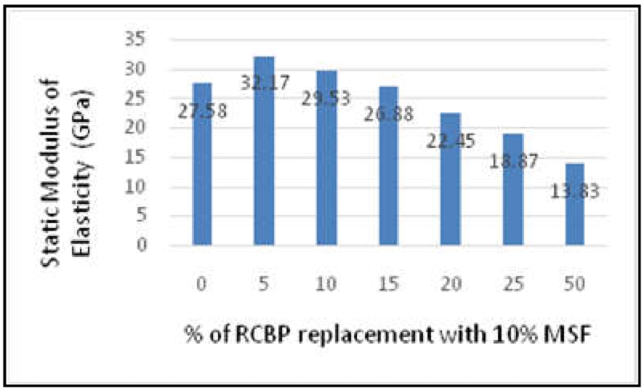


Figure 5. Static modulus of elasticity of %RCBP replacement

The modulus of elasticity can be defined as the stress change with respect to strain in elastic range for hardened concrete. Table 16 and figure 5, shows a comparison of the static modulus of elasticity for normal concrete mix and the type of concrete included RCBP with 10% MSF mixes.

Conclusion

Based on the results obtained from experimental work for normal and sustainable concrete with RCBP and 10% MSF, in this study that waste bricks can be used until 50 percent as a replacement of cement in concrete, besides to their corresponding cubes, cylinders and prisms specimens, the conclusions can be illustrated below:

1. When addition 10% of MSF from the cement weight in the sustainable concrete mix with RCBP replacement, the results show, the workability of concrete at fresh state are decrease about (27.92%, 34.23%, 40.54%, 48.64%, 56.75% and 67.56%) respectively when replacing (5%, 10%, 15%, 20%, 25% and 50%) of RCBP from the cement weight as compared with reference mix.
2. When replacing 10% of MSF from the cement weight in the sustainable concrete mix with RCBP replacement, the results show, the compressive strength development of sustainable concrete increase in 7 days curing about (16.68, 11.51 and 1.46) percent respectively when replacing (5%, 10% and 15%) of red powder of the clay brick waste RCBP from the cement weight and that strength decreasing about (10.73, 17.85 and 36.92) percent respectively when replacing (20%, 25% and 50%) of RCBP from the cement weight, but the compressive strength increase to (18.46 and 8.43) percent respectively when replacing (5% and 10%) of RCBP and decrease about (6.84, 11.36, 22.25 and 42.61) percent in 28 days curing respectively for replacing (10%, 15%, 20%, 25% and 50%) from the cement weight in the concrete mix by red powder of the clay brick waste RCBP with MSF.
3. The percentages of increase in splitting tensile strength in 7 days age for RCBP-10SF are (10.72 and 7.47) percent when replacing (5% and 10%) of RCBP respectively and that strength decreasing about (7.81, 22.92, 35.73 and 49.63) percent respectively when replacing (15%, 20%, 25% and 50%) of RCBP from the cement weight, but the splitting strength increase to (8.26 and 2.65) percent when replacing (5% and 10%) of RCBP respectively and that strength decreasing about (5.12, 12.44, 24.81 and 48.78) percent in 28 days curing respectively for replacing (15%, 20%, 25% and 50%) from the cement weight in the concrete mix by RCBP with MSF relative to the plain concrete specimen.
4. The maximum flexural strength of RCBP with 10% MSF is recorded. The percentages of increase in flexural strength are (12.62% and 9.38%) when replacing (5% and 10%) of RCBP respectively and that strength decreasing about (2.91, 11.45, 19.96 and 46.71) percent respectively for replacing (15%, 20%, 25% and 50%) from the cement weight in the concrete mix by RCBP with MSF relative to the reference concrete.
5. the maximum static modulus of elasticity of RCBP with 10% MSF is recorded. The percentages of increase in static modulus of elasticity are (16.62% and 7.07%) when replacing (5% and 10%) of RCBP respectively and that strength decreasing about (2.54, 18.60, 31.58 and 49.85) percent respectively for replacing (15%, 20%, 25% and 50%) from the cement weight in the concrete mix by RCBP with MSF relative to the reference concrete.
6. The concrete can be produce by using the 20% replacement of cement, which is giving the same mechanical properties of reference concrete.
7. Generally, the reduction in the mechanical properties of the concrete containing red clay brick waste could be due to the following:
    - The lower strength of clay brick waste (RCBP) compared with that of natural OPC.
    - The poor adhesive strength between clay brick powder and the cement paste.
    - The amount of weak bond areas in RCBP is significantly more than that in OPC-NC.

The objective of the research

- This research aims to investigate the mechanical properties of concrete containing 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.

- 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.
- That is consider as one of the opinion of sustainability.

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