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Use of Recycling Building Demolition waste As Coarse Aggregate in Hot Mix Asphalt

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ABSTRACT

At the recent years in Iraq, building demolition increase because of wars and the processes of destruction that lead to increase concrete waste, causing extreme pressure on the available land-filled sites that's becomes a new challenge to local environment, in addition to south region from country poor from aggregate source.

So this study make as first evaluation to return use concrete aggregate for old and demolition building in concrete asphalt mix, the concrete aggregate obtained from building to live long more than 20 years after crash reinforcement concrete and sieving to get requirement granular particle to make locally asphalt mixture (Type IIIB) depends on modified specification of State Commission of Roads and Bridges (2003) with percent (0,25,50,75,100)% from weight 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.

استخدام مخلفات البناء المعادة كركام خشن في الخلطات الإسفلتية

الخلاصة

في السنوات الأخيرة شهد العراق كثرة الأبنية المهدمة بسبب الحروب وإعمال التخريب والتدمير مما أدى إلى كثرة مخلفات الخرسانة وإشغالها لمساحات كبيرة فأصبح ذلك تحديا جديدا للبيئة المحلية، وإضافة إلى افتقار المناطق الجنوبية من القطر إلى مقالع الركام.

لذا أجريت هذه الدراسة كتقييم أولي لإعادة استخدام ركام الخرسانة للأبنية القديمة والمهدمة في الخلطات الإسفلتية، وقد تم الحصول على ركام خرسانة من مبنى عمره أكثر من 20 سنة وذلك بعد تكسير الخرسانة المسلحة ونخل الخرسانة المكسرة للحصول على الركام الحبيبي اللازم لعمل خلطة إسفلتية محلية (Type IIIB) وذلك حسب المواصفة العامة للطرق والجسور المعدلة 2003 وبنسب (100,75,50,25,0)% من وزن الركام الخشن.

وخضعت الخلطات الإسفلتية المختلفة لعدة اختبارات وهي مارشال واختبار الشد الغير مباشر وحساب فقدان الثبات.

الكلمات الدالة: الركام الخرساني المعاد، الخلطة الإسفلتية، مقاومة الشد الغير المباشر، الفقدان في الثبات.

ASTM= American society of testing and material.

WMA= Warm mix asphalt**.**

RAP = Recycled asphalt pavement.

RCA = Recycled concrete aggregates.

PCC = Portland cement concrete**.**

HMA= Hot mix asphalt.

RBM = Recycled building materials.

ICS = Igneous crushed stone.

SMA = Stone mastic asphalt.

XRD = X-ray diffraction.

SEM = Scanning electron microscopy.

SCRB= State commission of road & bridges.

P_{ult} =Ultimate applied load at failure.

t = Thickness of specimen.

d = Diameter of specimen.

TS= Temperature susceptibility.

O.A.C = Optimum asphalt content.

INTRODUCTION

In 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 adverse impacts on the environment. many countries and international establishments have been working for new regulations on how to minimize and reuse the generated waste [1]. in the asphalt highway industry, a considerable number of innovative materials and technologies are being explored to ascertain 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 believe holds the future to sustainability in the asphalt highway industry.

in utilizing these materials, the resulting merits are highly significant. these benefits range from natural resource conservation, optimization of landfill use, waste dumping charge savings, emission reductions and energy savings. the overall gain to the taxpayer cannot be under estimated[2].

one potential material that has seen little investigation for its recyclable use in asphalt pavement is recycled concrete aggregates (rca). rca has seen promising results when utilized as ordinary aggregates, base aggregates and portland cement concrete (pcc) aggregates in texas, california, minnesota, michigan and virginia. in terms of rca use in hma, the states of utah, minnesota, michigan, louisiana, florida, virginia, illinois and mississippi are the only ones using rca on a limited scale.

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 aggregates make it require extensive research to verify its suitability as a sustainable aggregate in hma[2].

the main objectives of this research are:-

- to investigate the viability of different percentage (0,25,50,75, 100)% of recycling building demolition waste as coarse aggregate in hot mix asphalt after determine the optimum asphalt content for each percentage of recycling building demolition waste.

review of literature

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[2].

Aljassar, Ah. H. et. al.[3] investigated the viability of recycling the aggregate obtained from building demolition waste in asphalt concrete mix with percentage (40%- 3/4 inch recycling concrete aggregate), and (30%-3/8 inch recycling concrete aggregate), the results showed that the asphalt concrete produced using an aggregate of demolition waste met all the requirements of local specifications.

A combination of reclaimed concrete building materials–waste concrete, brick, and tile – has been evaluated to determine its potential for use as aggregates in HMA. Shen et al. [4] used four aggregates types for the research project namely, 100% of igneous crushed stone (control mix), 100% recycled building materials (RBM), 50% coarse and fine RBM plus 50% coarse and 50% fine igneous crushed stone (ICS) (50% RBM plus 50% ICS), and coarse RBM plus fine ICS (C-RBM plus F-ICS). The C-RBM plus F-ICS mixture was identified as the best performing mix. The project proved that the rutting failure potential was affected to a large extent by the type of aggregate irrespective of the PG binder grade and test temperature. Furthermore, the research established that the PG binder grade and aggregate types do not influence the resilient modulus results at 25°C, but they do affect resilient modulus results at 40°C.

The applicability of substituting common virgin aggregates with waste concrete aggregates (RCA) has been shown to be promising[5] in Singapore. The noticeable finding in this research, which used the Marshall Mix design method, was the fact that it is possible to use recycled concrete materials in HMA.

Other research work done on RCA has shown that except for air voids%, all the volumetric properties of an RCA-based HMA, the resilient modulus, and creep values were lower for the RCA HMA than for a mix designed wholly with conventional natural aggregates [6].

Akbulut, H. et. al.[7] studied the use of recycled aggregates produced from homogeneous marble and andesite quarry wastes in Afyonkarahisar-Iscehisar region were compared to two other aggregate specimens currently used in Afyonkarahisar city asphalt pavements. Los Angles abrasion, aggregate impact value, freezing and thawing, flakiness index and Marshall stability flow tests were carried out on the aggregate specimens. The test results indicate that the physical properties of the aggregates are within specified limits and these waste materials can potentially be used as aggregates in light to medium trafficked asphalt pavement binder layers.

Shaopeng Wu. et al.[8] explored the feasibility of utilizing steel slag as aggregates in stone mastic asphalt (SMA) mixtures, and properties of such asphalt mixtures are evaluated as well. X-ray diffraction (XRD), scanning electron microscopy (SEM), and mercury intrusion porosimetry (MIP) were employed to study the compositions, structure and morphology of aggregates. Volume properties and pavement performances of SMA mixture with steel slag were also evaluated as compared to that with basalt as aggregates. Results indicated that volume properties of SMA mixture with steel slag satisfied the related specifications and expansion rate was below 1% after 7 days. When compared with basalt, high temperature property and the resistance to low temperature cracking of SMA mixture were improved by using steel slag as aggregate. In-service SMA pavement with steel slag also presented excellent performance on roughness and British Pendulum Number (BPN) coefficient of surface.

Reclaimed asphalt-concrete pavement (RAP) has been used successfully in the construction, rehabilitation, and maintenance of flexible pavement projects in the United States.[9] The state of California uses

15%RAP in its recycled mixtures.[10] In Kuwait, RAP is used for temporary parking and to cover other open areas. It has also been reported that the use of RAP increases the soil-bearing capacity of subgrades in Kuwait.[11] RAP is also used in asphalt concrete pavements made using the Superpave design methods.[12]

Nan Su et al.[13] studied the effect of recycled glass waste on performance of asphalt concrete. Four glass contents: 0, 5, 10, and 15%, in terms of the total aggregate weight, were used in the mixture designs for casting series of 10 cm diameter by 6.35 cm disk specimens. Tests including Marshall stability value, dry/wet moisture damage, skid resistance, light reflection, water permeability, and compaction were carried out in accordance with the ASTM and AASHTO procedures. The test results reveal that glass waste is a viable material for asphalt concrete that has been widely used in pavement that offers profound engineering and economic advantages.

Arabani M. et al.[14] studied the effect of waste tire thread mesh on performance of asphalt concrete. The crack potential of asphalt pavement reinforced with tire cord mesh is evaluated with emphasis on introducing experimental methods and analyzing their results. The results show that the tire cord mesh reinforcement significantly increases the asphalt pavement resistance against cracking and increases its service life while decreasing maintenance and rehabilitation costs.

Experimental Design And Testing Procedure

Testing Program

The following variables were used to prepare the asphalt concrete mixtures for different tests:

1. Five asphalt contents,(4,4.5,5,5.5, and 6)% by weight of mixture, as recommended by the SCRB[15] specification of wearing coarse was used to estimate optimum asphalt content.
2. Single penetration grade asphalt cement (40-50) from Baiji refinery was used.
3. One type of mineral filler (Limestone dust) was used employed as filler in limited mixture.
4. Five percentage of recycled concrete aggregates (RCA), (0, 25, 50, 75,100)% from weight of coarse aggregate used at dry and soaking condition (24 hr soaking).

Materials

To obtain laboratory specimens with the same engineering characteristics as those used in pavement, the materials used in this study are broadly used in asphalt paving industry in Iraq and they are described in the following sections.

Asphalt Cement

The binder used in this study is petroleum asphalt cement brought from Baiji refinery. The physical properties of the asphalt cement are presented in Table (1).

Table 1. Physical Properties of Asphalt Cement*

Tests	Unites	Penetration grade (40-50)
Penetration (25C,100 gm,5 sec) ASTM D-5	1/10 mm	44
Absolute viscosity at 60 C ASTM D-2171	Poise	2065
Kinematics viscosity at 60 C ASTM D-2170	cts	280
Ductility (25C ,5 cm /min)ASTM D-113	cm	>100
Softening point (ring and ball)ASTM D-36	°C	48.3
Specific gravity at 25 C ASTM D-70)	…..	1.040
Flash point ASTM D-92 (Cleveland open –cup)	°C	332

After thin film test		
Penetration (25C,100 gm,5 sec) ASTM D-5	1/10 mm	26
Ductility (25C ,5 cm /min |)ASTM D-113	cm	>100
Loss in weight (163 C,5 hr)	%	0. 2

(*)= The test was Conducted in Baiji refinery

The coarse aggregate (crushed) were taken from *AL-Sudoor quarry source*,. a typical dense gradation with a nominal maximum size of aggregate of (12.5 mm), physical properties and chemical composition of the coarse aggregate are shown in Table (2) and Table (3).

The selected gradation follows the mid band gradation of the State Commission of Roads and Bridges R9, (SCRB) (Iraq) for the dense graded paving mixtures[15].

Table 2. Physical Properties of Sudoor Aggregates

Property	Coarse Aggregate	Fine Aggregate
Bulk Specific Gravity ASTM C-127 and C-128	2.595	2.631
Apparent Specific Gravity ASTM C-127 and C-128	2.604	2.685
Percent Water Absorption ASTM C-127 and C-128	0.486	0.54
Percent Wear (Los Angeles Abrasion) ASTM C-131	23.86	-
% Soundness C88	2.06	-
% Clay lump & Friable Particles C 142	1.12	-
% Gypsum	0.04	-

Table 3. Mineral Composition of Sudoor Aggregates

Mineral Composition	
Quartz	81.4
Calcite	18.6

Mineral Filler

One type of Filler is used in this work. This type is the Limestone dust, from lime factory in Kerbala. The physical properties of this filler are presented in Table (4).

Table 4. Physical properties of Limestone dust (mineral filler)

Property	Filler type
	Limestone
Specific Gravity	2.73
% Passing Sieve no. 200	96

Recycled Concrete Aggregates

The recycled concrete aggregate obtained from building to live long more than 20 years after crash reinforcement concrete and sieving to get requirement granular particle to make locally asphalt mixture (Type IIIB) depends on modified specification of State Commission of Roads and Bridges (2003) with percent (0,25,50,75,100)% from weight of coarse aggregate.

Testing Plan

The test methods employed in this study in order to investigate the viability of different percentage of recycling building demolition waste as coarse aggregate in hot mix asphalt include indirect tensile strength test and Marshall test to determine the optimum asphalt contents, stability, mix resistance to plastic flow, and the loss of stability .

Preparation and Test of Marshall Specimens

This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixtures loaded on the lateral surface by means of the Marshall apparatus according to ASTM (D 1559) [16].

Marshall stability and flow tests are preformed on each specimen. The maximum load resistance and the corresponding flow value are recorded. The bulk specific gravity density ASTM (D2726)[16], and theoretical (maximum) specific gravity of voidless mixture are determined in accordance with ASTM (D 2041) [16]. The percent of air voids is then calculated.

In order to determine the optimum asphalt content for this type of mixture Five different percentages of asphalt cement used (4.0, 4.5, 5.0, 5.5, 6.0) % of Baiji (40-50), and Five percentage of recycled concrete aggregates (RCA), (0, 25, 50, 75, 100)% from weight of coarse aggregate used.

Preparation and Test of Indirect Tension Test

The indirect tensile strength is determined according to ASTM (D 4123) [16] at (25 & 40°C).

The indirect tensile test is one of the most popular tests used for HMA mixture characterization in evaluating pavement structures. The indirect tensile test has been extensively used in structural design research for flexible pavements since the 1960s and, to a lesser extent, in HMA mixture design research. The indirect tensile test is performed by loading a cylindrical specimen with a single or repeated compressive load, which acts parallel to and along the vertical diametral plane. This loading configuration develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametral plane, which ultimately causes the specimen to fail by splitting along the vertical diameter as shown in Fig.(1). A curved loading strip is used to provide a uniform loading width, which produces a nearly uniform stress distribution. The compressive load is applied at a constant rate of 5.08cm/min. (50.8mm/min) and the ultimate load at failure is recorded. The equations for tensile stress at failure have been developed and simplified. These equations assume the HMA is homogenous, isotropic, and elastic. None of these assumptions is exactly true, but estimates of properties based on these assumptions are standard procedure and are useful in evaluating relative properties of HMA mixtures[17].

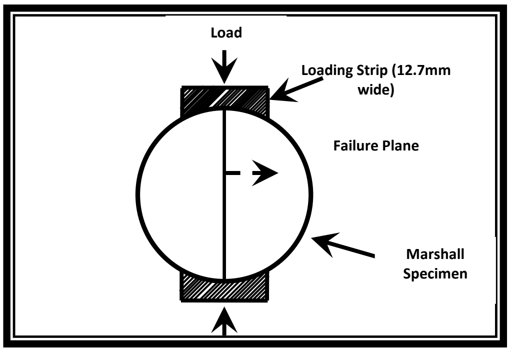

Fig. 1: Indirect Tensile test during Loading and at Failure

The indirect tensile strength (ITS) is calculated, as follows:

$$I.T.S = \frac{2P_{ult}}{\pi . t . d} \quad \text{.............................} \quad (1)$$

Where

I.T.S = Indirect tensile strength (kPa).

P_{ult} =Ultimate applied load at failure (kN).

t = Thickness of specimen (m).

d = Diameter of specimen (m).

The temperature susceptibility of mixture is calculated, as below[24]:

$$TS=[(I.T.S)_{t0}-(I.T.S)_{t1}]/(t_1-t_0)\ldots\ldots(2)$$

Where:-

$(I.T.S)_{t0}$=Indirect tensile strength at t_0 (^oC)

$(I.T.S)_{t1}$ = Indirect tensile strength at t_1 (^oC)

t_0 = 25 ^oC, t_1 = 40 ^oC.

Loss of stability test

The loss of stability test was conducted on Marshall specimens that were prepared using the optimum binder content obtained from the mix design. A total of six specimens were prepared, of which three specimens were conditioned in waterat 60°C for 30min, whereas the other three specimens were conditioned at 60°C for 24h before testing for loss of stability[3].

$$\text{loss of stability}=(S_1–S_2/S_1)*100\%\ldots\ldots(3)$$

where:-

S_1= Avg. stability of specimens submerged for 1/2 hr.

S_2= Avg. stability of specimens submerged for 24 hrs.

RESULTS AND DISCUSSION

Optimum Asphalt Content (Marshall Test Results)

The results of Marshall tests show almost typical relationships between Marshall properties and asphalt content.

Five different percentages of asphalt cement were used (4, 4.5, 5, 5.5, and 6) % from Baiji (40-50) grade with Limestone filler. In addition, (12.5) mm aggregate nominal maximum size for the original mixture is used for dense mix in accordance with SCRB specification[15] for surface course.

From Marshall Test result the optimum asphalt content (O.A.C) are (5.26,5.34,5.42,5.5,out of the limit)% for (0,25,50,75,100)% of the recycled concrete aggregate respectively as shown in Figures (2-6).

The main properties of original mixture including (bulk density, Marshal stability, flow, voids in total mix, and Marshall stiffness) and different percent of recycle concrete mix at optimum asphalt content for each percent are obtained and listed in table (5).

Table 5. Main Properties of Original Mixture and different percent of RCA.

%0f RCA / Marshall Properties	Original Mixture(0%of RCA)	Mixture at 25% 0f RCA)	Mixture at 50% 0f RCA)	Mixture at 75% 0f RCA)	Mixture at 100% 0f RCA)
Optimum Asphalt content, %	5.26	5.34	5.42	5.5	out of the limit
Bulk density, gm/cm^3	2.223	2.289	2.280	2.216	2.178
Marshall stability, KN	10.7	11.33	12.6	11.61	10.8
Marshall flow, mm	3.7	3.8	3.4	3.6	3.9
Marshall stiffness, KN/mm	2.89	2.98	3.71	3.23	2.77

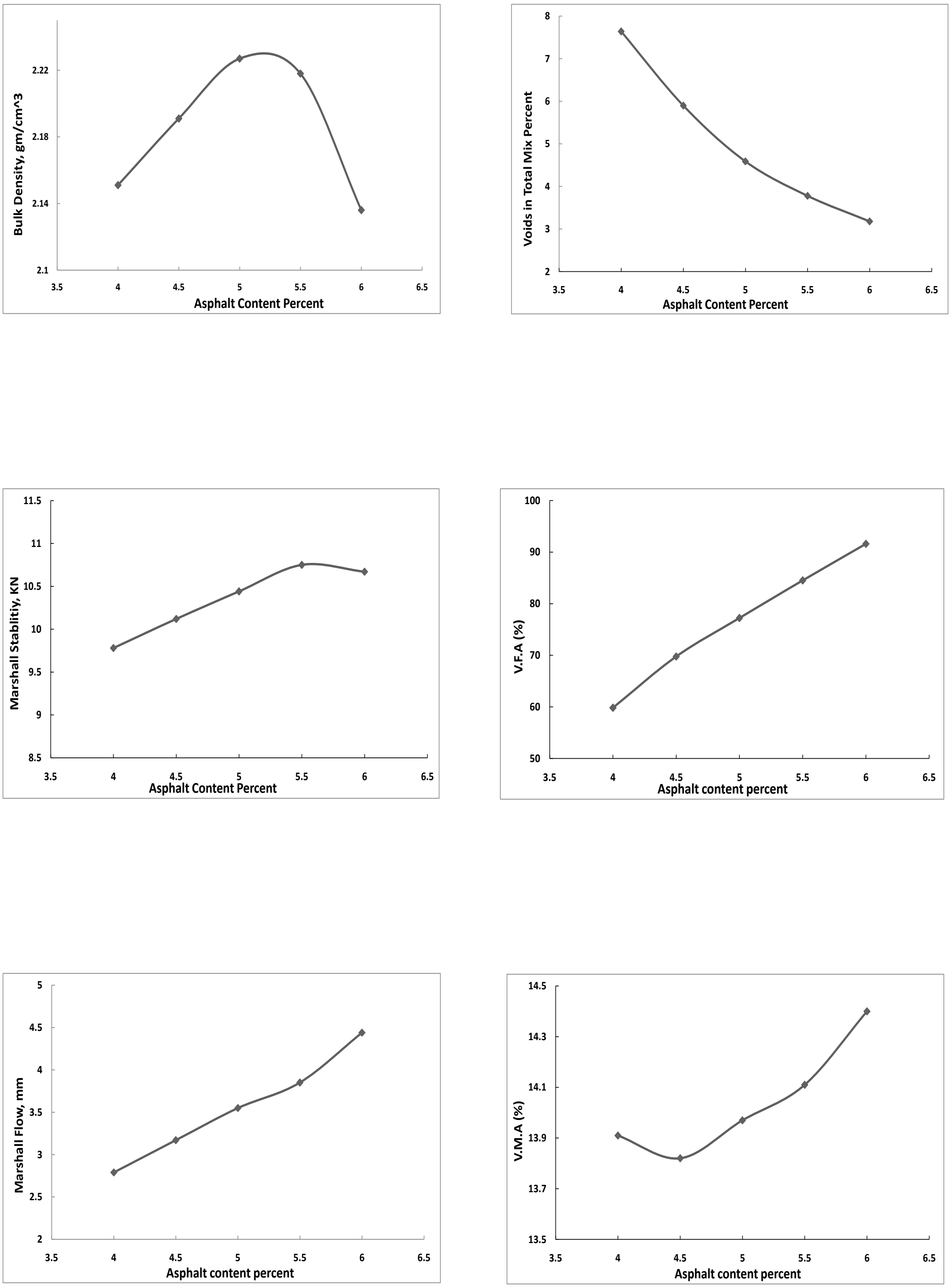

Fig.2:Influence of Asphalt Content on Marshall Test Properties at 0% of Recycle Concrete Mix.

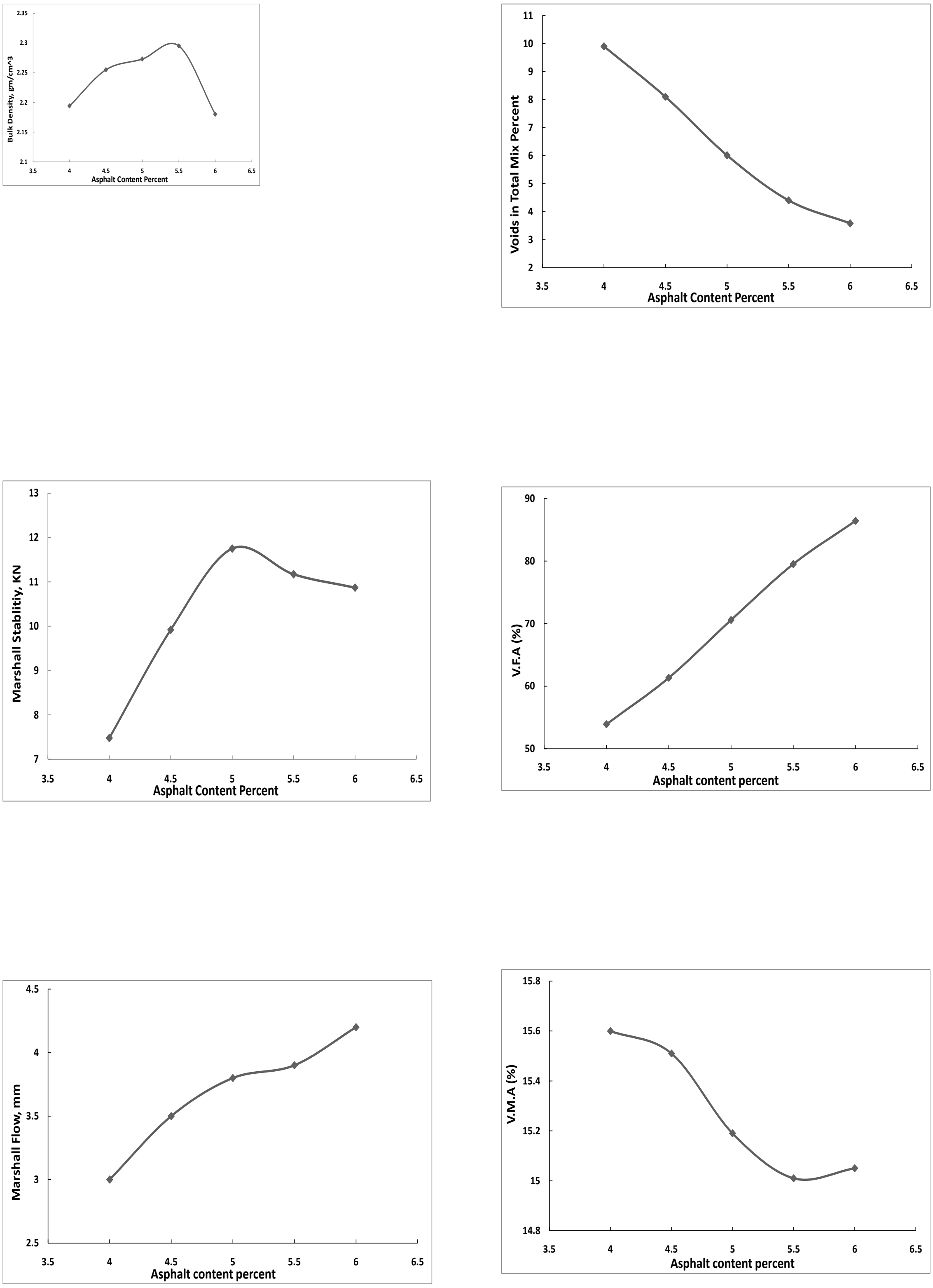

Fig. 3 Influence of Asphalt Content on Marshall Test Properties at 25% of Recycle Concrete Mix.

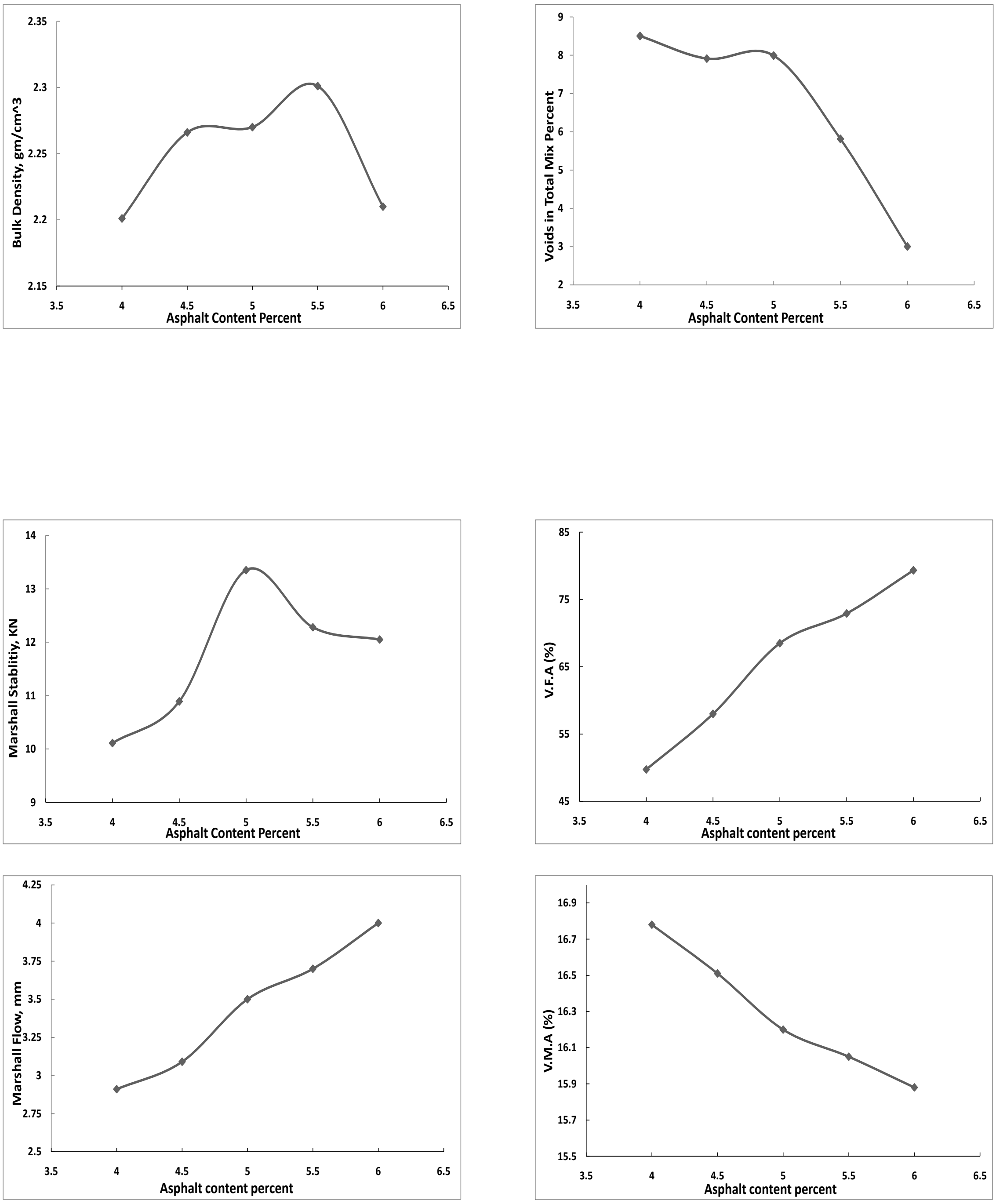

Fig. 4 Influence of Asphalt Content on Marshall Test Properties at 50% of Recycle Concrete Mix.

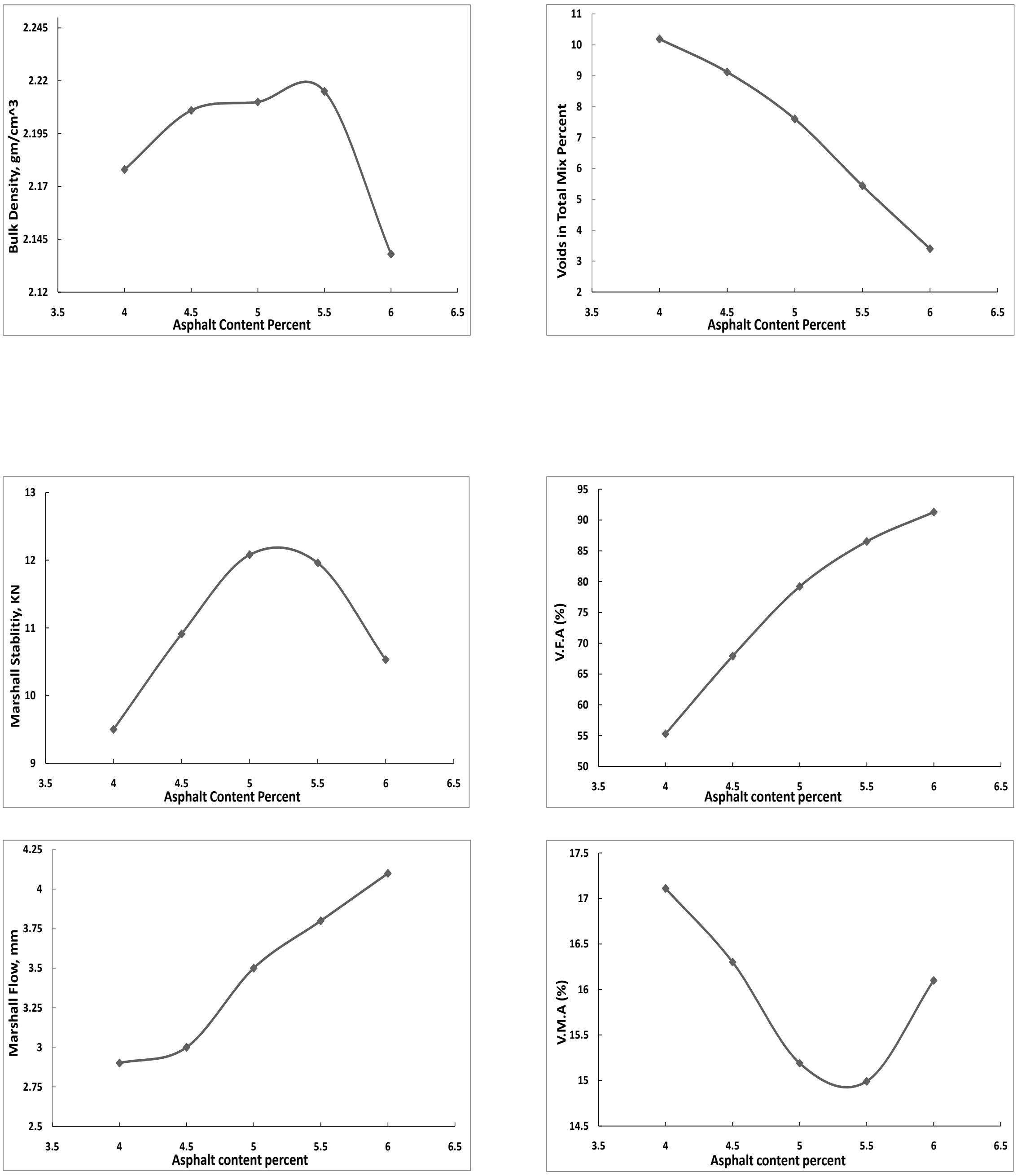

Fig. 5 Influence of Asphalt Content on Marshall Test Properties at 75% of Recycle Concrete Mix.

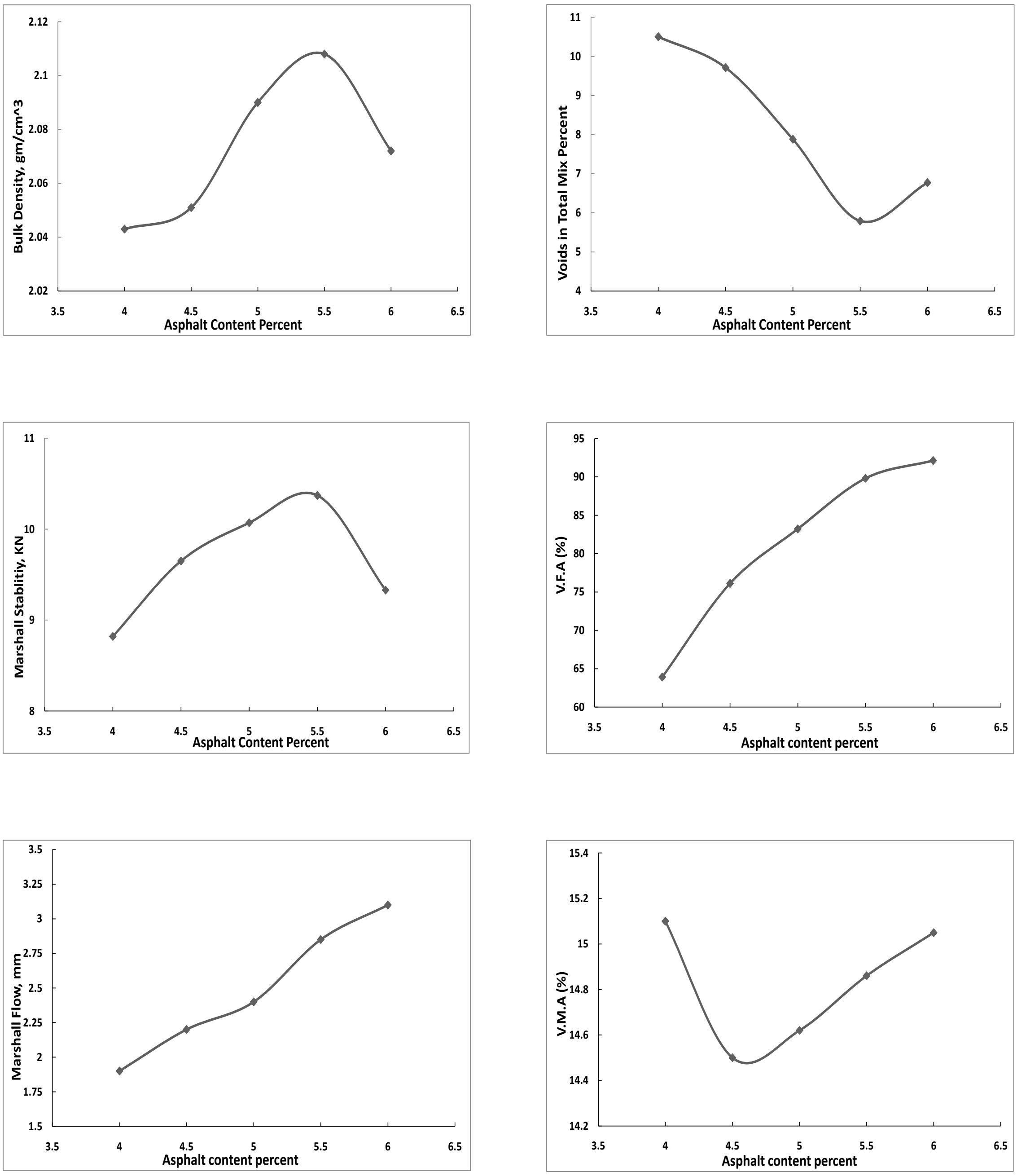

Fig. 6:Influence of Asphalt Content on Marshall Test Properties at 100% of Recycle Concrete Mix.

Indirect Tensile Strength

The evaluation of tensile strength for asphaltic concrete mixture used in construction of pavement becomes increasingly more important. This is partially due to the fact that pavements during service will be exposed to various traffic loading and climatic conditions. These conditions may cause tensile stresses to be developed within the pavement, and as a result, two types of cracks may be exhibited: one resulting from traffic loading, called fatigue cracking and the other type of crack resulting from climatic conditions and called thermal or shrinkage cracking. The indirect tensile test (I.T.S) has been used to evaluate the mixture resistance to low temperature cracking.

In this study the indirect tensile strength (I.T.S) have been used to evaluation the tensile properties of asphalt mixture.

Five recycled concrete aggregate (0,25,50,75, and100 percent by weight of coarse aggregate in hot mix asphalt) have been used to investigate the influence of recycled concrete aggregate on tensile strength. Mixture with limestone dust filler and 12.5 mm aggregate maximum size of AL-Sudoor crushed aggregate are prepared for dry and after soaking condition.

The relation between recycled concrete aggregate percent on tensile strength and temperature susceptibility are shown in figures (7 & 8). Indirect tensile strength was tested at (25, 40 °C) temperature.

From the result the tensile strength and temperature susceptibility increases by addition of recycled concrete aggregate reaching a peak value at 50% after that it tend to decrease.

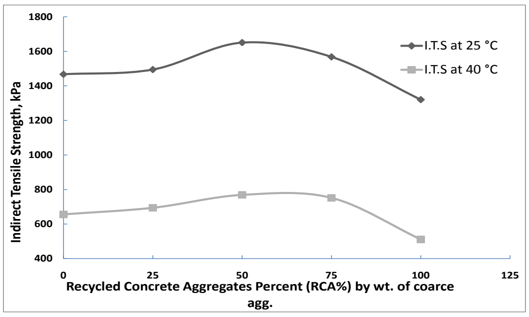

Fig. 7 Effect of Recycled Concrete Percent on Indirect Tensile Strength.

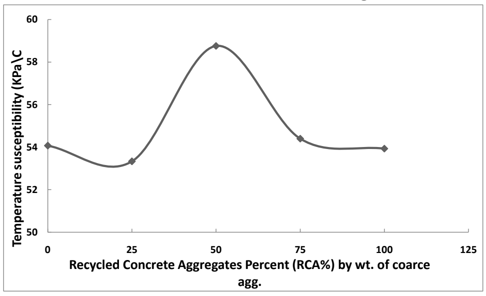

Fig.8 Effect of Recycled Concrete Percent on Temperature Susceptibility

Loss of Stability Test

Fig.(9) shows the relationship between recycled concrete aggregate percent and loss of stability.

From the result the loss of stability decreases by addition RCA until 50% after it tend to increase.

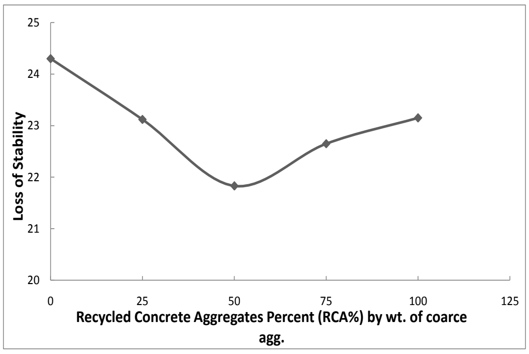

Fig.9 Effect of Recycled Concrete Percent on Loss of Stability

CONCLUSIONS

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 Aaggregate percent that improving the Marshall stability, bulk density, stiffness, flow, air void of asphalt mixture are (50

then75)% by weight of coarse aggregate.

2. The best content of recycled concrete aggregate percent that improving the tensile strength and temperature susceptibility of asphalt mixture are (50)% by weight of coarse aggregate. The best content of RCA that lead to minimizing Loss of stability of asphalt mixture is (50 then75))%.

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