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Production Load–bearing Concrete Masonry Units by Using Recycled Waste Crushed Clay Bricks; A Review

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ABSTRACT

There are serious environmental problems in all countries of the world, due to the waste material such as crushed clay bricks (CCB) and in huge quantities resulting from the demolition of buildings. In order to reduce the effects of this problem as well as to preserve natural resources, it is possible to work on recycling (CCB) and to use it in the manufacture of environmentally friendly loaded building units by replacing percentages in coarse aggregate by volume. It can be used as a powder and replacing of percentages in cement by weight and study the effect on the physical and mechanical properties of the concrete and the masonry unit. Evaluation of its performance through workability, dry density, compressive strength, thermal conductivity, and absorption test, and the experimental results obtained confirmed the possibility of using the recycling of clay bricks waste as aggregates instead of natural aggregates and reducing the weight, as well as recycling clay bricks waste and using it as a powder. It contains suitable pozzolanic that can be used as a supplementary cement material that reduces the cement content in concrete used to produce load-bearing units.

Keywords: waste clay bricks, powder clay bricks, clay brick, aggregate mechanical properties.

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إنتاج وحدات البناء الخرسانية الحاملة للأحمال باستخدام الطابوق الطيني المطحون من النفايات المعاد تدويرها :مراجعة

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الخلاصة

توجد مشاكل بيئية خطيرة في جميع دول العالم , بسبب نفايات المواد كالطوب الطيني المكسر (CCB) وبكميات هائلة والناتجة من هدم المباني . و للتقليل من اثار هذه المشكلة وكذلك المحافظة على الموارد الطبيعية , يمكن العمل على اعادة تدوير (CCB) واستخدامها في صناعة وحدات البناء المحملة الصديقة للبيئة من خلال استبدال نسب معينة من الركام الخشن بالحجم او استخدامها كمسحوق واستبدالها بنسب من الاسمنت بالوزن ودراسة التأثير على الخواص الفيزيائية والميكانيكية للكونكريت ووحدات البناء, ومن خلال الدراسات السابقة لتقييم ادائها من خلال قابلية العمل وكذلك الكثافة الجافة , وقوة الانضغاط والتوصيل الحراري وكذلك اختبار الامتصاص , اكدت امكانية استخدام اعادة تدوير نفايات الطوب الطيني كركام بدلا من الركام الطبيعي وتقليل الوزن , وكذلك اعادة تدوير نفايات الطوب الطيني واستخدامها كمسحوق فانه يحتوي على pozzolanic مناسبة يمكن استخدامها كمادة اسمنتية تكميلية تعمل على تقليل من محتوى الاسمنت في الخرسانة المستخدمة لإنتاج وحدات البناء المحملة .

الكلمات الرئيسية: مخلفات الطابوق الطين ، مسحوق الطابوق الطين ، ركام طابوق الطين ، الخواص الميكانيكية الإجمالية.

1. INTRODUCTION

The percentage of construction waste and brick waste is between 24% - 30% of the total waste resulting from demolition, which represents the highest percentage of demolition debris, and the replacement rate for more than 10% of the brick waste will lead to a significant reduction and change in the properties of fresh concrete. The increase in the substitution level of the brick powder has led to a decrease in the compressive strength during the early period **(Murthi and Kottiswaran, 2020)**. The blocks are hollow, and their behavior when manufactured from concrete that is prepared by replacing an amount of cement with a quantity of fly ash, as well as using different types of waste such as plastic waste, glass, and chopped wood as alternatives between 0-5 mm with the use of polyester fibers. The hollow blocks used were made of non-traditional concrete to make a non-load-bearing stone wall **(Hanuseac et al., 2020).** Waste porcelain is considered to affect the partial replacement of groups using natural sand used in manufacturing hollow masonry, as well as checking the quality through compressive strength. The rice husk was also used in the production of the masonry unit **(Ajayi-Banji et al., 2018).** The compressive strength and shear strength properties of hollow concrete change after replacing 80% of coarse aggregate and 100% using fine aggregate and replacing it with recycled aggregate. By controlling the amount of cement and the amount of water. The shear and compressive strength of the tested building were close to that of hollow concrete masonry.

In the study of **(Jie Li et al., 2021),** the aim was to produce concrete masonry units to be of a lighter weight and have a higher heat efficiency when building homes as well as commercial buildings through the use of materials that have lighter weight and less heat, and this led to the strengthening of work using the materials for the production of concrete building units. The average weight of the concrete masonry units produced was between 17-21 kg. This weight affects the construction efficiency when used, knowing that hollow blocks concrete has a low thermal mass compared to solid blocks concrete **(Youmna et al., 2020).**

2. WASTE MATERIAL CONCRETE

Scientists have been working in recent years to try in all countries of the world to recycle waste clay bricks as materials that can be recycled and used in concrete as well as used in the production of masonry units. This leads to work to reduce the amount of waste clay bricks. In the work of **(Huixia et al., 2021)**, they tried to recycle waste clay bricks to use them as recycled bricks aggregates (RBA) and replace them with natural aggregates, and used recycled brick powder (RBP) can also be used and replaced by volumetric cement.

2.1 Utilization of Waste clay bricks Powder (WBP) in concrete masonry units:-

The percentage of total oxides Al_2O_3, SiO_2, and Fe_2O_3, is 74.1%, which is higher than 70%, indicating the possibility of using brick powder as a pozzolanic material and partially replacing it in cement. The specific gravity of brick powder and density as specified in ASTM D854 is 2.18 and 1251 (kg/m^3) **(Rehan et al., 2021)**. It was observed when using (CBP) and replacing it with cement in an amount of up to 21%; it led to the formation of hydrates due to the reactions of pozzolana, which works to maintain a constant compressive strength. And that the hydrates formed will have less effect on maintaining the compressive strength of concrete if a large amount of (CBP) more than 20%, is used, and that the unreacted amount of it will work on the strength as a filler inside the concrete**(Letelier et al., 2018)**. The raw materials that made up RBP contained high percentages of silicon and oxygen elements, as well as aluminum, and the presence of silicon oxide, as well as the presence of aluminum oxide, will increase the work of the pozzolanic activity while working on the properties of the cement used **(Huixia et al., 2021).** The amount of clay content used is less than 7.5%, and the bonding ability of the materials in the building units is expected to increase due to the pozzolanic property of the materials contained in the clay **(Ajayi-Banji et al., 2018)**. The total oxides of ferric silicon, as well as aluminum oxide, were for more than 71% of the (CBP) used, and this is an indication that it has a high pozzolanic activity, and this leads to enhance the formation of (CSH) or (CAH) that is (calcium silicate hydrate) and (calcium aluminate hydrate), respectively, and this works on the performance of concrete and masonry units **(Lihua and Zengmei, 2020).**

Because waste brick powder has pozzolanic activity, it can be used to partially replace cement in concrete production, up to a replacement level of 10% (**Abbas et al., 2021**).

2.1.1 Effect of CBP on Material Properties in concrete masonry units:-

1- Mix preparation and Replacement ratio in CBP

Previous research showed the possibility of working in the use of waste brick powder (WBP) as a partial substitute for the cement used in concrete, as shown in **Table (1).**

Table 1. Results Summary of Using Waste Brick Powder in Concrete.

Refer.	Replacement ratio %	Remark
(Murthi et al., 2020)	Replacing the PPC with 6%, 11%, 16%, and 21% of WBP by weight of cement.	• Used Three mortar mixes (1:5, 1:7, and 1:9) • The crushed WBP was sieved by using 75 microns.
(Rehan et al., 2021)	M0, M6, and M11, which represent 0%, 6%, and 11%	• Three mortar mixes from 1:1.6:4 • WBP 0.075mm • W/C=0.46
(Resin et al., 2018)	0%, 6%, 11%,16%,	• W/C = 0.42-0.52 • 1.3, 1.5%HRWR by wt. for reference and brick modified concrete it used • respectively BP particles size = 100 µm, passing from the sieve no.150 µm
(Rani and Jenifer, 2016)	15% , 25%, and 35%	• Mix proportion from 1:1.13:2.68 • W/C = 0.45 • (BP) passing through the sieve 90 microns

2- Compressive strength of concrete

The compressive strength can be illustrated in **Fig. (1)** using different processing times. It was found that adding 30% of CBP and replacing it with cement will reduce the compressive strength. It was found that the mortar containing an amount of CBP and comparing it with the mortar returned through the compressive strength will increase with age. For example, the compressive strength at the age of 7 days was 67 % of reference M1, and compressive strength at 90 days of age for the M5 mixture was 93% of reference 1M mixture. This difference was due to the pozzolanic activity contained in CBP **(Yasong et al., 2018**) It was found that the compressive strength decreases when marble powder is replaced with a large amount of cement and that the compressive strength of concrete increases when a small amount of marble powder is used and replaced with cement **(Zerka et al., 2018**). The compressive strength of the CCBAC was lower than that of normal concrete (NC) because the CCB aggregate has a larger porosity, making it lighter and weaker than the natural aggregate **(Atyia et al., 2021**). It was a lack of strength .After 28 days, RBAC produced with 50% RBAs had a 44 percent loss in compressive strength **(Lihua and Zengmei, 2020)**. Regarding compressive strength, the optimum content of coarse brick aggregate was 10%, with maximum development of 5.6 percent compared to specimens with 0% CBA aggregate after 28 days. It also fell as the replacement level rose, reaching 26.73 percent at 30 percent of CBA at 150 days (**Duaa et al., 2021**). At 7 and 28 days of curing, the compressive strength of the recycled concrete with 25 percent and 50 percent replacement ratios was 8.7% - 15.9% and 15.1 percent -18.4% lower than that of the control concrete with no recycled material, respectively **(Zheng et al., 2018)**.

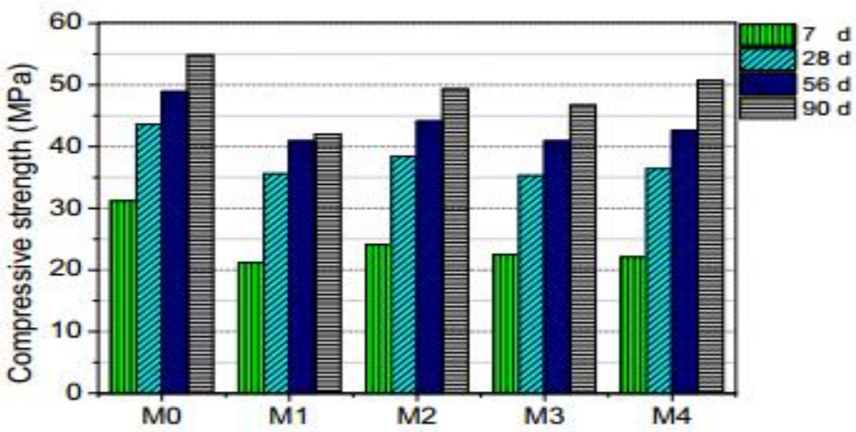

Figure (1). The Compressive test strength of concrete **(Yasong et al., 2018)**

3. Flexural strength of concrete

Increasing the use of the amount of CBP will decrease the Flexural strength at the age of 28 days. Replacing 10% of the CBP from the amount of mortar with an amount will be close to the resistance to Flexural of the reference mortars **(Mani et al., 2020)**. Flexural strength assays performed on test mortar used MREF, MFL, MOL, MP15L, MFH, MOH, and MP15H at the age of 7 days, 28 days, 90 days, and 120 days are as shown in **Fig. (2) (Eva and, Pavla, 2016)**. The Flexural strength of concrete was also increased at used 6% and 11% replacement of brick clay dust when compared with controlled units **(Rehan et al., 2021).**

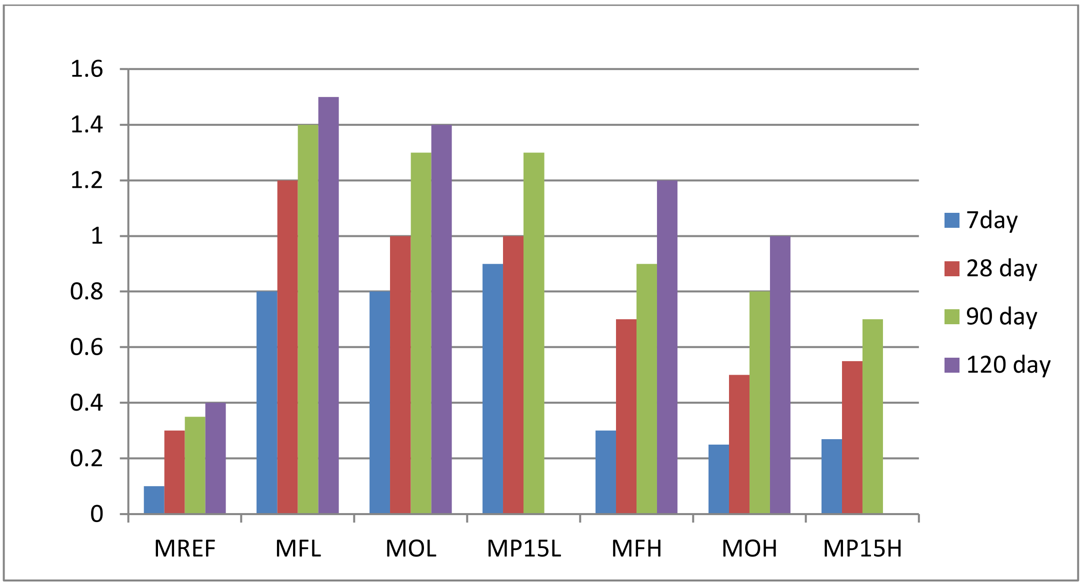

Figure (2). the test mortars in Flexural strength concrete at the age of 7, 28, 90, and 120 days **(Eva and Pavla, 2016)**

4- Dry density of concrete

The properties of limestone dust used in green concrete are affected by nanomaterials by increasing the dry density with an increase in the proportion of nanomaterials from Al_2O_3. The dry density used in the reference mixture, contains an amount of silica sand powder and plastic, which is shown in **Fig. (3) (Mohammed et al., 2021**). The low specific gravity and the low density of WBP reduce the density of the final product used. Thus, it will reduce the dead loads of the origin, which is a good effect **(Rehan et al., 2021),**

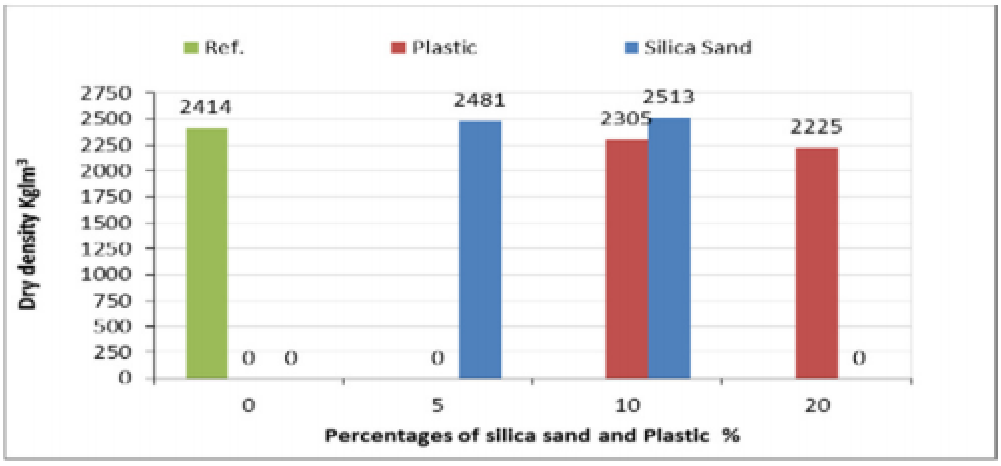

Figure (3): Percentages of the silica sand and plastic % in concrete **(Mohammed et al., 2021**)

2.2. Utilization of Waste Clay Bricks as Aggregate in Concrete Masonry Units:-

Recycled aggregate has lower water absorption capacity when compared with first-grade brick aggregate but higher when using picked brick aggregate **(Mohammed et al., 2014)**. Concrete that contains coarse aggregate using porcelain has a compressive strength of more than 42% compared to reference concrete that uses conventional aggregate due to the hardness of the porcelain **(Zahra and Davood, 2019)**. The recycled materials could positively affect some properties of hollow concrete blocks, such as thermal resistance and thermal conductivity **(Tereza et al., 2019**). The concrete produced from the use of CBA and its compressive strength is between 21 to 31 MPa and at the age of 28 days, so the replacement rate is less than 51%, but the compressive strength may decrease when replacing CBA in concrete more than 51% **(Jie Li et al., 2021**).

2.2.1Effect of (CBA) on Material Properties in concrete masonry units

1- Mix preparation of concrete

Previous research showed the possibility of working in the use of waste bricks in aggregates (WBA) as a partial substitute for ordinary aggregates used in concrete, as shown in **Table (2).**

Table (2). Results Summary of Using Waste Brick as aggregate in Concrete		
Refer.	**Replacement ratio %**	**Remark**
(Youmna et al., 2020)	0%, 11%, 16%, 21%, and 25%	• Expanded polystyrene (EPS) blocks are of different shapes, the size of the EPS crumbs ranges from 2.24 to 20 mm, and

		the unit weight ranges from 21 to 23 kg / m2 • w/c ratio of 0.34 • To enhance the mixing strength at work, silica fume (S.F.) is used, replacing the cement with a weighty amount of silica fume (S.F). It is 9.7% by weight of cement
Zheng et al., 2018)	C50 grade concrete and C25 grade concrete at five different concrete replacement rates, 0%, 26%, 51%, 76% and 100%	• One is the w/c = 0.54, which was used for the C25 grade concrete; the other is the w/c = 0.36, which was used for the C50 grade concert • Mixes that have a low water-cement ratio (w/w = 0.30) and superplasticizer P-C300 have been used to increase the workability of the mixture when mixing.
(Ahmed et al., 2017)	Hollow concrete masonry units containing 0, 15, 25, and 35% were used through the use of rubber crumb to replace by volume the fine natural aggregate	• An increase in the rubber content used from 0% to 35% will lead to an increase in water absorption from 108 kg/m3 to 175 kg/m^3 • The increase in the rubber content used in the mixtures from 0% to 35% leads to a reduction in the unit weight from (2205 kg / m3 to (1912 kg / m3)
(Lijun Yang, 2019)	The quality replacement rates for four models of using recycled fine aggregate are 0%, 35%, 65%, and 100%.	• water-cement ratios are 0.55 • water-cement ratios are 0.55 and 0.75 • the water absorption of the recycled fine aggregate is 12.35%, and used that of the fine natural aggregate is 4.85%,

2- Compressive Strength of concrete

The compressive strength of concrete is one of the important mechanical properties of concrete blocks, which can be greatly improved using recycled aggregates in the mixture. The compressive strength of the load-bearing wall blocks should not be less than 6 MPa **(Tereza et al., 2019)**. The type of mortar used was 8.6 MPa, and the type of mortar used was 15.9 MPa, calculated according to the method presented in the standard JGJ/T98-2010. It can be defined as a slurry of grades MB7.6 and Mb16 respectively **(Jie Li et al., 2020**). After curing the concrete for 28 days, the laboratory result for the compressive strength of concrete shown in **Table (3)** was the average mean values of the two types of concrete, 32.9 MPa and 40 MPa, respectively, which turned out to be C30 and C40 grade concrete, respectively **(Jie Li et al., 2020**). The used hollow concrete blocks were four types (perlite, control polyethylene, and rubber blocks), and the aim was to conduct a compressive strength test. The result of this examination for hollow concrete blocks is shown in **Table (3)** as well as in **Fig. (4) (Ahmed et al., 2020**). Considering the gross area, the hollow concrete blocks of sizes (40 x 20 x 20) cm constructed with the concrete grade 1:3:6 proportion have an average compressive strength of 11.25 kg/cm^2. The average compressive strength of hollow concrete blocks of dimension (40 x 20 x 20) cm manufactured with the concrete grade percentage is 22kg/cm^2 when considering the net cross-sectional area **(Maroliya, 2012).** The use of admixtures results in a 30-40% improvement in compressive strengths for the generated hollow block concrete units at all ages **(Dawood and Ramli, 2010)**. At these temperatures, the compressive strengths of concrete blocks using clay brick components rise for various reasons . First, the clay brick's nature made them stronger/sturdier in high temperatures. Second, at these temperatures, some of the unhydrated cement paste may hydrate further (**Zhao et al., 2020**). The control block had the highest compressive strength of 6.90 MPa, while the perlite block had the lowest compressive strength of 3.50 MPa, a reduction of 49%. Polyethylene and rubber blocks had strengths of 3.84 and 3.61 MPa, respectively, suggesting that all four types of mixtures met the ASTM C129 criterion of 3.45 MPa **(Al-Tamimi et al., 2020).** The use of admixtures results in a 30-40% improvement in compressive strengths for the generated hollow block concrete units at all ages **(Dawood and Ramli, 2010)**. As the percentage of plastic replacement increased, compression, split, and flexural strength declined **(Qasim et al., 2020**).

Table 3, Compressive Strength for the hollow concrete blocks (**Ahmed et al., 2020**)

Mix concrete	**Strength of Hollow Block (Mpa)(individual units)**	**Observation of Failure of Blocks**
control	6.91	Longitudinal cracks
Pl-HP.(perlite Hollow Block)	3.52	Longitudinal cracks
Ru-HB(Rubber Hollow Block)	3.65	High flexibility. Absorbed load
PE-HB(polyethylene Hollow Block)	3.85	Medium flexibility. Small cracks

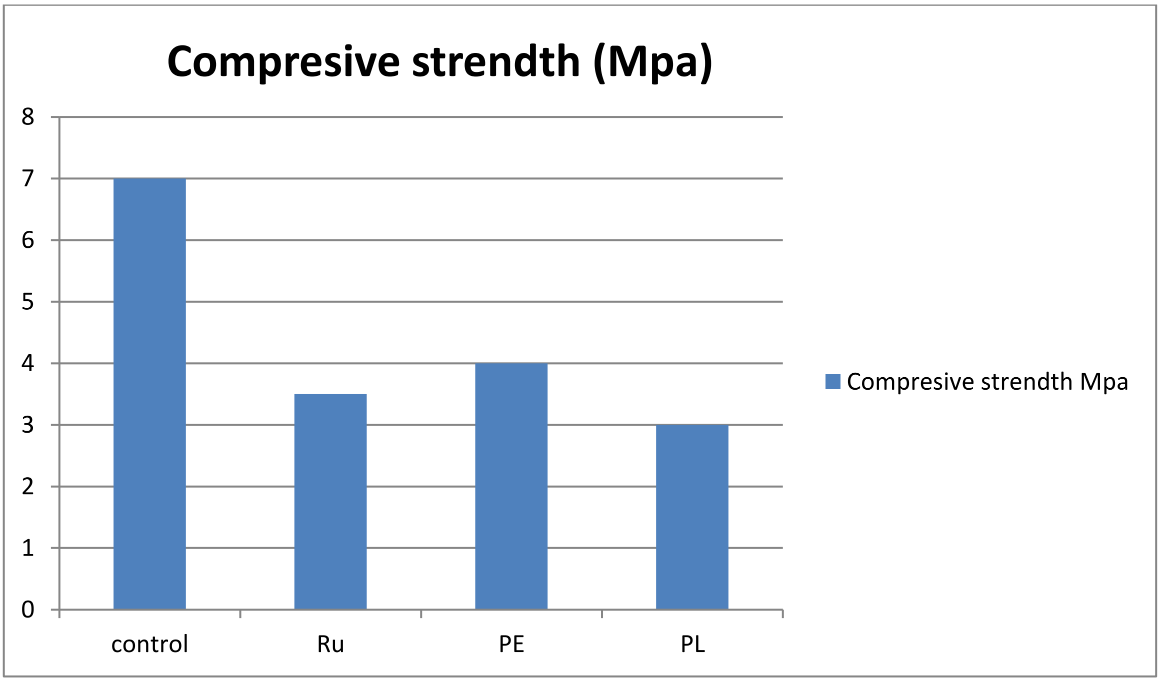

Figure (4). Compressive strengths of hollow concrete masonry blocks **(Ahmed et al., 2020**)

The compressive or crushing strength rate of hollow concrete blocks of size (16 x 8 x 8) and (8 x 8 x 8) was 35 kg/cm^2 and 28 kg/cm^2, respectively. While the rate of compressive or crushing strength of individual brick units of size (22 x 11 x 8) cm was 114, 35 kg/cm^2 **(Ahmad et al., 2014**).

3. Flexural strength of concrete

The type of waste, as well as the quantity, affected the flexural strength of the concrete. It was noted that there was a decrease in the flexural strength of the concrete when replacing the aggregate between 0-5 mm, and the flexural strength of the concrete increased by 11% when adding polyester fibers when compared with the reference mixture **(Ligia et al., 2019)**. When the percentage of replacement is increased when using ceramic, the flexural strength will increase by 65% of the reference concrete. It will increase when the replacement is by 100%. This increase in flexural strength was due to the increase in the proportion of ceramic replacement in the concrete mixture **(Zahra et al., 2019**). Concrete made of RCA will have 11% lower flexural strength than the NC. The flexural strength of concrete will decrease when using RCA, mainly if the recycled aggregate is used in the concrete mix **(Verian et al., 2018).**

4. Dry density of concrete

Replacing the plastic waste with 11% and 21% concrete, the dry density will decrease by 4.50% and 7.80%, respectively, at the age of 28 days. The reason for this decrease is due to a decrease in the density of plastic waste compared to natural coarse aggregate with high density **(Mohammed et al., 2021**). With the increase in the percentage of replacement, the density will decrease because the ceramic waste has low specific gravity. As a result, the structure's dead load will be reduced due to the decrease in the density of the masonry blocks **(Ravindra et al., 2015).** The density of concrete using RCA decreases due to the use of a high amount of RCA in the concrete **(Verian et al., 2018**). The dry density geopolymer concrete will be reduced due to recycled aggregate with low specific gravity and low density, as in **Fig. (5) (Wasan et al., 2019**).

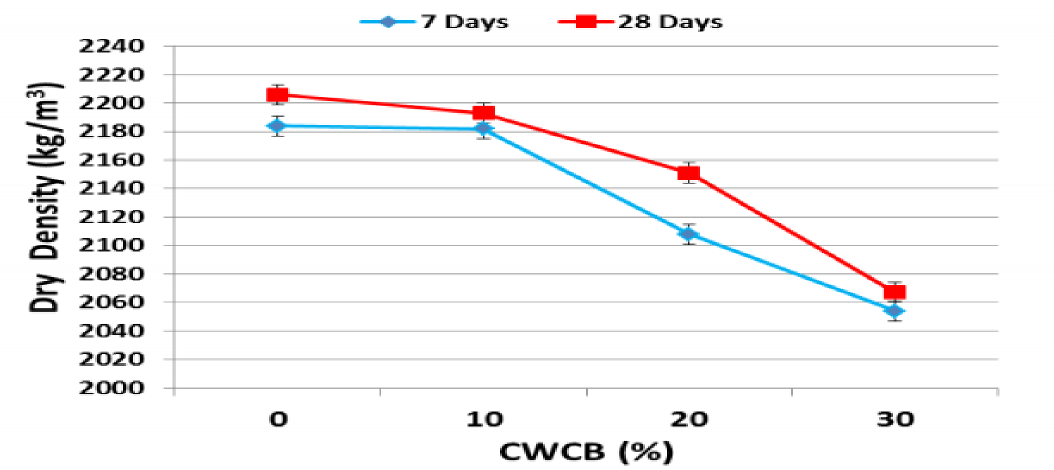

Figure (5) Dry density of MK-geopolymer concrete with varying CWCB aggregate contents **(Wasan et al., 2019)**

CONCLUSIONS

1- The PPC was replaced up to 16% by the use of WBP, and it can be concluded that this ratio is the optimal ratio of substitution.
2- The effect of bleeding can be reduced by using WBP in concrete due to the low density of WBP compared to cement. Also, the brick powder can be used to reduce the cost of cement production.
3- When the CBP is replaced by cement, the compressive strength and flexural and tensile strength in concrete will be increased at 28 days of age and 90 days of age. This is due to the effect of pozzolanic activity on CBP.
4- The compressive strength will decrease for hardened concrete when the replacement ratio of NCA increases when by using RCA or using RBA, and it has been shown that using concrete with an amount of RCA had a better effect than concrete using RBA
5- The weight replacement of cement to produce a good quality of concrete is to be used by weight of up to 11% through the use of clay bricks crushed to the degree of nano-brick powder.
6- It has been demonstrated that completely replacing natural aggregates with RBAs is achievable; this might minimize natural resource use and stimulate the reuse of construction waste. The application of RBAC in structures can be strengthened because the structural performance of RBAC is vital for constructional engineering.
7- In certain circumstances, the addition of RBAs enhanced RBAC's durability. RBAC might also cut shipping costs and dead loads, and it could be used to make units, beams, and columns
8- The investigation of high volume CBP replacement in concrete, as well as the influence of CBP replacement on rebar corrosion, can be included in the future scope.
9- Strength Activity Index values of 10–25% replacement by CBP are appropriate at 7 and 28 days. CBP-containing mortars had lower compressive strength than control mortars at first, but this improves with longer curing periods (90–180 days). For flexural strength tests, similar findings were reported.

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