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IMPACT OF RECLAIMED ASPHALT PAVEMENT (RAP) ON PROPERTIES OF ASPHALT MIXTURE FOR SURFACE LAYER

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ABSTRACT
Using Reclaimed Asphalt Pavement (RAP) not only reduces the cost of new asphalt mixtures but also conserve the natural resources. To incorporate RAP in asphalt mix design, it is vital to know the impact on properties of asphalt mixture. In this research, the effect of different percentage of RAP on performance asphalt mixture in terms of water sensitivity (Indirect Tensile Strength Ratio TSR) and ultrasonic test were studied. The best gradation of aggregate was selected and optimum asphalt content was determined according to Superpave design system. Superpave Gyratory Compactor (SGC) was used to compact asphalt samples with 100-mm diameter. Four different percentages (7, 13, 19 and 25) of RAP were used for preparation mixes to compare with virgin mixture. Two types of asphalt grade were used (40-50) and (60-70), The test results indicated that addition RAP to mixes shows significant increase on resistance of moisture damage (TSR) and modulus of elasticity(E*).

INTRODUCTION
Reclaimed asphalt pavement (RAP), is the existing asphalt pavement, which will be grinding and stored to be used as part of the new pier. The RAP can be obtained whenever the old current pavement needs to be replaced or whenever part of the pavement needs to be cut for access to underground facilities. If the existing old pavement is satisfactorily reclaimed, in a smooth and properly stored sense, its aggregation can be used as a valuable source when the total quality is scarce. Besides, the current binder in the rap can form some of the required binder in the hot Asphalt Mix (HMA). As mentioned earlier, RAP is the existing asphalt pavement that will be smooth and stocked to be used as part of the new pavement. RAP contains valuable amounts of aggregate and binder. During the years of service, both aggregates and binder were subject to changes affecting their characteristics. To ensure that these changes do not adversely affect the performance of the HMA, specific considerations must be taken (McDaniel and Anderson, 2001).

Colbert and You in (2012) showed that the addition of 15%, 35%, and 50% of RAP decreased rutting by 24%, and increased resilient modulus by 52%. Study also showed an increase in dynamic modulus and a decrease in resilient modulus as the RAP percentage increase. Incorporating high percentage of RAP indicate more rutting resistant mixtures.

Tabakovic et al. in (2006) indicated that addition (10%, 20% and 30%) of RAP decrease water sensitivity tests, the Indirect Tensile Strength Ratio (TSR) but was above the standard limit of 80%. Fatigue behavior was also very much for all mixes, especially with RAP percentages up to 30%, with dynamic modulus values increasing with increasing RAP content, whereas the stiffness modulus and density of plant mixes (without RAP preheating) tend to decline.

MATERIALS

Asphalt Cement

The grade of binder has used are (AC 40-50) and (AC 60-70), was obtained from the Al-Dora Refinery, south-west of Baghdad. The testing was conformed to Iraqi specification (SCRB, 2003) and ASTM Requirement. The physical properties of binder for (40-50) and (60-70) are showed in Table (1) and (2) respectively.

Table 1 Properties of Asphalt Cement (40-50) penetration

Test	Test Conditions	Standard	Test value (measured)		Standard Limit using (NCCLR, 2013) according to SCRB /R9, 2003
Penetration	100 gm, 25°C, 5 sec., (0.1mm)	ASTM D5	44		40-50
Ductility	25°C, 5cm/min	ASTM D113	+113		+100
Specific gravity	25°C	ASTM D70	1.032		-----
Flash and fire points	…..	ASTM D92	Flash	335°C	> 232 °C
			Fire	339°C	-------
Loss on heating	163 °C, 50gm, 5 hr	ASTM D1754	0.242%		
Kinematic Viscosity	Pa.sec	ASTM D88	0.537 @ 135°C* 0.15 @ 165°C**		

Table 2 Properties of Asphalt Cement (60-70) Penetration

Test	Test Conditions	Standard	Test value (measured)		Standard Limit using (NCCLR, 2013) according to SCRB /R9, 2003
Penetration	100 gm, 25°C, 5 sec., (0.1mm)	ASTM D5	66		60-70
Ductility	25°C, 5cm/min	ASTM D113	+125		+100
Specific gravity	25°C	ASTM D70	1.025		-----
Flash and fire points	…..	ASTM D92	Flash	296°C	> 232 °C
			Fire	320°C	-------
Loss on heating	163 °C, 50gm, 5 hr	ASTM D1754	0.365		< 0.75
Kinematic Viscosity	Pa.sec	ASTM D88	0.475 @ 135°C* 0.113@ 165°C**		

Aggregate

The crushed quartz aggregate used in this research was obtained from Al-Sedour quarry; this aggregate widely used in local asphalt paving in Baghdad. The physical properties of used aggregate were showed in Table (3).

Table 3 Physical properties of Aggregate

Laboratory Test		**ASTM Designation and Specification**	**Results**			
Specific gravity	Coarse aggregate	ASTM C127	sieve size	Apparent Gs	Bulk Gs	Abs.%
			1/2" (12.5mm)	2.64	2.623	0.41%
			3/8" (9.5mm)	2.614	2.583	0.54%
			#4 (4.75mm)	2.591	2.573	0.47%

			Crashed sand (<#4)	2.679	2.64	0.63%
Angularity for Coarse aggregate		ASTM D 5821 Min 95%	97%			
Soundness for Coarse aggregate		ASTM C88 10-20% Max	4.3%			
Equivalent sand (clay content)	Crashed(<#4)	ASTM D2419 Min 45%	96%			
Flat & Elongation aggregate	Flat	ASTM D4791 Max 10%	1%			
	Elongation		2%			
Toughness, (Los Angeles Abrasion)	Aggregate Size < 25mm	ASTM C131 35 Max	20.88%			

Mineral Filler

The filler used in this research was Portland cement brought limestone dust brought from the lime factory in Karbala' Governorate. The physical properties of limestone are presented in Tables (4).

Tables 4 Physical Properties of Limestone Dust

Property	Test Result
Specific gravity	2.72
%Passing Sieve No.200 (0.075 mm)	96%

Reclaimed Asphalt pavement

The reclaimed asphalt pavement materials (RAP) was brought from stoke of Reclaimed Asphalt for Mayoralty of Baghdad-project office at Altalbia-region in Baghdad city. Extraction test was conducted on the reclaimed asphalt pavement to extraction the asphalt from aggregate and filler. The testing procedure was done according to (ASTM-D2172). The percent of asphalt cement was (4%) and gradation of aggregate shown in Table (5) the according to (Iraq specifications R9, 2003).

Table 4. Sieve Analysis for RAP after Extraction

Sieve size		% Passing by weight Requirements by (SCRB 2003)	%Passing by weight (RAP)
IN	MM		
3/4	19	100	100
1/2	12.5	90-100	99
3/8	9.5	76-90	97*
No.4	4.75	44-74	73
No.8	2.36	28-58	54
No.50	0.3	5-21	30*
No.200	0.075	4-10	4.4

MIX DESIGN

Design aggregate structure and design asphalt binder content are determined according to Superppave design method. Aggregate gradation was selected according to FHWA and Iraq specifications (R9, 2003) for surface wearing course. Figure (1) shows the gradation of blend selection. The design asphalt binder content is established at 4.0% air voids, the design asphalt binder content was 4.8% and 4.7 % for (40-50) and (60-70)asphalt penetration respectively. All other mixture properties were checked at the design asphalt binder content to verify that they

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meet Iraq specifications' (R9) for wearing course and FHWA. Table (6) and (7) are shown design Mixture Properties for asphalt Binder (40-50) and (60-70) respectively.

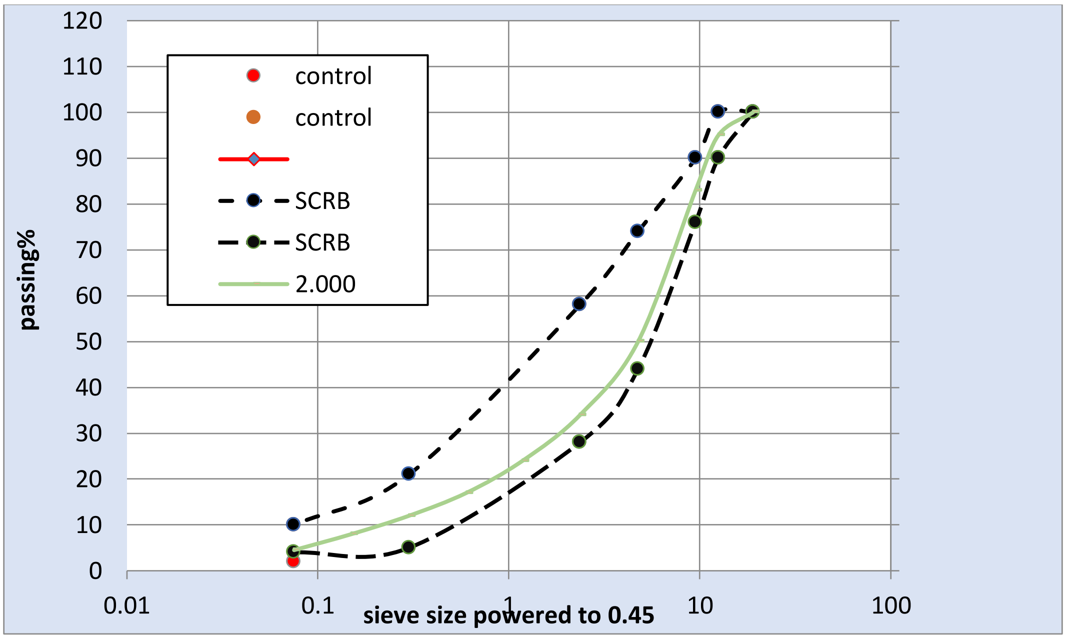

Fig.1. gradation of blend selection

Table (4-7) Design Mixture Properties at 4.8% Binder Content for asphalt grade (40-5)

Criteria	***Result***	***Mix Property***
4.00%	4	%VA
13 % min	15.05	%VMA Est.
65% - 75%	73.44	VFA est.
0.6 - 1.2	0.93	Dust proportion
less than 89%	88.47	% G_{mm}@N $_{ini}$

Table (4-8) Design Mixture Properties at 4.7% Binder Content for asphalt grade (60-70)

Mix Property	**Result**	**Criteria**
%VA	4	4.00%
%VMA Est.	14.97	13 % min
VFA est.	73.3	65% - 75%
Dust proportion	0.955	0.6 - 1.2
% $G_{mm}@N_{ini}$	87.8	less than 89%

EVALUATION OF MOISTURE SENSITIVITY

Because of the loss of bond, or stripping, caused by the presence of moisture between the asphalt and aggregate is a problem in some areas and can be severe in some cases, it is requiring to evaluate the design asphalt mixture to moisture susceptibility. Many factors such as aggregate characteristics, asphalt characteristics, environment, traffic, construction practices and drainage can contribute to stripping. This step is accomplished by performing ASTM D4867 "Effect of Moisture on Asphalt Concrete Paving Mixtures". Specimens are compacted to (6-8) % air voids. One subset of three specimens is considered control specimens. The other subset of three specimens is the conditioned subset. The conditioned subset is subjected to vacuum saturation followed by an optional freeze cycle, followed by a 24-hour thaw cycle at 60° C. All specimens are tested to determine their indirect tensile strengths. After conditioning both subsets are tested for indirect tensile strength which is accomplished by Indirect Tensile Machine in condition of equal speed (50.8mm/min) and the maximum load is recorded. The moisture sensitivity is determined as a ratio of the tensile strengths of the conditioned subset divided by the tensile strengths of the control subset. Indirect Tensile Stress is calculated as follows:

***St** = (2∗P/ πtD)……….. (1)*

Where: St = tensile strength, kPa

P = maximum load, N

t = specimen height immediately before tensile test, mm (in)

D = specimen diameter, mm (in.).

Then the Tensile Strength Ratio is calculated as follows:

***TSR** = (Stm/ Std)*100 …….. (2)*

Where: TSR= tensile strength ratio, percent

Stm = average tensile strength of the moisture conditioned subset, kPa

Std =average tensile strength of the dry subset, kPa.

Ultrasonic Testing

The ultrasonic device is a portable seismic device that measures travel time of seismic wave pulses though a material. The seismic waves are generated by a built-in pulse generator, which transforms an electrical pulse to a mechanical vibration though a transducer. The seismic wave arrival time is recorded by a receiver, which is connected to an internal clock. The internal clock has the capability of automatically measuring and displaying the travel time of the waves. The travel time and the density of the specimen are used to determine the resilience modulus of the HMA specimens. The main advantage of this test is that it is nondestructive. In addition, the test can be performed on both laboratory-prepared specimens and field cores. In this study, a 54 kHz frequency ultrasound wave was used to test asphalt concrete specimens. This frequency was recently employed by the authors Arabani, M. & Kheiry, T. P. (2006) and Mahdavinejad, R. (2005).

The specimens prepared for the test described above can be used to perform ultrasonic tests. The ultrasonic apparatus used in this study is shown in Figure (3-16). The elastic modulus of a specimen is measured using an ultrasonic device containing a pulse generator and a timing circuit, coupled with piezoelectric transmitting and receiving transducers. The dominant frequency of the energy imparted to the specimen is 54 kHz. The timing circuit digitally displays the time needed for a wave to travel through a specimen. To ensure full contact between the transducers and a specimen, special removable epoxy couplant caps are used on both transducers. The receiving transducer, which senses the propagating waves, is connected to an internal clock. The clock automatically displays the travel time, tv that can be used to calculate the constrained modulus, Mv, according to ASTM (C 597 – 02).

$$\mathbf{Mv = \rho Vp^2 = \rho\ (L/tv)^2}$$

Where: Mv= constrained modulus, ρ = Density, gm/mm^3, Vρ = Compression wave velocity mm/ms, and , L = Average length of the specimen mm. , tv = Travel time ms., This equation may be simplified to :

$$Mv = \frac{4ml}{\pi d^2 tv^2}$$

Where: M: Mass of the specimen gm, d: Average diameter of the specimen mm, and Then Young´s modulus, Ev, may be determined from

$$Ev = Mv\left[\frac{(1-2v)(1+v)}{(1-v)}\right]$$

The Poisson´s ratio, υ, can be assumed based on experience, for asphaltic material generally assumed from (0.3 - 0.4), Huang (2010).

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RESULTS AND DISCUSSION

- Indirect Tensile Strength Test Results at Optimum Asphalt Content (opt. AC) for 25ºC and 60ºC

Figure 2 illustrated the result for unconditioned sample tested at 25ºC and ºC60C.Indirect tensile strength value for unconditioned sample increase with increase in RAP percentage and decrease with increase temperatures from 25˚C to 60˚C.

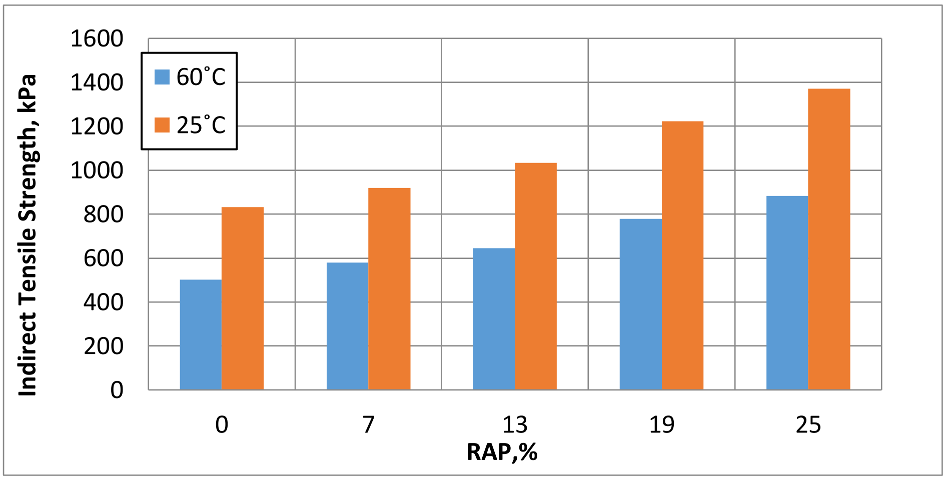

Figure (2) Indirect Tensile Strength for Unconditioned Sample

Figure 3 showed the result of ITS at 25ºC and 60ºC, its observed that the value of ITS when adding the quantity of RAP is higher than control mix and it is increase as increase in RAP percent.

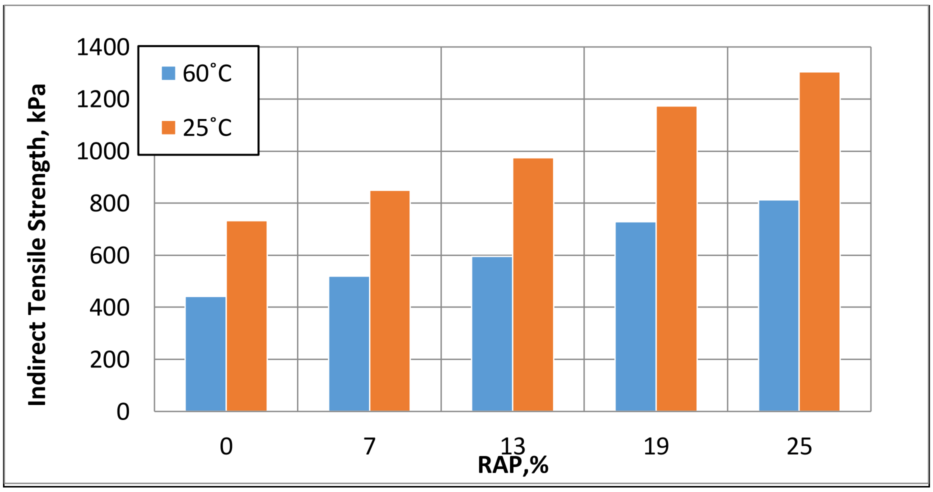

Figure (3) Indirect Tensile Strength for Conditioned Sample

- Indirect Tensile Strength Test Results at +0.5 Optimum Asphalt Content

Figure 4 illustrated the result for unconditioned sample tested at 25ºC and ºC60C. Indirect tensile strength value for unconditioned sample increase with increase in RAP percentage and decrease with increase temperatures from 25˚C to 60˚C.

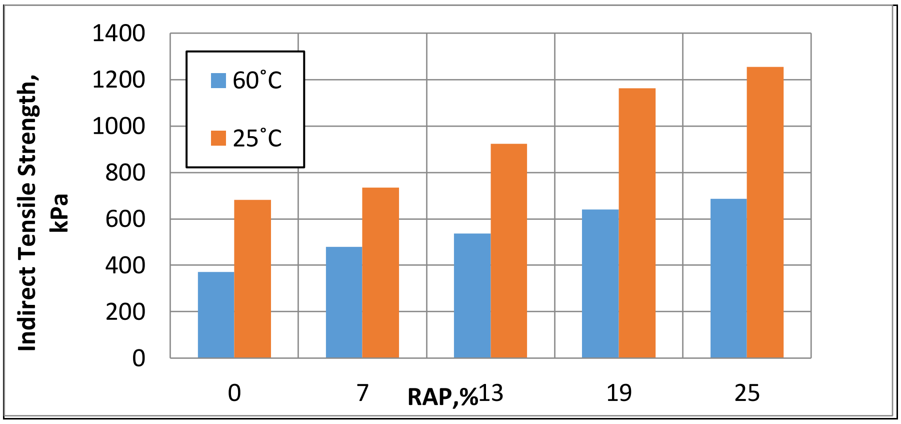

Figure (4) results between indirect tensile strength and RAP Percentage unconditioned sample

Fig.5 showed the result of ITS at 25ºC and 60ºC, its observed that the value of ITS when adding the quantity of RAP is higher than control mix and it is increase as increase in RAP percent.

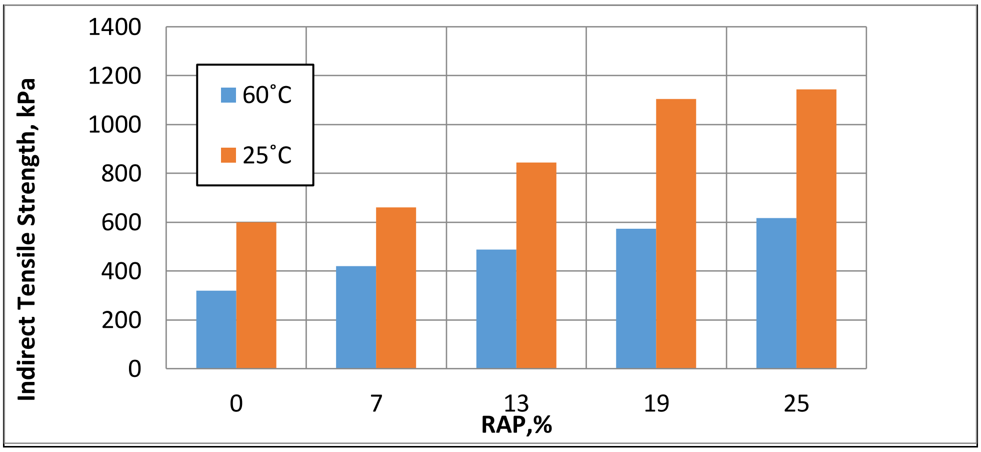

Figure (5) results between indirect tensile strength and RAP Percentage for conditioned sample

- **Tensile Strength Ratio TSR**

Figure 6 and 7 shows the result of tensile strength ratio (TSR) for the both mixes at (opt. AC and +0.5 opt. AC) respectively .Result shows that TSR for both mixes with containing RAP is higher than control mix and these value is increase with an increase in percentage of RAP.

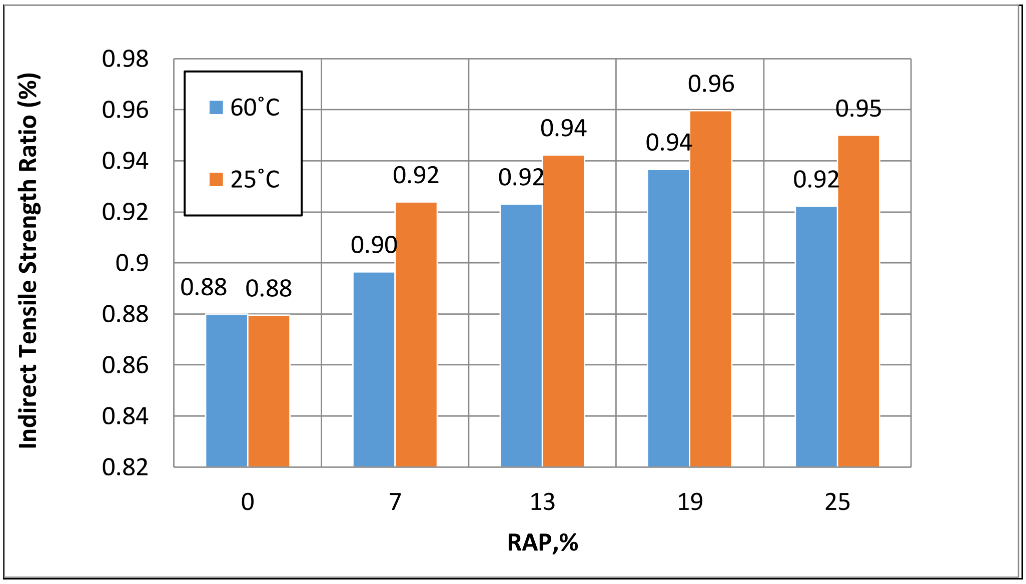

Figure (6) Result of TSR at opt. AC

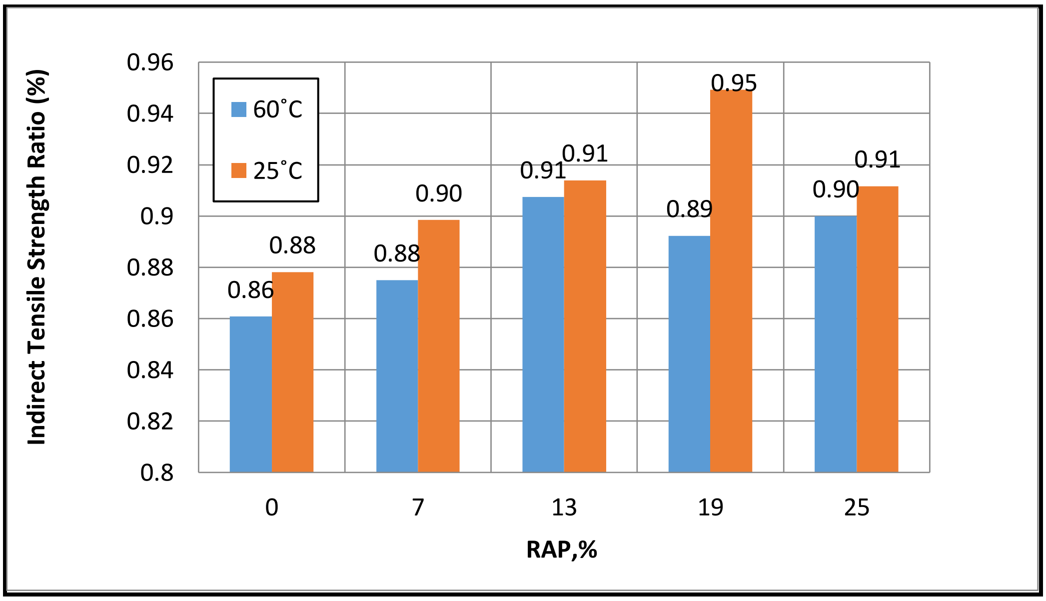

Figure (6) Result of TSR at +0.5 opt. AC

- **Elastic Modulus Results**

Figure 7 show the result of modulus of elasticity with different RAP percentage and different number of gyrations.it can be noticed that the value of elastic modulus increase with increase in RAP percentage that adding to mixture, also it is increase with an increase in number of gyrations.

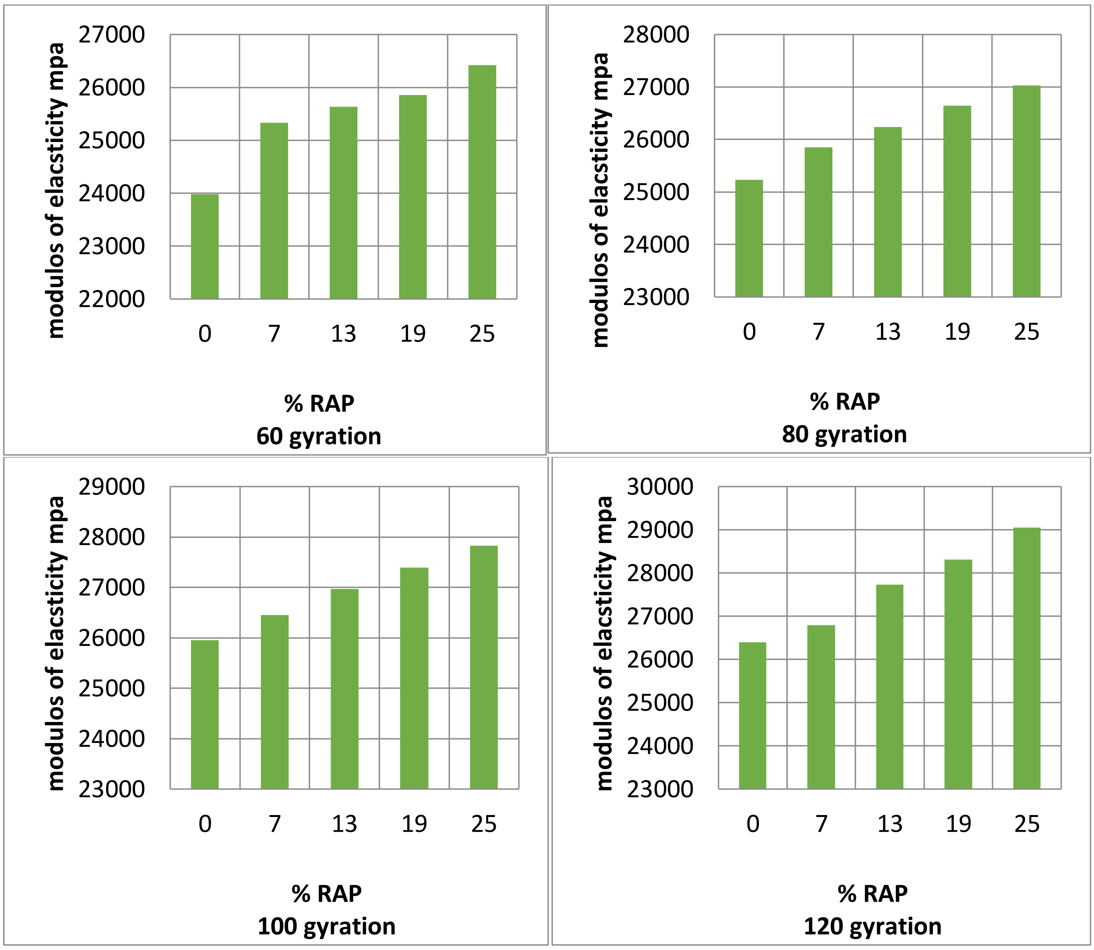

Figure (7) effect of number of gyration and RAP percent on modulus of elasticity

CONCLUSIONS

Based on laboratory test for control original mix prepared with different percentages of reclaimed asphalt pavement, the following conclusions can be drawn:

1- Indirect tensile strength for reclaimed asphalt pavement for mixing at optimum asphalt content and +0.5 optimum asphalt content for condition samples and unconditioned samples increase with increase of RAP percentage, and the higher value was obtained when 25%RAP percent is used.
2- The optimum value of Indirect tensile strength ratio for both mixture with opt. AC and +0.5 opt. AC when RAP percentage was 19% and small decrease in 25% RAP percent are used.
3- For all of the mixtures with different percentages of Reclaimed asphalt pavement is increase with increasing RAP percentage from 0 to 25%.
4- Increasing number of gyrations promotes better bonding at the aggregate-asphalt interface thereby maintaining a good continuity in the matrix, that's mean whenever increase number of gyrations this will lead to an increase in value of modulus of elasticity.

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