2nd Conference for Engineering Sciences and Technology -CEST2 29-31 October 2019 - Sabratha –Libya

Performance Evaluation of Hot Mix Asphalt Containing Recycled Concrete Aggregate

Ayad A.Mohammed[1*],Abdelmajeed Altlomate[2] ,Mohammed A.Al-Zarroug[3] , Muftah K.Hussain[4] , SafaaS.Al-Ramash[5]

[1]aermila@yahoo.com, [2]a.altlomate@su.edu.ly, [3]mohammed_alzroog@yahoo.com, [4]muftah9595@gmail.com,[5]safaa.salem1312@gmail.com

[1,2,3,4,5] Department of Civil Engineering, Faculty of Engineering, Sirte University, Libya

*Corresponding author email:

ABSTRACT

Application of building debris collected from destroyed buildings is an important issue in each country after crushing and inspection. This research includes evaluating the performance of the hot asphalt mixture containing the recycled concrete aggregate. Recycled coarse concrete aggregate were used in asphalt mixtures, and natural aggregate were used for comparison. A number of aggregate tests were performed, such as sieve analysis, specific gravity, absorption and abrasion. These tests are intended to verify the use of recycled concrete aggregate. Also, for comparison, the same tests were applied to natural aggregate. Furthermore, a number of bitumen tests are performed. They are penetration test, soften point, flash and fire point and specific gravity. The objective was to investigate their applicability to use as binder materials. Marshal samples are prepared using both natural aggregate and recycled coarse concrete aggregate to investigate the mechanical properties of the asphalt mix and compare results with specifications. The results showed that it is possible to use the recycled aggregate in hot mix asphalt taking into account the need to increase the bitumen content (about 0.6%) more than the mix Asphalt with the natural aggregate (i.e. the optimum bitumen content using recycled coarse aggregate is 5.8% and natural aggregate is 5.2%).

Keywords: Recycled ,Concrete ,Aggregate ,Asphalt, Marshal.

1. Introduction

In recent years, the city of Sirte has witnessed the large number of destroyed buildings due to wars, vandalism and destruction, which has led to the abundance of concrete residues and the occupancy of significant areas, thus becoming a new challenge for the local environment. The burial construction and demolition C&D waste is unsound and not practical in economic and environmental terms. Its use through recycling will provide opportunities for land, energy, time, resources and money[1].The use of C&D waste as a recycled aggregate is the main method of integrating waste into the construction and maintenance process, known as recycled concrete aggregate RCA.

RCA is obtained after the demolition of reinforced or plain cement concrete infrastructure. The initial demolition produces large fractions of concrete which could be reduced into smaller units for diverse uses. The physical, chemical and mechanical properties of RCA which are quite different from natural or virgin aggregate make it require extensive research to verify its suitability as a sustainable aggregate in hot mix asphalt HMA[2].

This research aims to evaluate the use of RCA obtained from C&D waste as coarse aggregate instead of natural aggregate in HMA. The objectives of this study are:

1. Determine the optimum bitumen content for the mixture.
2. Effect of RCA on the behavior and properties of asphalt mix.
3. Comparison between results of asphalt mix with both natural aggregate and RCA.

Several investigations examining the use of RCA from C&D waste in hot mix asphalt (HMA) have been conducted in recent years to pursue sustainable development. In these investigations, the mortar attached to the RCA surface caused the properties of RCA to be different from those of natural aggregate [3-4].

Aljassar et al., (2005) studied the use of aggregate obtained from building demolition waste in Kuwait to produce a mix of asphalt concrete with percentage (40%- 3/4 inch recycling concrete aggregate), and (30%-3/8 inch recycling concrete aggregate), The results obtained from this study showed that the asphalt concrete mix produced using aggregate from demolition waste can meet the requirements of local specifications[5].

Paranavithana and Mohajerani., (2006) compared the physical properties of asphalt samples containing RCA as an alternative to natural aggregate for roads pavement project. The RCA were obtained from crushing demolished concrete. These stone were highly porous due to the cement paste attached to the surface of the original stone. In addition to impurities, these pores had decreased its density, allowed more moisture ingress and eventually compromised its quality. The research results demonstrated that natural aggregate showed higher values than its recycled part in terms of resilient modulus, creep and physical properties. However, the RCA showed a higher percentage of air voids. Researchers recommended repeating the study using a different RCA[6].

Zhang et al., (2016) study the possibility of using RCA to replace coarse natural aggregate (NA) at different levels of substitution. The results showed that comparing NA with RCA has a less apparent relative density. The results showed that the HMA, which contains 50% recycled RCA, can be used satisfactorily in road construction. The study also recommended that more studies should be conducted on the RCA from multiple sources[7].

2. Materials and Methods

2.1 Materials

Materials required for this study are the component of hot mix asphalt. They are described in the following sections:

1. Bitumen

Asphalt binder 60/70 was used in this research brought from Mas company. The physical properties of the asphalt are presented in Table 1.

Table 1: *Physical Properties of the Asphalt*

Tests	Unites	Results
Penetration (25C,100 gm,5 sec) ASTM D-5	1/10 mm	63. 7
Softening point (ring and ball)ASTM D-36	°C	50.67
Specific gravity at 25 C ASTM D-70)	…..	1.019
Flash point ASTM D-92 (Cleveland open –cup)	°C	310.67
Fire Point ASTM D-92 (Cleveland open –cup)	°C	320

2. Aggregate

Three main types of aggregate were used in this experimental study which are coarse, fine and filler material brought from Crushed rocks Al Washka. The physical properties of the aggregate are shown in Table 2 and Table 3.

Table 2: *Physical Properties of the aggregate*

Property	Coarse Aggregate	Fine Aggregate
Bulk Specific Gravity ASTM C-127 and C-128	2.52	2.52
Apparent Specific Gravity ASTM C-127 and C-128	2.63	2.68
Percent Water Absorption ASTM C-127 and C-128	1.64	2.25
Percent Wear (Los Angeles Abrasion) ASTM C-131	10.8%	-

Table 3: *Physical Properties of the filler material*

Property	Filler material
Apparent Specific Gravity	2.63
% Passing Sieve no. 200	70.4

3. Recycled Concrete Aggregates

The source of the aggregate is the wreckage of the destroyed building in Sirte City See Figure 1, which was crushed and separated by the Crushing machine and then treated by Thermal- mechanical beneficiation method, also known as "heating and rubbing".

In this experiment, RCA samples were heated in a conventional oven at 300C° for 2 h. The heated RCA batches were then rubbed using a Los Angeles abrasion testing apparatus loaded with 10 steel balls for 100 revolutions[8]. The physical properties of the recycled concrete aggregates are shown in Table 4.

Figure 1: Demolished Building in Sirte City

Table 4: *Physical Properties of the recycled concrete aggregates*

Property	Coarse Aggregate (RCA)
Bulk Specific Gravity ASTM C-127 and C-128	2.39
Apparent Specific Gravity ASTM C-127 and C-128	2.61
Percent Water Absorption ASTM C-127 and C-128	3.47
Percent Wear (Los Angeles Abrasion) ASTM C-131	20.6%

2.2 Testing Program

- Preparation of a new gradient using coarse recycled aggregate that will be used for layers of flexible pavements (wearing course) within the standard gradient of these layers.
- Identifying Optimum Bitumen Content using Marshal Mix design procedure. Five percentages of bitumen have been examined to determine the best percentage of bitumen for the aggregate used, which include 4.5, 5, 5.5, 6 and 6.5% by weight of the mix.

3. Theory and Calculation

3.1Blending of Aggregate

Mixing more than one type of aggregate with different gradations is considered to be the first essential step in producing any asphalt mix. For this purpose, three different sizes of aggregate were blended with different proportions until reaching the acceptable limits of aggregate gradations used for asphalt according to ASTM specifications.

The method of trial and error is used. It is the most common and easy way to determine the mixing ratios. The calculations are performed using the following equation:

$$Pi = Aa + Bb + Cc \quad (1)$$

where,
Pi= % of material passing a given sieve for the blended aggregate.
A, B, C = % of material passing a given sieve for each aggregate.
a, b, c = Proportions (decimal fractions) of aggregate A, B, and C, where the total is 1.

An initial set of ratios of a ,b ,c is determined so that the total groups for all percentages are 100%, If the resulting gradient is within acceptable limits, then the process is completed without further modifications. This is the chosen choice; if not, an adjustment must be made to the overall volume ratios and repeat calculations until a gradient is reached.[9]

3.2Marshall Test

The optimum bitumen content to be added to specific aggregate blend is done utilizing the Marshall Method for asphalt mix content. This results in a mix that meets the desired strength and durability properties. According to standard 75-blow Marshall design method designated as (ASTM D1559) a number of 15 samples each of 1200 gm in weight approximately were prepared using five different bitumen contents (from 4.5 - 6.5% with 0.5 % incremental).

Various bitumen contents determine the Marshall properties of an asphalt mix. These properties include stability, flow, density, air voids in total mix, voids in mineral aggregate and voids filled with bitumen percentage.

3.2.1 Bulk Specific Gravity of Compacted Mixture

The density - voids analysis for an asphalt mix begins with the determination of the bulk specific gravity (G_{mb}) of compacted mixture .

$$G_{mb} = \frac{A}{B-C} \tag{2}$$

Where,

G_{mb} = bulk specific gravity of compacted specimen.

A = mass of the dry specimen in air, g.

B = mass of the saturated surface-dry specimen in air, g.

C = mass of the specimen in water, g.

3.2.2 Theoretical Maximum Specific Gravity

The theoretical maximum specific gravity of an asphalt concrete mixture is the specific gravity of the mixture at zero air void content.

$$G_{mm} = \frac{A}{A+D-E} \tag{3}$$

Where,

G_{mm} = theoretical maximum specific gravity of loose mixture.

A = mass of oven-dry specimen in air, g.

D = mass of container filled with water to calibration mark, g.

E = mass of container with specimen filled with water to calibration mark, g.

3.2.3 Volumetric Analysis

a) Air Void Content

Air void content is calculated from the mixture bulk and theoretical maximum specific gravity[10].

$$VA = 100\left(1 - \frac{G_{mb}}{G_{mm}}\right) \tag{4}$$

Where,

VA = Air void content, volume %.

b) Asphalt Binder Content.

$$VB = \frac{PbG_{mb}}{Gb} \tag{5}$$

where

VB =Total asphalt binder content, %by total mix volume.

P_b =Total asphalt binder content, % by mix mass.

G_b =Specific gravity of the asphalt binder.

$$VBA = G_{mb}\left(\frac{Pb}{Gb} + \frac{Ps}{Gsb} - \frac{100}{G_{mm}}\right) \qquad (6)$$

Where

VBA =Absorbed asphalt content, % by total mixture volume.

P_s=Total aggregate content, % by mix mass.

G_{sb} =Average bulk specific gravity for the aggregate blend.

$$VBE = VB - VBA \qquad (7)$$

Where

VBE =Effective asphalt content, % by total mixture volume

c) Voids in the Mineral Aggregate (VMA)

VMA is simply the sum of the air void content and the effective asphalt binder content by volume[10].

$$VMA = VA + VBE \qquad (8)$$

Where,

VMA = Voids in the mineral aggregate, % by total mixture volume.

d) Voids Filled With Asphalt (VFA)

VFA is the effective binder content expressed as a percentage of the VMA[10].

$$VFA = 100\left(\frac{VBE}{VMA}\right) \qquad (9)$$

Where,

VFA is the voids filled with asphalt, as a volume percentage.

4. Results and Discussion

4.1 Marshall Test Results

The results of Marshall tests show almost typical relationships between Marshall properties and asphalt content as shown in Figures (2-7).

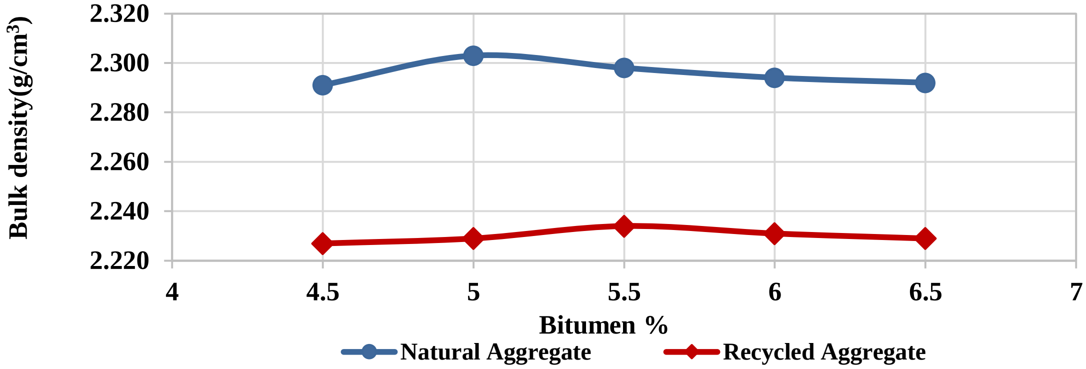

Figure 2: Bulk density vs bitumen content

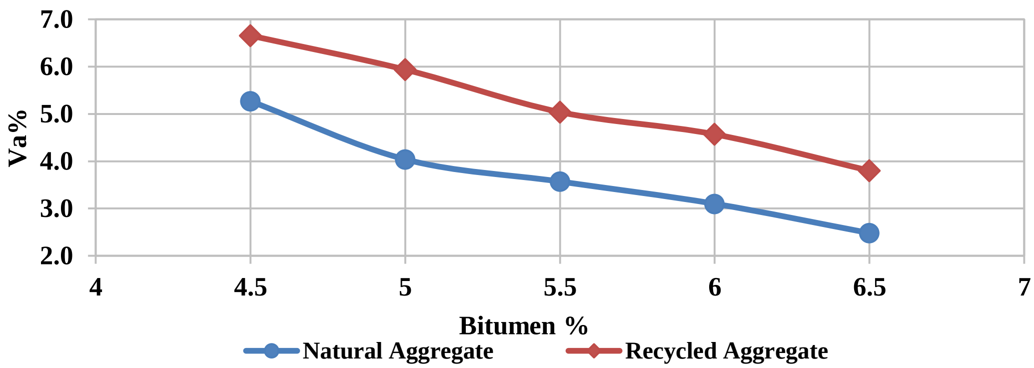

Figure 3: Air voids proportion vs bitumen content

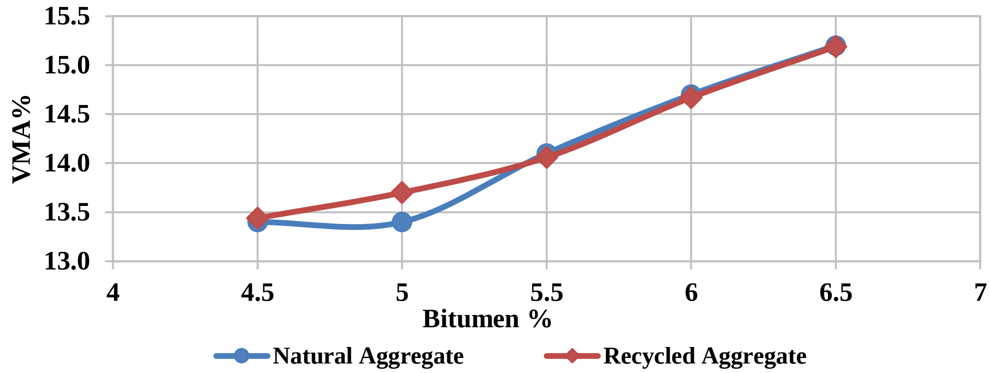

Figure 4: Voids of mineral aggregate proportion vs bitumen content

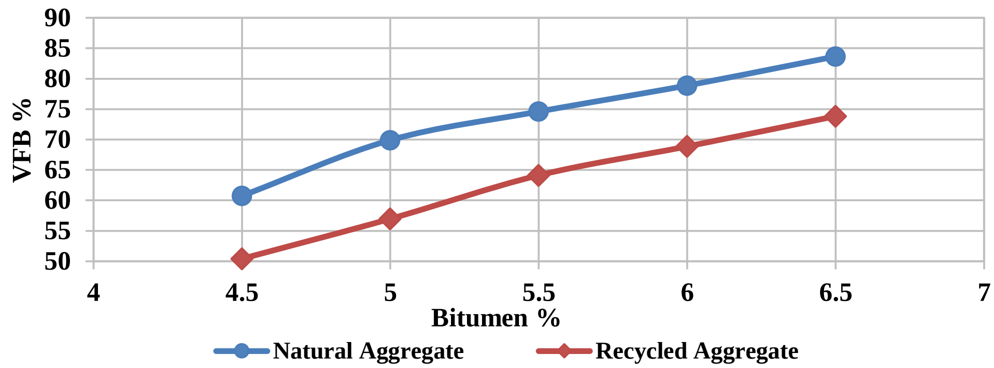

Figure 5: Voids filled bitumen proportion vs bitumen content

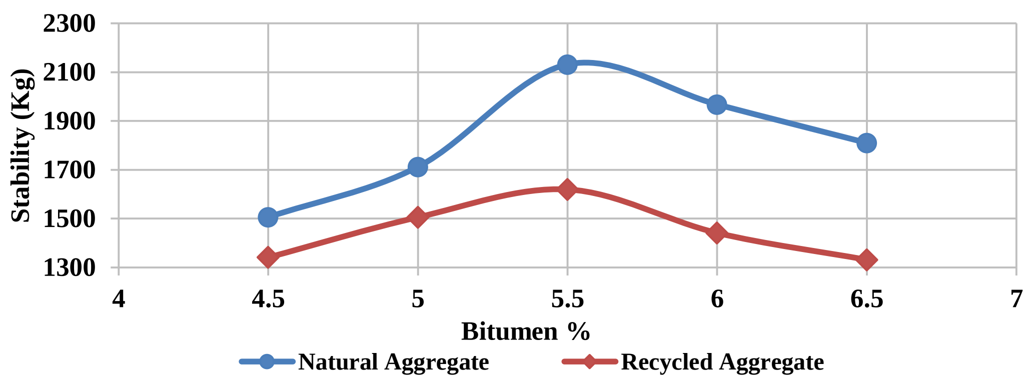

Figure 6: Stability vs bitumen content

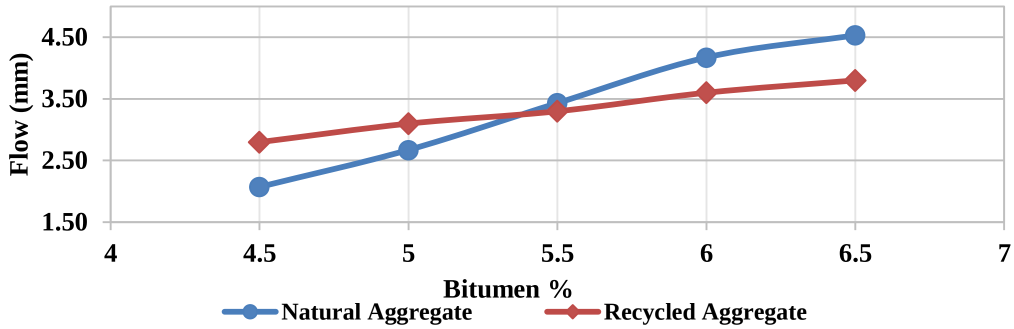

Figure7: Flow vs bitumen content

From Marshall Test result the optimum asphalt content are (5.2)% for conventional mixture and (5.8)% for mixture with RCA. It can be observed that the optimal bitumen ratio increases with the use of RCA , which is resulted from the absorption of asphalt into porous cement mortar that is adhered to the surface of the natural aggregate in RCA.

The main properties of the asphalt mix using the optimum bitumen content with both types of aggregate are shown in Table 5.

Table 5:*Marshall test results*

Marshall Properties	Units	conventional Mixture	Mixture with RCA
Stability	kg	1880	1520
Flow	mm	3.0	3.5
Bulk density	g/cm^3	2.302	2.232
Va	%	3.8	4.7
VMA	%	13.7	14.4
VFB	%	72	67

It’s obvious that asphalt mix with recycled aggregate have lower stability compared to the conventional asphalt mix, other properties of mix are still within the allowed range of the design criteria. Increase of flow, air voids and VMA% in asphalt mix with recycled aggregate is exhibited while VFA% and bulk density is lower. However, the asphalt mix with recycled aggregate satisfy the requirements of asphalt institute specifications for all tested properties[11].

5. Conclusions

Based on experimental work results for Asphalt mixtures with recycled aggregate compared with conventional asphalt mixtures, the following conclusions can be drawn:

1. The results showed that it is possible to use the RCA in hot mix asphalt taking into account the need to increase the bitumen content (about 0.6%) more than the mix asphalt with the

natural aggregate (i.e. the optimum bitumen content using recycled coarse aggregate is 5.8% and natural aggregate is 5.2%).

2. The effect of use RCA rather that NA on the investigated mechanical properties of the hot mix asphalt using the optimum bitumen content was as the following:

a) The bulk density of the mixture decreased from (2.302 to 2.232) g/cm^3 because of the residual mortar in the RCA.

b) A noticed Increase of the proportion of air voids in the mixture by about 23.6% this due to the high porosity of RCA comparing with NA.

c) A slight Increase of the proportion of VMA in the mixture from 13.7% to 14.4%.

d) VFB proportion in the mixture reduced by about 7% from 72% to 67%.

e) The Stability dropped by about 19.1% from 1880 to 1520 kg.

f) An increase of the Flow by about 16.66% from 3.0 to 3.5 mm.

3. The results obtained from this study showed that the asphalt concrete mix produced using aggregate from demolition waste can meet the requirements of the design criteria.

Acknowledgment

Our sincere thanks go to Allah almighty for being our guide throughout the duration that this work lasted .We wish to thank all lecturers in the department of Civil Engineering during the course of this work. Great people, Great work, Great work makes a great nation.To all those who helped us in one way or the other, though their names are not listed here, We say thank you all.

References

[1] Kartam, N., Al-Mutairi, N., Al-Ghusain, I., & Al-Humoud, J. (2004). *Environmental management of construction and demolition waste in Kuwait. Waste Management, 24(10), 1049–1059*.

[2]Mills-Beale, J., & You, Z. (2010). *The mechanical properties of asphalt mixtures with Recycled Concrete Aggregates. Construction and Building Materials, 24(3), 230–235.*

[3] Tam, V. W. Y., Tam, C. M., & Le, K. N. (2007). Removal of cement mortar remains from recycled aggregate using pre-soaking approaches. Resources, Conservation and Recycling, 50(1), 82–101.

[4] Pérez, I., Pasandín, A. R., & Medina, L. (2012). Hot mix asphalt using C&D waste as coarse aggregates. Materials & Design (1980-2015), 36, 840–846.

[5] Aljassar, A. H., Al-Fadala, K. B., & Ali, M. A. (2005). Recycling building demolition waste in hot-mix asphalt concrete: a case study in Kuwait. Journal of Material Cycles and Waste Management, 7(2), 112–115

[6] Paranavithana, S., & Mohajerani, A. (2006). Effects of recycled concrete aggregates on properties of asphalt concrete. Resources, Conservation and Recycling, 48(1), 1–12.

[7] Zhang, Z., Wang, K., Liu, H., & Deng, Z. (2016). Key performance properties of asphalt mixtures with recycled concrete aggregate from low strength concrete. Construction and Building Materials, 126, 711–719.

[8] Akbarnezhad, A., & Ong, K. C. G. (2013). Separation processes to improve the quality of recycled concrete aggregates (RCA). Handbook of Recycled Concrete and Demolition Waste, 246–269.

[9] Roberts FL، Kandhal PS، Brown ER، Lee D-Y، Kennedy TW. (1996) Hot Mix Asphalt Materials, Mixture Design and Construction. 2nd Edition, NAPA Education Foundation, Lanham

[10] Christensen, D. W., "A Manual for the Design of Hot Mix Asphalt Commentary" NCHRP Report 673, National Cooperative Highway Research Program, Washington, D.C., 2010.

[11] The Asphalt Institute (AI) 2014, 'Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types (MS-2)', The Asphalt Institute, 7th Ed.