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Advancing Sustainable Construction: Recycling Building Aggregates for Eco-Friendly Concrete Solutions in Benghazi, Libya

Halima S Saeid[1], Abdelsalam Abuzreda[2]* and Wanisa A gouma[3]

[1]Lecturer, at the Higher Institute of Engineering Technologies Benghazi, Libya

[2]Associate Professor & Postdoctoral Research fellow, Senior Advisor Department of Health Safety and Environmental (HSE), Arabian Gulf Oil Company (AGOCO) and University of Benghazi, and the higher Institute of Engineering Techniques Benghazi, Libya

[3]Technician at the General Company for Water and Sanitation

ABSTRACT

In the last ten years in the city of Benghazi, Libya, it has been observed that the increase in rubble resulting from demolition and construction operations due to wars and destruction operations leads to an increase in this waste, which has become a new challenge to the local environment. Due to environmental reasons and the lack of natural resources, it is very important to recycle construction and demolition waste as much as possible. , Therefore, this study was conducted as a preliminary evaluation of the reuse of concrete aggregates from old and demolished buildings in concrete mixtures. Concrete aggregates were obtained from a building that is more than 20 years old, after crushing the reinforced concrete and sifting the crushed concrete to obtain the granular aggregate needed to make the concrete mixture, according to international specifications. , In this study, the focus was on the use of recycled aggregates in combination with natural aggregates in the concrete industry, and then five percentages of recycled aggregates were adopted (0%, 25%, 50%, 75%, 100%), In this study, a number of tests were conducted on recycled aggregates, and these tests are (sieve analysis, specific gravity, absorption, abrasion, impact value and crushing value. Also, for comparison, the same tests were applied to natural aggregates. , To investigate the possibility of using recycled aggregates in the concrete industry. More than 15 samples of concrete cubes were prepared to conduct concrete tests such as (density and concrete operation for fresh concrete, and compressive strength within 3 days, 7 days, 28 days for hardened concrete) , Accordingly, and through the results obtained, we recommend the use of recycled aggregates in concrete mixtures, provided that it is used in ……. taking into account the necessary specifications in that.

***Corresponding author**

Abdelsalam Abuzreda, Associate Professor & Postdoctoral Research fellow, Senior Advisor Department of Health Safety and Environmental (HSE), Arabian Gulf Oil Company (AGOCO) and University of Benghazi, and the higher Institute of Engineering Techniques Benghazi, Libya.

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Introduction

Recycled aggregates are materials that are created from construction and demolition waste, such as concrete, bricks, asphalt, and other debris [1]. These materials are processed, crushed, and refined to create aggregates that can be reused in various construction applications [2]. The construction sector, in addition to being very important for the economy of several countries [3]. Also has a significant impact on the environment as it causes a huge natural resources depletion and generates an enormous amount of waste [4]. Recent wars, that struck our Benghazi city, have caused widespread damage, among which damage to building structures is dominant [5]. Society is not only faced with the problems of fin - ding solutions for the construction, reconstruction and repair of buildings, but also with huge issues concerning disposal of the construction and demolition waste, during the still ongoing cleaning of areas, is being indiscriminately disposed of at municipal waste landfills or often at the so-called illegal dumps [6].

To achieve sustainable issue in construction area, researchers and companies focus on using waste concrete as a new construction material [7]. It is called recycled aggregate which can be produced by concrete crusher. The aggregates are categorized by size as coarse and fine aggregate [8]. If recycled aggregates were practically useful in construction area, two aspects would be expected [9]. One is illustrated at the beginning of introduction, the other one is that we could reduce consumption of natural aggregate resources. Although using recycled aggregates has great opportunity to preserve healthy environment, the properties and characteristics of recycled aggregates has not been fully investigated yet. This paper suggests, to scientific and professional community, a possibility of recycling wasted construction material, primarily concrete, which is mostly used.

Aim: Recycling of building aggregate in concrete mixes.

Objective:

- To replace natural coarse aggregate by the recycled coarse aggregate in various percentages (0%, 25%, 50%,75% and 100%)
- To study and compare the mechanical properties - compressive strength of hardened concrete specimens with and without recycled aggregates

Materials used and Sample Collection Methods

The Cement Used was Portland Cement

Table 1 describe main and local sources of the recycled and natural aggregate used in this experiment. and Table 3 describe physical properties of the recycled and natural aggregate used in this experiment.

Table 1: The Main and Local Sources of the Required Materials for Concrete Mix

Material		Source
Recycled aggregates	course aggregates	Demolished buildings. See Figure (1)
Natural aggregates	course aggregates	Al-Abyar area crushers
	Fine aggregate	Shatt al-Badin crushers

Figure 1: Main Post Building **Figure 2:** Recycled Aggregate.

Figure 3: Classified Crushed Aggregates Grading and Recycled Aggregate

The study area was in the middle of the old city, Omar Al-Mukhtar Street, in Benghazi, where the sample was from a government building, which is the post office building, which was built approximately in the thirties and was developed in the sixties, as it was the only place available for entry. Also, samples were taken from the street because the place had traces of war. The samples were taken randomly in 2018, and the samples were ground manually with a hammer.

Research Methodology and Experimental Work

five series of concrete specimens with variable amount of coarse recycled aggregate (0%, 25%, 50%,75% and 100%) were prepared. All mixtures used in this investigation were proportioned using British method.

1. Mix NAC – concrete mixture with natural aggregate exclusively,
2. Mix RAC1 – concrete mixture with 25% of recycled aggregate,
3. Mix RAC2 – concrete mixture with 50% of recycled aggregate,
4. Mix RAC3 – concrete mixture with 75% of recycled aggregate
5. Mix RAC4 – concrete mixture with 100% of recycled aggregate

Table 2: Five Series of Concrete Specimens with Variable Amount of Coarse Recycled Aggregate (0%, 25%, 50%,75% and 100%)

Variable	Slump (cm)
NAC	17
RAC1	13
RAC2	16
RAC3	18
RAC4	13

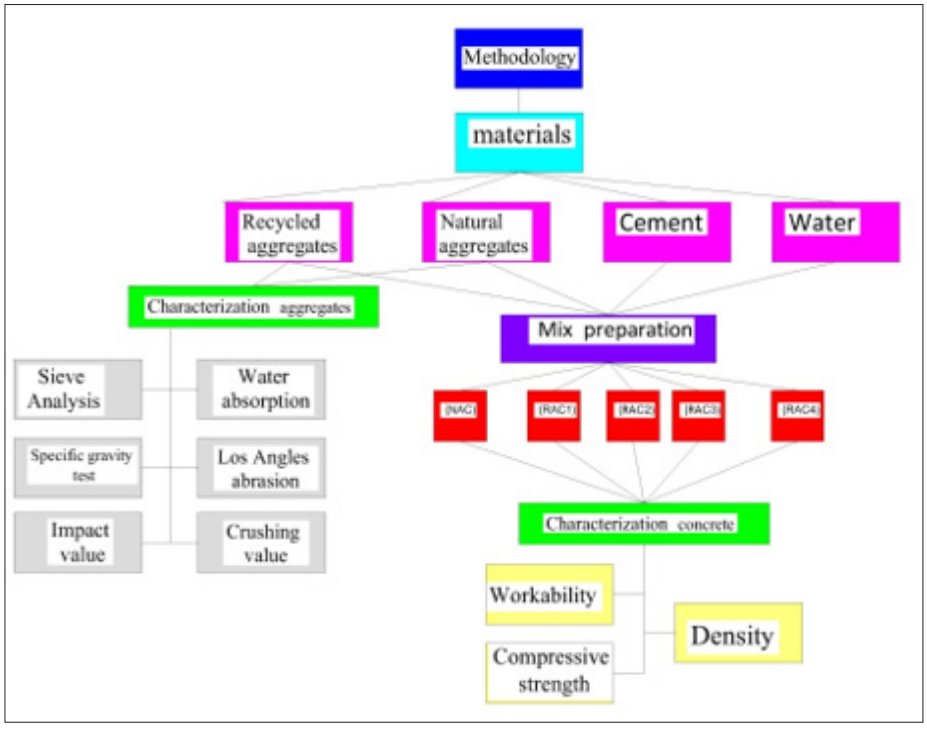

Figure 4: Experimental Work

All the mixes were designed for slump 80-100 mm, and designed for the same air content of 0.015 per unit volume. The same cement was used in all mixes, the variable material is the coarse and fine aggregate type. The proportions used in preparing the various mixes are shown Table (4) to Table (6):

Table 3: All the Mixes

Variable	Cement (Kg)	Water (Lt)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)			
				Natural		Recycled	
				5/10	10/20	5/10	10/20
NAC	325	197	559	303	598	0	0
RAC1	325	221	559	316.6	643.8	105.8	214.9
RAC2	325	239	630	219	443	206	421
RAC3	325	252	542.6	103.9	209.8	292.9	598.8
RAC4	325	255	529	0	0	349	814

Results and Discussion

Properties of Coarse Aggregate

Table (4)& Table (5) summarizes the physical & Mechanical properties of coarse aggregate. It can be seen from the table that the new recycled coarse aggregate showed lower bulk specific gravity, higher absorption, higher Abrasion value.

Table 4: Sieve Analysis Results of Natural and Recycled Coarse Aggregate

SIEVE SIZE (mm)	SIEVE #	CUMULATIVE RETAINED (g)		% CUMULATIVE RETAINED		% SAMPLE PASSING	
		NCR	RAC	NCR	RAC	NCR	RAC
31	11/2"	0	377	0	5.38	100	94.62
20	3/4"	95	3860	4.75	55.14	95.25	39.48
14	1/2"	1268	1509	63.4	21.55	31.85	17.93
10	3/8"	584	466	29.2	6.65	2.65	11.28
4.75	#4	42	409	2.1	5.84	---	5.44
2.363	#8	0	132	0	1.88	--	3.56
-	pas	0	238	0	3.4	--	--

Table 5: The Test Results of Natural and Recycled Coarse Aggregate

Property	Designation No.	Symbols and Results	
		NAs	RCA
Bulk dry S.G	BS812:PART2:1975	2.38	2.22
Bulk SSD S.G		2.44	2.36
Apparent S.G		2.54	2.58
Effective S.G		2.46	2.47
Absorption (% Abs.)	BS812:PART2:1975	2.69	6.18
Abrasion value(%A.V)	ASTM : C131-80	48.90%	52.30%
Impact value, %	BS812:PART 3:1975	25.80%	32.20%
Crushing value,%	BS812:PART 3:1975	32%	33%

Properties of Fine Aggregate

Table 6: The Test Results of Fine Aggregate

Property	Designation No.	Results
Bulk SSD S.G	ASTM : C127&C129	2.77
Apparent S.G		2.75
Absorption (% Abs.)		0.68

Properties of Plain Concrete Made

Fresh Properties

The recycled concrete aggregate can influence the properties of fresh concrete due to their greater angularity, surface roughness, absorption, and porosity. The effects of the recycled concrete aggregate on the key fresh properties of concrete, as observed from the available literature [10].

Workability

Slump test was conducted to assess the workability of fresh control concrete and concrete containing recycled aggregate. The slump test was carried out according to ASTM C143, for each mix in the test program, a sample of freshly mixed concrete is placed and compacted by rod in a frustum of cone mold as shown in Figure [5,11]. The slump value is equal to vertical distance between the original and displaced position of the center of the top surface of the concrete after raising a mold.

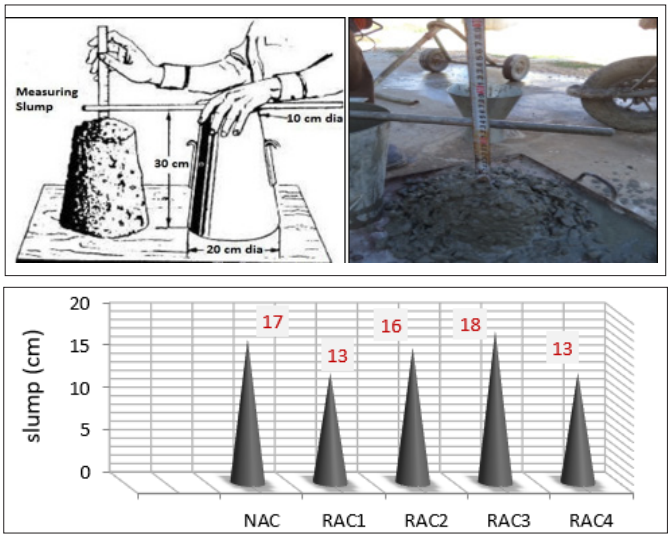

Figure 5: Slump Value Determination

Density

Density In this research, the density of concrete specimens was the theoretical density and it was calculated by dividing the weight of each cube on the cube volume. The same cube specimens which used to determine compressive strength were used to determine the density.

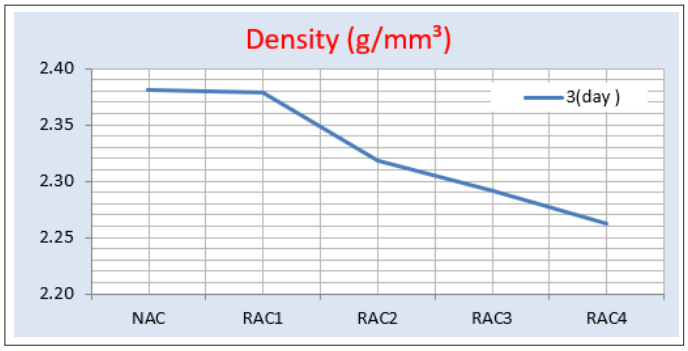

Figure 6: Concrete Density of Cube at 3 Days

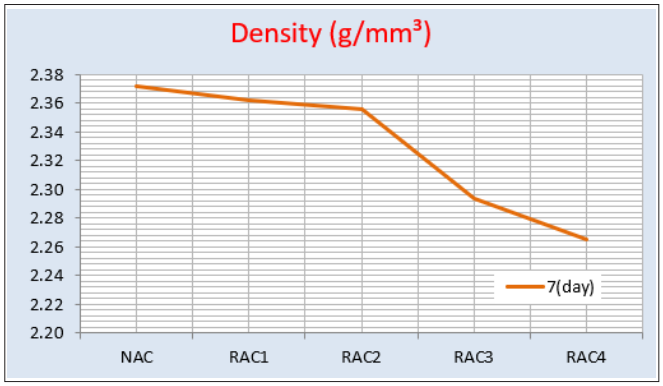

Figure 7: Concrete Density of Cube at 7 Days

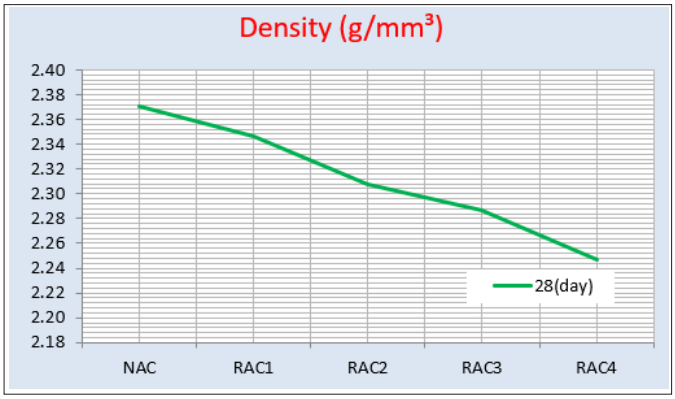

Figure 8: Concrete Density of Cube at 28 Days

Compressive Strength Test

The Compressive strength can be calculated by dividing the max load applied to the area of the cube. The formula for finding the Compressive strength is, C = P/A Where, P = Max load applied on the cube, A = Area of cross section of the cube

Table 7: Compressive Strength of Cube, 3Day, 7Day, 28 Day (Mpa).

	compressive strength of cube (Mpa)		
Variable	3(Day)	7(Day)	28(Day)
NAC	12.2948	21.1811	28.9473
RAC1	15.4785	21.5855	29.542
RAC2	11.255	19.8756	25.05
RAC3	12.9496	18.4733	25.67
RAC4	11.442	19.1255	26.559

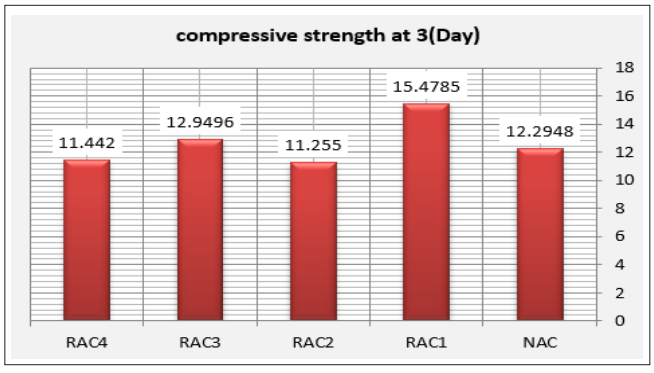

Figure 9: Compressive Strength of Cube at 3 Days

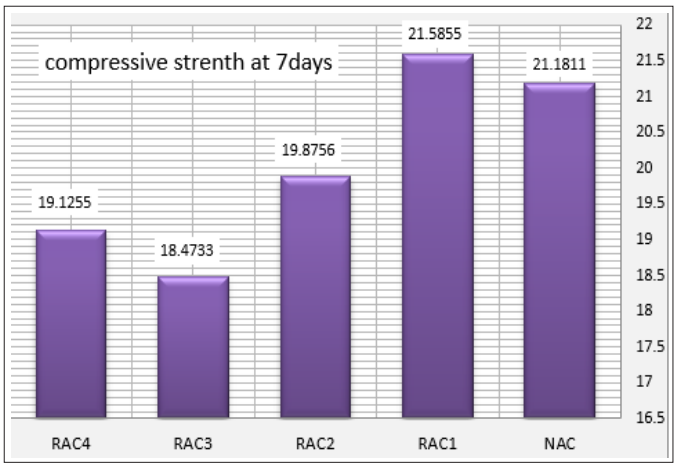

Figure 10: Compressive Strength of Cube at 7 Days

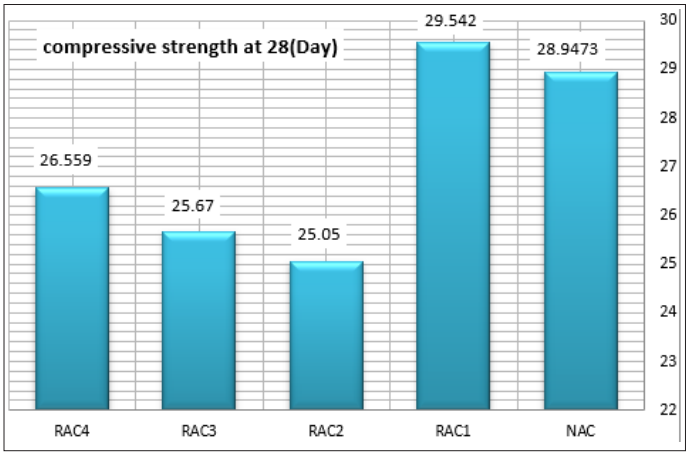

Figure 11: Compressive Strength of Cube at 28 Days

Conclusion and Recommendations

From the experimental work carried out on "Recycle of Concrete Aggregates", the following conclusion can be drawn:

1. Water absorption of RCA is higher than natural aggregate.
2. The compressive strength of concrete containing 25% recycled concrete aggregate has strength largest of concrete containing natural aggregate.
3. The compressive strength of concrete containing 50% recycled concrete aggregate has strength in close proximity to that of concrete containing 75% recycled concrete aggregate.
4. Public awareness must be achieved about Construction's and Demolition's wastes' problems and its effects, and importance of using this as new material in construction application to overcome this problem.
5. The slump of concrete containing recycled aggregate is observed to be less than the normal concrete one
6. Recommendations and specifications for recycled materials should be provided by local government or councils to promote their use. Detailed specifications should also be developed, including material properties and their appropriate applications. Recycled materials should be promoted as secondary materials in structural constructions.
7. Recycled concrete aggregate can be used for only roadwork, embankment, fill and non-structural applications.
8. Lack of awareness and absence of recycling in developing countries inhibits the growth of recycled concrete industry. However, engineering properties of recycled concrete aggregate needs conclusive evaluation and should be addressed by inclusion in codes.
9. Specifications and standards were found to be key to the future use of recycled aggregates. Work is required to develop specifications and standards in order to create opportunities for the increased use of recycled aggregates.
10. Development of relevant code standards for recycled aggregate and recycled aggregate concrete is necessary to provide manufacturers and consumers an assurance of quality.

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