Tikrit Journal of Engineering Sciences/Vol.19/No.1/March 2012, (80-96)

Evaluation and Study the Effect of Additives and Other Factors on Tensile Strength of Asphalt Paving Mixtures

Hanaa Khaleel A. Al-Baiti
Assistant Lecturer
Civil Engineering Department-University of Tikrit

Abstract

The resistance of asphaltic concrete to cracking is dependent upon its tensile strength and flexibility characteristics. Also the low tensile strength has recognized as a major contributor to other performance problems.

The fatigue life of mixtures decreases exponentially with decreasing of tensile strength. This trend is justified by the loss in stiffness and thereby initiating cracks and stripping.

The main objective of this research is intended to study the effect of different variables related with the used materials and the external conditions on the tensile strength and predict a model of indirect tensile strength in asphalt concrete paving materials under the local prevailing conditions and investigate the effect of percent of additives of (Polyestrene resins and Hydrated Lime) to enhance the resistance ability of asphalt concrete mixture against distresses.

The main affected factors; soaking, asphalt content, compaction, aggregate maximum size and temperature, influence on the indirect tensile strength and presented through a statistics analysis model for tensile strength in asphalt mixture.

Keywords: Indirect tensile strength; additives; Polystyrene resins; Hydrated Lime;

تقييم ودراسة تأثير المضافات والعوامل الأخرى على مقاومة الشد لخلطات التبليط الإسفلتي

الخلاصة

إن مقاومة الخرسانة الإسفلتية للتشققات تعتمد بصورة رئيسية على مقاومتها للشد وخصائص المرونة. كما أن مقاومة الشد الواطئة تعتبر بصورة رئيسية سببا في مشاكل أداء التبليط الأخرى.

إن عمر الكلل للخلطات يتناقص بعلامة آسية مع تناقص مقاومة الشد للتبليط. هذه العلاقة تتحقق بفقدان الصلابة وبذلك تنشأ التشققات والتعرية لطبقة التبليط الإسفلتية العليا.

إن الهدف الرئيسي من هذه البحث هو بيان تأثير العوامل المختلفة المتعلقة بالمواد المستعملة والظروف الخارجية على مقاومة الشد والتي تؤثر بشكل مباشر على حدوث التشققات في طبقات التبليط الإسفلتية. كذالك استحداث موديل تنبؤي لمقدار مقاومة الشد في طبقة التبليط الإسفلتي تحت الظروف المحلية وتحري تأثير النسب المختلفة للمواد المضافة (راتنج البولي ستايرين و الكلس المائي لتحسين قابلية الخلطة الإسفلتية ضد التشوهات.

إن العوامل الرئيسية المؤثرة على مقدار مقاومة الشد غير المباشر والتي تشمل (كمية الإسفلت وتأثير الغمر وعدد

الضـربات واخـتلاف درجـة الحـرارة والمقـاس الأقصـى للركـام والمضـافات تـم تمثيلهـا مـن خـلال موديـل التحليـل الإحصائي لمقاومة الشد للخلطة الإسفلتية).

الكلمات الدالة: مقاومة الشد الغير المباشر، المضافات، بولستر رزن، مسحوق النورة المطفأة.

Symbols

IDT = Indirect tensile strength.

VMA = voids in mineral aggregate.

APA = Asphalt Pavement Analyzer.

NMAS=Nominal maximum aggregate size.

PR= Polyester Resin.

TSR= Tensile strength ratio.

SCRB= State Commission of Roads and Bridges.

HMA= Hot mix asphalt

I.T.S = Indirect tensile strength.

P_{ult} =Ultimate applied load at failure.

t = Thickness of specimen.
d = Diameter of specimen.

TS= Temperature susceptibility.

E = Mean error,
δ = Variation Coefficient

S = Standard deviation, and.

$\overline{X}$ = Mean value.

Introduction

Tensile strength plays an important role in the performance of a mixture under fatigue, rutting, and moisture susceptibility. The tensile strength is primarily a function of the binder properties. The amount of asphalt binder in a mixture and its stiffness influence the tensile strength. Tensile strength also depends on the absorption capacity of the aggregates used. At given asphalt content, the film thickness of asphalt on the surface of aggregates and particle-to-particle contact influences the adhesion or tensile strength of a mixture. Various studies have repeatedly proved that the tensile strength increases with decreasing air voids. The tensile strength of a mixture is also strongly influenced by the consistency of the asphalt cement, which can influence rutting. Thus, tensile strength plays an important role as a design and evaluation tool for paving mixtures [1].

The main objectives of this research are:-

1- Evaluation of the effects of different variables related to asphalt concrete mixtures, additives, soaking, compaction, aggregate maximum size and temperature effects on tensile strength potential using the indirect tensile strength test.
2- Formulation of statistical relation for potential tensile strength in asphalt mixtures for flexible pavement at different asphalt mixture properties.

Review of Literature

Pavement lifetime is an important issue for a national economy. Good pavement must provide a smooth riding profile, withstand large traffic repetition and efficiently transmit the stress to the underlying sub-grade support[2]. The behavior of bituminous mixtures and the factors that affect their performance have been studied thoroughly, although the behaviour of bituminous mixtures under traffic and environmental conditions is highly complex. To perform satisfactorily in a pavement system, bituminous mixtures should be doing decrease distresses, ensure stability of pavement, resisting permanent deformation, resistance to cracking, and resistance to moisture damage [3].

Many factors contribute to the degradation of asphalt pavements. When high quality materials are used, distresses are typically due to traffic loading, resulting in rutting or fatigue cracking. Environmental conditions such as temperature and water, have a significant effect on a performance of asphalt concrete pavement. The presence of water often results failure of asphalt pavements caused by debonding of the asphalt film from the aggregate surface or early rutting/fatigue cracking due to reduced mix strength [4].

The indirect tensile strength represents the maximum load that a specimen will resist. And the tensile strain at failure represents the horizontal deformation and strain under this maximum load.

The indirect tensile test (IDT) is believed to simulate the state of stress caused by wheel loads in the lower portion of an asphalt concrete layer or tension zone, and the stress state caused by large temperature drops at the top surface [5].

The results of studies led to the conclusion that the indirect tensile test was the best practical test for operating agencies such as highway departments to use to obtain the tensile characteristics pavement materials. The basic reasons for this are [6]:

- The test is relatively simple to conduct,
- The type of specimen and the equipment are the same as those used for other testing,
- Failure is not seriously affected by surface conditions,
- Failure is initiated in a region of relatively uniform tensile stress,
- The coefficient of variation of test results is low compared to other test methods, and
- The test can be used to apply under a static load, i.e., a single load to failure, and under repeated loads.

Christensen, W. D. et. al.[7] found liner relationship between Mixture Cohesion and IDT Strength as shown in Figure (1).

Anderson, R.M. et. al.[8]found that rutting potential can be evaluated by considering indirect tensile strength (IDT), compaction slope measured with the Superpave Gyratory compactor and voids in mineral aggregate (VMA). Anderson evaluated IDT strength at a deformation rate of 3.75 mm/min and 34° C, and used repeated shear constant head.

Srinivasan[9] was studied if rutting potential can be evaluated with equipment readily available to state highway agencies. Rutting potential was evaluated with the Asphalt Pavement Analyzer (APA). The parameters that were evaluated as independent variables include the IDT strength, volumetric parameters, compaction slope, and the compacted aggregate resistance. IDT was measured using the Marshall Stabilometer with a split tensile head and with the samples at 60°C. The main factors included in the experiment were binder type, asphalt content, sand content, nominal maximum aggregate size (NMAS), and gradation. The analysis of variance demonstrated significant effects of all the main factors and their interactions on rutting potential. Further there is a strong correlation between rutting potential and indirect tensile strength as measured with the stabilometer.

Al-Ani and Zeki[10] found that, for three types of asphalt (40-50), (60-70), and (85-100) the higher values of tensile strength was achieved by harder asphalt.

Al-Ani and Qassim[11] found that, for two sources of asphalt (Daurah and Baiji) with (40-50) grade, Baiji indicated high tensile strength at low temperature and low tensile strength at high temperature.

The indirect tensile strength has been used to evaluate the mixture resistance to low temperature cracking. Three different testing temperatures are used (0,25, and 40) ˚C, with the optimum asphalt content, and (12.5, 19) mm aggregate maximum size (AMS). The result shows that the indirect tensile strength of the asphalt mixtures with 12.5mm (AMS) is greater than that of 19mm (AMS) for all temperature levels[12,13].

Ibrahim[14] found that, for three types of filler (Portland cement, limestone dust, and hydrated lime), hydrated lime filler gives the highest value of tensile strength at 5.5% asphalt content and 12.5 mm aggregate maximum size .

Advantages of Adding Hydrated Lime

<u>1-Hydrated Lime Improves Stiffness and Reduces Rutting:</u>

Unlike most mineral fillers, lime is chemically active rather than inert. It reacts with the bitumen, removing undesirable components at the same time that its tiny particles disperse throughout the mix, making it more resistant to rutting and fatigue cracking [15].

<u>2-Hydrated Lime Reduces Oxidation and Aging:</u>

Oxidation and aging occur over time to generate a brittle pavement, in particular, polar molecules react with the environment, breaking apart and contributing to pavement failure [16]. Hydrated lime combines with the polar molecules at the time that it is added to the asphalt and thus, they do not react with the environment. This is a result of the chemical reactions that occur between the calcium hydroxide and the highly polar molecules in the bitumen.[17]

❖ *Hydrated Lime Reduces Cracking:*

Asphalt cracking that can result from causes other than aging, such as fatigue and low temperatures. Also Progressive cracking is typically due to the formation of microcracks. the addition of lime improves fatigue characteristics and reduces cracking. The microcracks are intercepted and deflected by tiny particles of hydrated lime.[18,19]

Ahmedzade et al.[20] studied the effect of Polyester Resin (PR) with (0.75,1,2,3)% on physical and mechanical properties of asphalt mixture, and the results of this indicate that mixture modified by 0.75% PR increases physical and mechanical properties of asphalt mixtures.

Anurag et al.[21] investigated indirect tensile strength using roofing polyester waste fibers in hot mix asphalt. The experimental design included the use of three aggregate sources, two lengths (0.635 cm (1/4 in.) and 1.270 cm (1/2 in.)) of this fiber, and two fiber contents (0.35% and 0.50% by weight of total mixture). The results of the experiments found improving the wet tensile strength and tensile strength ratio (TSR) of the modified mixture, increasing the toughness value in both dry and wet conditions.

Experimental Design and Testing Procedures

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[22] specification of wearing coarse was used to estimate optimum asphalt content and indirect tensile strength at dry and after soaking condition.
2. Two types of additives with (1-9%)&(1.5-9%) Polyestrene resins and Hydrated Lime respectively (by weight of asphalt) were used.
3. Single penetration grade asphalt cement (40-50) from Baiji refinery was used.
4. One type of mineral filler (Limestone dust) was used employed as filler in limited mixture.
5. Five testing temperatures for Indirect tensile strength test (5, 25,35,50 and 60) ˚C.
6. Five testing compaction for Indirect tensile strength test (50,65,75,100 and 125 blows).
7. Four maximum aggregate size were used (9.5, 12.5, 19.0, 25.0) mm**.**

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).

Coarse and Fine Aggregate

The coarse aggregate (crushed) were taken from *AL-Sudoor quarry source*,. a typical dense gradation with a nominal maximum size of aggregate of (9.5,12.5,19,& 25 mm), 12.5 mm as a main aggregate max. size for the original mixture and the other gradation as a variables test. The 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[22], and accordance with ASTM D 3515[23] for 9.5m

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).

Additives

Two different types of additives have been used in this work.

- **Hydrated lime**

It was brought from the lime factory of Karbala. Lime particles finer than 0.075 mm are used in preparing the asphalt concrete mixtures. The physical properties of lime are presented in Table (4).

- **Polystyrene Resins**

Polystyrene Resins have been used in this study as additives. It was brought from the Dow Chemical Company. The main characteristics of Polystyrene Resins are:

- Unique combination of toughness and stiffness.
- Ease of processing.
- Excellent thermoforming behaviour.
- Good bendability with general purpose polystyrene, and
- Allows for down-gauging. The physical and mechanical properties of Polystyrene Resins are presented in Table (5).

Testing Plan

The test methods employed in this study in order to evaluate the tensile strength potentials of the mixture include indirect tensile strength test and Marshall test to determine the optimum asphalt contents and mix resistance to plastic flow.

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) [23].

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)[23], and theoretical (maximum) specific gravity of voidless mixture are determined in accordance with ASTM (D 2041) [23]. 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).The Polyester resin and Hydrated Lime blend consisting of (0, 1, 2, 3, 5, 7, 9) & (0,1.5,3,6,9) % respectively by weight of asphalt are added to asphalt which are prepared by heating the asphalt to (150-160)°C and adding the Polyester resin and Hydrated Lime while stirring for (25-30) minutes until obtaining a homogenous consistency. The asphalt-Polyester resin and Hydrated Lime blend is then mixed with the heated aggregate which is represented by 160°C for about 2 minutes in order to prepare the required mixture.

Marshall Stiffness is determined as the ratio between maximum load resistances of the standard specimen to the corresponding flow.

Preparation and Test of Indirect Tension Test

The indirect tensile strength is determined according to ASTM (D 4123) [23] at (5, 25,35,50, 60°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 diametric plane. This loading configuration develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametric plane, which ultimately causes the specimen to fail by splitting along the vertical diameter as shown in Figure (2). 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 [1].

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

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

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]:

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

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.

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(23) for surface course. For Polystyrene Resins & Hydrated Lime modifier mixtures, seven & five percentages content (0,1,2,3,5,7, and 9) & (0,1.5,3,6, and 9) %(by wt of Asphalt Cement) respectively were employed with the same other mixture composition.

From Marshall Test result the optimum asphalt content (O.A.C) is 5.37% for 12.5 mm and the (O.A.C) of other gradation (9.5, 19.0, 25.0) mm are selected (5.4, 5.19, 4.8) respectively.

The main properties of original mixture includes (bulk density, Marshal Stability, flow, air voids, and Marshall Stiffness) are obtained and listed in table (6).

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) has been used to evaluation the tensile properties of asphalt mixture.

Five asphalt cement contents of Baiji (40-50) (4, 4.5, 5, 5.5, and 6 percent by weight of mixture) have been used to investigate the influence of asphalt cement content 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 asphalt cement content and tensile strength is shown in figure (3 and 4). It indicates that tensile strength increases by the addition of asphalt and reaches peak value at 5.5 percent. After that tends to decrease.

Four maximum size of aggregate (9.5, 12.5, 19.0, and 25.0) mm have been chosen to evaluate the influence of aggregate maximum size on tensile strength with (5.4, 5.37, 5.19, and 4.8)% of Baiji asphalt cement content and hydrated lime filler are prepared.

Tikrit Journal of Engineering Sciences/Vol.19/No.1/March 2012, (80-96)

The relation between (AMS) content and tensile strength is shown in figure (5). It indicates that tensile strength decrease by the increase the aggregate max. size.

Figure (6) show the relation between temperature and tensile strength. Five different temperature (5, 25, 35, 50, 60) °C are used.

Generally the tensile strength decreases as the test temperature increases.

Five testing compaction (50, 65, 75,100 and 125 blows) have been chosen to evaluate the influence of compaction effort on tensile strength. The relation between compaction effort and tensile strength is shown in figure (7). It indicates that tensile strength increase by the increase the number of blows.

Effect of Additives Content on Tensile Strength of Mixture

For the purpose to evaluate the effect of various types of additives on mixture properties, two different types of additives were used (Polystyrene Resins & Hydrated Lime).

- ***Polystyrene Resins***

Seven different percentages of Polystyrene Resins (0,1,2,3,5,7, and 9) % by weight of asphalt have been used with (5.37)% of Baiji asphalt cement content and hydrated lime filler are prepared. Indirect tensile strength was tested at (25, 40 °C) temperature.

From the result the tensile strength and temperature susceptibility increases by addition of Polystyrene Resins reaching a peak value at 5% after that it tend to decrease. Figure (8&9)

- ***Hydrated lime***

Five different percentages of Hydrated lime (0, 1.5,3,6, and 9) % by weight of asphalt have been used with (5.37) % of Baiji asphalt cement content and hydrated lime filler are prepared. Indirect tensile strength was tested at (25, 40 °C) temperature.

Figure (10&11) show that ITS and temperature susceptibility increases by addition of Hydrated lime reaching a peak value at 6 % after that it tend to decrease.

Prediction of Tensile Strength Model

The statistical techniques used for the model development required for evaluation the tensile strength throughout the experimental work data.

A suitable amount of data representing many variables is presented in this investigation. For the purpose of model development of the tensile strength, these data include: Number of blows (compaction), Temperatures, Asphalt Content, soaking, aggregate gradation, and additives.

Selecting Sample Size

The following formula is used to determine the required sample size [25].

$$E = \delta t / (n)^{0.5} \quad \text{……….……} (3)$$

$$\delta = S / \overline{X} \quad \text{………….…….}(4)$$

Where

E = Error of the mean,

δ = Coefficient of Variation,

t = t – statistics,

n = Sample Size,

S= Standard deviation, and;

$\overline{X}$ = Mean value.

N =20

For confidence level = 95%, df =19.

Multicollinearity

It is a condition that exists when the independent variables are correlated with another one. The adverse effect of multicollinearity is that the estimated regression coefficient (b1, b2, etc.) tends to have large sampling variability.

By using STATISTICA software the correlation coefficients between all of the variables were calculated and the correlation matrix was setup. This matrix can be seen in Table (7). Then the variables having the highest correlation coefficient with the designated dependent variable are selected and calculated, the regression equation is formulated.

Model Development

Scatter plot was carried out between the dependent and independent variables for the requirements of tensile strength model building process. From the plots, the nature of relation between these variables can be expected and the best relations are selected.

By using ***STATISTICA*** software, other coefficients were determined from multiple linear regressions analysis to develop a model after entered a seven variable related to the tensile strength model, the following tensile strength model form results in equ.(5):

Tensile(S)=1390.759+44.896*X1+2.350*X2 - 1.327*X3+3.543047*X4+3.802763*X5+0.369488*X-0.987347*X7 ……………………….(5)

R= 0.97 $R^2 = 0.95$

Where:

TENSILE =Tensile Strength,Kpa

X1=Hydrated Lime%, (0, 1.5, 3, 6, 9%).

X2 =Polystyrene Resins %, (0, 1, 2, 3, 5, 7,9%).

X3=Aggregate maximum Size, (9.5, 12.5,19, 25)mm.

X4 = Soaking on Tensile, wet, and dry.

X5=Asphalt Content, (4%-6%)

X6=No of Blows (Compaction Effort), (50, 65, 75,100,125); then

X7= Temperature in °C.

The analysis was shown in Table (8)

Results of the Analysis

The multiple linear regression[26] ,using STATSTICA software served its purpose in drawing attention to predict model tensile strength by using a number of the independent variables. The statistics analysis model is shown at the end of the previous section as tensile strength model (equation5).

The independent variables; Hydrate Lime, aggregate max. size, soaking, Number of blow, temperature and asphalt content are used in the model estimation process show that value of tensile strength is strongly affected by these mentioned variables. The model indicates that the value of tensile strength increases with the increase of Hydrate Lime, aggregate max. size, Soaking, No. of blow, temperature and asphalt content in addition to the tensile strength value is decrease with increase of Polystrene Resins .

Results and Discussion

Referring to the tensile strength model ; seven variables were found to be contribute in the general formula of the model prediction these were type of material (Polystrene Resins, Hydrate Lime), aggregate max. size, Soaking, number of blow, temperature and asphalt content. The regression coefficient was found to be 0.95 that means; 95 percent of the tensile strength prediction can be explained by this model for all variables, which mean good correlation with the tensile strength model.

Validation of the estimated model

The final step in the model building process is validation of the proposed model.

Selection of Validation model

- First method. (Check on statistics analysis model and coefficients)
- The second Collection of new data.
- The third Comparison with previously Developed Models.
- The forth Data Splitting
- the last Predictions Sum of squares .

The second method (Collection of New Data Prouder) was selected to asses the predictive ability of the Tensile strength model.

Validation Results

The half of the observed data (those not used in the development process), is used in the validation process of the tensile strength _ model. The observed tensile strength values are plotted against those obtained by using of the developed model. This comparison is presented in Figure (12).

The best fit of the relation between observed and estimate Tensile Strength can be found in the following form:

Tensile strength observed = 1.0893 * tensile strength estimate………..……(6)

These finding seem to be in good agreement with the relation y=x .The results of checking the goodness of fit for the estimate Tensile model and observed model by using chi-squire test. This testing can be seen in the following paragraph.

X^2 –test :

Goodness of fit

Chi-squire – test

Tensile Model

N= 20 df=19 confidence level =95%

Variable	X^2 –value	X^2_c -value
X=Observed	20.49620	30.14
Y= Predicted Tensile strength model		

For $X^2 < X^2_c$ .Thus is no significant different between the observed and the predicted value

Conclusions

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

1. The best content of Hydrated lime and Polystyrene Resins as additives that improving the tensile strength and temperature susceptibility of asphalt mixture are (5&6)% respectively.
2. Indirect tensile strength of asphalt mixture decreases by increase the temperature and maximum aggregate size.
3. Based on the Indirect tensile test, a tensile strength model was developed for local asphalt paving mixtures in the general form of :

Tensile S=1390.759 + 44.896*HYDRATED +2.350*POLYESTRENE - 1.327*AGG__MAX + 3.543047*TENSIL_SO + 3.802763*ASP_CON + 0.369488 *NO__OF_B - 0.987347* TEMPERAT

4. It is appear that the above mentioned tensile strength model the effect of maximum aggregate size, and temperature is clearly throughout by the correlation matrix ,therefore, this failure is appear in the roads of Iraq by cause of increase of temperature.
5. Throughout the model limitation, the model is suitable by the range of data.

References

1. Krishnankuttynair H.," Evaluation of Indirect Tensile Strength as Design Criteria for Superpave Mixtures"., Doctor of Philosophy thesis, North Carolina State University, (2008).
2. Haghi AK., Arabani M., Shakeri M., Haghgoo M., Mirabdolazimi SM.," A study on the effects of polymers on the reduction of fatigue cracks in the asphalt pavement." (2005).
3. Kok BV., Kuloglu N.," The effects of different binders on mechanical

properties of hot mix asphalt. Int. J. Sci. Technol (2007).
4. Asphalt Institute. Asphalt Institute Manual Series No. 10 (MS-10), Cause and Prevention of Stripping in Asphalt Pavements. Lexington, KY, (1981).
5. Quintus, H. L. V., and Kennedy, T. W., "AAMS Mixture properties related to pavement performance", Proceeding Association of Asphalt Paving Technologists, volume 58, 1989.
6. Kennedy, T. W. "Characterization of asphalt pavement materials using the indirect tensile test", Proceeding Association of asphalt paving Technologists, vol.47, (1977).
7. Christensen, W. D., Bonaquist, R., and Jack, D.P., "Evaluation of Triaxial Strength as a Simple Test for Asphalt Concrete Rut Resistance", Final Report, Pennsylvania Department of Transportation, (2000).
8. Anderson, R.M., Christensen, W. D., and Bonaquist, R., "Estimating the Rutting Potential of Asphalt Mixtures Using Superpave Gyratory Compaction Properties and Indirect Tensile Strength", Association of Asphalt Paving Technologists-Proceedings of the Technical Sessions, Vol – 72, (2003).
9. Srinivasan G.," Evaluation of Indirect Tensile Strength to Identify Asphalt Concrete Rutting Potential", Department of Civil and Environmental Engineering Morgantown, West Virginia , Master thesis, (2004).
10. AL Ani, H. M. and Zike, R." Influence of asphalt overlay variables on pavement performance", Journal of Engineering, College of Engineering-University of Baghdad, Vol. 6, No. 4,(2000).
11. AL Ani, H. M. and Qassim, H. A. " Evaluation the need for a temperature susceptibility measure in local paving asphalt specification", Journal of Engineering, College of Engineering-University of Baghdad, Vol. 6, No. 1,(2000).
12. Rana A. Y., "Evaluation of Additives and Interlayer to Minimize Reflective Cracking in Flexible Overlay", M.Sc. Thesis, University of Al-Mustansiria (2005).
13. Alaaredi, H. K. Sh., "Reduction of Reflection Cracks in Overlay of Rigid Pavements", M.Sc. Thesis, University of Al-Mustansiria (2006).
14. Ibrahim M. Al-D. Abd-Al., "Evaluation of the factors influencing the tensile properties of asphalt paving materials", M.Sc. Thesis, University of Baghdad (2003).
15. Little, Dallas N. & Jon Epps. "The Benefits of Hydrated Lime in Hot Mix Asphalt," report for National Lime Association, (2001).
16. Hicks, R. Gary & Todd V. Scholz. "Life Cycle Costs for Lime in Hot Mix Asphalt." Report & Software for National Lime Association, (2001).
17. Petersen, J.C., H. Plancher, and P.M. Harnsbergen, "Lime Treatment of Asphalt to Reduce Age Hardening and Improve Flow Properties," Proceedings, AAPT, Vol. 56, (1987).
18. Mohammad, L, C. Abadie, R.Gokmen, and A. Puppala. "Mechanistic Evaluationof hydrated Lime in Hot-Mix Asphalt Mixtures," Transportation Research Record 1723. Washington D.C.: National Academy Press, (2000).
19. Lesueur, Didier & Dallas N. Little, "Effect of Hydrated Lime on Rheology, Fracture and Aging of Bitumen," Transportation Research Report 1661, Transportation Research Board, (1999).

Tikrit Journal of Engineering Sciences/Vol.19/No.1/March 2012, (80-96)

20. Ahmedzade P. and Yilmaz M., " Effect of polyester resin additive on the properties of binders and mixtures," Construction and building materials, 22 (2008).
21. Anurag K., Xiao F., Amirkhanian S. N., "Laboratory investigation of indirect tensile strength using roofing polyester waste fibers in hot mix asphalt," Construction and building materials, 23,(2009).
22. State Commission of Roads and Bridges (SCRB), "Hot Mix Asphalt Concrete Pavements", Iraq Standard Specification, Ministry of Housing and Construction, Department of Design and Study, section R9, Revised edition (2003).
23. "ASTM", Annual Book of ASTM Standers, Section 4, Volume 04.03, (1988).
24. Husham, Ab.-M., Q.," Evaluation of Suitable Temperature Susceptibility Index for Local Paving Asphalts", M.Sc. Thesis, University of Baghdad, (1999).
25. Kennedy, J. B.; & Neville A.M," Basic Statistical Methods for Engineers and Scientists ,2nd Edition, Thomas Y., Crowell Company, In, USA, (1975).
26. Ahmed N. G." The Development of Models For The Prediction of Thermal Cracking in Flexible Pavements" , PH.D. Thesis, College of Engineering, University of Baghdad, (2002).

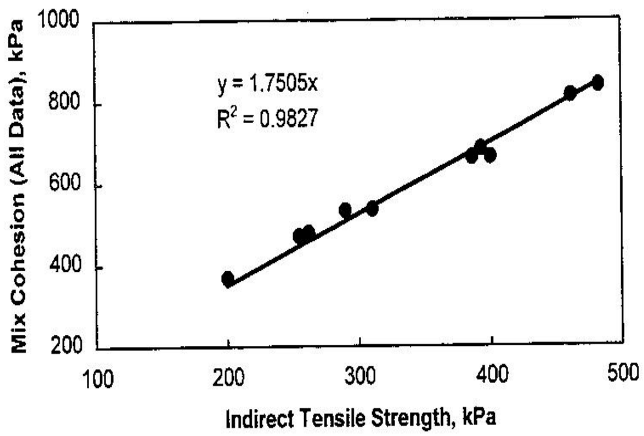


Figure (1): Relationship between mixtures cohesion and IDT strength.[7]

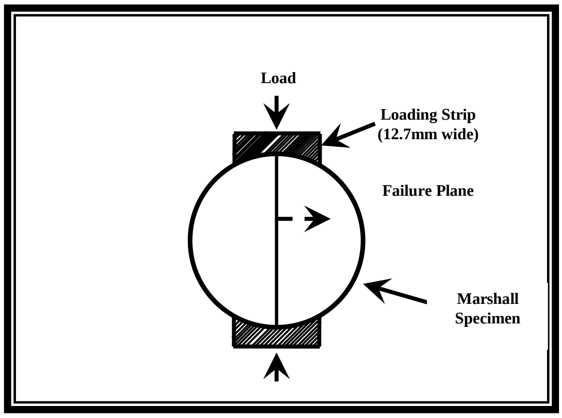


Figure (2): Indirect tensile test during loading and at failure

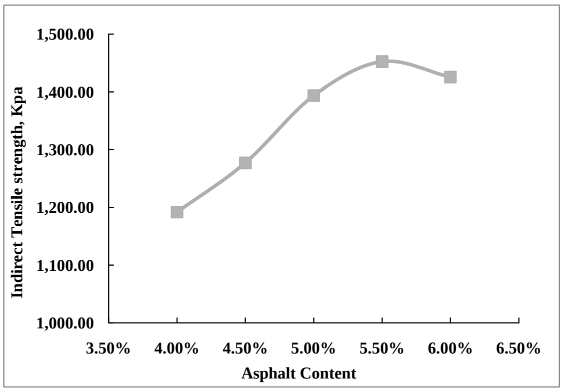


Figure (3):Effect of asphalt cement content on tensile strength corresponding to optimum asphalt content and 25 °C Test temperature.

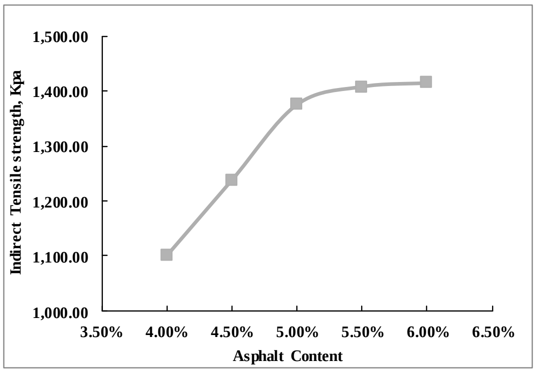
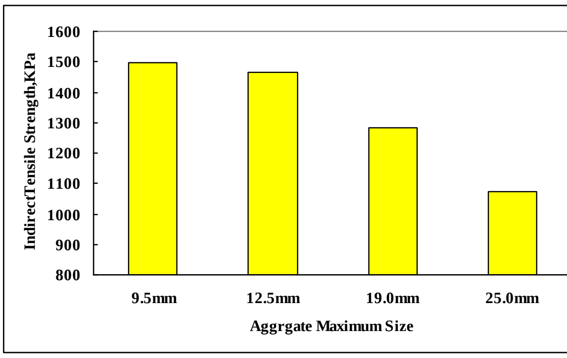


Figure (4):Effect of soaking on tensile strength corresponding to optimum asphalt content and 25 °C test temperature.



95

Figure (5):Effect of aggregate maximum size on tensile strength.

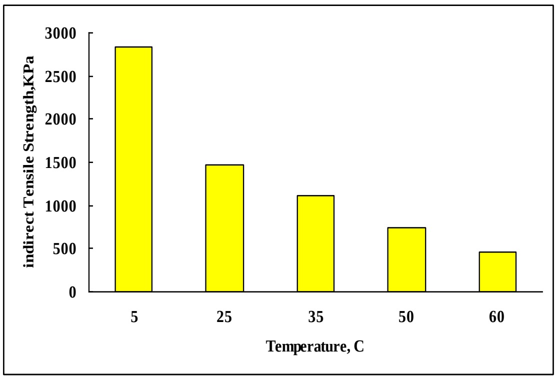


Figure (6):Effect of testing temperature on tensile strength.

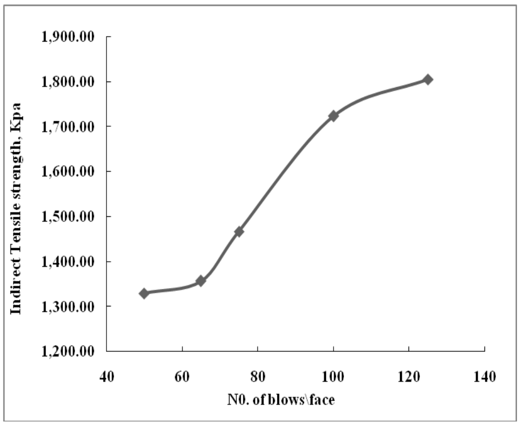


Figure (7):Effect of compaction effort on tensile strength

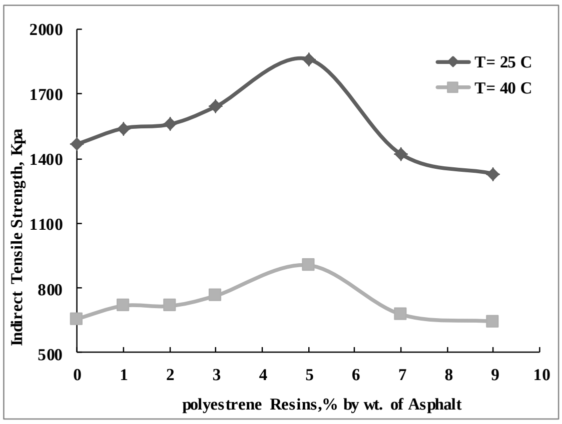


Figure (8): Effect of polyestrene resins content on indirect tensile strength

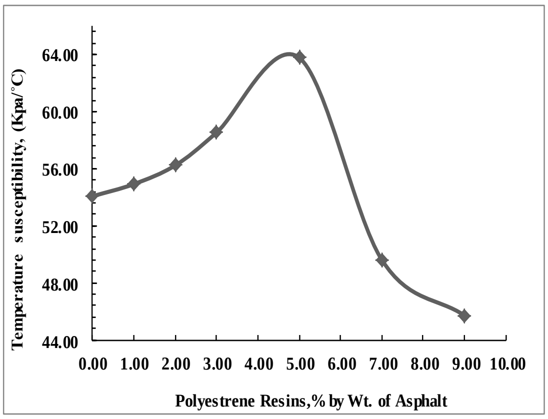


Figure (9):Effect of polyestrene resins content on temperature Susceptibility

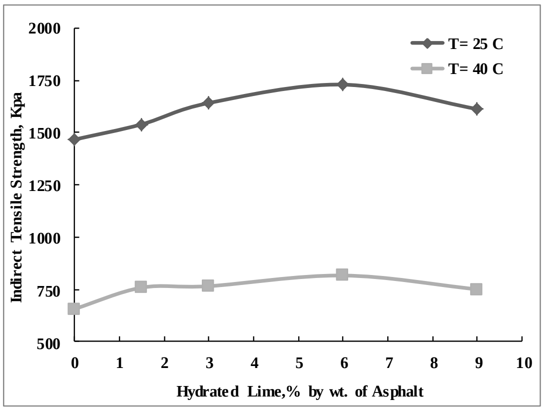


Figure (10): Effect of hydrated lime content on indirect tensile strength.

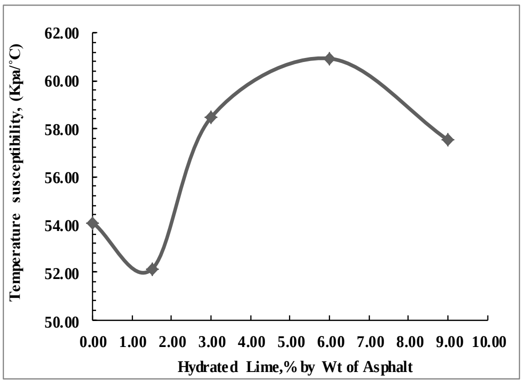


Figure (11): Effect of hydrated lime content on temperature susceptibility

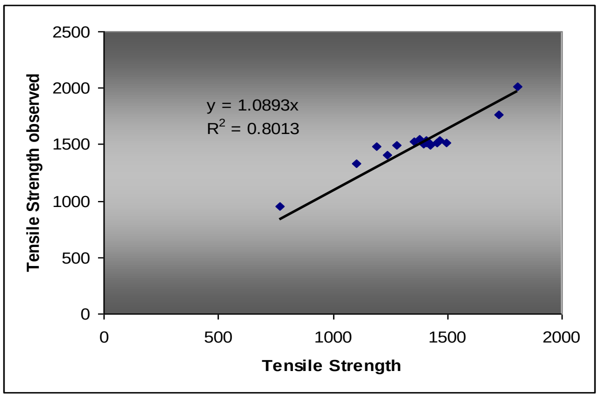


Figure (12): Observed tensile strength versus new estimate tensile strength model

Tikrit Journal of Engineering Sciences/Vol.19/No.1/March 2012, (80-96)

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

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

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

Property	Filler type	
	Limestone	Hydrated lime
specific Gravity	2.73	2.326
% Passing Sieve no. 200	96	100
Specific Surface (m^2 /kg)	595	781

Table (5): Physical& Mechanical properties of Polystyrene Resins

Property	Test Method ISO	Value
Physical[1]		
Melt flow rate (200 °C/5 kg),g/10 min.	1133	5.0
Density, Kg/m^3	1133	1050
Bulk density (granulation 7), kg/m^3	60	600
Mechanical[2]		
Izon notched impact strength, j/m	180	135
Tensile strength at yield, 5 mm/min.,Mpa	527	19.5
Tensile strength at rupture, 5 mm/min.,Mpa	527	22
Tensile elongation at rupture, 5 mm/min.,%	527	65
Tensile modulus, 1 mm/min.,Mpa	527	1750
Flexural strength,(3-points bending),Mpa	178	38
Flexural modulus,(3-points bending),Mpa	178	1950
Vicat softening temperature (120 C°/h, 1 kg),°C°	306A	100

1. Typical properties, not to be construed as specification limits.
2. Measured on injection moulded specimens.

Table (6): Main Properties of Original Mixture

Property	Max. size of aggregate 12.5 mm
Asphalt content,%	5.37
Bulk density, gm/cm^3	2.22
Marshall stability, kN	11.2
Marshall flow, mm	3.1
Marshall stiffness,kN/mm	3.61
Air voids, %	4.1
I.T.S at 25°c, kpa	1467.12
Temp. Suscep., kpa/°c	54.07

Table (7) Correlation Matrix

Correlations (tensile. model(n))								
	Hydr. Lime	**Pol. resin**	**Max. aggr.**	**Tensile strength**	**Asph. content**	**B**	**Temp.**	**Tensile**
Hydr. Lime	1							
Pol. resin	0.043201	1						
Max. aggr	0.084816	0.357694	1					
Tensile strength	0.179081	0.226574	0.115404	1				
Asph. content	0.582881	-0.14654	-0.1733	0.224585	1			
B	-0.32877	-0.43014	-0.10306	0.174242	0.158136	1		
Temp.	-0.2633	-0.15558	-0.3745	-0.54656	-0.3429	-0.40509	1	
Tensile	0.968168	-0.04301	0.065298	0.138995	0.605519	-0.26894	-0.20912	1

Table (8): Regression Summary for Dependent Variable: Tensile

Regression Summary for Dependent Variable: TENSILE						
$R=0.975$, $R^2= 0.952$ Adjusted $R^2= 0.924$						
$F(7,12)=34.289$ $p<.00000$ Std.Error of estimate: 42.267						
	β	**St. Err. of β**	**B**	**St. Err. of B**	**t(12)**	**P-level**
Intercept			1390.759	65.71757	21.16267	7.2E-11
Hydr. Lime	0.98708	0.102132	44.89634	4.645382	9.664724	5.17E-07
Pol. resin	-0.0452	0.084558	-2.35021	4.39653	-0.53456	0.602717
Max. aggr	0.063736	0.078174	1.326616	1.627144	0.815303	0.430784
Soaking	0.005147	0.077808	3.543047	53.56591	0.066144	0.948353
Asph. content	0.063454	0.091506	0.2763	5.483962	0.693433	0.50124
No. of Blow	0.08268	0.107763	0.369488	0.481583	0.767236	0.457772
Temp.	0.125676	0.106755	0.987347	0.838696	1.177241	0.261922