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Recycling construction and demolition waste: A case study in the Euphrates Basin area in the eastern region of Syria

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Abstract

This paper investigates using recycling and demolition waste from the Euphrates Basin in eastern Syria as concrete aggregate. The recycled aggregate samples were tested in comparison to natural river ones. Samples from governmental buildings and normal housing units (including lean concrete, white and black brick, and mixed brick with ceramic) were selected and tested individually in order to determine their properties. Normal Portland cement was used (350 kg/m^3, water-cement ratio 0.5 and tap water). The recycled building material was ground into various combinations of coarse and fine recycled aggregates. Natural aggregates were also used for comparison. The concrete was casted into cubes for up to 28 days and monitored under continuous curing in tap water. The cube compressive strength of the concrete made from recycled aggregate types ranged from 24 to 30 MPa. Comparing natural and recycled aggregate values showed similar results, except for the sample obtained from reinforced concrete taken from normal housing buildings, where the cube compressive strength value exceeded 6%. The compressive strength of concrete that made from other recycled aggregate types reached 90% of the natural one, which was 28.49 MPa in the natural samples. In addition, abrasion test values varied between 29.55% to 44.36%. Results showed that recycled concrete aggregates produced from construction and demolition waste in Euphrates Basin, Syria can be used in concrete works.

Keywords: Aggregate; concrete; construction and demolition; recycling; waste.

1. Introduction

Concrete is the world's second most consumed material after water, and its widespread use is the basis for urban development (Hendriks, C., Janssen G., 2001). It is estimated that 25 billion tons of concrete are manufactured each year.

By crushing and screening construction and demolition waste (CDW), it can be used as recycled aggregate in concrete (DG ENV, 2011). CDW can be defined as all non-hazardous solid waste resulting from construction and demolition activities (DG ENV, 2011).

Recycling or reusing building rubble collected from damaged and demolished structures is an important issue in most countries. CDW waste is a major concern facing the Ministry of the Environment and local governmental agencies in Syria because this waste occupies a large areas of landfills. CDW is oftentimes haphazardly located across the country, especially on the municipal boundaries of cities, villages and beside roads and highways. This matter is widely increasing due to the war in Syria. Huge amounts of CDW has been generated.

Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the construction and demolition debris (Nelson, 2004). The use of recycled aggregate as a replacement for natural aggregates has been known for many years. Many studies have been conducted that investigate the use of recycled aggregate of various compositions of building rubble composed of crushed rocks show that building rubble could be transformed into useful recycled aggregate by proper processing. The application of recycled aggregate for use in construction activities has been practiced in developed European countries and in some Asian countries, too (Rahman *et al.,* 2009; How-Ji, C., *et al*, 2003).

The future benefits of using recycled aggregate cannot be ignored (Olanike, 2013). Using recycled aggregate (RA) in concrete is environmentally and economically beneficial. Recycling or recovering concrete materials has two main advantages. First, it conserves the use of natural aggregate and the associated environmental costs of exploitation and transportation. Second, it reduces landfill waste. Crushed concrete can be used as a sub-base material for pavements, roads and other civil engineering projects (CCANZ, 2011).

The need to reduce CDW is hugely important across Syria. In order to accomplish this, the massive amounts of

Table 1. The list of achieved tests on the engineering properties of recycled and natural aggregate.

SN	Type of test	Remarks
1	Grain size analyses	For all types
2	Abrasion test (Los Angeles test)	For recycled aggregate
3	Specific gravity	For all types
4	Water absorption test	For recycled aggregate (coarse and soft material)
5	Dry density	For recycled aggregate (coarse and soft material)
6	Casting cubic samples including slump test	For all type of concrete batches (Cube: 15x15x15 cm)
7	Compression test value for cubic samples	For each type of concrete and each cube

rubble must be statistically evaluated in order to establish a database of CDW. This study is an attempt to find out solutions that could facilitate C&D waste management in Syria via developing appropriate policy supported by proper legislations.

Syrian governing authorities should set a goal of recycling and re-using CDW. City engineers in conjunction with architects and builders should adapt a national rebuilding plan similar to those of European countries, which have adopted a national target of 70% use of CDW by 2020 (DG ENV, 2011).

This paper covers the C&D waste management in Euphrates basin in the eastern region of Syria, as the virgin materials of recycled concrete have been made of Euphrates River aggregates, and it was considered to be as an important research that could facilitate solutions of C&D waste management in Syria.

2. Materials & methods

Table 1 shows the different types of tests conducted on the various concrete types used in this study.

Collection of CDW was from the Mayadeen area near the Euphrates River in the eastern region of Syria as shown in Figure 1. The dumpsite is used by local people who seek to enlarge the land area and fortify the bank of Euphrates River. However, using CDW to create reclaimed land may negatively affect the quality of groundwater (Alsharifa H. M. *et al.,* 2016).

The CDW in this area reflects the worst type of mixtures. The specimens were selected to cover building components

Fig. 1. Sample location (the right bank of Euphrates River in Quriyeh City in the east of Syria)

such as reinforced concrete, lean concrete, white and black brick and mixed brick with ceramic (Figure 2).

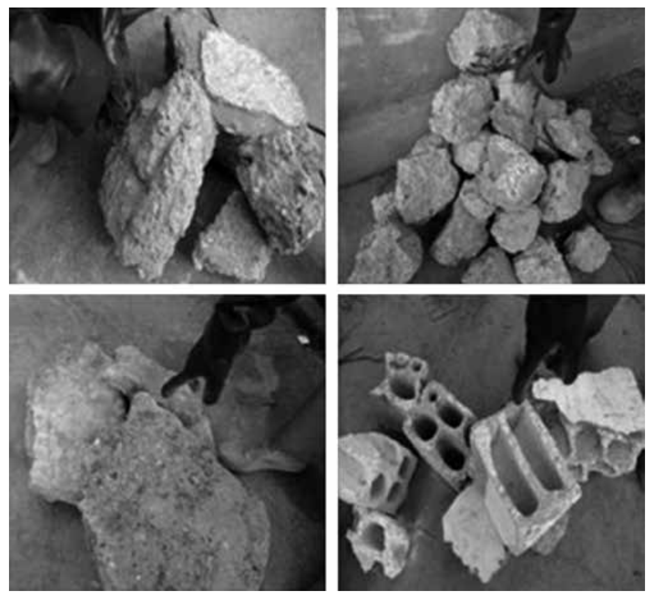

Fig. 2. Types of specimens

CDW processing samples were manually crushed because there is no recycling center in the area. The recycled aggregates are shown in the Figure 3.

There are two construction types in Syria. The first is governmental, while the second is local (without standards). The recycled aggregate was produced by hand crushing and was classified as shown in Table 2.

Fig. 3. Some types of recycled aggregate after hand crushing.

Table 2. Types of recycled aggregate and their indicator code.

SN	Type of recycled aggregate	Indicator code
1	Recycled aggregate from governmental structures	RCO1*
2	Recycled aggregate from normal housing units	RCO2**
3	Recycled aggregate from lean concrete	Lean (plain) concrete
4	Recycled aggregate from black brick	Black brick
5	Mixed (black & white) brick with ceramic (RA)	Mixed brick
6	Mixture of RCO1 (40%), lean concrete (15%) and mixed brick (RA) (45%)	Total mixture

*RCO1 = Structures built to governmental standards

**RCO2 = Normal housings units built by local with no standards applied

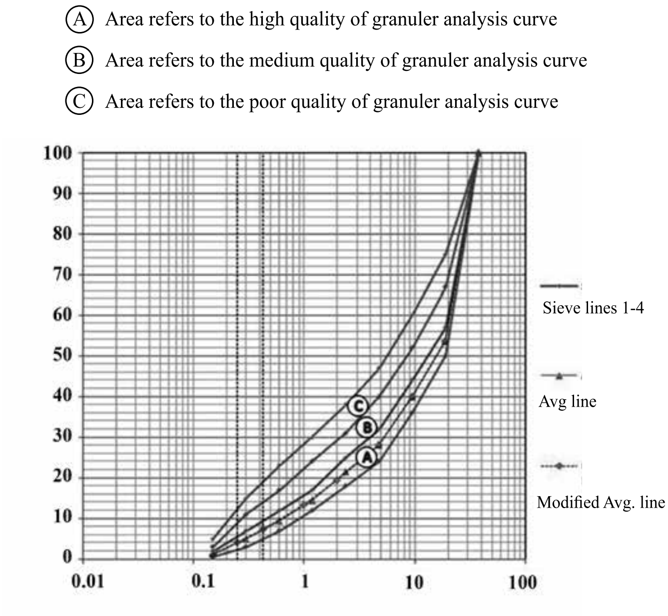

Fig. 4. BS grain size curves

Fig. 5. Part of sieving process in the laboratory

Aggregate classification recycled materials were tested individually. The grain size analyses were achieved according to British Standards (BS 812-103). The curves were selected to design the ideal concrete batch with a D_{MAX} of 38mm. For this purpose, a series of different sieves was used with diameters from 38 mm to 0.075 mm (Table 3). Figure 4 shows the British Standards for grain size curves that was used to classify the recycled aggregate.

The sieving process was achieved in two ways: mechanic sieving when electrical power was on and manual sieving when the electricity was off. Figure 5 shows part of the sieving process in the laboratory of Aljazeera Private University, DierEzzor, Syria.

First, the natural aggregate was sieved. Then each type of recycled aggregate was sieved. Both average and modified granular lines of the aggregates conformed. Replaced sieves of 2.38 mm to 0.3 mm did not affect the design of the approved concrete batch (Figure 4, Area A), according to the modified opening columns (passed through sieve with openings of 38 mm, 19 mm, 9.5 mm, 4.75 mm, 2 mm, 1 mm, 0.425 mm, 0.250 mm, 0.150 mm, 0.075 mm, and pan (Table 3)).

Concrete batches were designed according to American standards (ASTM C469) for both natural and recycled

Table 3. Grain size details.

Openings (mm)	Passing %				3 & 4 Avg.	Modified openings	Modified avg.
	1	2	3	4			
38	100	100	100	100	100	38	100
19	75	67	57	50	53.5	19	53.5
9.5	60	52	44	36	40	9.5	40
4.75	47	40	32	24	28	4.75	28
2.38	38	31	25	18	21.5	2	19.5
1.18	30	24	17	12	14.5	1	13.25
0.6	23	17	12	7	9.5	0.425	7.3
0.3	15	11	7	3	5	0.25	4
0.15	5	3	2	0.5	1.25	0.15	1
0.075	2	1.5	1	0	0.5	0.075	0.5

Table 4. Physical properties of natural and recycled aggregate samples.

Type	Specific Gravity		Dry Density (gr/cm3)			Water Absorption Percentage		
	Gravel	Sand	Gravel	Sand	Mix	Gravel	Sand	Mix
Natural	2.65	2.66	1.95	1.68	1.87	0.00	0.00	0.00
RCO1	2.46	2.56	1.58	1.32	1.51	5.2	15.3	8.0
RCO2	2.55	2.61	1.23	1.40	1.28	4.5	11.4	6.5
Lean concrete	2.38	2.46	1.16	1.36	1.22	4.3	14.9	7.3
Black brick	2.39	2.47	1.59	1.41	1.54	6.0	15.3	8.6
Mixed brick with ceramic	2.45	2.57	1.13	1.30	1.18	6.2	21.8	10.6
RCO4 Mixed (45%)+RCO2(40%)+Lean(plain) concrete.(15%)	2.48	2.57	1.18	1.35	1.23	5.2	16.6	8.4

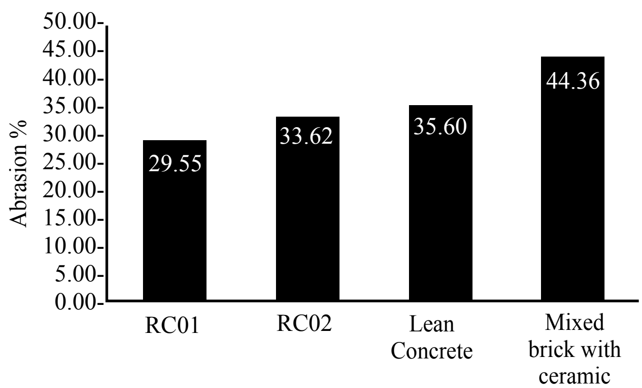

Fig. 6. Results of abrasion test for recycled aggregates

aggregates. Note that there were no increments of natural gravel or sand added to the recycled mixes. In this study, 72% coarse and 28% fine aggregates from the total mixture were used. Cube size was 15x15x15cm in all concrete batches. The water-cement ratio was 0.5 using normal tap water. Normal Portland cement was used (350 kg/m^3). The slump value was 0-9.5 cm, and 0.1 m^3 was the basin for hand mixing. No plasticizers were used. The cubic samples were casted and kept for 28 days in a laboratory water storage tank at 15^o C.

The ASTM-C97 specific gravity test, dry density test, and water absorption test were carried out to determine the influential physical properties of the concrete (Roesler *et al*., 2006). To check abrasion resistance of the recycled aggregate, ASTM-C131, C535 was used (Sarkis F. M., 2000).

3. Results

The abrasion test results are presented in Figure 6. Physical properties of natural and recycled aggregates are shown in the Table 4. The compression test and slump values plus slump are given in Figures 7 and 8.

Figure 9 shows compression strength values (CSVR) for recycled concrete samples compared to the natural sample (CSVN).

4. Discussion

The results show that the abrasion value (AV) of recycled aggregate (RA) varied between 29.55% to 44.36%, which reflects the conformity of these materials for most concrete works (Sarkis F.M., 2000). Specific gravity value (SGV) of natural aggregates (NA) gravel was 2.65, whereas it was 2.66 for natural sand. It varied between 2.38 to 2.55 for RA, while it was between 2.46 to 2.61 for sand RA. Therefore, the SGV in RA is less than the SGV in NA. These values imply that it can be used in light construction.

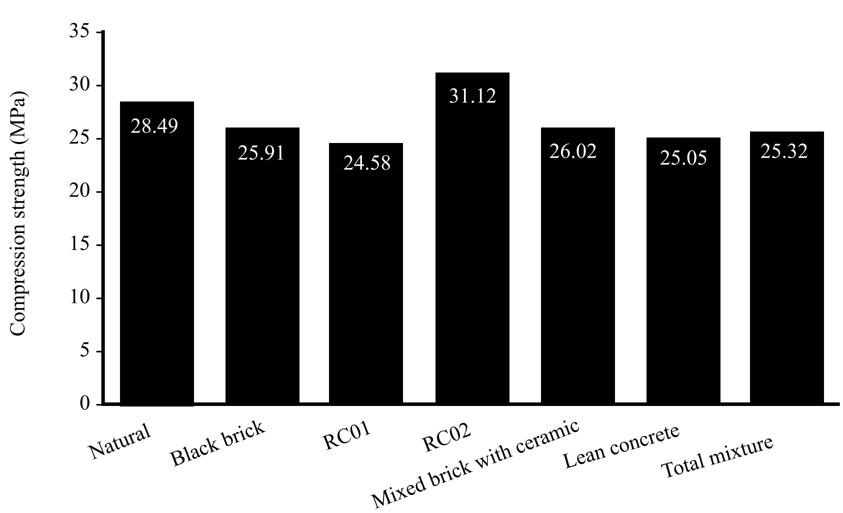

Fig.7. Compression test values samples

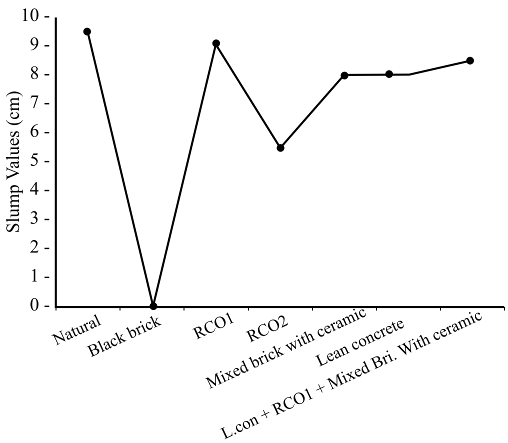

Fig. 8. Sample slump values

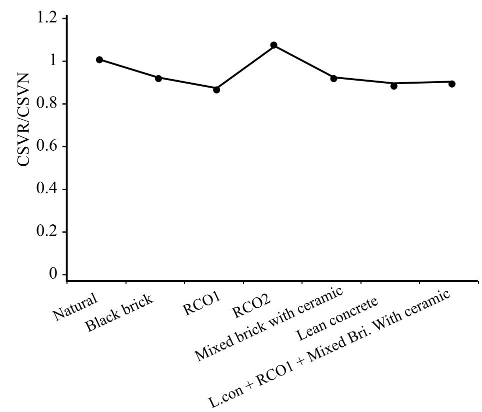

Fig. 9. A comparison between the compression strength values (CSVR) for recycled concrete samples and natural sample (CSVN).

As for the water absorption value (WAV), it was 0% in the NA sample but it was high in the recycled aggregates. Values varied between 4.3% to 6.2% in RA gravel, 11.4% to 21.8% in sand RA, and from 6.5% to 10.6% in the RA mixture. Gomez-Soberon (2002), and Scanchez & Guiterrez (2009) suggest that high WAVs occur because the attached mortar raises the porosity of the concrete.

Dry density values (DDVs) were 1.95, 1.68, and 1.87 g/cm^3 in gravel, sand and natural mixture, respectively. However, it varied between 1.13 to 1.59 g/cm^3 in RA gravel, and between 1.30 and 1.41 g/cm^3 in RA sand. Thus, DDVs were lower than those of the NA samples. The compression strength value for RCO2 (30.12 MPa) was higher than the value of the NA (28.49 MPa), whereas the values were lower for the recycled samples than for the others. The strength values varied between 24 MPa and 26.02 MPa.

The compression value for the RCO2 sample exceeded the value of the NA sample, as the slump value was 5.5 cm. Yet, they were very close in value to the rest of the recycled samples, having values between approximately 8 cm and 9 cm.

The slump value in the black brick sample was 0 cm. However, the compression strength value was 25.91 MPa. This result indicates that this particular recycled aggregate can be widely used in brick manufacturing.

Figure 9 shows compression strength values for recycled and natural samples. The proportion of CSVR to CSVN was 1.06 for the RCO2. The extra value reached was 6% of the natural sample, whereas the proportion values were approximately 90% of the natural sample. This is actually a positive outcome since it means that housing rubble can be used in construction as an aggregate. However, these data are inconsistent with some European studies since the recycled values are less than the natural ones in most cases (Nelson, 2004).

As for the grain size issue, dust was retained on the pan and was excluded in all the concrete batch mixtures because it contains most of the harmful materials, like dusty clay and silt (Mehta & Monteiro, 2006). Proper removal is recommended and should be applied in crushing plants in the future.

Finally, the compression strength of the concrete samples follows the water-cement ratio and slump value because the amount of added water was calculated according to WAV, which varies from one sample to another. In comparison with the international experiments, RA properties show a high level of strength because the crushing processes release remarkable amounts of virgin Euphrates gravel from attached mortar.

5. Conclusion

Experimental results show that CDW produced from Euphrates River aggregates can be recycled and re-used in new concrete, as much of the concrete was originally made from the same source rock. In other words, a lot of the virgin aggregate was released during recycling in the crushing process. The mortar separates from virgin gravel and the process appeared as if we added new natural aggregates to the recycled aggregate. This result is attributed to the smoothness of external surface of virgin aggregates.

Test results have shown that RA produced from concrete of Euphrates River aggregate can be used in most types of concrete construction, such as reinforced concrete, lean concrete, and brick work because it has a slump value of 5.5 cm and an increased strength value of recycled concrete of 6% compared with natural aggregate concrete. When the slump value varied between 8 cm and 10 cm, the strength value formed 90% from the one in the natural concrete.

This methodology can develop the method of the demolition process in future and provide suitable proportions of recycled aggregate in concrete mixtures as well as the sorting material process.

The research shows that CDW can be used as building material. Using CDW as a main source for new construction will reduce waste. Engineers in Syria can work towards a better way of utilizing CDW from government and housing rubble. The quality of the concrete produced solely depends on the origin of the source aggregate (Sironic & Grad, 2012).

Recycling and reusing CDW should be part of the national rebuilding plan in Syria. Proper legislative procedures need to be implemented. Systematic management and the enactment of CDW recovery will need to be mandated. Future research should investigate the cost-effectiveness of create concrete from recycled CDW in comparison to using natural aggregates. (Malešev *et al.*, 2010).

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إمكانية تدوير مخلفات الهدم والبناء: دراسة حالة في حوض الفرات في المنطقة الشرقية من سوريا

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الملخص

تهدف هذه الورقة إلى دراسة إمكانية تدوير مخلفات الهدم في منطقة حوض الفرات شرقي سوريا والاستفادة منها في مجال الانشاءات. تم اختبار عينات من الركام الخشن والناعم المعاد تدويره في المنطقة ومقارنته مع عينات نهرية طبيعية. ولمعرفة نقاط القوة والضعف في الركام المعاد تدويره تم اختيار عينات من مختلف عناصر البناء: ركام خرسانة مسلحة من أبنية حكومية ومن أبنية أهلية, خرسانة أرضيات, بلوك من النوع الأبيض والأسود والمختلط مع السيراميك. تم صب العديد من الخلطات الخرسانية للحصويات المعاد تدويرها (الخشن والناعم) وكذلك للحصويات المستخرجة من نهر الفرات , وذلك باستخدام اسمنت بورتلندي عادي بعيار 350 كغ/م3 والماء العذب حيث كانت نسبة الماء إلى الاسمنت 0.5 في تلك الخلطات وبدون استخدام مواد ملدّنة . تمت مراقبة تطور المقاومة لتلك الخلطات بعد غمرها في الماء العذب خلال 28 يوماً. تراوحت مقاومة ضغط المكعب لخلطات البحص المعاد تدويره بين 24 ميجاباسكال و30 ميجاباسكال وكانت القيم متقاربة في معظم الأحيان باستثناء عينة الخرسانة المسلحة الخاصة بالأبنية الأهلية, حيث زادت المقاومة المكعبية لها بنسبة 6% عنها في عينات البحص الطبيعي, بينما بلغت نسبة المقاومة المكعبية لباقي عينات الركام المعاد تدويره 90% منها في الحصويات الطبيعية حيث كانت المقاومة المكعبية للعينات الطبيعية 28.49 ميجاباسكال. أظهرت النتائج أن الركام المعاد تدويره في منطقة حوض الفرات شرقي سوريا يمكن استخدامه في أعمال الخرسانة.