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TENSILE STRENGTH FOR MIXTURE CONTENT RECLAIMED ASPHALT PAVEMENT

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KEYWORDS: Asphalt, Asphalt pavement, Reclaimed Asphalt pavement, Tensile strength, Base course, Base course content RAP, Recycling.

ABSTRACT
This paper is studying the effect of two different heating temperature of RAP on performance of water sensitivity tests, the Indirect Tensile Strength Ratio (TSR). the best gradation and optimum asphalt content was Selected according to Superpave method. Superpave Gyratory Compactor (SGC) used to compact mixture with 100-mm diameter. Four different percentages (20,30,40 and 50) of RAP used for preparation mixes to compared with virgin mixture. The test results indicated that addition RAP to mixes shows significant increase on resistance of moisture damage (TSR) for 110 c˚ for all percent. For 140 c˚ showed (TSR) increase to threshold (20%) of RAP while (TSR) decline for another percent but still above the standard limit of 80%.

INTRODUCTION
The use of Reclaimed Asphalt Pavement (RAP) in different road applications become more widespread in last two decades. Using RAP has proven to be economical and environmentally sound. The materials present in old asphalt pavements have residual value even when the pavements have reached to ends of their service lives for that many agencies and contractors in different countries have made extensive use of RAP in producing new asphalt pavements to recognize the value of existing aggregate and asphalt **(Arshad and Qiu 2013)**. Researchs has focused on the effect of RAP addition to bituminous mixes on the variability of volumetric and mechanical properties of recycled mixtures also the effect of RAP on pavement mechanical behavior. Some of these researches conclusion, mixtures with similar features as conventional ones were obtained using RAP contents between 10% and 30% **(Alex K. et al. 2011).** High RAP contents as 60% have also been prepared but its behavior depending mainly on the previous RAP homogenization and characterization treatments **(Rodrigo Miró et al. 2011)**. Performance of pavements with properly prepared recycled asphalt in terms of fatigue, rutting, thermal resistance and durability proved to be satisfactory **(Al-Qadi et al. 2007)**. **Colbert and You (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. **A.Tabakovic et al. (2006)** indicated that addition (10%,20%,30%) of RAP decrease water sensitivity tests, the Indirect Tensile Strength Ratio (TSR) but was above the standard limit of 80%, also conclusion the fatigue (ITFT), Circular Wheel Track (CWT) and Dynamic strain test (DAQ) have slightly improvement in mix performance with the inclusion of 30% RAP into the mix. **Rodrigo Miró et al. (2011)** Four mixtures of RAP 0%, 15%, 30% and 50%, was used with low penetration virgin bitumen. Evaluated moisture sensitivity (TSR) values was dropped with increasing RAP content but values were higher than 80%. Resistance to rutting, levels of all RAP mixtures being very similar and lower than that of the high modulus mixture without RAP (rut depth decreased by 30% for 50% RAP and 4.75% asphalt content). 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 USED

Asphalt cement

The grade of binder had used (AC 40-50) or PG (64-16), was obtained from the Dora Refinery, south-west of Baghdad. The testing was conformed to Iraqi specification (SCRB,2003) and ASTM Requirement. The physical properties of binder are showing in table (1).

Table 1. Properties of Asphalt Cement

Property	**ASTM designation**	**Test results**	**SCRB specification**
Penetration, (25°C, 100 g, 5s), 0.1 mm	D-5	47.3	40-50
Softening Point. (◦C)	D-36	51.5	……
Ductility at 25 C, 5cm/min, (cm)	D-113	>100	>100
Specific Gravity	D-70	1.03	……
Rotational Viscometer, at 135ºC (Pa.sec)	D-4402	0.52	…..
Rotational Viscometer, at 60ºC (Pa.sec)	D-4402	0.13	

Aggregate

The crushed quartz aggregate used in this work was gotten from Al-Sadour quarry; this aggregate widely used in local asphalt paving in Baghdad. The physical properties of used aggregate were showed in Table (2)

Table 2. Physical properties of aggregate

Laboratory Test	ASTM designation	Test results	SCRB Specification
Coarse aggregate			
Apparent specific gravity	C-127	2.66	…
Bulk specific gravity	C-127	2.61	…
Water absorption, %	C-127	0.66	…
Percent wear by (Los Angeles abrasion), %	C-131	14.6	35-45 Max
Soundness loss by sodium sulfate solution, %	C-88	3.12	10-20 Max
Fractured pieces, %		96%	95 Min
Fine aggregate			
Apparent specific gravity	C-128	2.66	…
Bulk specific gravity	C-128	2.62	…
Water absorption, %	C-128	0.68	…

Mineral Filler

The filler used in this work was Portland cement brought from Al-Mas company which provided from local market. The physical properties of Portland cement are presented in Tables (3).

Tables 3. physical properties of Portland cement

Property	**Test Result**
Specific Gravity	3.2
%Passing Sieve No.200 (0.075 mm)	100

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

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pavement to extraction the asphalt from aggregate and filler. The testing procedure according to (**ASTM-D2172**). The percent of asphalt cement was (4%) and gradation of aggregate shown in table (4) the according to (**Iraq specifications' R9**).

Table 4. showed sieve analysis for RAP after extraction

Standard Sieves (mm)	% Passing by weight (R9)	%Passing by weight (RAP)
19	100	100
12.5	90-100	99
9.5	76-90	97
4.75	44-74	73
2.36	28-58	54
0.3	21-5	30
0.075	4-10	4.4

MIX DESIGN

Superppave pavement design method was used to Select Design aggregate structure and Design Asphalt Binder Content for getting optimum asphalt pavement. Selected aggregate gradation was according to FHWA and Iraq specifications' (R9) for base course. Figure (1) shown the gradation of blend selection. after that Four Asphalt Binder Content was selected (3.45%,3.95%,4.45%,4.95%). The design asphalt binder content is established at 4.0% air voids the design asphalt binder content was 4.42% All other mixture properties were checked at the design asphalt binder content to verify that they meet Iraq specifications' (R9) for base course and FHWA. Table (5) shown design Mixture Properties at 4.42% Binder Content.

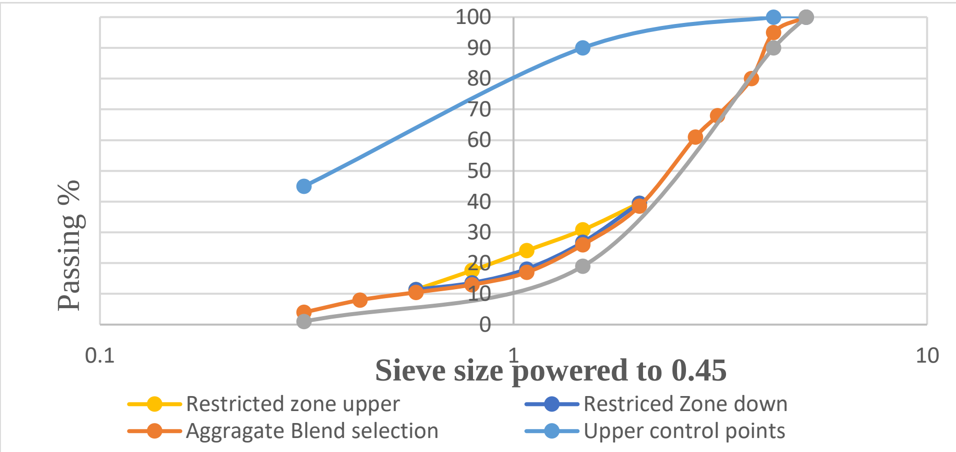

Fig.1. gradation of blend selection

Table 5. Design Mixture Properties at 4.42% Binder Content

Mix Property	**Result**	**Criteria**
%V A	4	4.00%
%VMA Est.	14.5	12 % min
VFA Est.	72.3	65% - 75%
Dust	1.16	0.6 - 1.3
% Gmm @ N_{ini}	87.3	less than 89%

METHODOLOGY

Recycled hot mix asphalt mixture is a multiphase system, which consists of sized recycled asphalt material, new asphalt, and/or recycling agents and new aggregates **Shaopeng Wu, et al. (2007).** Heating RAP should be kept to a minimum to avoid changing the RAP binder properties**. Randy West et.al. (2013)**. Considering mixing temperature, recycled aggregates are preheated at a temperature ranging from 110 to 140 ◦C, which is much lower than the conventional preheated temperatures of fresh aggregates and asphalt binders. The result of rheological properties of asphalt binders which contain recycled and fresh asphalt binders showed advantages with the optimization control of recycled hot mix asphalt mixture **Shaopeng Wu, et al. (2007)**. Generally, when the temperature is higher, the mix workability would be better, since the viscosity of the binder decreases as the temperature increases **(Gudimettla et al., 2003).** Based on an experiment **(Randy West et.al. (2013))** showed that Heating stiff RAP for less than 4 hours at 150°C did not significantly change the RAP binder stiffness, while heating soft RAP at either 110°C or 150°C for more than 2 hours significantly increased the RAP binder stiffness. **Gudimettla JM, et al (2003)** recommended that heating RAP temperature at 110°C (230°F) for a time of no more than 2 h is recommended for sample sizes of 1 to 2 kg. while the virgin aggregate should be heated to 10°C above the mixing temperature prior to mixing with the RAP and virgin binder. Then the mix components should be mixed, aged, and compacted as usual and **McDaniel, R., and R. M. Anderson (2001)** recommended Heat the RAP for no more than 2 hours in a separate oven set to 110°C (230°F) and the new aggregates should be heated from 10 to 20 °C above the mixing temperature before combining with the RAP and new binder. Research carried out by **McDaniel et al. (2000)** indicated that the properties of RAP binders showed no significant difference between preheat temperature of 110 and 150 ◦C within 2 h. Exercise care when preparing laboratory specimens with RAP to avoid changing the properties of the RAP binder, Higher temperatures and longer heating times have been shown to change the properties of some RAPs **McDaniel, R., and R. M. Anderson (2001).**

- Based on above discussed the Reclaimed asphalt pavement was Heated at 110 C˚ and 140 C˚ for (1-2) hour. And new aggregate was heating at (170 C˚), asphalt pavement (PG 64-16), at (160 C˚). After heating the aggregate and asphalt mixed together and then added heating reclaimed asphalt pavement to mixture. The percent of reclaimed asphalt pavement (RAP) was added (20%,30%,40%,50%) from total weight

EVALUATION OF MOISTURE SSENSITIVITY

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:

$$St = \left(\frac{2*P}{\pi t D}\right) \ldots \quad (1)$$

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:

$$TSR = \left(\frac{Stm}{Std}\right)*100 \ldots \quad (2)$$

where: TSR= tensile strength ratio, percent

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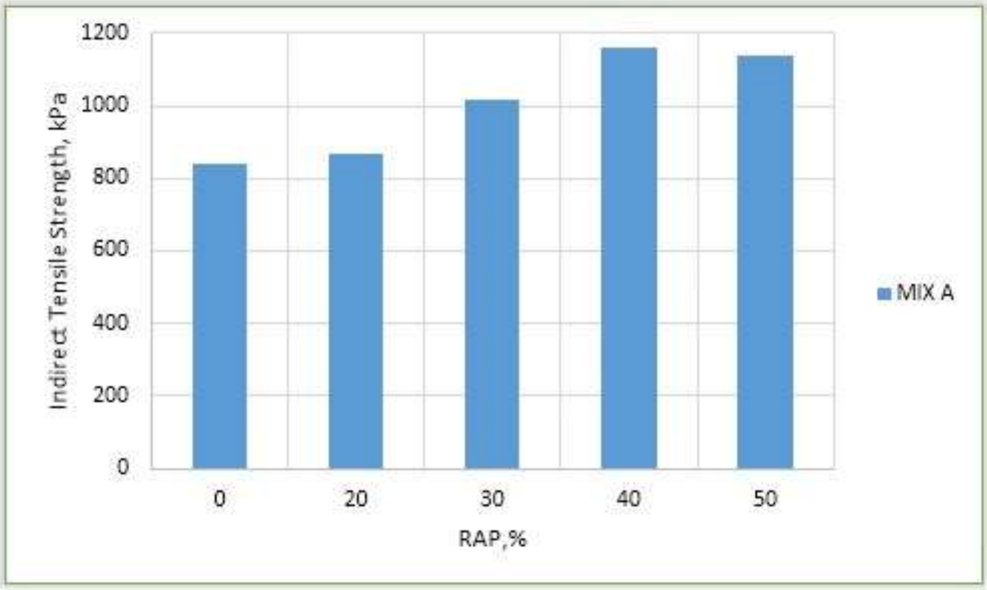
Stm = average tensile strength of the moisture conditioned subset, kPa
Std =average tensile strength of the dry subset, kPa.

RESULTS AND DISCUSSION

Indirect Tensile Strength Test for Unconditioned Samples

Fig .2. Illustrates the result for (Mix A, Mix B) compared with original mix (0 %, RAP) for unconditioned samples. The results show indirect tensile strength increase with increase RAP until 40% and the decrease slightly at 50% of RAP but the value still above the value of original mix. For Mix B indicates that slightly decline for 20% RAP for TSR value compared with the original mix.



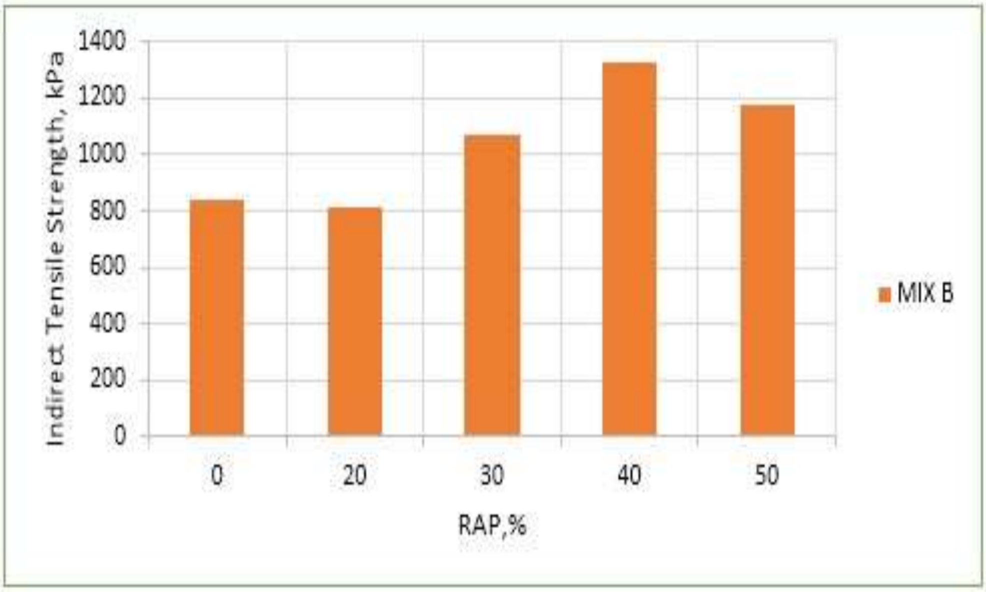


Fig. 2 Indirect tensile strength for unconditioned for Mix A, Mix B

Fig.3.Shows the compared between Mix A and Mix B. The indirect tensile strength for Mix B shows values higher than Mix A for (30%,40%,50%) but slightly lower for 20% of RAP.

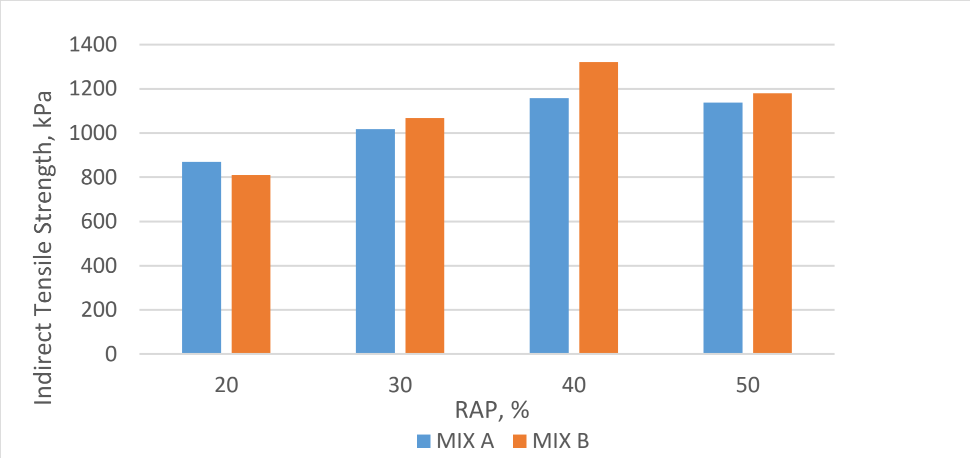


Fig. 3 Indirect tensile strength for unconditioned samples

Indirect Tensile Strength Test for Conditioned Samples

Fig.4. Illustrates the result for (Mix A, Mix B) compared with original mix (0 %, RAP) for conditioned samples. the results show that the indirect tensile strength increases with an increase in RAP content to threshold (40%) and then decline at (50%) for both mix.

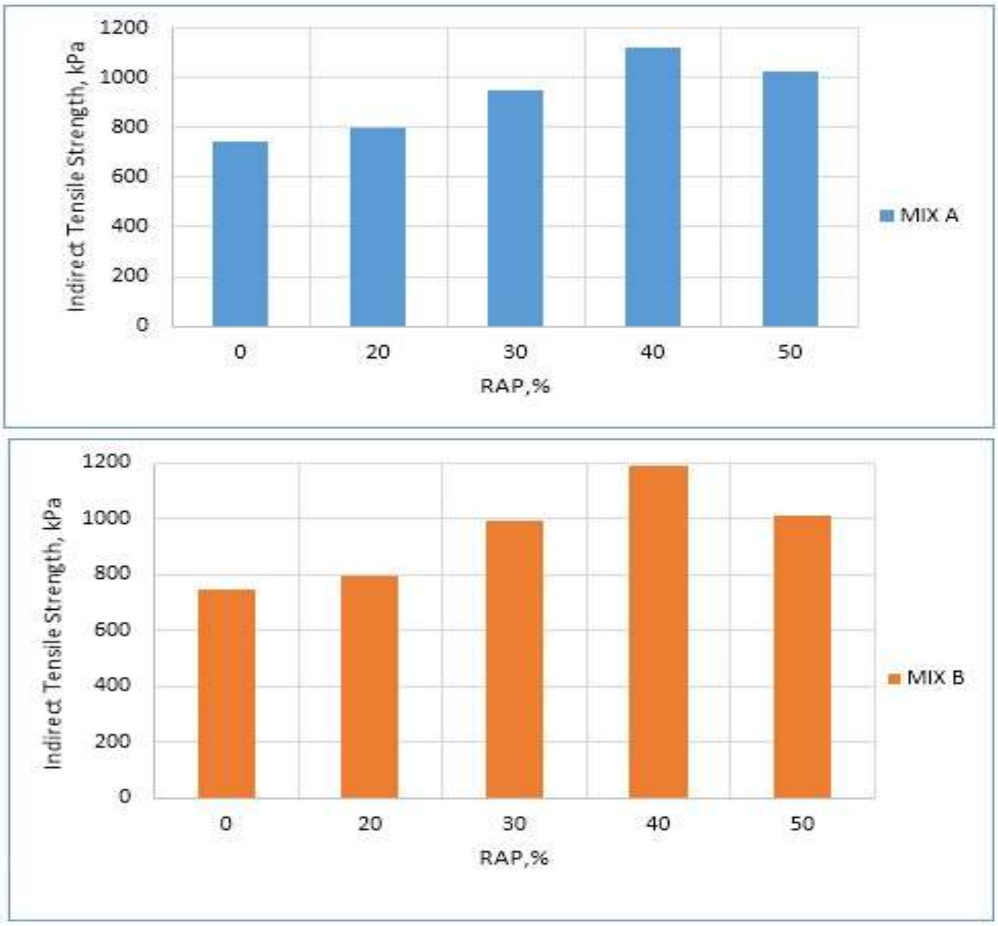


Fig.4. Indirect tensile strength for conditioned for Mix A, Mix B

Fig. 5. Shows the compared between Mix A and Mix B. The indirect tensile strength for Mix A shows values for 20% RAP slightly same that in Mix B and closely value for 50% of RAP.

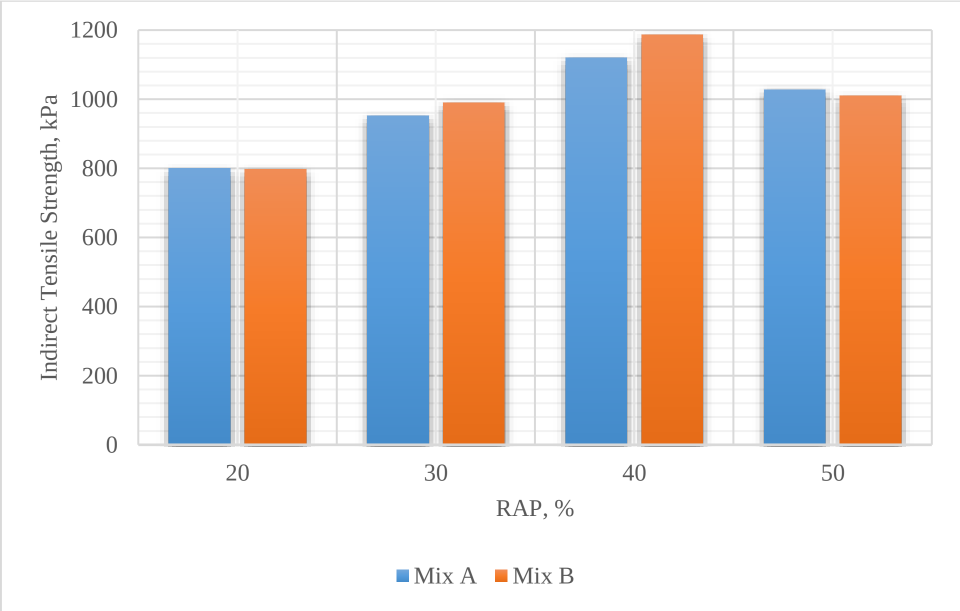
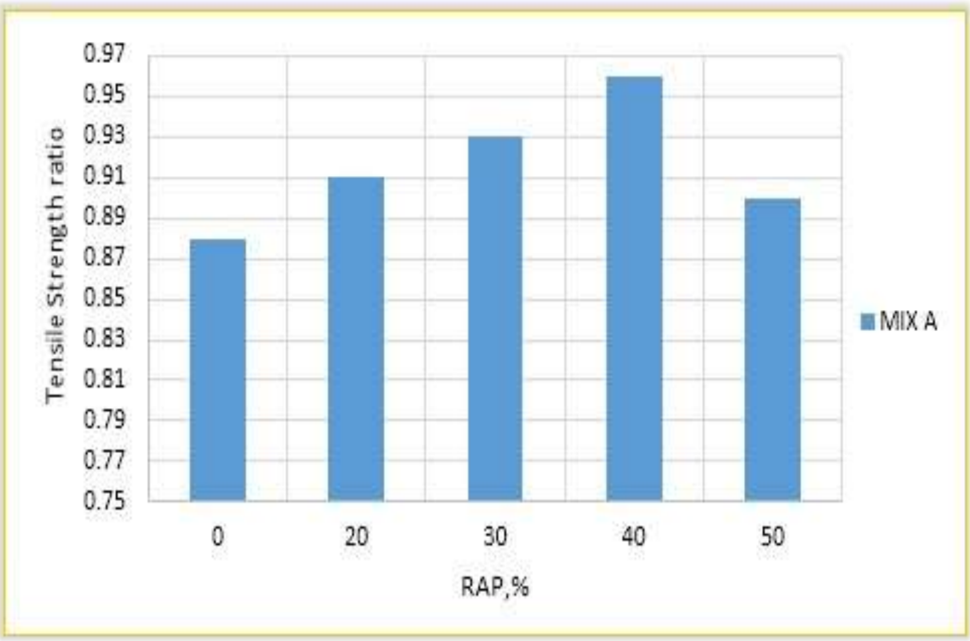


Fig.5. Indirect tensile strength for conditioned samples

Tensile Strength ratio

Fig. 6. shows the tensile strength ratio (TSR) for the both mixes A and B compared with the original mix. Results show that TSR for Mix A (RAP Heating to110 C˚) increases with increase RAP content until 40% RAP content and the decrease after that for (50%, RAP) but the values still above value that have 20% RAP. For Mix B (RAP Heating to140 C˚) shows that the optimum the value for 20% RAP content and then decline with increase RAP. The value of 40% RAP content still above the original mix.



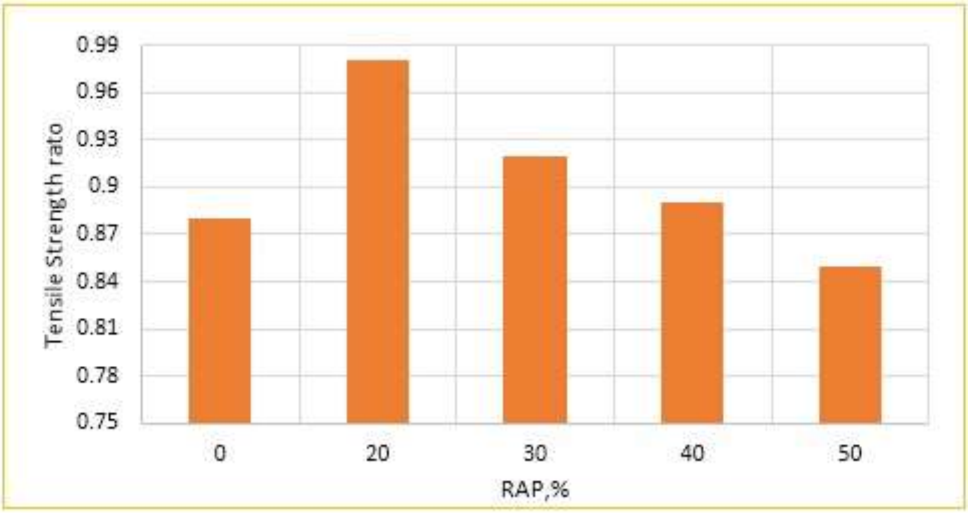


Fig.6. Indirect tensile strength for ratio for Mix A and Mix B

Fig.7. Illustrates tensile strength ratio (TSR) the result for (Mix A, Mix B). The optimum value for Mix A is (40%) of RAP and then downward but the optimum value For Mix B is (20%) of RAP.

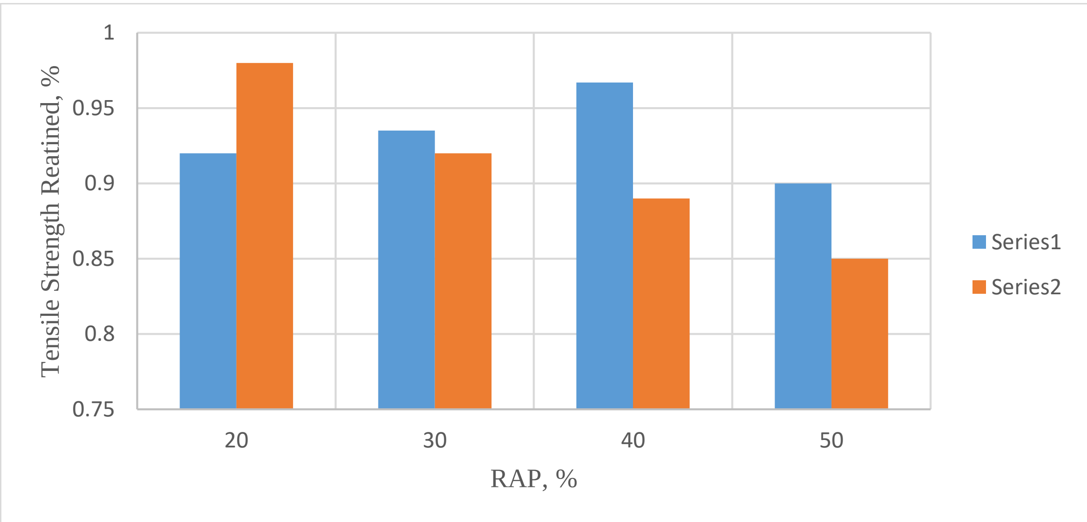


Fig.7. Indirect tensile strength for ratio

CONCLUSIONS

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

1- Indirect tensile strength for reclaimed asphalt pavement heating with 110˚ C for condition samples and unconditioned samples increase with increase RAP. The optimum value was 40% and the decline but still over the original mix value.
2- The optimum value of Indirect tensile strength ratio for RAP heating with 110˚ C samples was 40% and then decline but still above the standard limit of 80%.
3- Indirect tensile strength for reclaimed asphalt pavement heating with 140˚ C for condition samples and unconditioned samples increase with increase RAP. The optimum value was 40% and the decline but still over the original mix value.
4- The optimum value of Indirect tensile strength ratio for RAP heating with 140˚ C

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samples were 20% and then decline but still above the standard limit of 80%

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