Journal of University of Duhok, Vol. 20,No.1 (Pure and Eng. Sciences), Pp 561-569, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.49

PERFORMANCE OF CONCRETE MADE WITH CRUSHED CLAY BRICKS AS COARSE AGGREGATE

GHANIM HUSSEIN QOJA and YOUKHANNA ZAYIA DINKHA
Dept. of Civil Engineering, University of Duhok, Kurdistan Region-Iraq

ABSTRACT

Because of economic considerations and thermal insulation requirements, it seems necessary therefor to produce lightweight concrete obtained by crushing an enormous tons of building demolition wastes have been produced. In this study, it is gintended to investigate smashed and the possibility of using crushed clay bricks to replace the coarse aggregate (gravel) in concrete mies. Four nominal normal concrete mixes and four more mixes of crushed clay brick aggregate were prepared and tested. The crushed clay brick aggregates were produced by crushing the brick units (locally available and manufactured in Iran) manually and collected into described size (20 mm). From the analysis of the results, it was found that the unit weight of the crushed brick concrete ranged from (1685-1760) kg/m^3 and its compressive strength was about 61% of that of the natural aggregate concrete while the flexural strength was 70% of natural aggregate concrete. Also, the relation between compressive and flexural strength for the lightweight concrete produced is similar to that of normal concrete. Moreover, the results indicated the suitability of the crushed clay brick aggregate concrete to be used in buildings.

***KEYWORDS*:** Recycled aggregate, Lightweight concrete, Crushed clay brick, Demolition waste.

1. INTRODUCTION

The self-weight of normal cement concrete varies from 2200 to 2600 kg/m^3. This is one of the main disadvantages of conventional cement concrete as this heavy weight of concrete makes it uneconomical structural material. To increase the efficiency of cement as a structural material attempts have been made to reduce the weight of normal cement concrete.

A cement concrete having self-weight ranging from 300 to 1850 kg/m^3 is called lightweight concrete (Neville & Brooks, 2010). In recent years lightweight concrete has become more popular due to manifold advantages it offers over the conventional concrete. A better understanding and development of modern technologies have also helped in the promotion and use of light weight concrete.

Concrete can be effectively produced using reprocessed materials. The use of recycled aggregate concrete has gradually increased during the last decades and its recent field of uses including lightweight concrete, lightweight aggregate, asphalt concrete and concrete used in road construction (swamy, 1983)

The use of crushed waste as aggregate in concrete has begun in Europe and Japan since the Second World War. Many buildings are constructed from crushed waste because of the need for low-cost and rapidly constructed buildings.

Crushed bricks are widely used in parts of India and Bangladesh as a substitute source of coarse aggregate and the performance of this concrete is found to be quite satisfactory (Schulz, 1988).

Brick aggregates are effortlessly presented in Bangladesh and with low cost compared to other sources of aggregates. In addition, strength of 20 MPa can be reached easily using this type of aggregate and according to the usual practice of making concrete (Rashid, Hossain, & Islam, 2008). And the use of brick aggregate concrete effectively reduced the dead load on columns in addition to foundations. Therefore, the process of replacing the aggregates effectively reduced the cost in making concrete.

The research done by (Akhtoruzzaman & Hasnal, 1983) mainly focused on determining the mechanical properties of brick aggregate concrete. They used burned brick in concrete as an alternative to coarse aggregate. The study showed that high strength concrete can’t be achieved through using crushed brick when used as coarse aggregate.

(Khaloo, 1994) Stated that when using crushed clinker bricks in concrete as coarse aggregate, a

Journal of University of Duhok, Vol. 20,No.1 (Pure and Eng. Sciences), Pp 561-569, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.49

reduction in concrete strength of 7% have marinated when compared with concrete manufactured with natural aggregate. Furthermore to this reduction in strength, there is a reduction in the unit-weight of crushed brick concrete of 9.5%.

In a study carried out by (Husain, Al-Hamad, & Mustafa, 1995), they used treated or untreated crushed brick as an alternative to coarse aggregate. Cement syrups of different consistencies have be used to treat the aggregates. They found a reduction in compressive strength up to 75-85 % when compared to normal concrete at 28 days, and a lower modulus of elasticity, even though the results of splitting tensile strength using crushed brick were more than the normal concrete.

Also, (Bolouri, Mahmood, & Navid, 2006) used crushed brick in their study, they found that the compressive strength of concrete prepared with crushed bricks is comparatively low in comparison with ordinary concrete. Nevertheless, concrete bricks made with crushed bricks have higher strength than ordinary bricks, they could be used as new constructions.

(Abdur, Md. Abdul Salam, Sakanta, & Md. Kowsur , June,2012) Indicated that the weight of brick aggregate concrete reduced about 14.5% compared to that of normal aggregate concrete. Also, they showed a decrease of 33% in compressive strength of concrete when using brick aggregate instead of stone aggregate moreover a 28% decrease in elastic modulus of concrete.

Widespread work on recycled aggregate concrete has proven that using of numerous types of recycled aggregate in concrete yields to a concrete with light weight and less expenses (Hughes D.A.B.,, Basheer, Elliot, & Hackett) (Ibrahim, Shahram, Ahmed, & Mohammed, May, 1996) (Alduaij, Alshaleh, Haque, & Ellaithy) (Crwaford & Cullum-Kenyon, May, 2001) (Fouad, khalaf, & Alan, 2005).

In present study, an endeavor has been made to study the possibility of using crushed clay bricks of locally existing construction waste for production of recycled brick aggregate concrete.

2. MATERIALS

Cement:

Ordinary Portland cement manufactured in Sulaymaniyah-Iraq was used in the present work with properties given in Table (1).

Table (1): physical and chemical properties of the used cement

Chemical Tests		**Physical Tests**		
Chemical Requirements	Test Results	Physical Requirements		Test Results
Loss on ignition	1.52 %	Setting Time	Initial	137.7 minutes
Insoluble Residue	0.76 %		Final	3.30 hours
LSF	0.86	Soundness (Le-Chatelier)		1 mm
C3S	41.14 %	Fineness		276 m^2/kg
C2S	34.94 %	Compressive Strength	3 days	31 Mpa
C3A	7.367 %		7 days	36 Mpa
C4AF	9.819 %		-	-

Fine Aggregate (Sand):

The fine aggregate used was river locally available in Duhok region, it's grading satisfied the ASTM specifications (C 33-03) as shown in Table (2).

Table (2): Sieve Analysis of fine aggregate

Sieve size (sieve No.)	% passing	ASTM Specifications
4	100	95-100
8	92	80-100
16	75	50-85
30	49	24-60
50	17	10-30
100	5	2-10

Journal of University of Duhok, Vol. 20,No.1 (Pure and Eng. Sciences), Pp 561-569, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.49

Coarse Aggregate:

Natural coarse aggregate was used in reference mixes of 20mm maximum size, 60% retained on sieve (20 mm) and 40% passing sieve (10mm) and retaining on sieve (4.75mm).

Crushed Clay Brick Aggregate:

Crushed clay brick aggregates were prepared by crushing the clay bricks manually as shown in Figure (1). Crushed products were screened into two size fractions, (20 to 10 mm) and (10 to 4.75 mm). In order to produce the crushed clay brick coarse aggregate, the two size fractions were re-combined by the same ratios as natural coarse aggregate to give a similar grading. The properties of crushed brick aggregate are presented in Table (3).

Table (3): Crushed clay brick properties

Bulk specific gravity	Dry- unit weight, kg/m^3	Absorption capacity
2.1	820	26 %

Fig. (1): Prepared Samples of Clay Brick Aggregate.

Mixing Water:

Ordinary drinking (Tap) water was used in preparing all concrete mixes.

3. EXPERIMENTAL WORK

3.1 Mix Proportions:

Four different nominal mixes were tried throughout the present work, their main characteristics are listed in Table (4).

Table (4): Characteristics of nominal mixes

Mix No.	Mix proportion	Cement content kg/m³
1	1:1.5:3 (1:4.5)	400
2	1:2:4 (1:6)	320
3	1:2.5:5 (1:7.5)	270
4	1:3:6 (1:9)	230

3.2 Preparation and Testing of Specimens:

The coarse aggregate was prepared as saturated surface dry condition before mixing with other ingredients. Whereas the fine aggregate was used as air-dry condition.

The values of slump of fresh concretes for different mixes ranged from (50mm to 100mm). The mixes tried with natural coarse aggregate considered as reference mixes and are indicated as A1, A2, A3 and A4, while the mixes with crushed brick are indicated as B1, B2, B3, and B4.

The specimens used for compressive strength test are cubes of size (150×150×150) mm, while the specimens used for flexural strength test are prisms of size (400×100×100) mm.

Mixing concrete test specimens were carried out in accordance with British Standards. For each mix, six cubes were casted and tested at ages 7

Journal of University of Duhok, Vol. 20,No.1 (Pure and Eng. Sciences), Pp 561-569, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.49

and 28 days. Also three beams were casted and tested at the age 28 days for each type of concrete.

4. DISCUSION OF RESULTS

Test results for natural aggregate concrete (NAC) and brick aggregate concrete (BAC) are shown in Tables (5, 6 and 7).

Table (5): Unit weight for NAC and BAC

Mix No	Mix proportions	Water/cement Ratio	Unit weight, kg/m³ (NAC)	Unit weight, kg/m³ (BAC)
1	1:1.5:3	0.42	2420	1760
2	1:2:4	0.46	2350	1728
3	1:2.5:5	0.52	2280	1704
4	1:3:6	0.62	2230	1685

Table (6): Compressive and Flexural Strength for NAC

Mix No	Comp. Strength (7 days) , (MPa)	Comp. Strength (28 days) , MPa	Flexural Strength (28 days) , MPa
A1	30.4	41.7	7.9
A2	24.8	37.5	7.2
A3	19.5	30.0	6.3
A4	16	22.5	5.4

Table (7): Compressive and Flexural Strength for BAC

Mix No	Comp. Strength (7 days) , (MPa)	Comp. Strength (28 days) , MPa	Flexural Strength (28 days) , MPa
B1	18.8	23.5	5.6
B2	17.0	20.4	4.8
B3	13.7	17.6	4.2
B4	11.5	15.5	4.0

4.1 Effect of Brick Aggregate on concrete Properties:

4.1.1 Unit Weight:

Table (4) illustrates the unit weight of normal aggregate concrete and brick aggregate concrete for the four mixes tried throughout the present study. The unit weight of normal concrete is ranging between 2230 kg/m^{3}and 2420 kg/m^3 while the unit weight of crushed brick aggregate concrete is ranging between 1685 kg/m^3 and 1760 kg/m^3. It is clear that, when the natural coarse aggregate is replaced by crushed clay brick, the unit weight decreases by about 25% and the resulting concrete may be classified as light weight concrete (Neville M. A., 1996).

Figure-2 illustrate the relationship between the aggregate/cement ratio and the unit weight for both types of the concretes. The figure shows that the unit weight of the concrete decreases with an increase in aggregate/cement ratio. Also, the unit weight of the brick aggregate concrete is about 75% of the normal aggregate concrete.

Journal of University of Duhok, Vol. 20,No.1 (Pure and Eng. Sciences), Pp 561-569, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.49

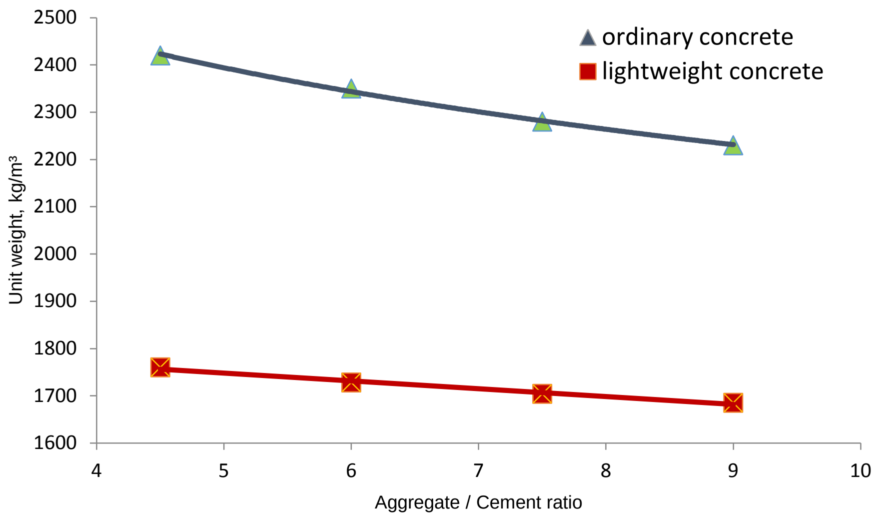

Fig. (2): Relationship between unit weight and aggregate/cement ratio

4.1.2 Compressive Strength

The results of compressive strength are summarized in Tables (5, and 6). It is observable that the relationship between the compressive strength and the age were similar for both natural and crushed brick aggregate concrete and that the compressive strength of concrete increases as the age of concrete increases. (The specimens of concrete were tested at ages 7 and 28 days respectively).

In general, the compressive strength of concrete produced with clay brick aggregate were always lower than the compressive strength of natural aggregate concrete. (See figures 3 and 4). We conclude from Tables (5) and (6) and from Figure (3) that the compressive strength of brick aggregate concrete is ranging between 53% and 69% of the compressive strength of normal aggregate concrete.

Also, the compressive strength of brick aggregate concrete increases by a ratio of 52% with an increase in cement content. While the compressive strength of normal concrete increases by a ratio of approximately 85% as the cement content increases.

The effectiveness of crushed brick aggregate concrete can be predictable to be less, in terms of strength than the natural aggregate concrete due to the higher porosity of crushed aggregate of crushed brick aggregate concrete compared to normal concrete.

Moreover, the resistance to mechanical actions of crushed brick aggregates is lesser than that of natural aggregates, because of developed micro-cracks which are suffered during crushing of bricks.

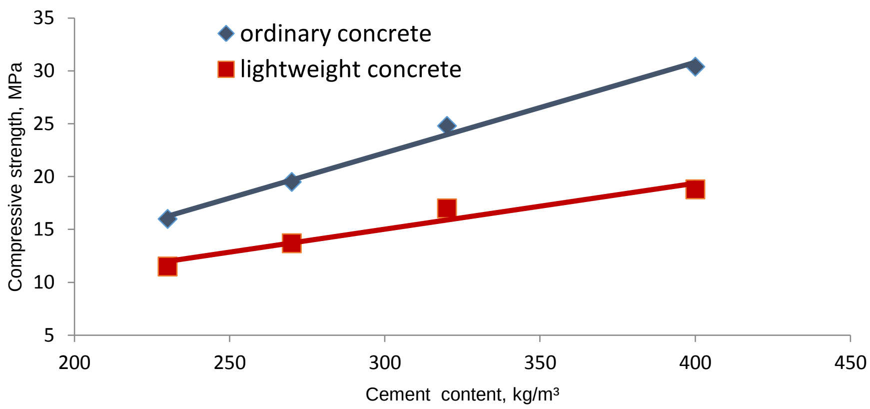

Fig. (3): Relationship between cement content and compressive Strength at 7 days

Journal of University of Duhok, Vol. 20,No.1 (Pure and Eng. Sciences), Pp 561-569, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.49

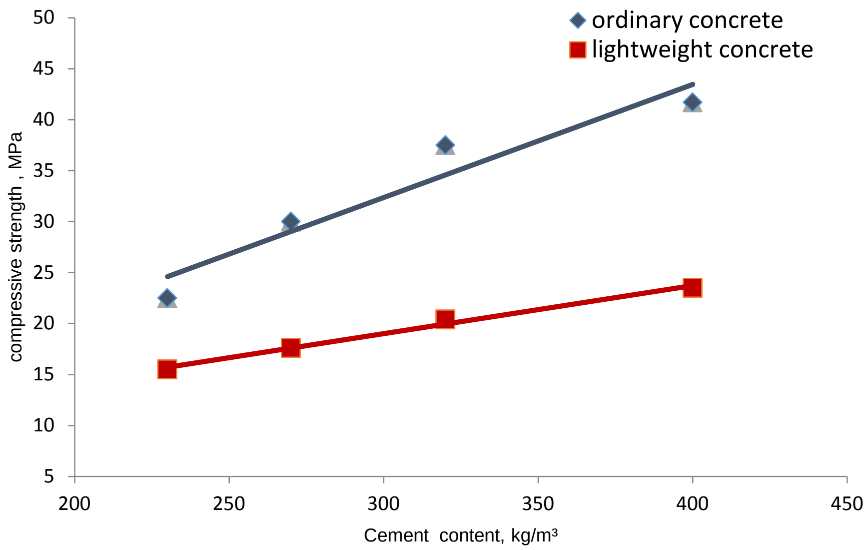

Fig. (4): Relationship between cement content and compressive Strength at28 days

4.1.3 Flexural Strength

The results of flexural tests for natural and crushed brick aggregate concretes are summarized in Tables (5) and (6) and Figure (5).

In general, the flexural strength of crushed clay brick aggregate concretes were always lower than natural aggregate concrete. The flexural strength of crushed brick concrete increases with an increase in cement content similar to normal concrete.

From the Tables, it seems that the flexural strength of crushed brick concrete is about 66% to 74% of that of normal concrete. This shows that the performance of crushed brick concrete is better than that its performance in compression strength and this may be due to the surface texture and the angularity of crushed clay brick aggregate.

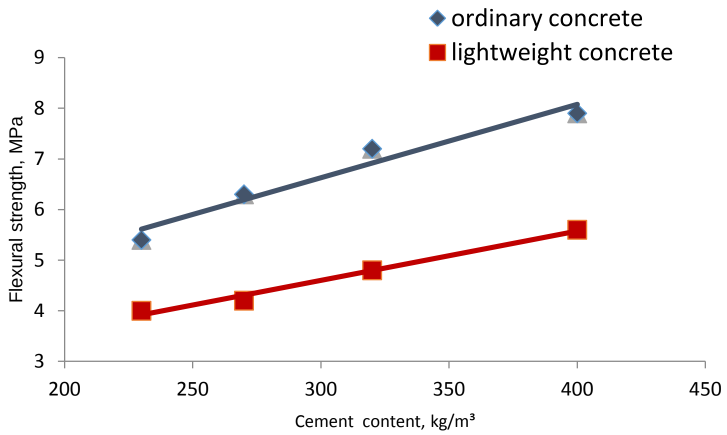

Fig. (5): Relationship between cement content and Flexural Strength at 28 days

4.2 RELATIONSHIP BETWEEN COMPRESSIVE AND FLEXURAL STRENGTHS

Figure (6) shows the relationship between compressive and flexural strength for both types of concretes. The flexural strength of normal concrete equals 19% to 24% of compressive strength, while the flexural strength of crushed brick concrete equals 24% to 26% of compressive strength. This means that the crushed brick aggregate concrete behaves similar to the natural aggregate concrete. But the ratios are higher in case of crushed brick aggregate for all mixes have been tried as shown in Figure (6) below.

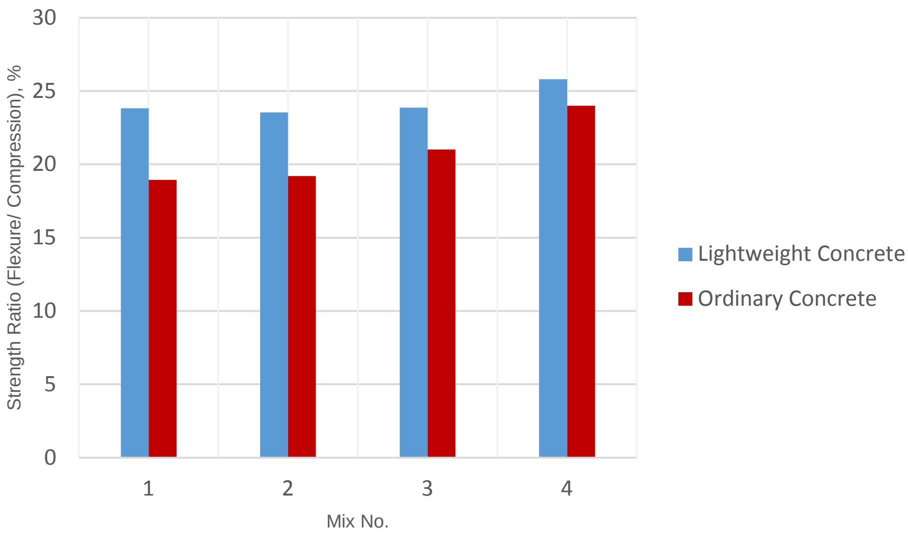

Fig. (6): Relationship between Flexural strength and Compressive Strength for NAC and BAC at 28-day

5 CONCLUSIONS

The following conclusions can be drawn from the present study.

1. Ability of utilization of crushed clay brick as coarse aggregate replacement of natural aggregate (gravel) to produce lightweight concrete of unit weight ranges between (1685-1760) kg/m^3 used in production of building units.

2. The compressive strength of crushed brick aggregate concrete is about 61% (as average) of compressive strength of natural aggregate concrete if the both have the same workability. Also, the compressive strength of crushed brick concrete increases with the increase of age and cement content.

3. The flexural strength of crushed brick aggregate concrete is about 70% of that of natural aggregate concrete. This means that the performance of concrete produced with crushed clay is better in flexure.

4. Throughout the study of the properties of crushed clay brick aggregate concrete, it is concluded the same known relations between the compressive and flexural strength, and this type of lightweight concrete produced, behaves the same as normal concrete regarding the properties that have been studied.

REFERENCES

– Abdur, R. M., Md. Abdul Salam, Sakanta, K., and Md. Kowsur , H. (June,2012). Effect of Replacing Natural Coarse Aggregate by Brick Aggregate on the Properties of Concrete. *DUET Journal*, *Gasipur,Vol.1*.

– Akhatoruzzaman, A. A., and Hasnal, A. (1983). Properties of Concrete Using Crushed Brick as Aggregate. *concrete International and Construction Vol.5, No.2*. pp.58 -63

– Alduaij, J., Alshaleh, K., Haque, M., N and Ellaithy, K. (N.D.). (1999) "Lightweight Concrete in Hot Coastal Areas. *Cement and Concrete Composites*, Vol. 21, No. 5, pp.453-458.

– Bolouri, B. J., Mahmood, K., and Navid, A. (2006). Performance of Concrete Produced with Crushed Bricks as the Coarse and Fine Aggregate. *IAEG Journal, London*.

– Crwaford, H., and Cullum-Kenyon, S. (May, 2001). *Market Development Study For Recycled Aggregate Products.* Report to Waste Reduction Advisory Committee.

– Fouad, M., khalaf, and Alan, S. D. (2005). Properties of New and Recycled Clay Brick Aggregates for Use in Concrete. *Journal of materials in civil engineering (J. mater. civ.eng.)*, Vol. 17, No4, pp. 456- 464.

– Hughes D.A.B.,, D., Basheer, P., Elliot, T., and Hackett, A. (n.d.). Use of Building Demolition Waste as Aggregate in concrete. European social fund, Demolition Waste.

– Husain, M., H., Al-Hamad, A. H., and Mustafa, k. K. (1995). The Use of Crushed Brick Treated with Cement Syrup as Aggregate for Concrete. *Tikrit Journal of Eng. Sciences, Vol.2, No.2*

– Ibrahim, S., Shahram, V., Ahmed, E., and Mohammed, F. (May, 1996). The Use of Solid Waste Materials as Fine Aggregate Substitutes in Cementitious Concrete Composites.

Journal of University of Duhok, Vol. 20,No.1 (Pure and Eng. Sciences), Pp 561-569, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.49

Semisequicentennial Transportation Conference. Iowa State University, Ames, Iowa.
– Khaloo, A. R. (1994). Properties of Concrete Using Crushed Clinker Brick as Coarse Aggregate. *ACI Materials Journal, Vol.91, No.2*, 401-407.
– Neville, A. M., and Brooks, J. J. (2010). *Concrete Technology, 2nd Edition.* UK: Longman Group.
– Neville, M. A. (1996). *Properties of Concrete.* Longman, 4th Edition.
– Fouad, M., khalaf, and Alan, S. D. (2005). Properties of New and Recycled Clay Brick Aggregates for Use in Concrete. *Journal of materials in civil engineering (J. mater. civ.eng.)*, Vol. 17, No4, pp. 456- 464.
– Hughes D.A.B.,, D., Basheer, P., Elliot, T., and Hackett, A. (n.d.). Use of Building Demolition Waste as Aggregate in concrete. European social fund, Demolition Waste.
– Husain, M., H., Al-Hamad, A. H., and Mustafa, k. K. (1995). The Use of Crushed Brick Treated with Cement Syrup as Aggregate for Concrete. *Tikrit Journal of Eng. Sciences, Vol.2, No.2*
– Ibrahim, S., Shahram, V., Ahmed, E., and Mohammed, F. (May, 1996). The Use of Solid Waste Materials as Fine Aggregate Substitutes in Cementitious Concrete Composites.
– Rashid, M. A., Hossain, T., & Islam, M. A. (2008). Higher Strength Concrete Using Crushed Brick as Coarse Aggregate. *Indian Concrete Journal, Vol. 82, No. 10*, pp.18-23.
– Schulz, R. R. (1988). Concrete with Rubble-Development. *in Demolition and Reuse of Concrete and Masonry, Proceedings.*
– swamy, R. N. (1983). *New Concrete Materials.* London: Surrey University Press. *Semisequicentennial Transportation Conference.* Iowa State University, Ames, Iowa.
– Khaloo, A. R. (1994). Properties of Concrete Using Crushed Clinker Brick as Coarse Aggregate. *ACI Materials Journal, Vol.91, No.2*, 401-407.
– Neville, A. M., and Brooks, J. J. (2010). *Concrete Technology, 2nd Edition.* UK: Longman Group.
– Neville, M. A. (1996). *Properties of Concrete.* Longman, 4th Edition.
– Rashid, M. A., Hossain, T., & Islam, M. A. (2008). Higher Strength Concrete Using Crushed Brick as Coarse Aggregate. *Indian Concrete Journal, Vol. 82, No. 10*, pp.18-23.
– Schulz, R. R. (1988). Concrete with Rubble-Development. *in Demolition and Reuse of Concrete and Masonry, Proceedings.*
– swamy, R. N. (1983). *New Concrete Materials.* London: Surrey University Press.

سەرەدە ريا كونكريتا ئامادە كرى ژتابوكێ ئاخێ يێ شكاندى وە ك حە سو

پوختە

لبەر ئە گە رێن ئابورى و پێدڤيێن پاراستنا گە رماتيێ ، بە رهەمئينانا كونكريتا سڤك پەيدا دبيت ، ئەو ژى بمفا وەرگرتن ل هژمارا زورا ئاڤاهيێن كەڤنێن هەرفاندى و تەنێن بەرمايكێن پەيدا دبن ل هەرفاندنا ئافاهييا.

ئارمانجا ڤەكولێن ئەوە بو دياركرنا شيانا بكارئينانا تابوكى ئاخێ يێ شكاندى ل جهێ حەسوى ل ناف كونكريتى دا .

چوار تێكەلێن كونكريتێ نورمال هاتنە ئامادە كرن و تاقيكرن و چوار تێكەلێن كونكريتى حەسوى شكاندى ژتابوكى خومالى و ئيرانى . حەسو هاتە ئامادە كرن بريكا هەرشاندنا تابوكى بدەستى پاشى كومكرنا وان لدويڤ پيڤەرێ داخاز كرى .

برێكا شيتەل كرنا ئەنجاما هاتە ديتن كو كێشا كونكريتا سڤك د كەڤيتە ناڤبەرا ١٦٨٥-١٧٦٠ كگم/م ٣ و بەرگريا گڤاشتنێ نێزيكى ٦١٪ ژ بەرگريا گڤاشتنا كونكريتێ نورمال ، بەلێ پا بەرگريا خاركرنێ و چەماندنێ ٧٠٪ ژ بەرگريا چەماندنا كونكريتا نورمال .

هەروەسا پەيوەندى د ناڤبەرا بەرگريا گڤاشتنێ و بەرگريا چەماندنێێ بو كونكريتا سڤك وەكى پەيوەنديا كونكريتا نورمال بوو. زێدەبارى كو ئەنجاما دياركر شيانا بكارئينانا كونكريتا شكاندنا تابوكى ئاخێ د ئاڤاهيا و رێكا دا .

اداء الخرسانة المنتجة من الطابوق الطيني المكسر كركام خشن

Journal of University of Duhok, Vol. 20,No.1 (Pure and Eng. Sciences), Pp 561-569, 2017
eISSN: 2521-4861 & pISSN: 1812-7568
https://doi.org/10.26682/sjuod.2017.20.1.49

الخلاصة

بسبب الاعتبارات الاقتصادية و متطلبات العزل الحراري تظهر الحاجة لانتاج خرسانة خفيفة الوزن، وذلك بالاستفادة من العدد الكبير من الابنية القديمة المهدمة و اطنان من الفضلات الناتجة من هدم المشآت.

يهدف البحث الحالي الى امكانية استخدام الطابوق الطيني المكسر بدلا من الركام الخشن **(الحصى)** في الخلطات الخرسانية.

تم تحضير و فحص اربع خلطات خرسانية اعتيادية و اربع خلطات اخرى فيها الركام الخشن عبارة عن كسر الطابوق المتوفر محليا و المصنوع في ايران. وقد تم الحصول على ركام الطابوق الطيني عن طريق تهشيم وحدات الطابوق يدويا وثم تجميعها حسب المقاس المطلوب.

من خلال تحليل النتائج، وجد ان وحدة الوزن للخرسانة الخفيفة تتراوح ما بين **1685-1760** كغم\م^3 و مقاومة انضغاطها حوالي **61%** من مقاومة الانضغاط للخرسانة الاعتيادية بينما مقاومة الانثناء كانت **70%** من مقاومة الانثناء للخرسانة الاعتيادية. كما وان، العلاقة بين مقاومة الانضغاط و مقاومة الانثناء للخرسانة الخفيفة تشبه تلك العلاقة للخرسانة الاعتيادية. بالاضافة ان النتائج بينت امكانية استخدام خرسانة كسر الطابوق الطيني في انشاء الابنية والطرق.