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Producing Load Bearing Block Using LECA as Partial Replacement of Coarse Aggregate

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ABSTRACT

The ability to produce load-bearing masonry units adopting ACI 211.1 mix design using (1:3.2:2.5) as (cement: fine aggregate: coarse aggregate) with slump range (25-50mm) which can conform (dimension, absorption, and compressive strength) within IQS 1077/1987 requirements type A was our main goal of the study. The ability to use low cement content (300kg/m3) to handle our market price products since the most consumption in wall construction for low-cost buildings was encouraging. The use of (10 and 20%) of LECA as partial volume replacement of coarse aggregate to reduce the huge weight of masonry blocks can also be recommended. The types of production of the load-bearing masonry units were A and B for (10 and 20%), respectively. Finally, the use of the spray curing method was the more suitable simulation of reality and easier for factory producers, taking into consideration that the increasing curing time from 14 days (recommended in IQS 1077/1987) to 28 days may be led to conversation masonry type from B to A as in R20%-300.

Keywords: LECA, Absorption, Compressive Strength, Load Bearing Block, Partial Replacement.

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انتاج بلوك محمل باستخدام الليكا باستبدال جزئي للركام الخشن

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الخلاصة

القابلية على إنتاج الوحدات البنائية المحملة التي وحسب ACI 211.1 بنسب خلط (1: 3.2: 2.5) كـــ (السمنت: الركام ناعم: الركام الخشن) مع مدى الهبوط (25–50 مم) والذي يمكن أن يتوافق (الابعاد، الامتصاص وقوة الضغط (ضمن متطلبات المواصفة العراقية 1987/1077، كان النوع A هدفنا الرئيسي للدراسة .القابلية على استخدام محتوى السمنت المنخفض (300 كجم/م^3)، وكذلك التوافق مع منتجات وأسعار السوق لدينا لأن الاستهلاك الأكبر للمواد في بناء الجدران وكذلك التكلفة المنخفضة كان مشجعًا. يمكن أيضًا التوصية باستخدام نسب استبدال (10 و20 ٪) من LECA كبديل جزئي للحجم من الركام الخشن لتقليل الوزن العالي من كتلة البناء .كانت إنتاج أنواع وحدات البنائية المحملة نوع A و B لنسب (10 و20 ٪) على التوالي . أخيرًا، كان استخدام طريقة الإنضاج هي طريقة الرش لأنها أكثر ملاءمة ومحاكاة للواقع وأسهل لإنتاج ويأخذ في الاعتبار أن وقت الإنضاج أكثر من 14 يومًا (الموصي به في المواصفة العراقية 1987/1077) إلى 28 يومًا قد يؤدي إلى تحويل نوع الوحدات البنائية المحملة من B إلى A كما في 300–R20% .

الكلمات المفتاحية: LECA، الامتصاص ، مقاومة الانضغاط ، الكتل المحملة ، الاستبدال الجزئي.

1. INTRODUCTION

The evolution of residential amenities over time demonstrates how man has modeled his environment for more comfortable living. These goals can be partially met by manufacturing and utilizing easily accessible, inexpensive building materials in the local area. It is crucial to look for ways for developing nations to lower construction costs, particularly for affordable housing, and to put into practice simple and effective solutions for their upkeep and repair. **(Nandhakumar et al., 2020).** This study investigates the possibility of using waste plastic as one of the components of lead-acid batteries to replace the fine aggregate by 50 and 70% by volume of concrete masonry units (**Aljubori et al., 2019)**. This study focused on creating load-bearing concrete masonry units (blocks) that were environmentally friendly, and five concrete mixtures were crushed at the blocks-producing machine **(Qasim et al., 2022)**. Light Expanded Clay Aggregate (LECA) is one type of lightweight aggregate produced by heating clay in a rotary kiln at 1200°C. LECA is circular and has continuous pores. LECA can be used to make lightweight blocks, concrete, partition panels, heat insulation tiles, thermal roofing plaster, and concrete aggregates (**Banawair et al., 2019**). LECA comprises rounded pellets with a vesicular texture when broken open **(Akroyd, 2016)**. Following the calcination process, fire is used to destroy the organic chemicals, which causes the bubbles to swell and create the product's honeycomb structure. The resulting ceramic pellets have great resistance

to crushing and are lightweight and porous **(Rajprakash and Krishnamoorthi, 2017).** LECA is chemical content primarily comprises SiO_2, Al_2O_3, Fe_2O_3, CaO, and a few alkalis such as Na_2O and K_2O **(Alexander, 1999**). The numerous air voids that are present inside and between the aggregates may contribute to LECA's lightness. From 250 to 710 kg/m^3, the loose bulk densities in LECA range widely **(Hall, 2010).** Aggregates of lightweight expanded clay (LECA) are made by heating natural clay to 1200°C **(Ardakani and Yazdani, 2014).**
As a result, LECA material can be used to build underground areas, detachment walls within rooms, and ceilings. The goal of this research is to create an alternative to the conventional block in terms of strength, low cost, and weight of the blocks, thus promoting sustainable development in the construction field. Traditional blocks can only be used in ordinary environments and will fail in the case of excessive loading and handling energy. We also investigated the behavior of solid blocks and their compressive strength. **(Nandhakumar, et al., 2020).**

2. MATERIALS AND THEIR PROPERTIES

2.1 Cement

Ordinary Portland cement (**42.5 R**) produced by the Tasluja cement plant was used in this work. The chemical analysis and physical properties of the cement used are listed in **Tables 1 and 2,** respectively. Results indicate that the available cement conformed to the Iraqi standard specification **No.5/2019**. These chemical and physical tests were conducted in the laboratories of the Al- Mustaqbal University College.

Table 1. Chemical composition and main compounds of cement

Oxides composition	Content %	Limits of IQS NO.5/2019
Lime, CaO	61.23	-
Silica, SiO_2	20.42	-
Alumina, Al_2O_3	5.44	-
Iron Oxide, Fe_2O_3	3.91	-
Magnesia, MgO	4.35	< 5%
Sulfate, SO_3	1.65	≤ 2.8% for $C_3A > 3.5\%$
Loose on ignition, L.O.I	0.73	< 4%
Insoluble residue	1.35	< 1.5%
Main compounds (Bogus equations)		
C_3S	49.02	-
C_2S	21.65	-
C_3A	7.81	-
C_4AF	11.89	-

Table 2. Physical properties of cement

Physical properties	Test result	Limits of IQS NO.5/2019
Specific surface area(Blaine method), m^2/kg	372	≥ 280
Setting time (Vicate apparatus) The initial setting, min The final setting, min	 125 339	 ≥ 45 ≤ 600
Compressive strength, N/mm^2 2-day 28-day	 23.3 44.7	 ≥ 20.00 ≥ 42.50
Soundness (autoclave) method, %	0.32	≤ 0.8

2.2 Fine Aggregate

Natural sand from the Al-Obaidy region was used in the condition of saturated surface dry (SSD) in the mixture. The grading of fine aggregate is shown in **Table 3.** and the physical and chemical properties are shown in **Table 4.**; they are within the requirements of the Iraqi Specification **No.45/1984** zone two. These results were conducted in the laboratories in Al-Mustqbal University College.

Table 3. Sieve analysis of fine aggregate (sand).

Sieve Size (mm)	Passing by weight %	Limits of IQS NO.45/1984 zone two
10	100	100
4.75	95	90-100
2.36	85	75-100
1.18	70	55-90
0.60	42	35-59
0.30	12	8-30
0.15	4	0-10

Table 4. Chemical and physical properties of fine aggregate

Properties	Test result	Standard test method	Limits of IQS NO.45/1984
Specific gravity	2.57	ASTM C128-07a	-
Dry rodded-unit weight kg/m^3	1760	ASTM C29/C29M	-
Sulfate content as SO_3 %	0.323	Guidelines IQS . No.3/500,2018	For construction concrete ≤ 0.5 For masonry units ≤ 1.0
Fineness modulus, %	2.92	ASTM C125-07	-
Absorption, %	0.85	ASTM C128-07a	-

2.3 Rounded Coarse Aggregate

Natural coarse aggregate rounded shape single size with a nominal maximum size of 10 mm was used from the AL-Nibaey region in condition saturated surface dry (SSD). The sieve analysis of this aggregate is shown in **Table 5.** The specific gravity, sulfate content, and absorption of coarse aggregate are summarized in **Table 6** and it conforms to the requirement of the Iraqi Specification **No.45/1984.** These results were conducted in the laboratories in Al-Mustqbal University College.

Table 5. Sieve Analysis of normal coarse aggregate.

Sieve size (mm)	Passing %	Requirements of IQS NO .45/1984 (single size 10) (mm)
14	100	100
10	99	85 – 100
5	10	0-25
2.36	1	0-5

Table 6. Chemical and Physical tests of coarse aggregate

Property	Test result	Standard test method	Requirements of IQS NO.45/1984 single size (10)(mm)
Sulfate content as SO_3, %	0.07	Guidelines IQS. No.3/500,2018	≤ 0.1
Specific gravity	2.608	ASTM C127-07	-
Aggregate impact value, %	14	BS 812:part112:1990	≤ 45
Abrasion test (Loss Angeles),%	8	ASTM C131-06	≤ 35
Aggregate crushing value, %	8.5	BS81:part110:1990	-
Dry rodded density kg/m^3	1675	ASTM C29/C29M	-
Absorption, %	0.69	ASTM C127-07	-

2.4 Lightweight Rounded Coarse Aggregate (Expanded Clay Lightweight Aggregate-LECA)

Lightweight expanded clay from Bahrain Majmae Company in Najaf was used as lightweight coarse aggregate in this work. The physical and chemical properties of the LECA aggregate are shown in **Table 7.** A rounded shape with a maximum size of 10 mm was used as shown in **Table 8** used as a partial replacement for natural weight coarse aggregate (NCA) and it conforms to the requirement of the Iraqi Specification **No. 45/1984**. **Fig. 1** shows the lightweight expanded clay aggregate. These results were conducted in the laboratories in Al-Mustqbal University College.

Table 7. Chemical and physical tests of coarse aggregate (LECA)

Property	Test result	Requirements of IQS NO. 45/1984
Sulfate content as a SO_3, %	0.05	≤ 0.1
Specific gravity	0.8	-
Aggregate impact value, %	43	≤ 45
Abrasion test (Loss Angeles), %	32	≤ 35
Aggregate crushing value, %	36	-
Dry rodded density kg/m^3	415	-
Absorption, %	19	-

Table 8. Sieve analysis of coarse aggregate (LECA).

Sieve size (mm)	Passing %	Requirements of IQS NO .45/1984 (single size 10) mm
14	100	100
10	97	85 – 100
5	20	0-25
2.36	3	0-5

Figure 1. Lightweight Expanded Clay (LECA)

2.5 Mixing Water

The water used was potable water from the water-supply network system (tap water) conformable with Iraqi Specification **No. 1703 / 2018**.

3. CONTROL CONCRETE MIXTURE AND PROPORTIONS

ACI 211.1 code mix design was used to realize a required compressive strength of 20 MPa for the cylinder at 28 days [25 MPa for standard cube size] and a slump range of (25-50 mm) for reference mix. Using lightweight expanded clay aggregate (LECA) as replacement volume of coarse aggregate by (10% and 20%). The details of mixes are shown below for normal concrete and masonry units as presented in **Tables 9 and 10.**

Table 9. Materials content for concrete and load-bearing block

Cube mix	Cement kg/m^3	Sand kg/m^3	Rounded gravel kg/m^3	Water kg/m^3	w/c	Mix proportion
R-300*	300	975	750	189 **	0.69	1:3.2 :2.5
Properties of fresh concrete						
Slump mm						42
Air void %						3

*Reference masonry units **after reducing 18 kg/m^3 according to the recommendation of ACI 211.1 for rounded aggregate.

Table 10. The material used in the mixes

Mixes Number	R10%.300*	R20%.300**
Cement(kg/m^3)	300	300
Sand(kg/m^3)	975	975
Rounded coarse aggregate (kg/m^3)	675	600
Leca (kg/m^3)	18.6	37.2
Water(kg/m^3)	189	189

*Replacement 10% LECA ** Replacement 20% LECA

4. PRODUCING LOAD BEARING (BLOCK)

The design of the mixture is identical to the reference mixture and the partially replace (10% and 20%) of the normal coarse aggregate with LECA aggregate takes into consideration the water content reduction at a rate ranging (3-7) % attributed to the compacting machine can only compress the dry mixture. Then it is poured into block molds with dimensions (200 * 200 * 400) mm, and vibrator and mechanical pressure are actuated to compact the block as shown in Figure (2). Concrete blocks were manufactured by (Al Bida Automatic Factory on Hilla - Baghdad Road).

Concrete building blocks are classified according to their uses according to Iraqi standard specification **NO. 1077 / 1987** for hollow and solid.

Type A: For general use in external, internal, or internal walls exposed to moisture or climatic influences below or above ground level.

Type B: For use above ground level in internal or external walls that are protected from moisture or climatic influences.

Figure 2. Compression machine with a capacity of six blocks

5. CURING CONCRETE MASONRY UNITS (BLOCKS)

Spray Curing Using water spray can be an effective way to provide additional moisture for curing and, during hot weather, help reduce the temperature of the concrete. As with other methods of wet curing, it is important to keep the concrete sprinklers permanently wet. However, sprinklers do not have to be permanent. You may be on intermittent timing. Sprinklers need a main source of water, can be a waste of water and may need a drainage system to treat runoff. An alternative is to have a "closed" system where the water is collected and recycled. Monitoring is required to ensure that all concrete is hydrated and no part is subjected to wetting and drying.

6. TESTS

The test is carried out after the completion of block production according to the Iraqi standard specification **NO 1077 /1987**. These results were conducted in the laboratories in Al- Mustaqbal University College.

6.1 Dimensions of Concrete Masonry Units (blocks)

The dimensions of the samples are taken well and include the length, width, height, and thickness of the shell and web at 14 days according to Iraqi Guide **NO. 32/1989**.

6.2 Absorption Test of Concrete Masonry Units (blocks) at 14 and 28 Days.

The samples were immersed in water for 24 hours then wipe with a piece of wet cloth and weighed to take the saturated surface dry weight, the samples were dried in a ventilated oven at a temperature of (100 - 150) °C for not less than 24 hours. The weight loss should not exceed 0.2% for two consecutive readings in a time of 2 hours. The absorption is calculated according to Eq. (1) below according to Iraqi Guide **NO. 32/1989**.

$$\text{Absorption \%} = (M2-M1 / M1) \times 100 \quad (1)$$

where M1 is the dry weight (kg) and M2 is the saturated surface dry weight (kg)

6.3 Compressive Strength Test of Concrete Masonry Units (blocks).

The samples are placed in a compressive strength test machine between two wooden boards, use any suitable load speed up to half of the expected maximum load and then apply a constant speed for the remaining period between (1-2) minutes according to the Iraqi guide **NO. 32 /1989** as shown in table 11 and **Fig. 3.** The age of examination of masonry units' samples was (14) days. To calculate the compressive strength using the equation below:

$$F = P/A \quad (2)$$

where:
F is the compressive strength at MPa.
P is the maximum applied load at N.
A is the area of applied load (400×200) mm^2

Table 11. Results of compressive strength for concrete masonry units (blocks).

Block type		Ref.-300	R10%.300	R20%.300
Comp. MPa for one block at 14 days		7.2	6.8	6.3
		7.6	7.2	5.9
		7.4	7	6.7
Comp. MPa for an average of three blocks at 14 days		7.4	7	6.3
Comp. MPa for one block at 28 days		8.2	8.1	6.8
		7.9	7.8	7.4
		8.5	7.5	8
Comp. MPa for an average of three blocks at 28 days		8.2	7.8	7.4
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.	

Figure 3. Compressive strength test for concrete masonry units (blocks).

7. RESULTS AND DISCUSSION

7.1 Dimensions of Concrete Masonry Units (blocks)

Masonry unit dimensions results as shown in **Table 11.**

Table 11. Dimensions results for concrete masonry units (blocks).

No.	Dimensions (mm)					Limits of IQS 1077 / 1987 (mm)				
	L*	W**	H***	Web	Shall	L	W	H	Web	Shall
R-300	400	200	199	39	40	400 ±3	200 ± 3	200 ± 3	≥20	≥20
R10%-300	400	200	198	38	40					
R20%-300	399	200	200	39	40					

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

7.2 Absorption Test of Concrete Masonry Units (blocks) at 14 and 28 Days.

Masonry units absorption results as shown in **Table 12.**

Table 12 Absorption Results for concrete masonry units (blocks)

No.	Absorption %		Limits of IQS 1077/ 1987.	
	14 day	28 day	Block type A %	Block type B %
R-300	6	4	15 Max.	20 Max.
R10%-300	8	7		
R20%-300	10	8		

7.3 Compressive Strength Test of Concrete Masonry Units (blocks).

Masonry units compressive strength results as shown in **Table 13.** To produce concrete masonry units, the dimension, absorption, and compressive strength must be checked within IQS 1077/ 1987 requirements for the local market. All production concrete masonry units' dimensions were within the limits of IQS 1077/ 1987, and that's encouragement and indicated to good manufacture factory producer. The absorbance of the samples increased with the increase of the LECA content at a slight rate compared to the reference which increased by 2% and 1% to replace 10% and increased by 4% and 4% to replace 20% of the natural coarse aggregate respectively, at 14 and 28 days of treatment. The test results presented in Table (12) and Figure (4) for compressive strength of reference mix and mixes containing (10% LECA or 20%) as replacement volume of coarse aggregate, show that the reference mix (R-300) can be classified as type A. The production of masonry units containing 10% as partial volume replacement of coarse aggregate was very successful since the production unit was still in type A with less weight. While the masonry units contain 10% as partial volume replacement of coarse aggregate were in type B. The effect of curing age (from 14 days to 28 days) was significant for more factors of safety and may be led to converting masonry units type from B to A, as in the case of R20%-300.

Table 13. Results of compressive strength for concrete masonry units (blocks).

Block type		R-300	R10%.300	R20%.300
Comp. MPa for one block at 14 days		7.2	6.8	6.3
		7.6	7.2	5.9
		7.4	7	6.7
Comp. MPa for an average of three blocks at 14 days		7.4	7	6.3
Comp. MPa for one block at 28 days		8.2	8.1	6.8
		7.9	7.8	7.4
		8.5	7.5	8
Comp. MPa for an average of three blocks at 28 days		8.2	7.8	7.4
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.	

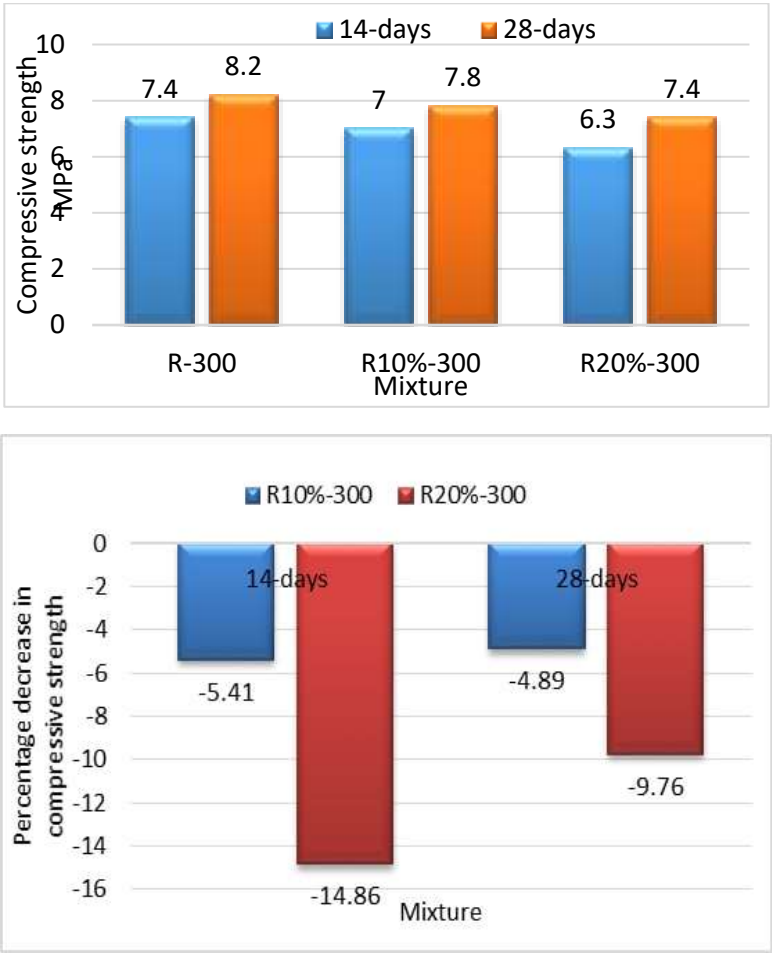

Figure 4. Compressive strength of reference mix

8. CONCLUSIONS

The following conclusions were drawn from the research:

- The ability to produce load-bearing masonry unite adopting ACI 211.1 mix design using (1:3.2:2.5) as (cement: fine aggregate: coarse aggregate) with slum range (25-50mm), that conforms (dimension, absorption, and compressive strength) within IQS 1077/1987 requirements type A.
- The success of using LECA as partial volume replacement by 10% of the coarse rounded aggregate, which acts by IQS 1077/1987 requirements type A with less weight.
- The 20% partial volume replacement of LECA by coarse rounded aggregate showed a reduction in compressive strength, and the types converted from A to B with less weight.
- The increasing curing time from 14 days (recommended in IQS 1077/1987) to 28 days may be led to converting masonry type from B to A as in R20%-300.

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