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Manufacture of Load Bearing Concrete Masonry Units Using Waste Demolishing Material

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ABSTRACT

The presence of construction wastes such as clay bricks, glass, wood, plastic, and others in large quantities causes serious environmental problems in the world. Where these wastes can be used to preserve the natural resources used in construction and reduce the impact of this problem on the environment, it also works to reduce the problem of high loads of concrete blocks. Clay bricks aggregate (AB) can be recycled as coarse aggregate and replaced with volumetric proportions of coarse aggregate by (5% and 10%), as well as the use of clay brick powder (PB) by replacing its weight of cement (5% and 10%) and reduced in the manufacture of concrete blocks (blocks). Four mixtures will be prepared and tested to learn how to reuse the brick coarse aggregate ACB and PB powder brick as substitute materials for producing concrete blocks, use the water spray method to treat concrete building blocks (blocks) and check the Dimensions and compressive strength, and absorption.

Keywords: Waste clay bricks, Powder clay bricks, Clay brick, Aggregate mechanical properties.

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تصنيع وحدات البناء الخرسانية الحاملة باستخدام نفايات مواد الهدم

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الخلاصة

يعد وجود مخلفات البناء مثل الطابوق الطيني والزجاج والخشب والبلاستيك وغيرها بكميات كبيرة يسبب مشاكل بيئية خطيرة في العالم. حيث يمكن استخدام هذه المخلفات لغرض الحفاظ على الموارد الطبيعية المستخدمة بالبناء والتقليل من تأثير هذه المشكلة على البيئة , وتعمل كذلك على تقليل مشكلة الأحمال العالية من الكتل الخرسانية, والطابوق الطيني (AB) يمكن إعادة تدويرها بشكل ركام خشن واستبدالها بنسب حجمية من للركام الخشن بنسبة (5٪ و 10٪), وكذلك استخدام مسحوق الطابوق الطيني (PB) من خلال استبدالها وزنيا من الإسمنت بنسبة (5٪ و 10٪) ويعاد استخدامه في صناعة الكتل الخرسانية (البلوك)، وسيتم تحضير أربع خلطات واختبارها لمعرفة كيفية إعادة استخدام الطابوق الطيني كركام (ACB) , ومسحوق الطابوق (PB) كمواد مستبدله للإنتاج لكتل الخرسانة، واستخدام طريقة الرش بالماء لمعالجة لكتل البناء الخرسانية (البلوك), واجراء فحص الأبعاد و قوة الانضغاط والامتصاص.

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

1. INTRODUCTION

In various civil engineering projects, recycled aggregate created from building and demolition debris can be employed, substantially contributing to the nation's economic and environmental sustainability **(Tunc, 2018).** One of the most recent advancements in concrete design is the inclusion of pozzolanic nano-particles in the concrete matrix .Utilizing pozzolanic nanoparticles, the formation of the strength-bearing crystals in cement paste can be accelerated or controlled **(Belkowitz, 2018)**. Concrete comprises several components, including cement, water, coarse aggregate, and fine aggregate, combined in various ratios to achieve the desired strength. Estimates place the annual production of concrete at 11 billion metric tons .The concrete industry has used many strategies to reach this goal, including replacing various waste materials with fine aggregate and coarse aggregate in response to growing environmental pressure to reduce solid waste and recycle as much as feasible . Waste from construction and demolition projects is created in enormous amounts worldwide. The primary trend with these wastes is an annual increase **(Animesh and Sharifi, 2017).** using fired CBP, it was discovered how durable mortars are. CBP increased strength by up to 40%, which is an excellent finding for compressive strength. They explained these outcomes as being produced by CBP, which they blamed on the filler effect of the fine CBP particles, which decreased the pore structure of the mortars. Amorphous compounds (silica, alumina, and calcium hydroxide) form silicate/aluminate hydrates similar to those produced in cement hydrations due to the filling action of the fine CBP particles, which also contributes to the improved strength **(Mohammed et al., 2015).**
When coarse aggregate is replaced by 80 percent, fine aggregate by 100 percent, and recycled aggregate by 100 percent, the attributes of hollow concrete's compressive strength and shear strength change. By managing the amounts of water and cement used . The tested

building's compressive and shear strengths were comparable to those of hollow concrete masonry **(Li et al., 2021)**. Regarding compressive strength, the optimum content of coarse brick aggregate was 10%, with a 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 (**Ain et al., 2021**). As the percentage of plastic replacement increased, compression, split, and flexural strength declined **(Qasim et al., 2021)**. Using brick powder helps to raise the density of concrete, resulting in lower pores and more compacted concrete **(Abdullah et al., 2021)**. Compressive, split, and flexural strength decreased by increasing the percentage of plastic replacement (**Qasim et al., 2021**).

2. MATERIALS

2.1 Cement

Tasloga ordinary Portland cement (OPC 42.5 R) manufactured in Iraq was used in this work. The representative sample's chemical analysis and Physical properties are shown in **Tables 1 and 2,** respectively. The cement satisfies (Iraq standard **IQS No.5/ 2019**) for ordinary Portland cement. The tests were carried out in the testing cement laboratory of AL-Mustaqbal University College.

Table 1. Chemical Analysis of the Ordinary Portland cement

Oxide composition and chemical properties	Test result	IQS No.5/2019 requirements for OPC
Lime (CaO)	61.81	_
Silica (SiO_2)	20.52	_
Alumina(Al_2O_3)	5.35	_
Iron oxide(Fe_2O_3)	3.93	_
Magnesia(MgO)	4.32	< 5.0%
Sulfate(SO_3)	1.88	< 2.8% for C_3A >3.5%
Loss On Ignition (L.O.I)	1.37	< 4.0%
Insoluble residue (I.R)	0.88	< 1.5 %
Main Compounds (Bogue's equation)		
Tri calcium silicate (C_3S)	44.56	-
Di calcium silicate (C_2S)	25.32	-
Tri calcium aluminate (C_3A)	5.57	-
Tetra calcium aluminate - ferrite (C_4AF)	11.92	-

Table 2. Physical Properties of the Ordinary Portland cement

Physical properties	Test result	IQS No.5/2019 requirements for OPC
Fineness (Blaine method) kg /m^2	376	≥280
Initial setting (min)	124	≥45
Final setting (min)	341	≤600
Soundness (autoclave method), %	0.32	≤ 0.8
Compressive strength (MPa) at 2 days	24.13	≥ 20
Compressive strength (MPa) at 28 days	43.6	≥42.5

2.2 Natural Aggregates

2.2.1 Fine Aggregate

The fine aggregate from Karbala was used. The grading of the fine aggregate satisfies (Iraqi standard specification **No. 45 /1984 zone 2**) as shown in **Table 3**. The physical and chemical properties of fine aggregate are shown in **Table 4.**

Table 3. Grading of Natural Fine Aggregate

Sieve size (mm)	Passing %	IQS No.45/1984 zone tow requirements
10	100	100
5	91	90-100
2.36	78	75-100
1.18	65	55-90
0.6	52	35-59
0.3	15	8-30
0.15	3	0-10

Table 4. Physical and Chemical Properties of Fine Aggregate

Physical properties	Test result	IQS No.45/1984 requirements
Sulfate content %	0.33	For constriction concrete ≤ 0.5 For masonry units ≤ 1.0
Fine materials Pass from 75µm sieve, %	2.6	≤ 5.0
Specific gravity	2.55	-
Fineness modulus, %	2.95	-
Dry rodded density, kg/m^3	1764	-
Absorption, %	0.85	-

2.2.2. Coarse Aggregate

River-rounded gravel of the Al Nabai region is used as coarse aggregate in natural concrete mixes. The coarse creation aggregate has a different nominal maximum size of 10 mm. The nominal size (10)mm of aggregate is a single size according to (Iraqi standard specifications

No. 45 / 1984) as shown in **Table 5**. The aggregate used in the mixture was in saturated surface dry condition (SSD).

Table 5. Single Size of Natural coarse aggregate.

Sieve size (mm)	Passing %	IQS No.45/1984 requirements of 14mm
14	100	100
10	97	85-100
5	11	0-25
2.36	4	0-5

Table 6. Physical and Chemical Properties of Creation Coarse Aggregate.

Physical properties	Test result	IQS No.5/2019 requirements for OPC
Sulfate content (SO_3), %	0.065	≤ 0.1
Specific gravity (S.G)	2.62	-
Impact value,%	14	≤ 45
Abrasion test (Los Angeles),%	9.65	≤ 35
Crushing value, %	7.7	-
Dry rodded density, kg/m^3	1676	-
Absorption %	0.72	-

2.2.3 Recycled Materials

The crushed waste clay brick aggregate (BA) was prepared by crushing used hollow bricks' residue (waste). It is the remnants of the demolition of buildings (usually quarters and a half pieces) from different sites using crusher hammers. Then the crushed clay brick was graded on sieves to comply with the natural coarse aggregate used in this study (size 10mm), as shown in **Table 7.** The properties of aggregates are illustrated in the below **Tables 1 to 8**. The crushed waste clay brick aggregate (BA), as shown in **Figs. 1 and 2.**

Figure 1. waste clay brick

Figure 2. Crushed waste clay brick aggregate.`

Table 7. Single Size Crushed Recycled Coarse Aggregate

Sieve size (mm)	Passing %	IQS No.45/1984 requirements(5-14) mm
14	100	100
10	98	85-100
5	14	0-25
2.36	5	0-5

Table 8. Properties of the BA aggregates

Physical properties crushed waste clay brick (BA)	Test result	IQS No.45/1984 requirements
Sulfate content (SO_3), %	0.02	≤ 0.1
Specific gravity (S.G)	2.11	-
Impact value,%	17	≤ 45
Abrasion test (loos Angeles),%	24.7	≤ 35
Crushing value,%	39.188	-
Dry rodded density, kg/m^3	918	-
Absorption %	22.63	-

The passed crushed particles of waste clay brick from sieve No. 4.75 mm were collected and grinded to powder bricks (BP). The BP was prepared by crushing the residue of used hollow bricks (usually quarters and half pieces) from different sites using a crusher machine (Los Angeles). After that, the brick powder sieving from sieve No.1.18mm, the remaining retained to crushed, and the passing convert to powder by blending and using a powder machine then the Sieving powder. The Passing from sieve No.75 µm will be tested for chemical and physical. The properties of aggregates are illustrated in **Table 9**.

Table 9. Chemical Analysis of the powder bricks

Oxide composition and chemical properties	Test result	Requirements of class N pozzolans (ASTM C618-15)
Lime (CaO)	2.55	
Silica (SiO_2)	75.57	88.13 ≥ 70
Alumina(Al_2O_3)	9.44	
Iron oxide(Fe_2O_3)	3.13	
Magnesia(MgO)	2.47	< 5.0%
Sulfate(SO_3)	0. 02	≤ 4
L.O.I	1.50	≤ 10
Physical properties		
Fineness (Blaine method) kg/m^2	384	-
Strength activity index for **(ASTM C311-05,2005)**	92	≥75

The cement is partially replaced by 5 and 10% weights of powder glass waste and powder brick waste to produce normal concrete masonry unit concrete. The used details of concrete mixes in this study are shown in **Table 10**.

2.3 Mix Design and Proportion (Normal Concrete)

The concrete mix design has been made according to the **(Comitte, A.C.I., 211)** recommendations to obtain the required compressive strength (20 MPa) for the cylinder at 28 days (25 MPa in cube), with slump ring (25-50)mm. The designed reference mixture (without any partial replacement of concrete components) that was used in this study

contains: (300 kg/m^3) cement (975 kg/ m^3) sand (750 kg/m^3) gravel and the water-to-cement ratio (w/c) was (0.69) to produce a normal concrete with proportion (1:3.25:2.5) as explained in (cement: sand: gravel) that achieved the requirements. The notation mixture and mix quantity were listed in **Table 11.**
The other mixes can be divided in two series :

Series One: The coarse aggregate replaced by 5% (AB5) and 10% (AB10) by volume of brick aggregate to produce masonry unit concrete**.**
Series Two: The cement is partially replaced by 5% (PB5) and 10% (PB10) weights powder brick to produce masonry unit concrete.
The used details of concrete mixes through this study are shown in **Table 12.**

Table 10. Details for a mixture containing powder brick waste

Mix Symbol	Materials					Water kg/m^3
	Cement kg/m^3	Sand kg/m^3	Gravel kg/m^3	powder brick waste kg/m^3	Percentage of waste %	
Re	300	975	750	0	0	207
PB1	285	975	750	15	5%	207
PB2	270	975	750	30	10%	207

Table 11. Mixes of The Experiment Work

Mix No.	Cement kg/m^3	Fine aggregate kg/m^3	Coarse aggregate kg/m^3	Water kg/m^3
Reference Mix, Slump (25-50) mm	300	975	750	207

Table 12. Symbols of the Mixture

Type of waste	Mixture Symbol	Waste Percentage replacement (%)	Partially replacing by
Crushed bricks	AB5	5	Rounded coarse aggregate
	AB10	10	
Powder brick	PB5	5	Cement
	PB10	10	

3. MOLDS PREPARATION

Steel molds have been utilized for casting all the samples. They are well-cleaned and coated with mineral oil before casting to ensure no water escapes and avoid adhesion between the concrete mixture and the mold. Dimensions of the cubes' steel molds (150 × 150 × 150) mm for compressive strength and density, and the dimensions of the prism (100 × 100 × 400) mm were used for flexural strength.

4. PRODUCTION OF LOAD BEARING ACCORDING TO IQS NO. (1077)

4.1 Mixing and Casting of masonry units Concrete:-

The production of the load-bearing masonry units (block) adopting the IQS No. (1077) and the Iraqi guide No. (32/1989) for methods of sampling and testing. Experimental works were carried out in the Hilla - Al-Musayyib road factory to produce concrete hollow block units. The mixing steps were:-

1- Mixing materials was carried out by adding saturated surface dry aggregates (fine and coarse) in the mixer.
2-Adding approximately (1/2)of the required water to the mixing machine with aggregates and continuously mixing for 1min. Subsequently, adding cement gradually until we get to the mixing machine on the aggregates mixture, adding the residue water after justification reduction of water content, then mixing continues until the cement paste completely covers the aggregate in dry-semi dry mixture.
3- Concrete mixture was transported mechanically to the block-making machine using metal pans. The mold of blocks was filled with the concrete mixture and vibrated. During mold filling, the head and shoes were raised clear of the mold to allow the concrete mixture to move inappropriately.
4- When the mold was filled and during the vibration, and pressed on the top of the green blocks. as seen in the image of **Fig. 3**.

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Figure 3. Digital image of Blocks pressing

4.2 Curing of Masonry Unit

The curing of masonry Unit (hollow block concrete units) in the factory was done by leaving them in the storage place for the factory 24 hours and use of a water sprinkler system at a temperature of (23 ± 2 °C) and making the hollow block completely submerged according to (IQS 1077 / 1987 and testing at ages (14 and 28) days.

4.3 Hardened Properties of Masonry Unit Concrete

4.3.1 Dimensions of Concrete Masonry Units (Blocks)

All dimensions of concrete masonry units, including (length, width, height, thickness of the web, and shall) conform to the Iraqi standard specification. IQS 1077/ 1987, as presented in **Table 13.** The Hollow volume (168 × 16 × 2) is 5376 cm^3. To find the hollow volume ration, Eq.3 is applied:

$$\text{Hollow volume ratio \%} = \frac{\textbf{Hollow volume}*}{\textbf{Block volume}} \quad (1)$$

$$\text{Hollow volume ratio \%} = \frac{(5376)mm^3}{(400\times200\times200)mm^3}\times 100 = 33\ \%$$

which is between (25-50) %, So the masonry units (blocks) are considered hollow block

Table 13. Dimensions result for concrete masonry units (blocks).

Block symbol	Dimensions (mm)					Limits of IQS 1077 / 1987 (mm)				
R Ref%	L*	W**	H***	Web	Shall	L	W	H	Web	Shall
PA 5%	400	199	200	39	40	400 ±3	200 ± 3	200 ± 3	≥20	≥20
PA10%	400	200	199	38	40					
PB 5%	399	200	200	39	40					
PB 10%	399	200	200	39	40					

*L: length, ** W: width, *** H: height

4.3.2 Water Absorption

To determine the water absorption, hollow block specimens have been carried out according to (**Standard Specification No. (1077)).** An average of three specimens is adopted for each mixture, and the test is conducted at 28 days. According to the steps :

1-Saturation process

The specimens are immersed for 24 hours, then lifted and placed on a metal clip with an opening of 10 cm or more to drain the water. Then wipe the water visible on the surface with a cloth and weigh it immediately.

2- Drying

The sample was dried in an oven at a temperature between 100-115, whether or not the drying period is not less than 24 hours, and the loss must not be less than 2% for two consecutive readings, then weighing the specimens. The following formula is used to calculate the water absorption of the specimens the following Eq. (2).

$$\text{Absorption \%} = (W\,s - W\,d)/(W\,d) \times 100 \quad (2)$$

where :

Ws= The saturated mass (gm) of specimens after picking them from the curing basin.

Wd= The specimens' dry mass (gm) after weighing and drying in an oven at 90±2°C for 24 hours, as shown in **Table 14**.

Table 14. Absorption of Load bearing Concrete Masonry Units (blocks)

Mix. No	Absorption %	
	14 day	28 day
Ref.	6.5	4.7
AB 5%	6.7	4.8
AB 10%	7.3	6.5
PB 5%	5.8	4.5
PB 10%	5.6	4.2

4.3.3 Compressive strength of hollow block concrete units.

This test was carried out according to Standard Specification No. (1077). The compressive strength of masonry unit concrete for mixes with two percentages of cement (5% and 10%) at 7 and 28 days and two percentages of coarse aggregate (5% and 10%), the samples are placed between two wood boards in a compressive strength test machine. Use any reasonable load speed up to half the estimated maximum load and then apply a steady speed for the remaining period between (1-2) minutes, as shown in **Table 15.**

Table 15. Compressive strength of hollow block concrete units

Block type	Ref.	RB5	RB10	RP5	RP10
Comp. MPa for each block at 14 days	7. 4	7.5	7.6	7. 8	7.9
	7.5	7.4	7.5	7.7	7.8
	7.3	7.5	7.7	7.7	7.9
Average Comp. MPa for 3- blocks at 14 days	7.4	7.5	7.6	7.8	7.9
Comp. MPa for each block at 28 days	8. 3	8.3	8.3	8.6	8.9
	7.8	8.4	8.4	8.7	8.8
	8.4	8.4	8.4	8.7	8.9
Average Comp. MPa for 3- blocks at 28 days	8.2	8.4	8.5	8.7	8.9

Limits of IQS 1077/ 1987.			
Block type A		Block type B	
Comp. MPa for one block	Comp. MPa for an average of three blocks	Comp. MPa for one block	Comp. MPa for an average of three blocks
6 Min.	7 Min.	4.5 Min.	5 Min.

(Ref) Reference masonry units, (RB5) Replacement 5% brick aggregate, (RB10)Replacement 10% brick aggregate, (RP5)Replacement 5% powder brick, (RP10)Replacement 10% powder brick.

5. RESULTS AND DISCUSSION

5.1 Absorption

Absorption of Load-bearing Concrete Masonry Units (blocks). The absorption results are presented in **Fig. 2.** Using 5 % brick aggregate and replacement from the volume of coarse aggregate in (750 kg/m^3) led to a slight increase in absorption up to 3.1 % at 14 days and 2.1 % at 28 days compared to the reference mix (B-300). While using 10 % brick aggregate and replacement from the volume of coarse aggregate in (750 kg/m^3) led to increased absorption up to 12.3% at 14 days and 38.3% at 28 days compared to the reference mix (B-300), which is much less than the requirement of masonry units in IQS 1077/1987.

The use of 5% of brick powder and replacement from the weight of cement in (B- 300) led to a slight decrease in absorption up to (-10.7 %) at 14 days and (- 4%) at 28 days compared to the reference mix(B-300) and that is very encouraging results by using waste brick safely . Using (10%) of brick powder from the weight of cement in (B-300) led to decreasing in absorption up to (-13.8%) at 14 days and (-10.6%) at 28 days compared to reference mix (B -300), which results much less than the requirement of masonry units in IQS 1077/1987.

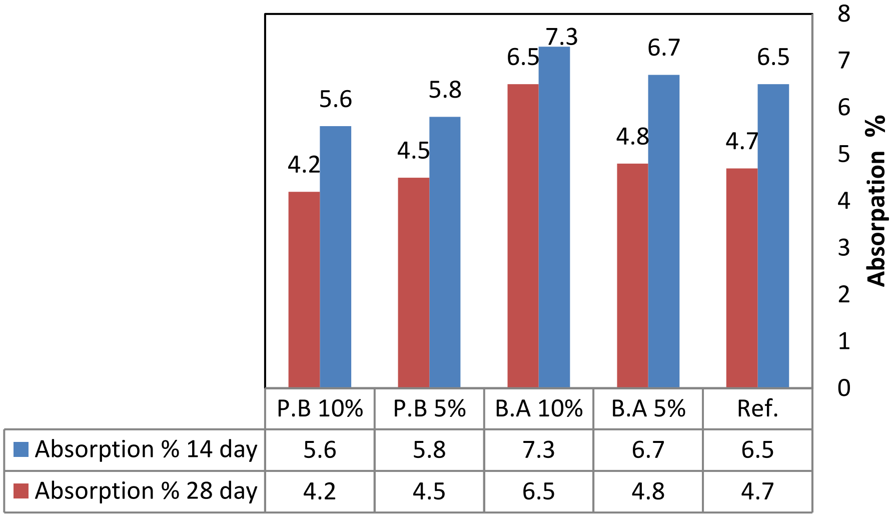


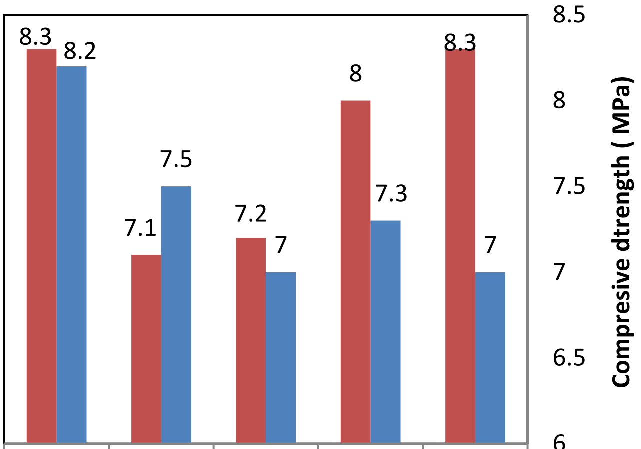
Figure 2. Water absorption results for the different mixes of block

5.2 Compressive Concrete Masonry Units (Blocks)

The compressive strength results for all block mixes are presented in **Table 16.** and shown in **Fig. 3.** When replacing 5% of brick aggregate from the volume of coarse aggregate, the increased masonry unit increased up to (1.4 and 2.4) % at (14 and 28) days, respectively, compared to R-300, when replacement of 10% of brick aggregate from the volume of coarse aggregate led to an increased in compressive strength in masonry unit up to (2.7 and 3.6) % at (14 and 28) days, respectively, compared to R-300. However, the block is still in type A with (7 MPa) Min. average for three blocks.
Replacing 5% of brick powder from the cement weight for a mix containing 300 kg/m^3 led to an increase in compressive strength (5.4 and 6.0)% at (14 and 28) days, respectively, compared to R-300. Replacing 10% of brick powder from the cement weight of for mix containing 300 kg /m^3 led to an increase in compressive strength (6.7 and 8.5) % at (14 and 28) days, respectively, compared to R-300. However, the block is still in type A with (7 Mpa) Min. average for three blocks.

Table 16. Compressive strength of hollow block concrete units.

Mix. No	Compressive strength	
	14 day	28 day
Ref.	7	8.3
B.A 5%	7.3	8.0
B.A 10%	7	7.2
P.B 5%	7.5	7.1
P.B 10%	8.2	8.3



	P.B 10%	P.B 5%	B.A 10%	B.A 5%	Ref.
Compressive strength 14 day	8.2	7.5	7	7.3	7
Compressive strength 28 day	8.3	7.1	7.2	8	8.3

Figure 2. Compressive strength results with curing age for different block mix

6. CONCLUSIONS

Based on the obtained experimental results, the most notable outcomes of the current study are:

1-All dimensions of the production concrete masonry units (hollow block), including (length, width, height, thickness, web, and shall) conform to the Iraqi standard specification IQS 1077/ 1987.

3- The decrease in the absorption load-bearing concrete masonry units (block) containing for percentage (5 and 10)% by (3.1, 2.1)%and(12.3, 38.3) %, respectively, at 14 and 28 days of brick aggregate volume replacement of coarse aggregate compared to reference mixture, take to consideration the results still much less than requirement of masonry units in IQS 1077/ 1987.

4- The decrease in the absorption load-bearing concrete masonry units (block) containing brick powder as a percentage replacement by the weight of cement by (5 or 10)% up to (10.7, 4.0)%, and (13.8, 10.6)% at 14 and 28 days, which is significantly less than the amount required for masonry units in IQS 1077/ 1987.

5-The compressive strength of concrete mixture containing (5 or 10)% of brick aggregate as volume replacement of natural coarse aggregate increased by (1.4, 2.4)%, and (2.7, 3.6)%, respectively, at (14 and 28) days, respectively. The manufactured block classification (type A) according to Iraqi standard specification IQS 1077/ 1987.

6-The compressive strength of concrete mixture containing (5 or 10)% of brick powder increased by (5.4, 6.0)%, and (6.7, 8.5)%, respectively, at (14 and 28) days respectively. The manufactured block classification (type A) according to Iraqi standard specification IQS 1077/ 1987.

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