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# EVALUATION OF MOISTURE DAMAGE FOR RECYCLED ASPHALT PAVEMENT MIXTURES IN TERMS OF TENSILE STRENGTH WITH AGING FACTORS

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**KEYWORDS:** Asphalt cement, AGGREGATE, MINERAL FILLER, Reclaimed Asphalt pavement.

## ABSTRACT
This research include studying the effect of moisture on virgin and recycled asphalt mixtures, the best gradation and design asphalt content was selected according to superpave method. Superpave Gyratory compactor (SGC) is used to compact mixtures with (100, and 150) mm in diameter of asphaltic specimens, the volumetric properties and mix design for binder layer are determined according to superpave design system, four different percent of (6 ,13, 19 and 25%) of RAP are used, the design asphalt contents are (4.4% and 4.21%) for asphalt grade (40-50),(60-70)mixtures respectively for preparation mixes to compared to virgin mixtures , where tensile strength ratio TSR is the measure of water sensitivity was determined and the Indirect Tensile strength was calculated via ITS test to measure the resistance of mixtures containing RAP materials to moisture and compared to virgin mixtures .the test results indicated that addition of RAP to mixes shows a significant increase on resistance to moisture damage.

## 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)**. The existing deteriorated highways networks in Iraq need huge reconstruction and major maintenance costs. It is essential to consider recycling as one of the imposed solutions in the future for rehabilitation of asphalt pavement. The target is to reuse the existing pavement materials for several causes, mainly to preserve natural resources such as aggregate, and to satisfy economic requirement by reducing the cost of highway construction. Recycling of asphalt pavement can save money, save energy when recycling is done on site, conserve diminishing resources of petroleum products, and help to meet the goal of reducing disposal of construction waste. **(Sarsam, 2007)**. **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%. **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%.

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## MATERIALS USED

### Asphalt cement

The asphalt cement of grade (40-50) and (6-70) was used in the study and which obtained from Al-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 (40-50)***

| *Property* | *ASTM Designation No.* | *Test Results* | *SCRB specification Requirement* |
|---|---|---|---|
| *Penetration, (25°C, 100 g, 5s), 0.1 mm* | *D5-06* | *43.6* | *40-50* |
| *Softening Point. (◦C)* | *D36-95* | *53.5* | *---* |
| *Ductility at 25 C, 5cm/min, (cm)* | *D113-99* | *113 cm* | *+100* |
| *Specific Gravity* | *D70-97* | *1.032* | *---* |
| *Flash point*<br><br>*Fire point* | *D92-05*<br><br>*D92-05* | *335*<br><br>*339* | *>232*<br><br>*>232* |
| ***Properties after Rolling film Oven Test ASTM D1754*** | | | |
| *Retained Penetration of residue, 25°c, 100gm, 5sec* | *D5-06* | *72%* | *>55%* |
| *Ductility of Residue , 25°c, 5cm/min* | *D 113-99* | *66 cm* | *>25* |
| *Rotational Viscometer, at 135°C (Pa.sec)* | *ASTM D4402* | | *0.537 @ 135° C*<br>*0.150 @ 165 ° C* |

***Table (2) The physical Properties and Standard Specification for Asphalt cement (60-70)***

| ***Property*** | ***Test condition*** | ***ASTM Designation*** | ***Test Value*** | ***Standard Limit 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 point*** | *----* | *ASTM D92* | *296°C* | *>232 °C* |

| | | | | |
|---|---|---|---|---|
| ***Fire point*** | ---- | ASTM D92 | 320°C | ---- |
| ***Loss on heating*** | 163 °C, 50gm, 5 hr | ASTM D1754 | 0.365 | <0.75 |
| ***Viscosity*** | Pa.s | ASTM D4402 | 0.475 @135 º C<br>0.113 @ 165 º C | |

**AGGREGATE :**

The crushed quartz aggregate used in this work was gotten from Al-Nibaae 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 Coarse and Fine aggregates***

| ***Property*** | ***Value*** | | ***ASTM Designation*** |
|---|---|---|---|
| ***Coarse Aggregate*** | | | |
| *Sieve size* | *Bulk Specific Gravity* | *Water Absorption* | |
| *Sieve 19mm (3/4")* | *2.6344* | *0.508* | *C127-04* |
| *Sieve 12.5mm (1/2")* | *2.646* | *0.409* | *C127-04* |
| *Sieve 9.5mm (3/8")* | *2.622* | *0.636* | *C127-04* |
| *Sieve 4.75mm (No.4)* | *2.640* | *0.510* | *C127-04* |
| ***Apparent Specific Gravity*** | | | |
| *Sieve 19mm (3/4")* | *2.657* | | *C127-04* |
| *Sieve 12.5mm (1/2")* | *2.664* | | *C127-04* |
| *Sieve 9.5mm (3/8")* | *2.649* | | *C127-04* |
| *Sieve 4.75mm (No.4)* | *2.662* | | *C127-04* |

| | | |
|---|---|---|
| *Wear %(Loss Angeles abrasion)* | *20.88%* | *C131-03 35(MAX.)* |
| *Soundness (Loss by Na2SO4 Solution),%* | *4.3%* | *ASTM C88 12(Max.)* |
| *Angularity,%* | *97%* | *ASTM D5821 ,95(Min.)* |
| *Flatness,%* | *1%* | *ASTM D 4791 10(Max.)* |
| ***Fine Aggregate Properties(Crushed Sand < 4.75)*** | | |
| *Bulk Specific Gravity* | *2.642* | *C128-04* |
| *Apparent Specific Gravity* | *2.691* | *C128-04* |
| *Water Absorption % Crushed Sand(<4.75mm)* | *1.98* | *C128-04* |
| *Equivalent Sand (Clay Content, %)* | *96* | *ASTM D2419,45(Min.)* |

| | | |
|---|---|---|
| *Deleterious Material, %* | *1.1* | *ASTM C142 3(Max.)* |

**MINERAL FILLER:**
Filler is a non-plastic material passing sieve No.200 (0.075mm), usually used to improve mixture properties. Mineral filler used in this study is limestone dust obtained from Karbalaa ,the physical properties of the used filler are presernted in table (4).

***Table (4) physical properties of Mineral Filler***

| Property | Value |
|---|---|
| Bulk specific Gravity | 2.72 |
| % passing sieve No.200 | 96 |

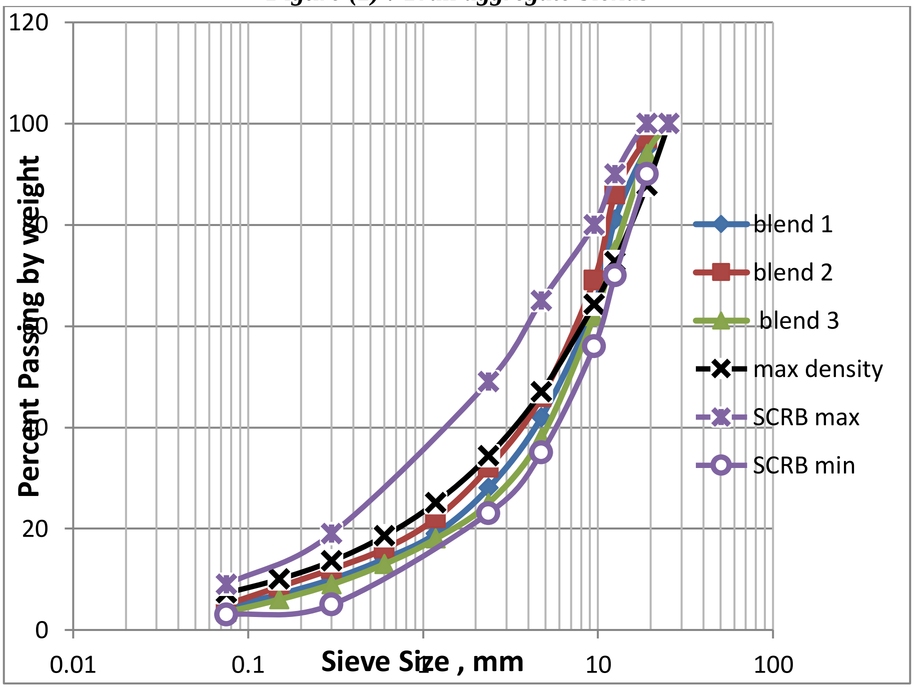
**Reclaimed Asphalt pavement**
The reclaimed asphalt pavement materials (RAP) was brought from stoke of Reclaimed Asphalt for Mayoralty of Baghdad-project office in Baghdad city. Extraction test was conducted on the reclaimed asphalt pavement to extraction the asphalt from aggregate and filler. The testing procedure according to (**ASTM-D2172**).

The percent of asphalt cement was (4%) and gradation of aggregate shown in table (5) the according to (**Iraq specifications' R9).**

| *Standard sieves (mm)* | *%Passing by weight (R9)* | *% Passing by weight (RAP)* |
|---|---|---|
| *25.0* | *---* | |
| *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* | *5-21* | *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 .Selected aggregate gradation was according to **Iraq specification R9 and AASHTO M 323** for binder course. Figure (1) shown the gradation of aggregate blends. The design asphalt binder content is established at 4% air voids and the design asphalt content was 4.4% for asphalt grade (40-50) and that for asphalt grade (60-70) was 4.21%. All other mixture properties were checked at the design asphalt binder content to verify that they meet Iraq specifications' (R9) for binder course and AASHTO M323. Table (6) and (7) show the design mixture properties at design asphalt content (4.4%) and (4.21%) respectively

*Figure (1) : Trail aggregate blends*




*Table(6): the design mixture properties for asphalt grade (40-50) at 4.4% asphalt binder content.*

| Mix property | Result | Criteria |
|---|---|---|
| Air Void, % | 4.0 | 4.0 |
| VMA,% | 15.52 | 13.0 min. |
| VFA,% | 75.19 | 65-75 |
| Dust Proportion | 0.83 | 0.6-1.2 |
| %Gmm @Nini =8 | 87.91 | Less than 89 |
| %Gmm @ Nmax = 160 | 97.87 | Less than 98 |

*Table (7): the design mixture properties for asphalt grade (60-70) at 4.21% asphalt binder content.*

| Mix Property | Result | Criteria |
|---|---|---|
| Air void, % | 4.0 | 4.0 |
| VMA, % | 15.34 | 13.0 min. |
| VFA, % | 73.92 | 65-75 |
| Dust Proportion | 1.18 | 1.6-1.2 |
| %Gmm @Nini =8 | 87.52 | Less than 89 |
| %Gmm @ Nmax = 160 | 97.74 | Less than 98 |

## METHODOLOGY

Recycled hot mix asphalt is a multiphase system which consist of recycled sized old asphalt material. Heating of RAP material should be kept at minimum ranges in order to avoid changing 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)** and he 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.

Specimens fabricated at lab are usually differs from those produced in a HMA plant for a number of reasons .one of these reasons that the binder in HMA mixture react with oxygen in the air and become harder and brittle and the aging of asphalt continues at slow rate of service life of the pavement and one method to account for the changes in the mixture properties is to fabricate specimens that simulate the aging during service life of pavement **AASHTOR30.( Prithvi S. and Sanjoy1996)**both evaluated the rheological properties of the asphalt cement due to aging for both short (loos mixture at 135˚C) and long term aging (compacted specimen at 85˚C) and tested for tensile strength after short and long term aging process in relation to asphalt film thickness and they resulted that the tensile strength decrease as asphalt film increase for long term aging specimens. **Saad I. and Samer M.** studied the influence of aging time on asphalt pavement performance where specimens were prepared and subjected the loos mix to short term aging at135˚C for(2-4) hr and then compacted and subjected to long term aging at 85˚C for (2-5)days ,they concluded that the stiffness of the mixture increases by increasing aging period that lead to increase of Marshall Stability and indirect tensile strength at 25˚C by 52% and 34% as compared to control mix .

-Based on the researches mentioned above the RAP material was heated to 110˚C for (1-2) hours and new aggregate was heated to150-160˚C.after heating the aggregate and asphalt mixed together and then added heated RAP material to mixture , the percent of RAP material was added (6%, 13%,19%,25%) from total weight.
- Short term aging for loos mix at 135˚C for (2-4)hr and long term aging was applied at compacted specimens at 85˚C for 5 days(120 hr) and applying the specimens for three immersion periods (1,3,7 ) days and tested for indirect tensile strength test and tensile strength ratio
-

## EVALUATION OF MOISTURE SENSITIVITY

The bond between aggregate mixture and asphalt binder film may lost due to presence of water or cause stripping, and it depends on several factors, asphalt characteristics, environment, traffic and aggregate characteristics. This accomplished by applying **AASHTO T283"Resistance of Compacted Bituminous Mixture to Moisture-Induced Damage"** specimens are compacted to 7% air voids . one subset of three specimens is considered as 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 for three conditioning periods (1,3 and 7 days). 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:

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

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:

$$\boldsymbol{TSR = \frac{St\ cond}{Stunc} * 100 \ldots .(2)}$$

Where :
TSR =Tensile Strength Ratio, percent
Stcond= average tensile strength for the moisture conditioned specimens,Mpa
Stunc= average tensile strength for unconditioned (dry) specimens , Mpa

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## RESULTS AND DISCUSSION

**Un condition Indirect Tensile Strength Results Case at 25˚C for Short Term Aging Specimens:**
Figure(1) illustrates that the tensile strength increases as RAP increases and it increased by 34.9 % from virgin mix (0% RAP) to 13 % RAP

**Un condition Indirect Tensile Strength Results Case at 60˚C for Short Term Aging Specimens :**
It could be noticed from figure (2) that the highest tensile strength at 13 % RAP with (1338.28 kPa) and the lowest value at 19 % RAP with (576.22 kPa ) .

**Condition Specimens Tensile Strength Test Results for Recycled Asphalt Mixtures with Time of soaking:**
figure (3) clarifies that tensile strength increases as RAP percentages increases too, it increased by about 40 % from 0 to 6% RAP and by 39 % from 6 to 13% RAP, and 10% from 13 to 19 %. Figure (4) shows At 60˚C the tensile strength begin to rise when adding RAP to mixture from virgin through 6 % RAP until 13% RAP at which tensile strength decrease at 19 %RAP by 23.7 %. For 7 days conditioning ,specimens when testing at 25˚C as shown at figure (6) the tensile strength decreased by 72.9% between un condition virgin mix (0% RAP) and virgin mix conditioned for 7 day. At 60˚C testing temperature the results are usually lower than those tested at 25˚C this can be noticed at figure (7),

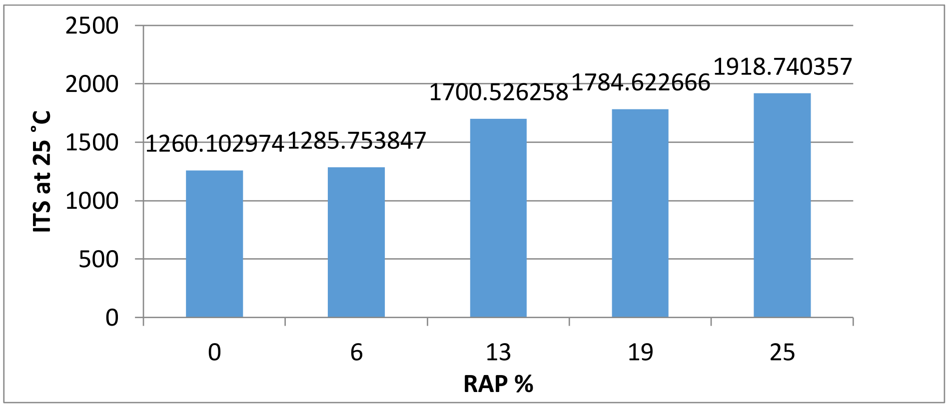


*Figure (1): ITS for un condition specimens for S.T.A at 25˚C*

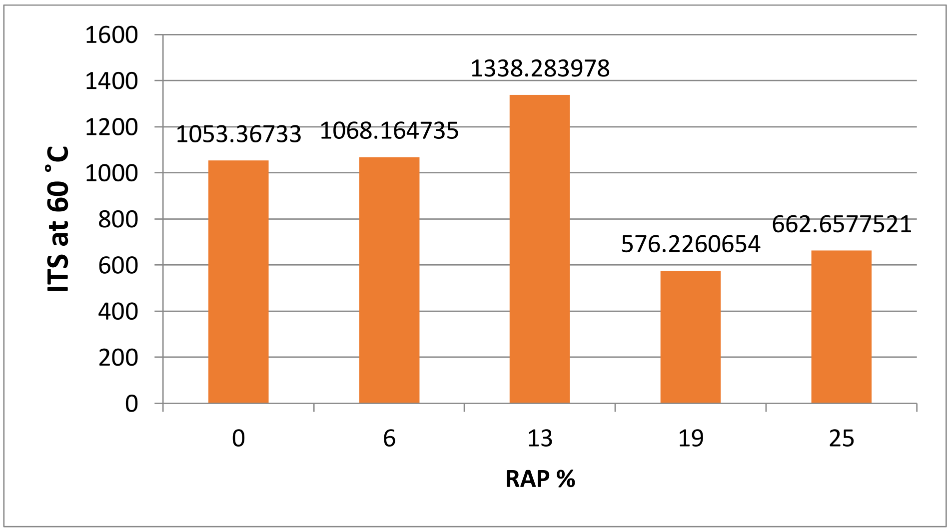


*Figure (2): ITS for un condition specimens for S.T.A at 60˚C*

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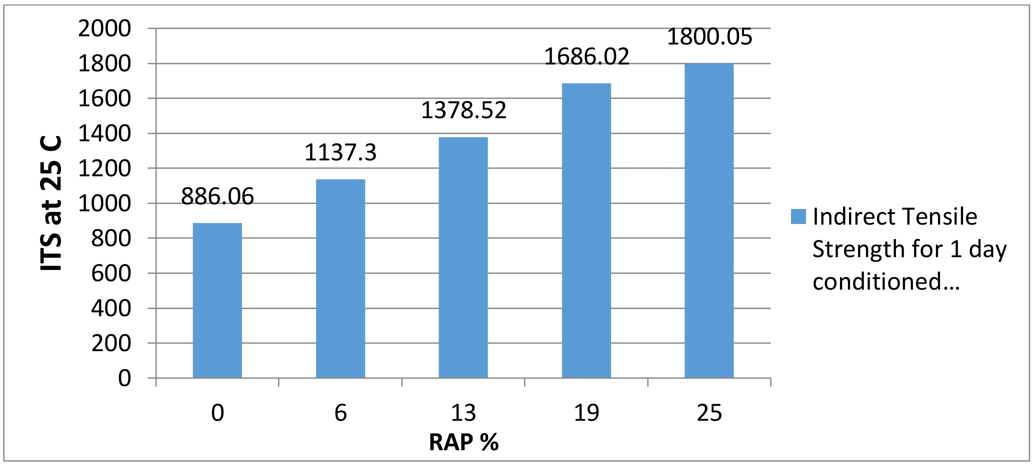


*Figure (2): ITS for 1 day conditioned specimens for S.T.A*

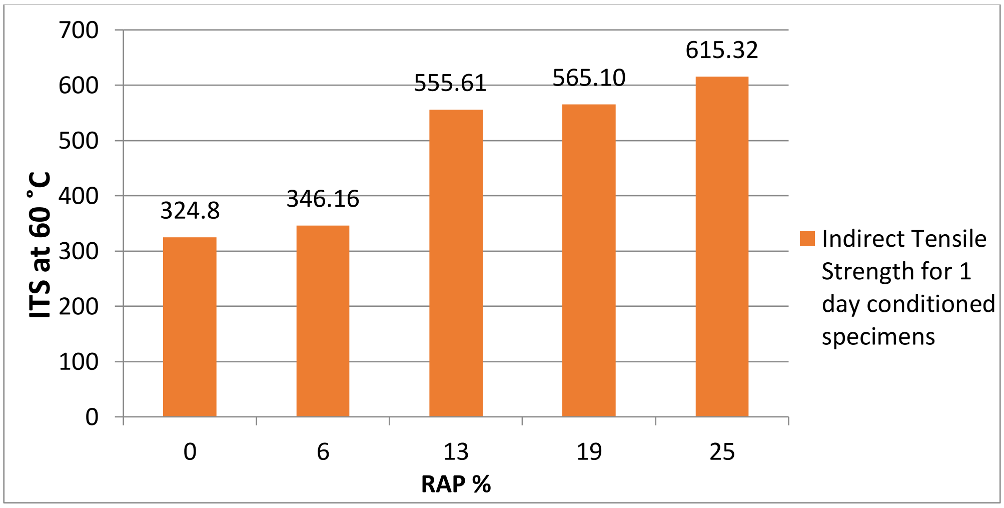


**Figure (3): ITS for 1 day conditioned specimens for S.T.A**

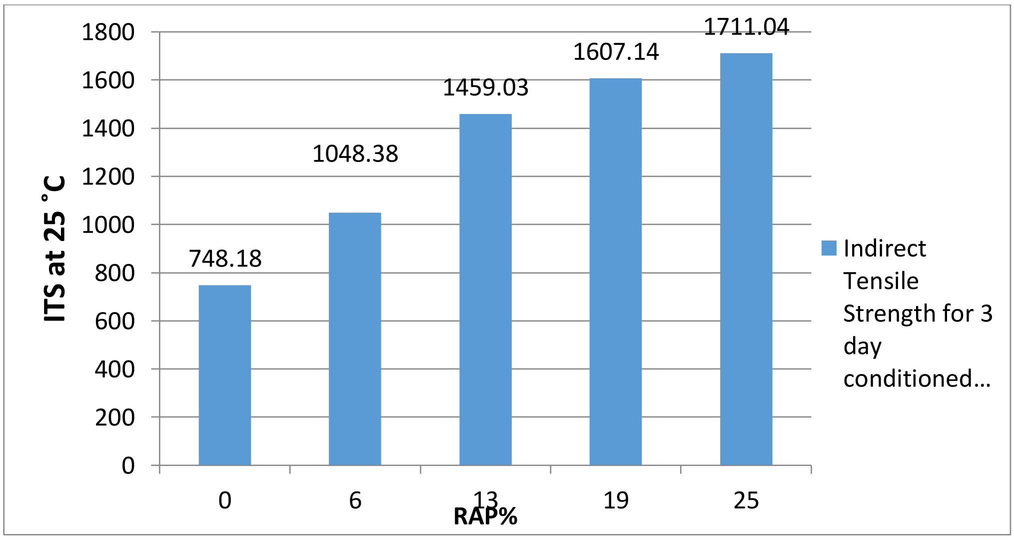


*Figure (4) : ITS for 3 day conditioned specimens for S.T.A*

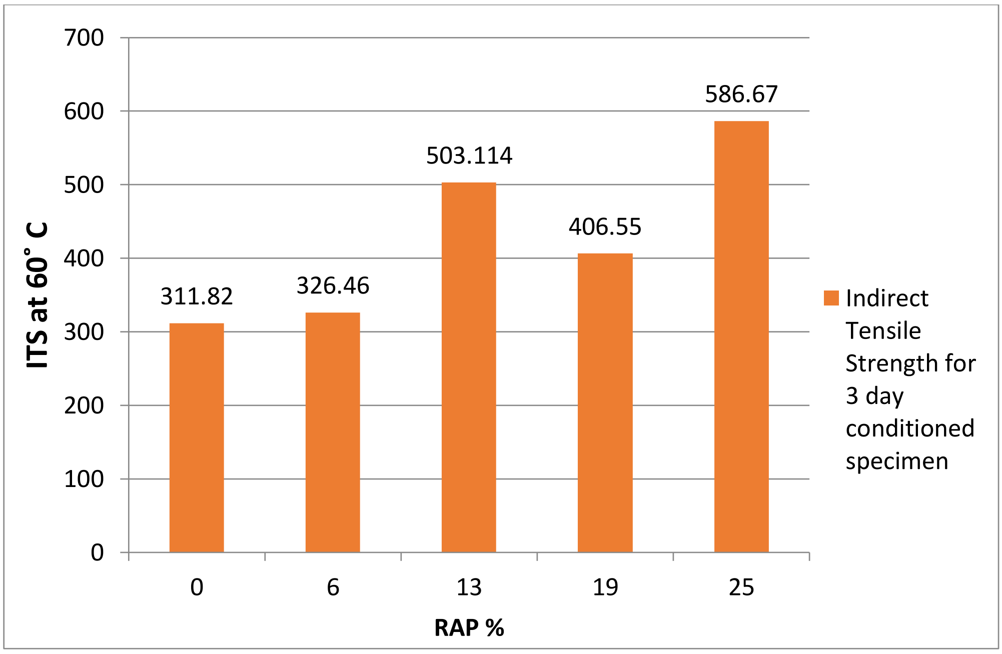


*Figure (5): ITS for 3 day conditioned specimens for S.T.A*

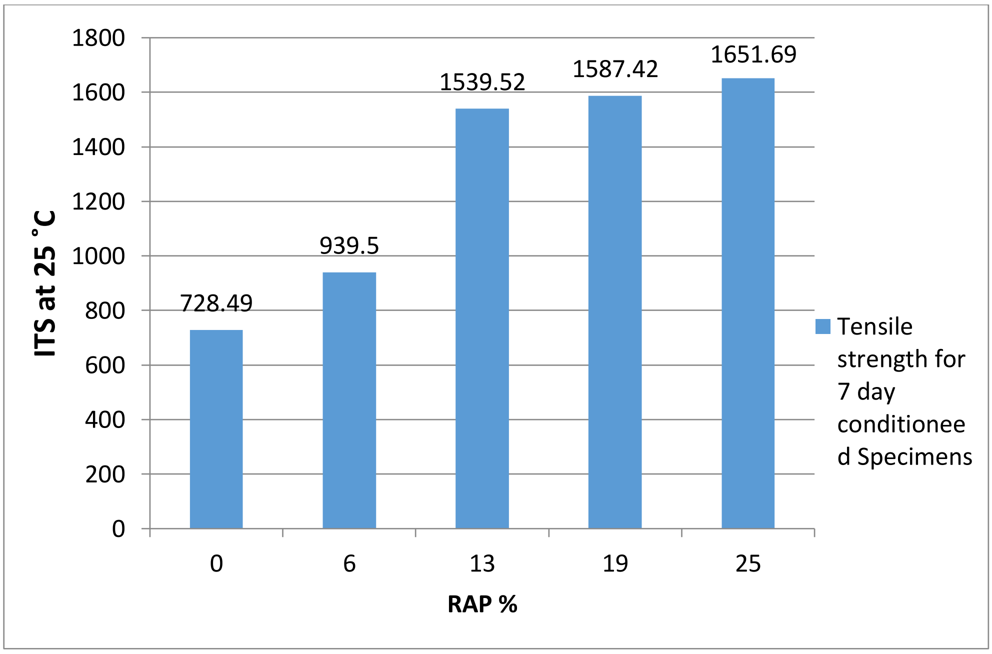


*Figure (6): ITS for 7 days conditioned specimens for S.T.A*

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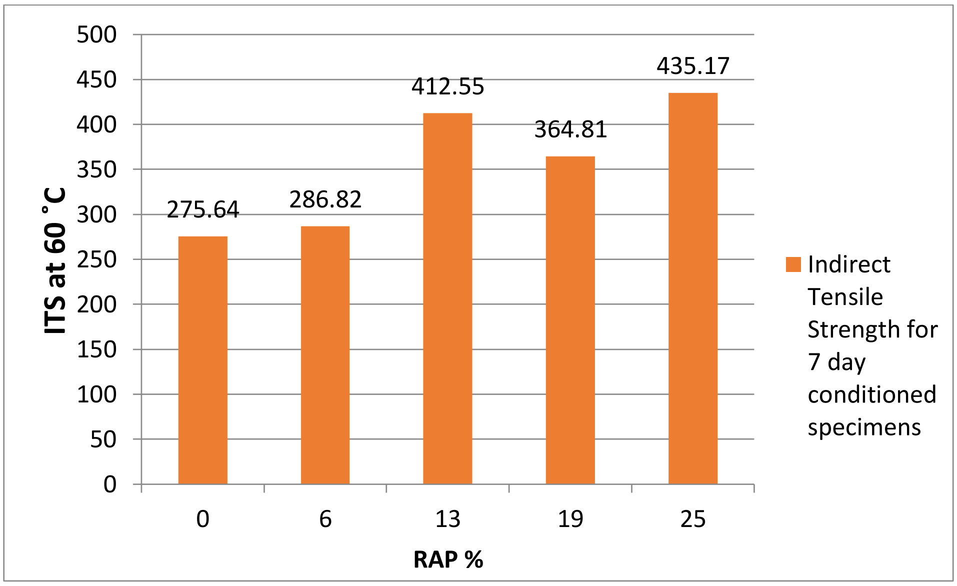


***Figure (7): ITS for 7 days conditioned specimens for S.T.A***

**Un condition  Indirect Tensile Strength Results Case at 25˚C for  Long Term Aging Specimens :**
Figure (8) shows that ITS strength increased by 54.5%   when adding 13% RAP and by 99.7% when adding 25% RAP which explains that the RAP material has improved the strength of  a specimen.

**Un condition  Indirect Tensile Strength Results Case at 60˚C for  Long Term Aging Specimens :**
Figure (9) shows that ITS increases as RAP percent increase the highest strength is at 25% RAP addition with a value of  734.89 kPa., figure (10) shows that ITS for 1 day immersion period decreased from 1321.59 kPa to 915.894 kPa when conditioned for 1 day. At 60˚C the results are shown in figure (11) at which are lower than those specimens mentioned above whose tested at 25˚C.  Figures (12),(13) have a similar behavior  to specimens tested at 60˚C. all results indicates that un condition specimens are higher than conditioned specimens

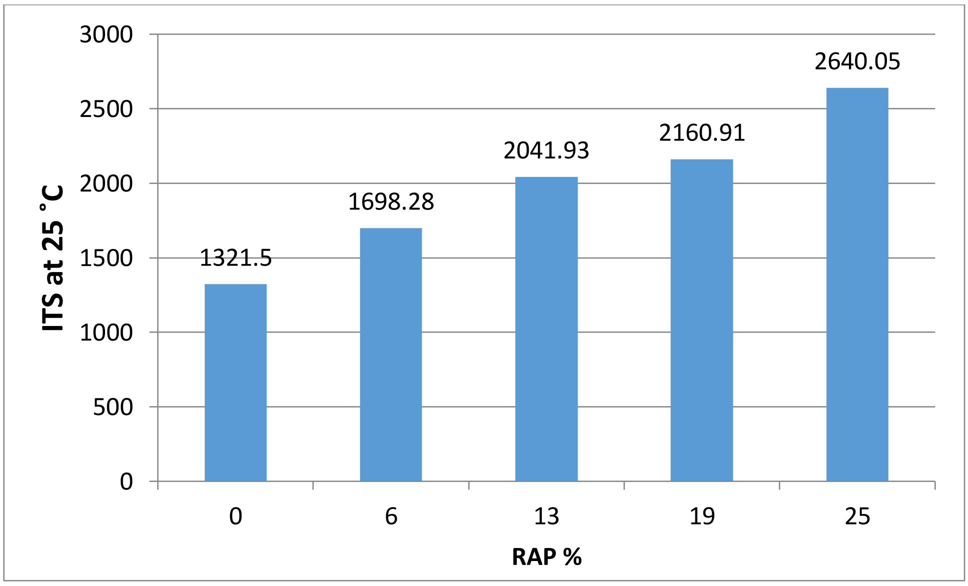


***Figure (8): Indirect Tensile Strength for un condition specimens for L.T.A***

 

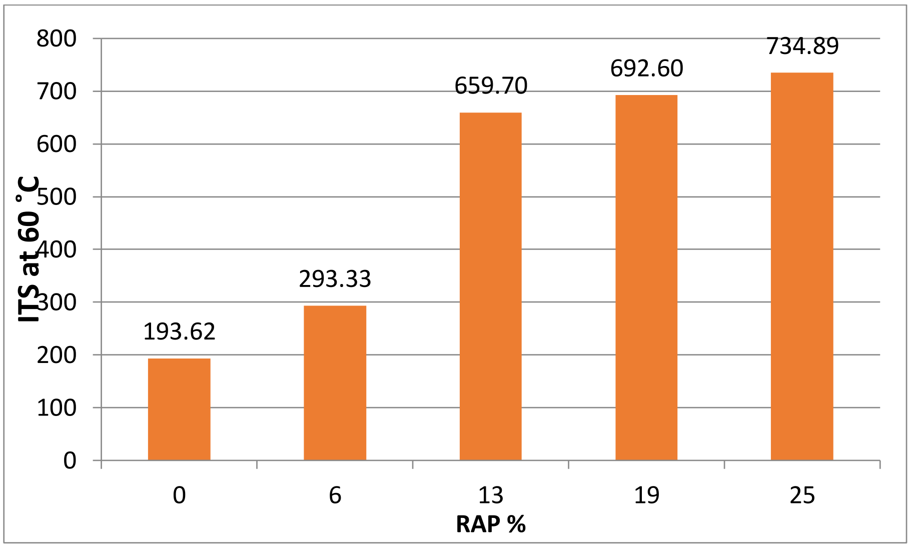


*Figure (9): Indirect Tensile Strength for un condition specimens for L.T.A*

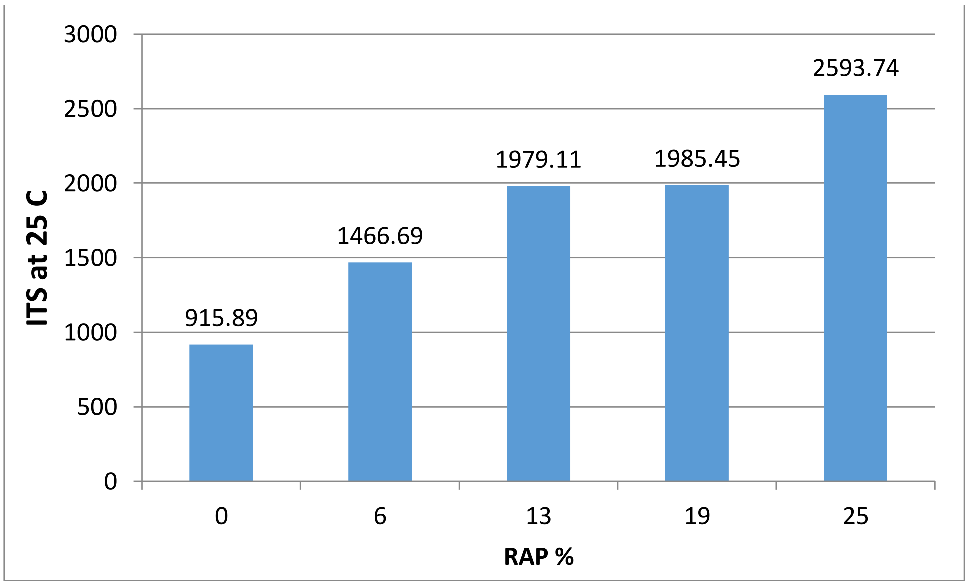


*Figure (10): Indirect Tensile Strength for 1 day conditioned specimens at L.T.A*

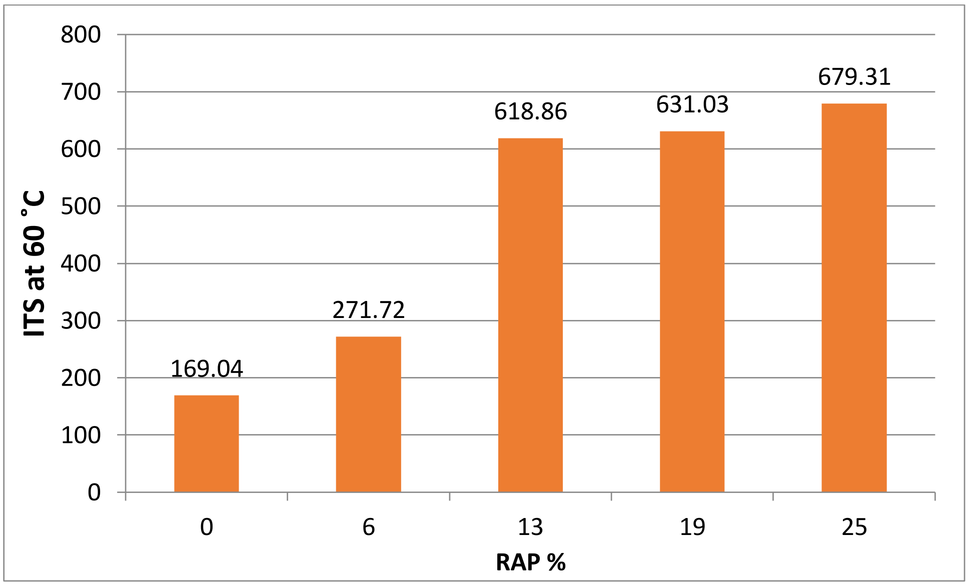


***Figure (11): indirect Tensile Strength for 1 day conditioned specimens at L.T.A***

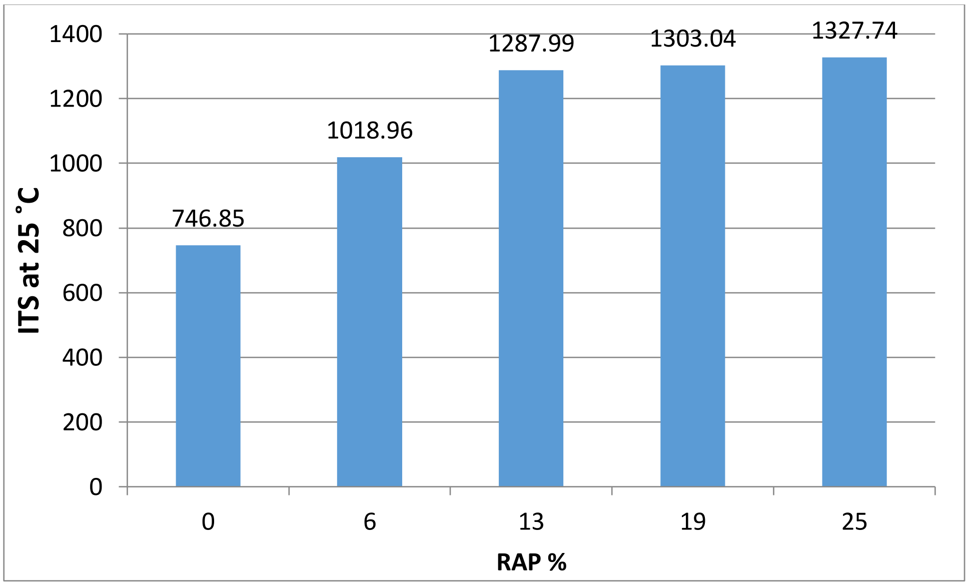


***Figure (12): Indirect Tensile Strength for 3 day conditioned specimens at L.T.A***

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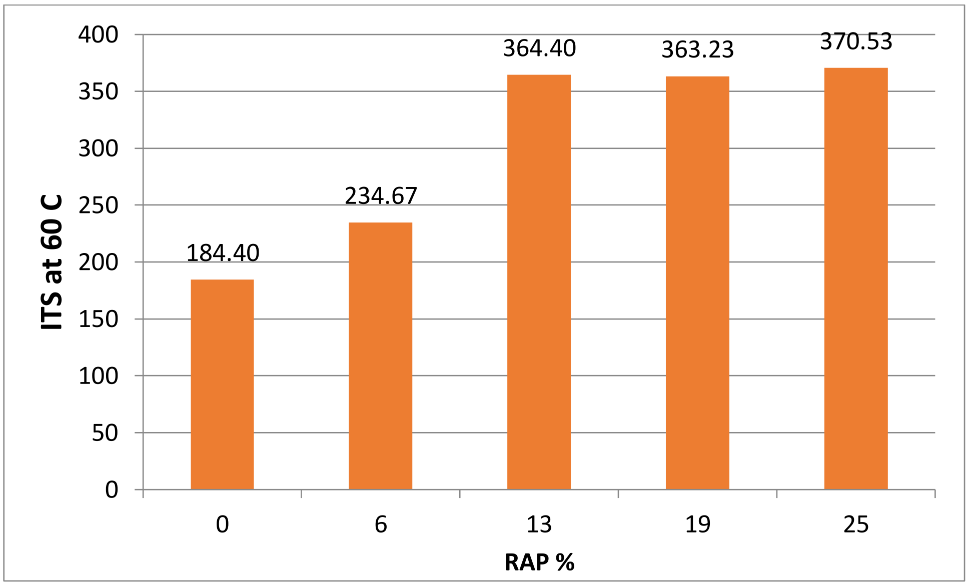



*Figure (13): Indirect Tensile Strength for 3 day conditioned specimens at L.T.A*

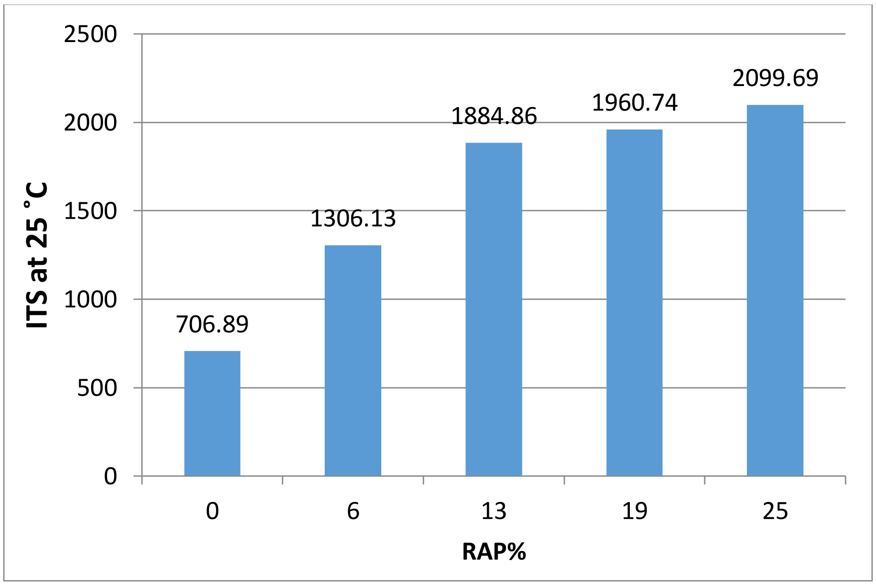
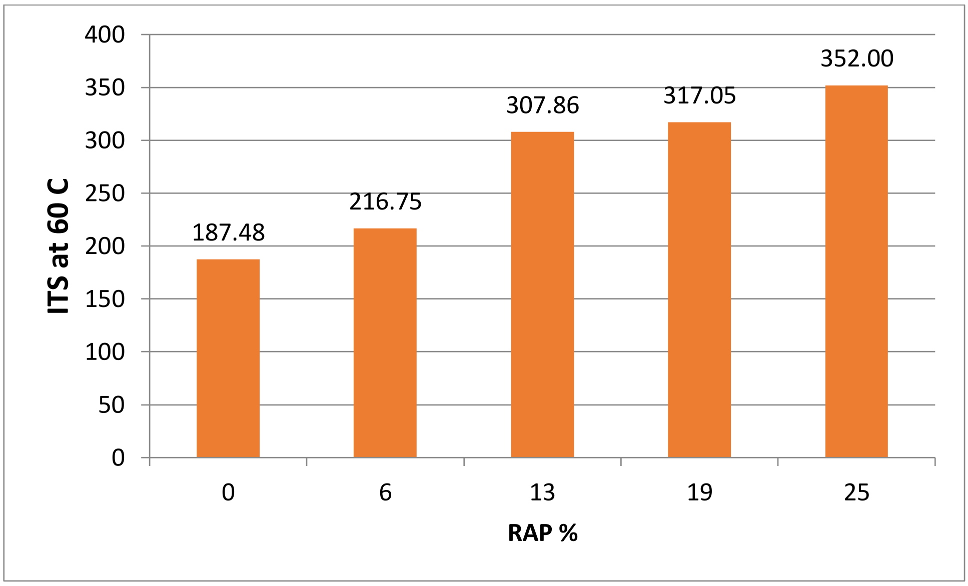



*Figure (14): Indirect Tensile Strength for 7 day conditioned specimens at L.T.A*




*Figure(15):Indirect Tensile Strength for 7 day conditioned specimens at L.T.A*

## TENSILE STRENGTH RATIO FOR RECYCLED ASPHALT PAVEMENT MIXTURES

Figure (16) presents the TSR for virgin/RAP mixture when conditioning in water path of 60˚C for 1,3 and 7 days at mixtures short term aged (S.T.A) and tested at 25˚C , the results for 1 day shows that TSR for virgin mix(0%) is (70.3%) which less than 80%. For specimens conditioned for 3 days , the TSR values are already declined for some mixtures , 0 and 6% RAP mixtures shows more susceptible to moisture while 13,19and 25% RAP mixture shows a better performance. Generally, TSR for virgin mixture has decrease by 18% when conditioning from one to 3 days and 21.6% when conditioning from one to 7 days. Figure (17) clarified the TSR results for virgin/RAP mixtures when aged for long term aged (L.T.A) and conditioned for 1,3 and 7 days and tested at 25˚C . When conditioning for 1 day, virgin mixture is more susceptible to moisture than mixtures containing RAP which clearly indicates that mixes made up with RAP are less sensitive to moisture damage as compared to virgin mixes.

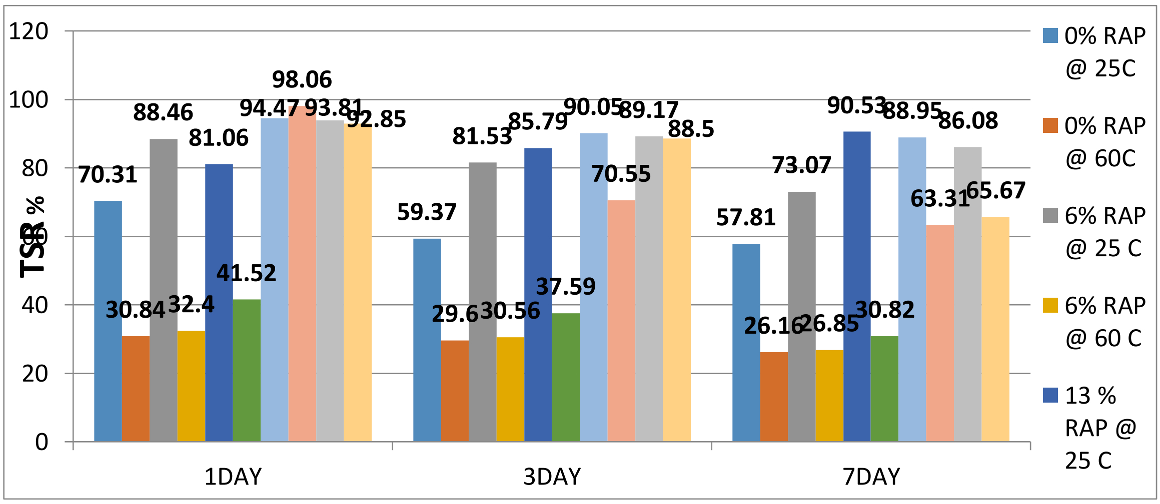



*Figure (16): Tensile strength Ratio for short term aging conditioned specimens*

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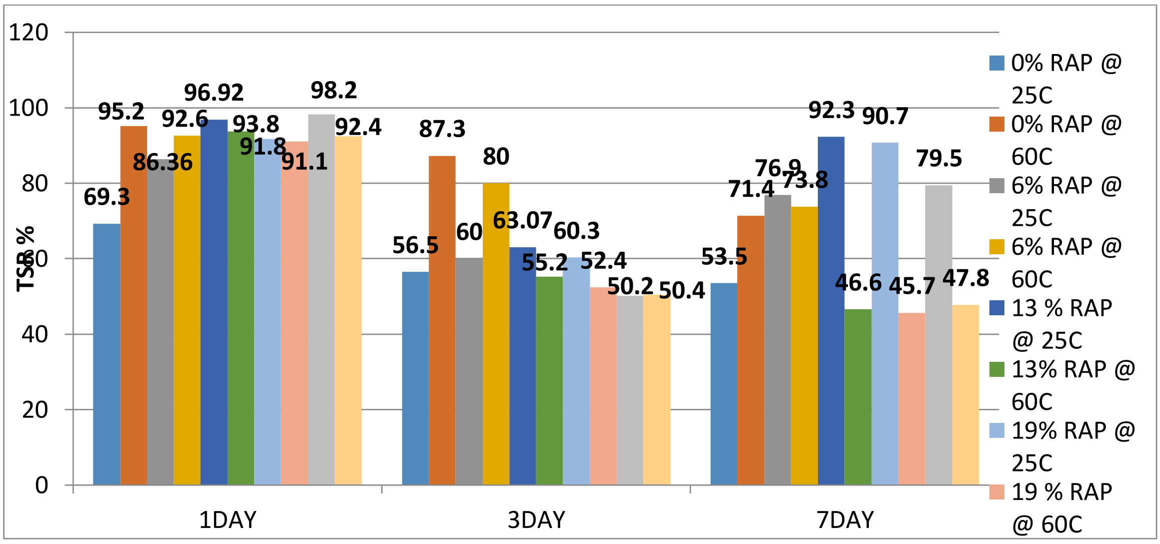


***Figure (17): Tensile Strength Ratio for long term conditioned specimen***

## CONCLUSION

Based on laboratory for test for virgin/RAP mixtures the following conclusion can be drawn:

1- Indirect tensile strength for condition and un condition samples increase with increase RAP percentages.
2- The long term aging of specimens has the highest strength than short term aging .at long term aging 25% RAP is higher than un aged mix by 122%. at short term aging 25% RAP is higher than un aged mix by 61.9% .
3- The dry specimens (un condition) has the highest strength than condition specimens.
4- The optimum increase at tensile strength from case of S.T.A to L.T.A is at 25% RAP addition by 37.5%
5- Conditioning the specimens for 7 days soaked in water bath of 60˚C and measured at 25˚C has the lowest tensile strength with a value of (706.8 kPa) when not using reclaimed asphalt pavement.

## REFERENCES

**1.** Randy West et.al. (2013) Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content, NCHRP Report 752, Final Report**.**
**2.** Shaopeng Wu, et al. Investigation of temperature characteristics of recycled hot mix asphalt mixtures Volume 51, Issue 3, Pages 511-710 (2007).
**3.** AASHTO R30,standard practice for mixture conditioning of hot mix asphalt.
**4.** Prithvi S. Kandhal and Sanjoy Chakraborty .(1996),Effect of asphalt film thickness on short and long term aging of asphalt paving mixtures **,** National Center for Asphalt Technology Auburn University, Alabama
**5.** Saad I. and Samer M. (2014),Influence of Aging Time on Asphalt Pavement Performance**,** Department of Civil Engineering College of Engineering- University of Baghdad
**6.** AASHTO T283 .(2015)**"**Resistance of Compacted Bituminous Mixture to Moisture-Induced Damage"**.**