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Evaluation of Recycled Demolition Waste Aggregates for base and sub-base use in Roads

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Abstract. Recycling of debris to obtain the recycled aggregates for sub-base materials in road construction is a foremost application to be promoted to gain economical and sustainable benefits. In this study, different types of demolition waste samples were subjected classification tests such as chemical tests, particle size distribution, compaction, California Bearing Ratio (CBR) test. The experimental work included fourteen samples at different weight were taken to determine the proportion of demolition waste subbase. The result of sampling tests were compared with the general specifications for roads and bridges (SORB/R₆), it was found that the effect of SO₃, gypsum and total soluble salt (TSS) parameter on the demolition waste subbase were low and the gradation of demolition waste subbase was class A. the California bearing ratio CBR value was 37% with maximum dry density 2035 kg/m³, in addition the average compaction test was 95.98%, whereas the optimum moisture content of the study materials was 8%.

Keywords: Demolition waste, sub-base, Recycling, Road materials, TSS.

1. Introduction

The difficulty of disposing of building material waste and lack of mineral resources has led to the interest in the recycling of demolition materials. The debris is described as a demolition waste includes damaged buildings materials, furnishings and other miscellaneous products. The sources typical debris in Ramadi city after damaged more buildings and infrastructure are comprises concrete, masonry bricks, building stones, gypsum used in traditional mortar and plastering, tiles, reinforcement bars, corrugated iron sheets, timber, doors and window frames, pipes and tanks, electrical wires and cables, and other material. Recycling of debris requires more mechanical processes. Therefore, additional organization and management is required to enable this activity. More study is required to determine debris composition and potential end user applications. Nevertheless, this should not discourage recycling efforts as a substantial volume of debris in Ramadi does not contain gypsum.

The developed countries are used the recycled concrete aggregate such as concrete slab, columns and foundation materials as a material building. In the present study, the available crushed debris as a demolition waste material in Ramadi city is evaluated and feasibility utilization it's as a sub base material in paving roads.



Jendia and Besaiso [1] were studied recycle of debris in Gaza district resulting from the war and this material were crushed by UN crusher. The researchers found that the aggregate of debris can be used successfully in road layers such as base and subbase. O'Mahony and Milligan[2] carried out a project to reuse of construction waste, particularly as aggregate to use it in the subbase layer in road pavement construction. This research has been investigating the properties of crushed concrete, the aggregate acquired from the beak up, the crushing of concrete slabs from road paving. The research found that the particle bigger than 37.5 mm did not have a significant impact on the demolition debris density. In addition, the site compaction was more efficient than the standard compatibility test generated. Furthermore, [3] mentioned that the recycled materials for pavement building, including recycled materials such as, concrete aggregate, asphalt concrete pavement, glass and pavement material. However, in base layers there are other materials used in construction and design, the using of this material are few in base course. The engineers of roads investigated all tests and they compared it with the local materials.

2. Material and methods

2.1. Describe the Interest Area

The province of Anbar lies in west of Iraq. It is a largest province of Iraq in the area and constitutes one third of the area of Iraq which amount of 138500 Km², as shown in Figure 1. the population of Anbar province is about 1600000 according to the census of 12 January 2014. There are about 80% of Ramadi city has been destroyed based on the military events for the period 14 May 2014 to 9 February 2016 as shown in Photo 1. There are three destroyed regions in anbar province, they are middle region which includes Ramadi center, Tameem, Al-Tash,Sofia, Jazeera, Sujariya, Khalidia and 5km area second region is east region which includes Fallujah, ameryat al-falujah ,qarma and saqlawya city . The third region is west region which includes heet ,rutba,, ana ,rawa ,kubaisa and al-qaim city . The study of debris was focus on Ramadi city only in addition the southern of Ramadi neighborhoods such as Al-aramil, Al-Bakr, AL-Huz, Al-Andulis and Adel district have also a great destroyed which reached about 90% [4]. A survey conducted by the United Nations last February of satellite images that about 5700 buildings in Ramadi were damaged Since mid-2014 and about 2,000 homes were completely destroyed, [5] Figures.2 and Figure 3 .The satellite images show the percentage of buildings damaged in Ramadi city from 6 July 2014 to 29 January 2016. The distribution of debris across the Ramadi city is displayed in which show a strong destroyed in most Ramadi Neighborhoods. The total quantity of debris in Ramadi city reached about 7,000,000 m³ due to Terror Wars from 2014 to 2016 where as there are other quantities of debris not raised in the city which estimated about 4 million m³. [6]



Figure 1. Map of Anbar province



Photo 1. The destroyed constructions of Ramadi city,[1].

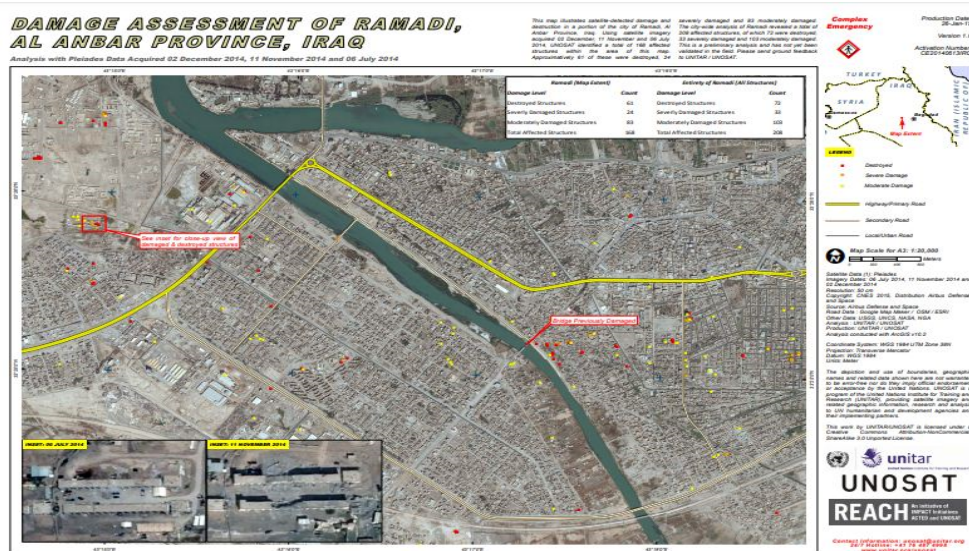


Figure 2. Damage scale the destruction of Ramadi city, Al Anbar Province, Iraq[3]

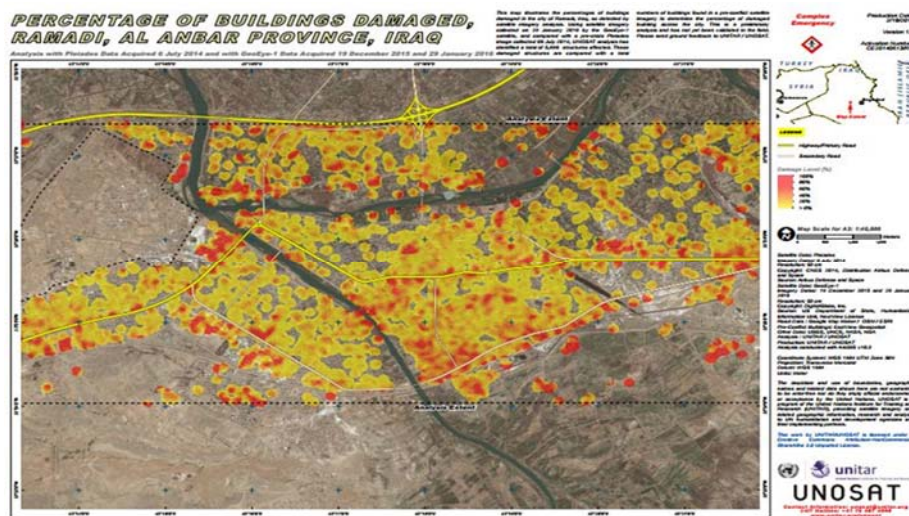


Figure 3. Damage scale the destruction of Ramadi city, Al Anbar Province, Iraq[7]

Disposal the debris in the planned landfill in Ramadi city was required costs of transportation but in future after the development of city and grow of infrastructure, other cost of debris transportation can be named as future transportation costs. There are two randomly landfill in Ramadi city, the first is Alhafria site in the city center with length of 1450 m and 100 width with depth of 8m and the second is Al-Sarah landfill in Al-Sofia area with dimensions of 3000m length, 250 m width and 5m to 7 depth as shown in Figure 4.



Figure 4. Locations of landfills in Ramadi City

2.2. Samples Collection and preparation

Thirty random samples were selected every twenty-five meters by utilization Loader machinery from AL-Sarah landfill location, the total quantity of the samples was 40 m³, as shown in Photo 2. The samples of demolition waste subbase were crushed in a small Crusher located near of University of Anbar; forty meters cubic of demolition waste subbase materials was crashed within two hours with maximum size of demolition waste subbase is 75mm.

The wood and plastic materials were throwing away by the sieve which was installed after the stage of debris crashing, as shown in Photo 3. The cost of crashing the demolition waste subbase per cubic meter is about 1500 Iraqi Dinar which is a cheaper than price of a cubic meter of natural subbase from quarries which it is 2000 Iraqi Dinars.



Photo 2. Debris materials Sampling process inside the hopper



Photo 3. The demolition waste subbase on the belt of crusher and sieve process after crushing.

3. Results of testing and Discussions:

3.1. Chemical tests for demolition waste subbase

Four samples were selected randomly to test SO₃, Gypsum and TSS parameter according to the British Standard Institutions [8] and its adjustments for 1999 and 2003. Table 1 shows the chemical tests for demolition waste sub base which indicated that the average values was in the limitations of British Standards.

Table 1. Chemical tests for demolition waste subbase

Type of tests	Sample 1	Sample 2	Sample 3	Sample 4	Average	British standard 1377[8]
Sulphate content tests SO₃%	1.20	1.18	1.28	1.24	1.22	Max. 5 %
Total soluble salts test (TSS)%	5.59	5.30	5.04	6.07	5.5	Max. 10 %
Gypsum content tests%	2.58	2.70	2.51	2.65	2.61	Max . 10.75%

3.2. Grain Size Distribution of demolition waste sub base

Based on maximum particle size limitations, the Iraqi specifications, [9] and National Center [10]. the granular demolition waste was classified into four classes A, B, C and D as shown in Table 2. The sieve analysis revealed that the granular size distribution in the present study within the specified range class A according of sieve passing as a percentage value.

3.3. Proportion of demolition waste subbase

Actually we took Fourteen samples randomly of demolition waste subbase were selected randomly at different weight to calculate the proportions of the debris components. Actually manually method to find the Proportion of demolition waste subbase The calculated percentages values of materials based on the total weight of samples were shown in Table 3.

Table 2. Sieve analysis of demolition waste subbase

Sieve mm	% of passing	Iraqi specification class,[9]			
		A	B	C	D
75	100	100	--	-	-
50	100	95-100	100	-	-
25	81	---	75-95	100	100
9.5	43	30-65	40-75	50-85	60-100
4.75	31	25-55	30-60	35-65	50-85
2.36	23	16-42	21-42	26-52	42-72
0.3	7.2	7-18	14-28	14-28	23-42
0.075	4.4	2-8	5-15	5-15	5-20

Table 3. Proportion of demolition waste subbase.

Sample NO.	Total Weight Gr.	Concrete and Gravel %	Brick %	Rock s%	Gypsum m%	Ceramic c%	Asphalt Concrete e%	Fine Material s%	Glass %	Wood d%	Plastic Material s%
1	3000	59.96	5.22	1.5	0.91	0.58	0.18	31.29	0.2	0.16	0
2	6431.5	31.5	1.64	5.2	0.87	3.9	0.37	56.2	0.007	0.03	0.15
3	5577	35.16	0.37	2.24	0.23	0.16	0.08	61.35	0.26	0.08	0.01
4	7065	29.46	4.11	0.96	0.04	1.24	0.5	63.45	0.07	0.08	0.04
5	7586	26.49	0.89	2.41	0.01	0.46	0.97	68.60	0.05	0.09	0
6	7050	40.58	0.15	0.93	0.01	0.22	2.36	55.68	0.01	0	0.01
7	7849	45.16	2.01	0.52	0.06	0.03	0.02	52.10	0.02	0.01	0.02
8	8268	34.96	0.33	2.67	0.22	0.14	0.03	61.58	0.01	0	0.01
9	5847	47.64	0.47	1.59	0.22	0.32	0.10	49.47	0.08	0.03	0.03
10	4078	29.42	1.15	9.12	0.34	0.02	0	59.66	0.09	0.02	0.14
11	6111	38.79	0.73	0.75	0.11	0.26	0	59.10	0.11	0.08	0.03
12	6945	38.12	0.54	22.75	1.35	0.56	0	36.54	0.05	0.01	0.04
13	6208	32.21	1.32	3.91	1.20	0.25	0.01	60.61	0.41	0.01	0.01
14	6388	47.37	0.04	0.68	0.23	0.18	10.42	41.01	0	0.01	0.01
Average %	6314.53	38.34	1.35	3.94	0.41	0.59	1.07	54.04	0.09	0.04	0.03

3.4. Compaction Test

A random 6-meter wide road selected for construction where the demolition waste subbase was spread over a section of (6m*6m) Laying the demolition waste subbase materials with 20 cm thickness as shown in Photo 4, however spraying with water then compact the materials by using steel roller as shown in Photo 5.



Photo 4. Shows laying the demolition waste subbase for testing



Photo 5. Shows the sprinkle with water, compaction and test the samples

Five samples of demolition waste subbase were taken to calculate the compaction test. The max. Dry density was 2035 kg/m³ and the optimum moisture content was 8%, as shown in Figure 5 whereas the average percentage of compaction test was 95.98 % as shown in Figure 6. The CBR value was 37%. According to Iraqi Standards for Roads and Bridges (SORB/R6). Resilient modules of demolition waste subbase were 377.7 Mpa. According to the AASHTO[11].

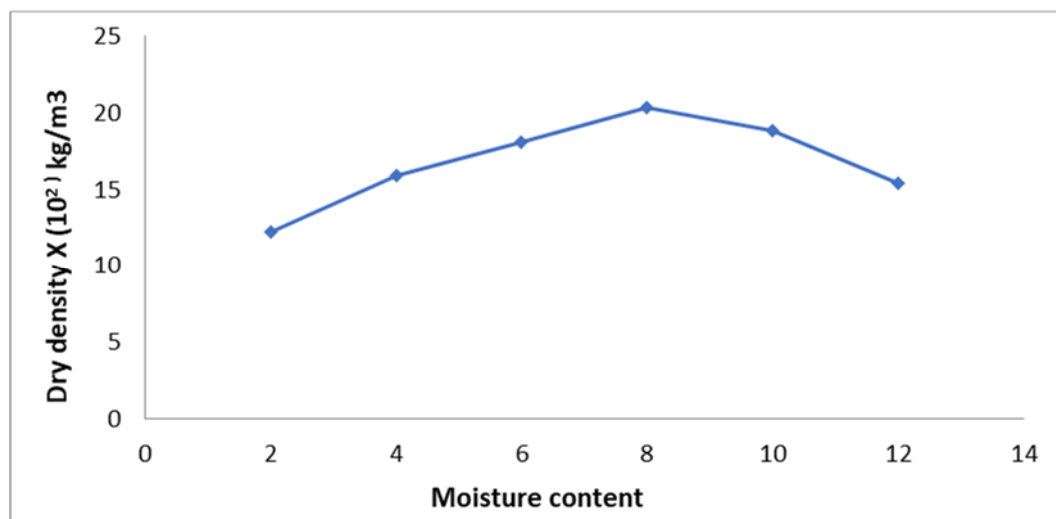


Figure 5. Relation between the moisture content and dry density for demolition waste.

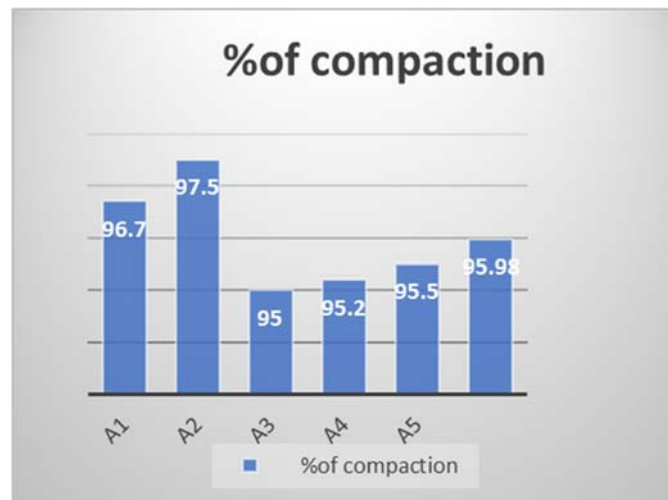


Figure 6. Compaction test of five samples

4. Conclusions

1. The chemical tests of demolition waste subbase such as SO₃, Gypsum and TSS tests were 1.22, 2.61 and 5.5 %, respectively which were within the limitation of British Standards.
2. The gradation of demolition waste subbase was class (A) for roads construction which was within the range of (81%-4.4%) passing through the sieve No. 25 mm to 0.075 mm
3. The Proportion of demolition waste subbase was suitable for base or sub-base layer in the road construction; however, the effect of gypsum, glass, wood and plastic materials on the demolition waste is very low.
4. The demolition waste subbase has a maximum dry density about 2035 kg/m³ with the moisture content of 8%, whereas CBR and compaction test were 37% and 95.98% respectively. Since the concrete and gravel were 38.34% and fine materials in the debris waste were 54.04%, it is suitable for using the materials as base or subbase layer in the road construction.

5. Recommendations:

To Preserve the natural resources of natural subbase in Anbar province and to protect the Ramadi city from the pollution, the study was recommended to utilize the demolition waste subbase in the service projects for Anbar province such as construction of roads and buildings and installed the debris crusher in the site of Al-Sarah landfill which is considered the biggest place to disposal the debris of demolition waste subbase with dimensions of 3000 meters length , 250 meters width and a depth was varying from (5 to 7) meters .

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