Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (40) No. (3) July, 2018

Use of Recycled Concrete in Hot Mix Asphalt

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ملخص البحث

- في الآونة الأخيرة، شهدت مصر طفرة في بناء شبكات الطرق. وهذا يتطلب توافر مواد بناء الطرق، وأهم هذه المواد هو الركام الطبيعي و الذي يمثل إنتاجه عبئا بيئيا كبيرا، ومع توفر كميات هائلة من نفايات الهدم والبناء في مصر، بدأ التفكير في استخدام هذه النفايات كبديل للركام الطبيعي في تشييد الطرق لأن استخدام هذه النفايات سيحافظ على البيئة ويوفر تكلفة إنشاء الطرق. ومن أهم عناصر مخلفات البناء والهدم هي كسر الخرسانة و التي يتم إعادة تدويرها لتكون صالحة للاستخدام في الأغراض الصناعية المختلفة. و قد أظهر استخدام الخرسانة المعاد تدويرها نتائج جيدة في أكثر من عنصر من عناصر إنشاء الطريق مثل : طبقة الأساس و الأساس المساعد ، و الفواصل الخرسانية و البردورات. و في هذا البحث ندرس إمكانية استخدام الخرسانة المعاد تدويرها في عمل الخلطات الأسفلتية الساخنة لتكون بديلا للركام الطبيعي و ذلك بنسب مختلفة بحيث تمثل (25% ، 50% ، 75% ، 100%) من نسب الركام الخشن في الخلطة الأسفلتية الساخنة باستخدام طريقة مارشال.

Abstract:

Recently, Egypt witnessed a boom in the construction of road networks. This boom requires the availability of road construction materials, the most important of which is natural aggregates, whose production represents a great pressure on the environment. And with the availability of huge quantities of demolition and construction wastes in Egypt, began to think about the use of these wastes as an alternative to natural aggregates in the construction of roads because the use of these wastes will preserve the environment and provide the cost of roads construction. One of the most important elements of the construction and demolition waste is Recycled Concrete Aggregates (RCA). RCA has seen promising results when utilized as ordinary aggregates, base aggregates and Portland Cement Concrete (PCC) aggregates.

In this research, we investigate the use of RCA in the design of hot asphalt mixtures using Marshall mix design method. The concrete aggregate obtained from crushing the concrete cubes and beams from Concrete Laboratory at Ain Shams University and sieving to get the required sizes of aggregate particles to make locally asphalt mixtures (Type 4C and 3D) with percent (25,50,75,100) % from the percentage of coarse aggregate.

Asphalt mixtures were tested by Marshall test, Indirect tensile strength test, and the loss of stability test.

Keywords: Recycled Concrete Aggregate; Asphalt mixture; Indirect tensile strength; Loss of stability; Optimum Bitumen Content.

1. Introduction

In the recent decades, the growth in industrial production and consequent increase in consumption has led to a fast decrease of available natural resources (raw materials or energy sources). On the other hand, a high volume of production has generated a considerable amount of waste materials which have destructive impacts on the environment. Many countries have been working for new regulations on how to minimize and reuse the generated waste. In the asphalt highway industry, a considerable number of innovative materials and technologies are being explored to achieve their suitability for the design, construction and maintenance of these pavements. Warm Mix Asphalt (WMA), Recycled Asphalt Pavement (RAP), fly ash, bottom ash and shingles are some of the materials that transportation researchers suppose hold the future to sustainability in the asphalt highway industry.

In Egypt, there is a continuous and urgent demand for paving roads, especially in villages and suburbs far from Cairo, and this needs high costs and large energies. It is important to consider inexpensive resources and meet the continuous needs of paved roads. This will contribute to the use of demolition and construction waste, especially since these wastes represent a large proportion of the total solid waste that pollutes the environment daily. Thus, the use of concrete waste resulting from demolition and construction will save the cost of road construction and significantly help in preserving the environment.

1.1 Objective

1. To investigate the portability of using different percentage (0,25,50,75) % of recycling building demolition waste as coarse aggregate in hot mix asphalt after determining the optimum asphalt content for pure mixture (0 % RCA).
2. Design a mixture with 100 % RCA and compare it to the pure mixture.

2. Literature Review

RCA is being used in many transportation infrastructure applications such as in base aggregate, PCC aggregate, unbound and bound pavement layers across the United States. Nevertheless, the use of RCA in HMA has seen limited use due to minimal research investigations into its suitability. With rising transportation and disposal-related costs, depleting natural aggregate sources, and landfill availability, using RCA in asphalt pavements is being studied worldwide to determine its suitability or otherwise. In studying the use of RCA in HMA, it is pertinent to understand key aspects of its interaction with asphalt such as its absorptive behavior under dynamic loading conditions.

Paranavithana and Mohajerani (2006) performed experiments on the effects of recycled concrete aggregates on the properties of HMA, in which 50% RCA by dry weight of total aggregates was used as coarse aggregate in the asphalt mixtures. The performance tests carried out on these mixes showed that, using RCA in HMA mixtures lowered the resilient modulus and creep resistance of the mix and increased the stripping potential of them. In addition, the mixes containing RCA showed large variations in strength under dry and wet conditions.

Wong et al., (2007), studied on the utilization of RCA as a partial aggregate substitution in HMA. Three HMA mixes were included in the study by substituting granite filler/fines with 6% untreated, 45% untreated, and 45% heat-treated recycled concrete, respectively. All three mixes passed the wearing course criteria specified by the Singapore Land Transport Authority (SLTA), based on the Marshall mix design method. The performance tests on the mix with 6% RCA showed comparable resilient modulus and creep resistance to those of the traditional HMA mix. The mixes with the higher percentage of RCA showed higher resilient modulus and resistance to creep.

Another research was conducted by Topal et al., (2006), who studied on use of recycled concrete aggregates in hot-mix asphalt. They found that, RCA can substitute HMA aggregates and achieve the required Marshall Stability (MS) and Indirect Tensile Strength (IDT) of the mixtures. The test results indicated that, the Marshall Stability values increased with the increase of RCA in the mix. However, the voids in mineral aggregate (VMA) and the voids filled with asphalt (VFA) decreased with the increase in RCA content. This was believed to be due to crushing of RCA by the Marshall compactor during compaction. The tensile strength of the mix containing RCA was found to be higher than that of the control mix as the internal friction of RCA was higher than that of natural limestone aggregates. Eventually, RCA was not recommended to be used in the wearing course due to RCA's susceptibility to abrasion by vehicles.

Hassanied et al., (2016) assessed a case study on performance of recycled construction demolition wastes in asphalt mixtures. In this study various percentages of fine aggregates in hot mix asphalt mixtures were replaced by fine RCA. Test results indicated the feasibility of up to 30% fine RCA in hot mix asphalt mixtures in terms of Marshall stability and indirect tensile strength tests.

Marques et al., (2014) investigated the comparative study between asphalt mixtures containing natural and recycled concrete aggregates. In this study, 25, 50 and 100% of virgin aggregates were replaced by recycled concrete aggregates. Test results showed that the values of air voids and voids filled with asphalt in mixtures containing 50% and 100% RCA did not meet the relevant standard requirement. Therefore, it was concluded that replacing the virgin aggregates with 25% of RCA not only have environmental and economic benefits, but also can satisfy the standard requirements for pavement surface.

Moghadas Nejad et al., (2013) performed research on fatigue performance of hot mix asphalt mixtures containing recycled concrete aggregates. The indirect tensile fatigue test was used to measure the behavior of hot mix asphalt mixtures containing 0%, 35%, 70% and 100% RCA. It was found that, use of RCA in asphalt mixtures reduces the production costs and prevents much fullness of the recycled materials in the environment. It was found that using up to 100% RCA instead of virgin limestone in the asphalt mixtures improved the fatigue performance of the asphalt specimens.

3. Experimental Design and Testing Procedure

- Materials

We obtained limestone aggregates, 60/70 penetration grade bitumen, natural sand, sand produced from crushing limestone, fillers from cement dust, and recycled concrete aggregates (RCA) for use in this research. The crushed limestone aggregates were provided from rock quarry near Cairo. To obtain the RCA, concrete infrastructures were first demolished and crushed manually into suitable sizes using a medium hammer. The RCA was produced from the concrete cubes and beams from concrete laboratory at Ain Shams University. The concrete had a density of 2400 kg/cm3 and compressive strength of 40 MPa.

- The physical properties of used materials described in the following tables:

Table 1. Physical Properties of Asphalt Cement

Test	Unites	Penetration grade (60-70)
Penetration (25C,100 gm,5 sec) - ASTM D-5	1/10 mm	64
Rotational viscosity at 135° C - ASTM D-4402	cP	415
Softening point (ring and ball) - ASTM D-36	°C	48.0
Specific gravity at 25° C - ASTM D-70	…..	1.020

Table 2. Physical Properties of Natural Coarse Aggregates and RCA

Property	Coarse Aggregate (Size 1)	Coarse Aggregate (Size 2)	RCA
Bulk Specific Gravity ASTM C-127 and C-128	2.475	2.583	2.346
Apparent Specific Gravity ASTM C-127 and C-128	2.723	2.727	2.619
Percent Water Absorption (%) ASTM C-127 and C-128	3.677	2.051	4.483
(Los Angeles Abrasion) ASTM C-131	20.10%	18.28%	32.00%

Table 3. Physical Properties of Fine Aggregate and Mineral Filler

Type	Specific Gravity
Natural Sand	.609
Crushed Sand	2.727
Cement Dust (Filler)	2.715

Table 4. The aggregate gradation used in hot asphalt mixtures type 3d & 4c

Mix Type / Sieve Size	3 D (Open graded)	4C (Dense graded)
50 mm	-	-
37.5 mm	-	-
25 mm	100	100
19 mm	75 - 100	80 - 100
12.5 mm	-	-
9.5 mm	45 - 70	60 - 80
4.76 mm	30 - 50	48 - 65
2.36 mm	30 - 35	30 - 35
1.18 mm	-	-
600 µm	5 - 20	19 - 30
300 µm	3 - 12	13 - 23
150 µm	2 - 8	7 - 15
75 µm	0 - 4	3 - 8

- Testing Program

This study was conducted in two stages. The first stage was to design the control mixture that contained 0 % RCA to determine the optimum bitumen content (OBC), and then make mixtures with different percentages of RCA (25, 50, and 75) % using the OBC of the control mixture. In the second stage, mixture of pure RCA (100% RCA) was designed to determine the OBC of this mixture.

1- Stage I: Control Mixture "RCA = 0%"

- The control mix design was carried out using 4.80 % asphalt contents, which is the optimum bitumen content for the binder coarse mixtures and 5.25 % for the wearing surface mixtures. All mixtures were prepared according to the Egyptian standard assuming heavy traffic. The two types of mixtures were:

  1) 3 D for binder coarse mixture. 2) 4 C for wearing surface mixture.

  - Three different percentages of coarse RCA (25%, 50%, and 75%) were blended with the natural coarse aggregate**.**

  - The main properties of control mixture and different percentages of RCA mixtures at optimum bitumen content of control mixture including (Bulk Density, Marshal Stability, Flow, Voids in Total Mix, Marshall Stiffness, Voids in Mineral Aggregates, Voids Filled with Bitumen, Loss of stability, and Indirect Tensile Strength) were obtained.

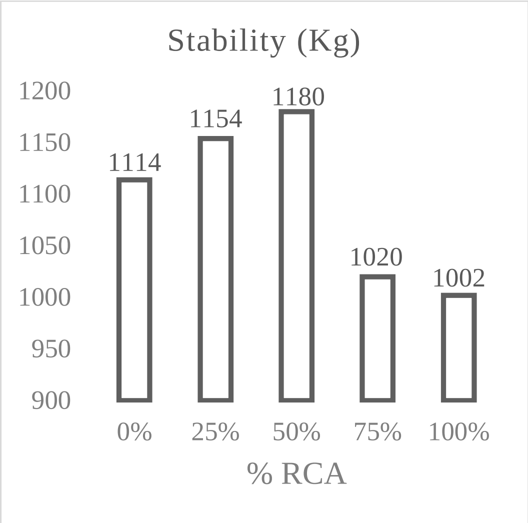
2- Stage II: 100% RCA Mixture

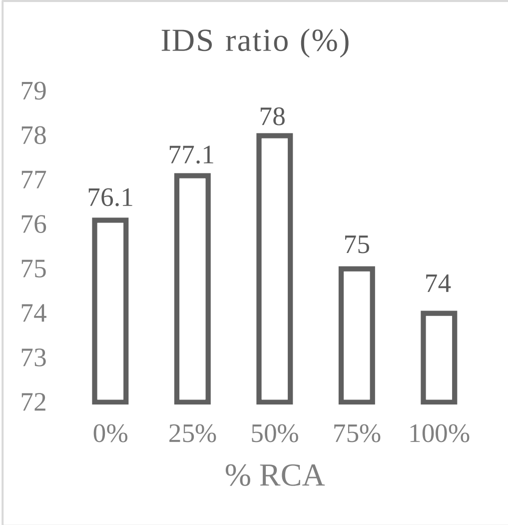
- Mixture of pure RCA (100% RCA) was conducted using 5.0 % asphalt contents, which is the optimum bitumen content for the binder coarse mixtures and 5.25 % for the wearing surface mixtures. Also, the main properties mentioned above of this mixture were obtained.

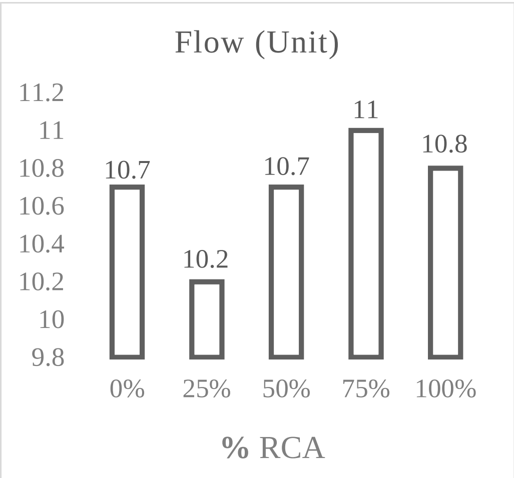
4. Results

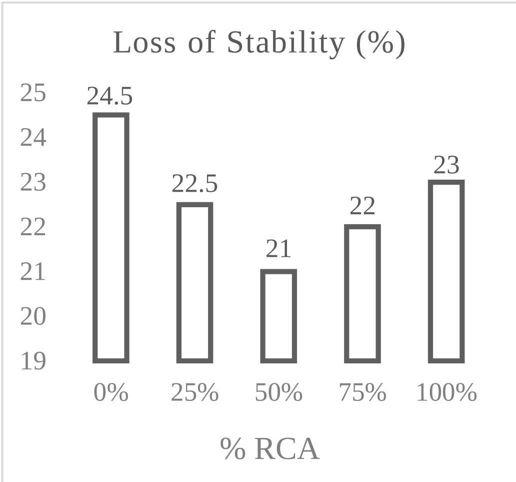
The following charts show the obtained results of different characteristics for the various percentages of RCA (0, 25, 50, 75, 100) % RCA for the two types of asphalt mixtures, which are the binder coarse mixture and wearing surface mixture:

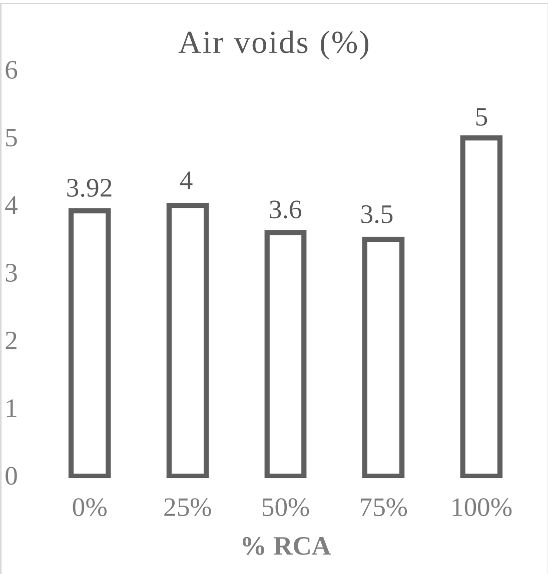
First: Binder coarse Mixture:

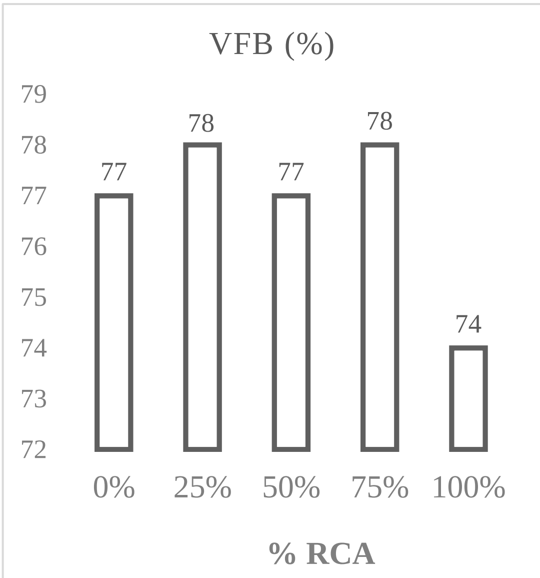




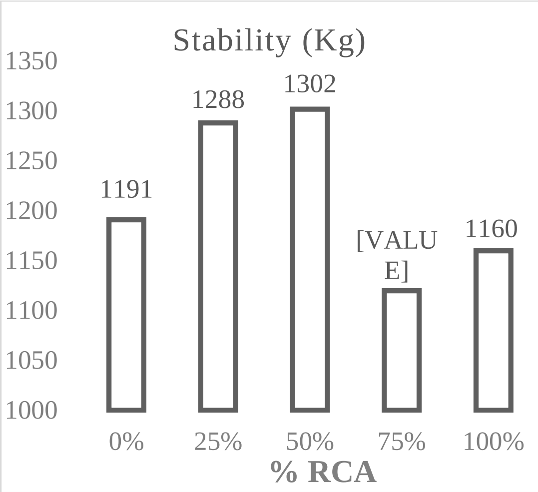


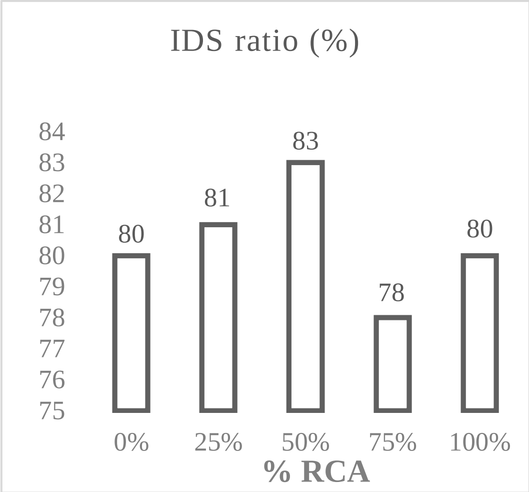


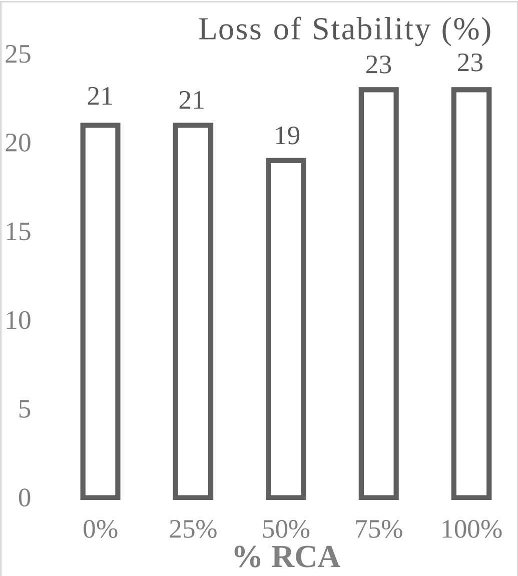


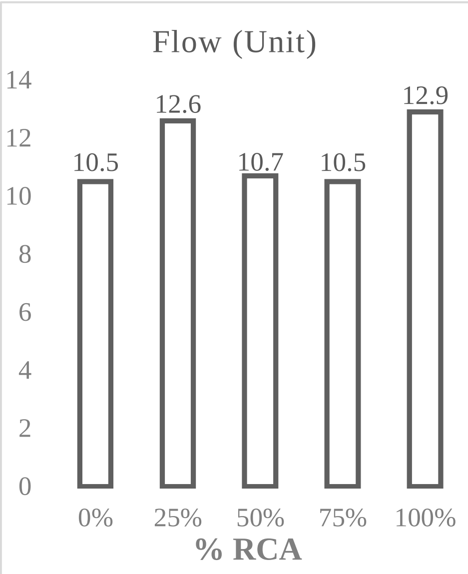


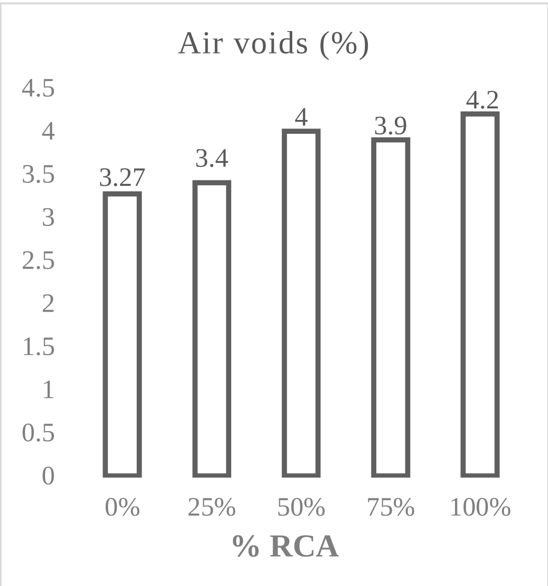
Second: Wearing Surface Mixture:

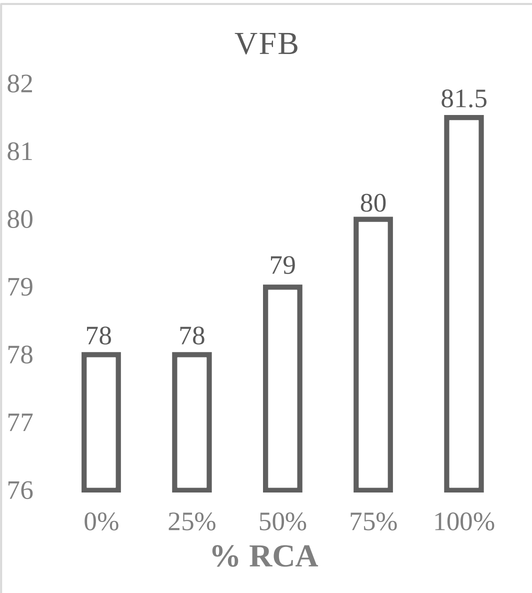












5. Conclusion

Within the limitations of materials and testing program used in this work, the following conclusions could be drawn:

1. The best content of recycled concrete Aggregate percent that improving the Marshall stability, flow, air void, tensile strength, and loss of stability of asphalt mixture is 50% by weight of coarse aggregate.

2. All samples with different RCA contents meet the specifications of Egyptian code.

3. We can try to use pavement section containing the best content of RCA in the asphalt mixtures in local roads in Egypt and see the performance of the asphalt mixture under the traffic loads and surrounded environmental conditions for one year.

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