Modification Asphalt Mixture Performance By Rubber Silicon Additive

Taher M.A. Al-ani
Al-Anbar University/ Engineering College
Civil Dept.

Asmiet Ramizy Abd-Alghafour
Al-Anbar University/ Sciences College
Physics Dept.

Abstract :-

This study is the second stage of the paper "Study the Effect of Rubber Silicon on Physical Properties of Asphalt Cement". This study took the effect of additives on asphalt mixture performance.

Asphalt mixture has been designed by Marshall method for determining the optimum asphalt content and geophysics properties of mix according to ASTM (D-1559). Rubber silicon at different percentage (1%, 2%, 3% and 5%) was added to asphalt binder and three specimens of asphalt rubber silicon mixture (ARSM) are prepared and evaluating according to Marshall method. Diametric tensile creep test ASTM (D-1075) at 60 Co used to evaluating permanent deformation and modulus of elasticity for ARSM.

The study shown that the Rubber-Silicon has more effects increasing the marshal stability, air voids, and reducing the flow and bulk density compared with the original mix.. Increase the flexibility properties of the mix and this appear from reducing the permeate deformation at test temperature (60C), the reduction percent is about (30 to 70)%.

1.Introduction:-

Polymer modified asphalt binder (PMBs) are becoming more wide speared in road building to meet today's high traffic loading (1) . Many efforts are directed towards modifying the asphalt or paving mixture properties to get superior performance and serviceability under local conditions and to economize the construction of pavement(1).

There have been many investigations on polymer modified asphalt binders as counter measure to prevent plastic flow (2). Modification of bitumen with polymers decreases it's temperature susceptibility chiefly by increasing its ring and ball softening point, increases its cohesion and modifies its rheological characteristics (3). The purposes of modification is also increase the viscosity at the high temperature, increase the flexibility and elasticity of binders at the low temperature, improve the adhesion to aggregates and many improve high thermostability and aging resistance (4).

The aim of this paper is studying the effect of rubber silicon on the performance of asphalt mixture for different percent of added (1%, 2% 3% and 5%). For this purposes the performance changes were evaluated by Marshall tests and diametric tensile creep test at $60C^o$.

2.Review of Literature :-

The properties of asphalt important for its consideration as a paving material are its rheological properties, adhesion, and durability (3asal). Since the highway engineer is usually limited to his choice of asphalt source, there is need for a practical way to improve asphalt quality by the addition of modifying ingredients. In this regard it is believed that PMBs may proved durability and wear resistance(6).

Reclaind rubber obtained from used tiers, polyethylene in the form of low density (LDPE), styrene-butadiene-styrene copolymer, latex are used for modification of asphalt cement and test sections were found to perform satisfactorily (5).

During world war II a number of synthetic elastomers were developed and since then several of these also have been used as additives for asphaltic materials in road construction. The data show that the properties of an asphalt-rubberized with natural rubber latex can be varied not only by the amount of rubber but also by using different amounts of sulfur. Also it show that the properties of asphalt-rubberized with natural rubber latex containing small amounts of sulfur compare quite favorably with the properties of asphalt-rubberized with synthetic rubbers (7).

During the end of fiftieth there has been more interest in using rubber with asphaltic materials for surface treatments and seal coat construction. It has been observed that rubberized binders used in this type of construction were tougher, reduced the tendency of the surface to crack and bleed, and improved aggregate retention. (7).

In Sweden size of rubber particles in asphaltic pavement were evaluated. Large rubber particles (1/16 in to ¼ in) were used into an asphalt pavement. It was determined that using (3-4)% by weight of rubber is sufficient to increase skid resistance and, durability as well as reducing noises level.(8).

Battelle was investigating the use of scrap tiers as an additive in black top dressings for driveways and parking lots. Improved durability, resistance to abrasion , and resiliency are said to be possible with minor cost increases. Also reclaimed rubber is being used in asphalt patching and under foundations as a cushioning agent in Tucson, Arizona. (9)

M.J.. Fernando and H.R. Guirguis found that natural rubber with its inherent chemical constitution, is an excellent organic polymer for incorporation into asphalt in order to produce a superior form of road binder. The resultant binder is more viscous at high temperature, more flexible at low temperature, more resistance to distortion and more durable (10).

Hugo and Nachenius (11) described three test methods which may be usefully employed to study the properties of bitumen-rubber binders and asphalt, sliding plate rheometer tests for binder-rubber blinders and indirect tensile strain measurement and freeze-thaw test for bitumen-rubber asphalt.

Mahabir Panda and Magajit Muzumdar (11) were used reclained low density polyethylene (LDPE) from carry bags of goods for modification asphalt mixture performance as fatigue life, resilient modulus, resistance to moisture susceptibility in addition to marshal characteristics.

Wlodyslaw Milkowski (13) used polyethylene as an additive to achieve asphalt concrete of much higher stability and lower thermal susceptibility. Adding polyethylene (PE) in small percent reduce penetration, raised the softening point and increased the shear strength of asphalt joints.

Lee, Morrison and Hesp (14) found that the additive of polyethylene and chlorinated polyethylene to asphalt binders does significantly increase their low temperature fracture toughness and fracture energy.

Taher. M.A (15) shown that Increasing in the law density polyethylene (LDPE) percentage decreasing the susceptibility of asphalt cement for temperature**.**

3.Materials and Tests :-

1. Asphalt Cement:-

One binder of asphalt cement was tested, from Daurah Refinery with a grade of (40-50) penetration. The physical properties of this type are illustrated in table (1)

Table (1). Physical Properties of Asphalt Cement.

Test	Unite	*Daurah (40-50)*
Pentration @ 25 C^o	*0.1 mm*	*45*
Ductility @ 25 C^o	*Centimeter*	*+100*
Softening Point	*C^o*	*50*
Flash Point	*C^o*	*351*
Specific Gravity	*---*	*1.033*
Kinematic Viscosity	*cst.*	*270*

2. Additive:-

Rubber-Silicone was used with asphalt binder , it is available in the local market. Rubber-Silicone was added to binder at different percent (1% ,2% ,3% and 5%). The method of adding Rubber-Silicon to binder at temperature (150) C^0 with stirrer for (20) minute.

3. Aggregate (coarse and fine materials):-

Crushed aggregate are used in this work with a fixed dense gradation for all the specimens and from Al-Jaraishe source. The mid limits of the (19 mm) size dense gradation has been selected as a basic gradation in accordance with (ASTM D-3515) as shown in figure (1)

4. Mineral Filler:-

One type of filler is used in this work which was Limestone dust (Karbala Factory).

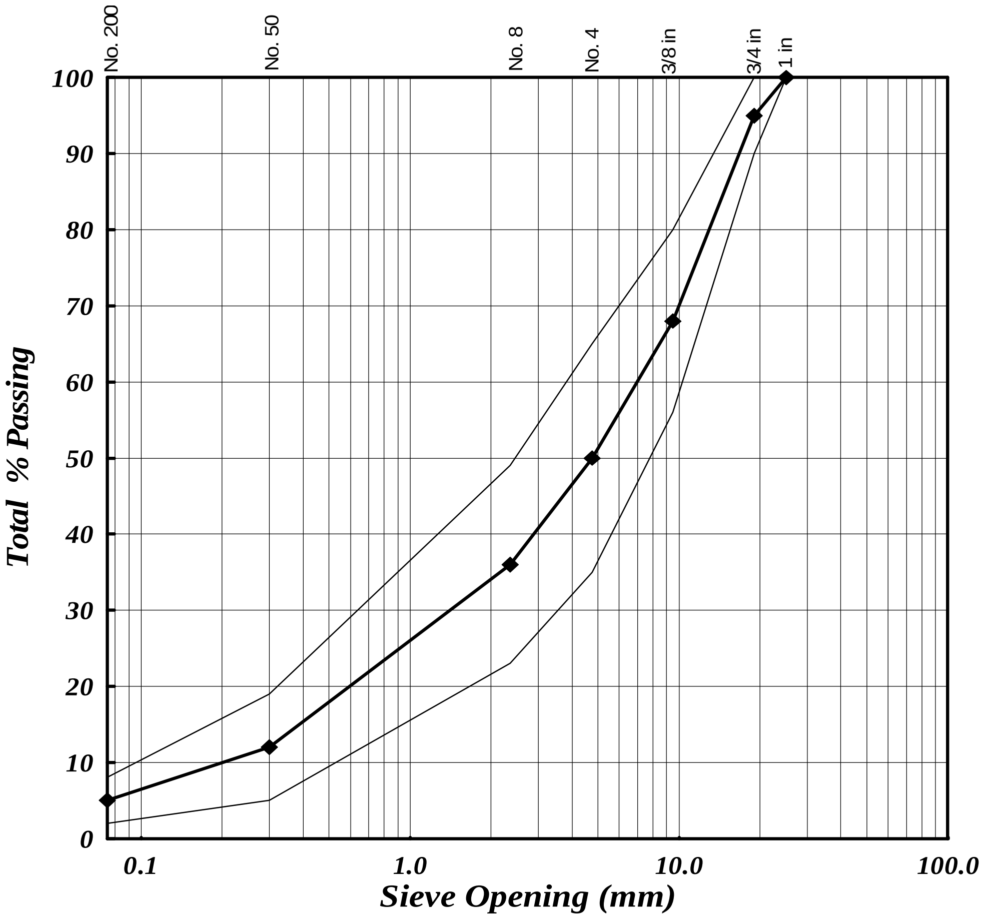

Figure (1):- Specification Limits and Selected Gradation of Aggregate Maximum Size (19 mm)

5. Test Methods:-

The following tests were used in this work to evaluate the asphalt concrete mixture.

1- resistance to plastic flow (Marshall Stiffness)
2- Permanent Deformation (diametric tensile creep test)

5.1. Preparation of Mixtures:-

The aggregate are first dried to constant weight at (110 C^0), separated into the desired sizes and recombined with mineral filler in order to meet the required gradation for each specimen. The aggregate are then heated to temperature off (155C^0) before mixing with asphalt cement. The asphalt cement is heated to the temperature , which produce a kinematic viscosity of (170±20) centistokes up to (163C^0) as an upper limit. Then, asphalt cement is weighed to desired amount and added to the heated aggregates, and mixed thoroughly until all aggregate particles are coated with asphalt.

5.2. Resistance to Plastic Flow (Marshall Method):-

This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus according to (ASTM D-1559). The test specimens were compacted using one comparative effort, which is (75) blows/end.

The bulk specific gravity density (ASTM D-2726), theoretical (maximum) specific gravity (ASTM D-2041) and percent air voids (ASTM D-3203) are determined for each specimen.

Marshall stability and flow test are performed on each specimen according to the method described by (ASTM D-1559). The cylindrical specimen (2.5" (62.5 mm) height * 4" (101.6 mm) diameter) is compressed on lateral surface with a constant rate of (50.8 mm/min) until the maximum load is reached. The maximum load resistance and corresponding flow values are recorded. Three specimens for each combination are prepared and the average results are reported.

5.3. Creep Test:-

The diametric indirect tensile creep test has been used for testing asphalt mixture to determine the permanent deformation and the stiffness of asphalt mixture by measuring the strain – time value. The same Marshall specimens have been used in this test. The specimens are then left to cool at room temperature for (24) hrs. and, placed in water bath at the specific test temperature of (60C^0) for (30) minutes before the test is conducted. The strain (deformation) was recorded at a strain time of loading and unloading (0.1, 0.25, 0.5, 1, 2, 4, 8, 15, 30, 45, and 60 minutes). The test was conducted while the specimen was submerged in water bath maintained at the test temperatures (60C^0) with a static constant stress of (14.5 psi = 0.1 Mpa). The vertical strain calculated from the measured deformation is determined as follows:-

$$\varepsilon = \Delta H / H_o \quad \text{mm/mm}$$

where:-
ΔH = the total measured vertical deformation at a certain loading time,
H_o = the original diameter of the specimen.
The stiffness modulus of the mixture is calculated by:-

$$(S_{creep})t = \sigma / \varepsilon \quad \text{N/mm}^2$$

σ = stress of test (14.5 psi (0.1 Mpa)

4.Result and Discussions :

The first result of this work was selecting the optimum asphalt content depending on marshal stability ,stiffness, and flow, bulk density, theoretical gravity density, and air voids. This optimum percentage (4.3%) was used with different percent of Rubber silicon for preparing asphalt rubber silicon mixture (ARSM).

The data of study effect of Rubber-Silicon on asphalt mixture are evaluated laboratory and arranged in table (2).

Table (2). Properties of Asphalt Rubber Silicone Mixture (ARSM)

No	% Rubber-Silicone	Marshall Properties					
		Stability Kn	Flow mm	Stiffness Kn/mm	% Air voids	Theoretical Density	Bulk density gm/cm^3
1.	0	9.2	**2.8**	3.286	7.1	2.488	2.31
2.	1	11.1	2.7	4.111	7.05	2.485	2.31
3.	2	12.01	2.4	5.004	7.7	2.481	2.291
4.	3	11.2	2.4	4.667	7.8	2.48	2.283
5.	5	10.8	2.1	5.143	8	2.477	2.28

4.1. Properties of ARSM.:-

Data of table (2) are presented in the following figures:

Figure (2) show the effect of rubber silicon on Marshall stability. Stability increase rapidly with increasing rubber silicon content until (2%) after that there are slowing in redaction. The stability increase about (30)% compared with original mixing.

Figure (3) show the effect of rubber silicon on Marshall flow. Flow decrease with increasing the rubber silicon contents.

Figure (4) show the effect of rubber silicon on Marshall stiffness.

Marshall Stiffness = (Marshall Stability / Marshall Flow) (Kn/mm)

Marshall stiffness increase with increasing the rubber silicon contents. The rate of increasing is very speed as shown in figure(4)

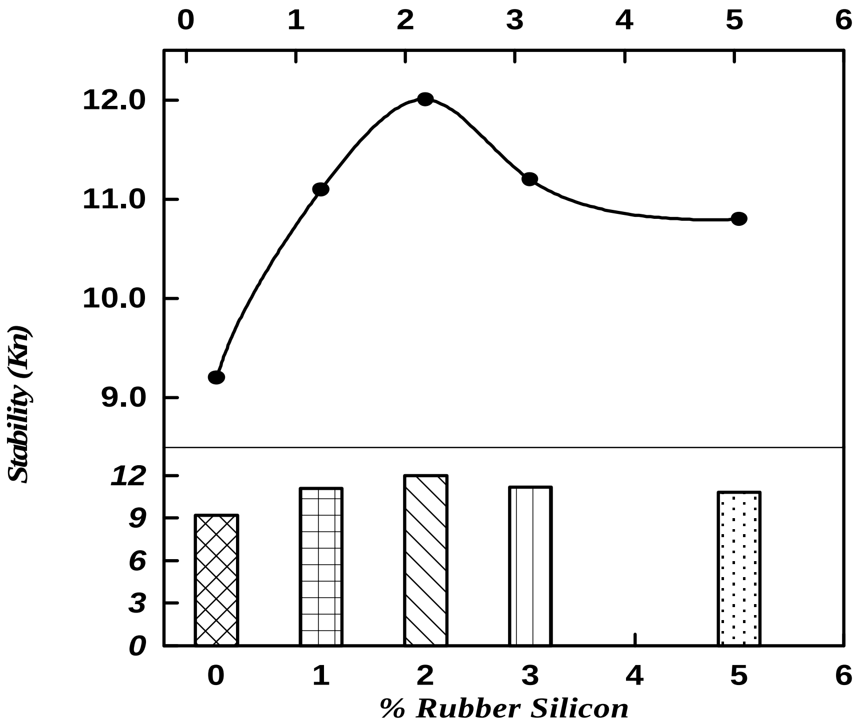

Fig.(2) Effect of Rubber Silicon Additive on Marshall Stability of Asphalt Mixture

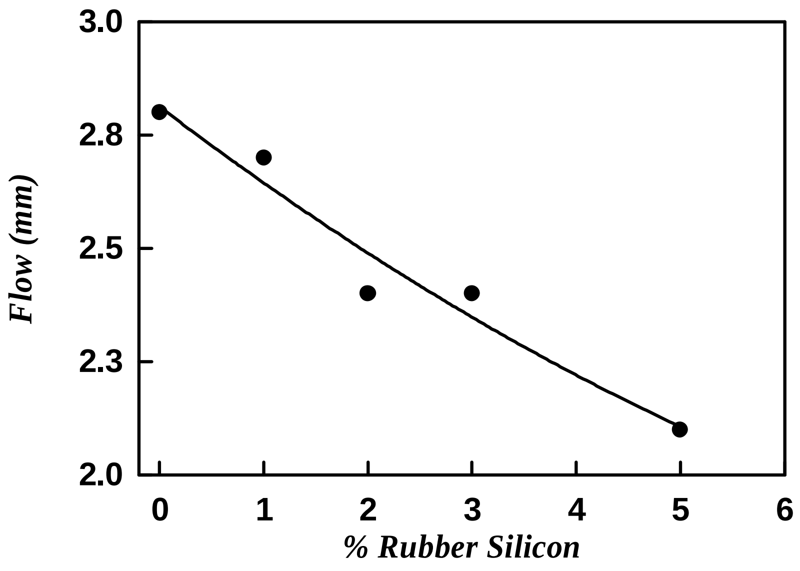

Fig.(3) Effect of Rubber Silicon Additive on Marshall Flow of Asphalt Mixture

Figure (5) show the effect of rubber silicon on Maximum bulk density. The rubber silicon content insignificant effect on maximum bulk density.

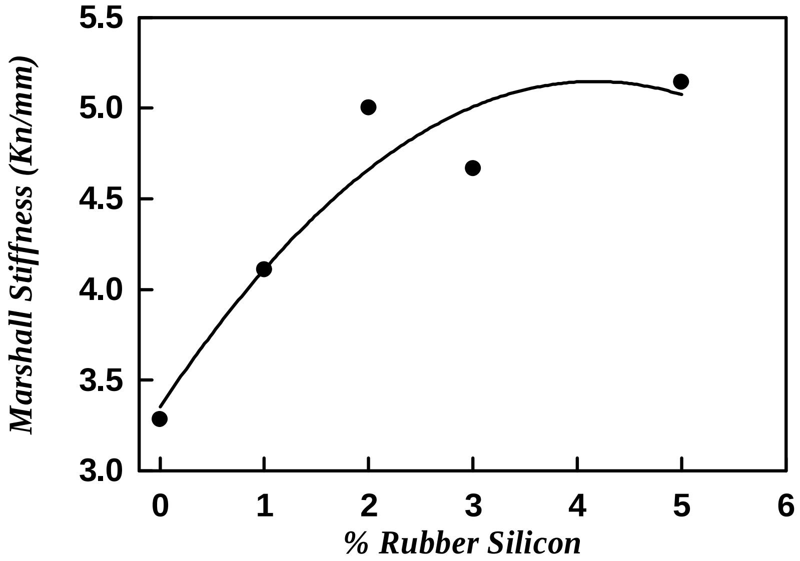

Fig.(4) Effect of Rubber Silicon Additive on Marshall Stiffness of Asphalt Mixture

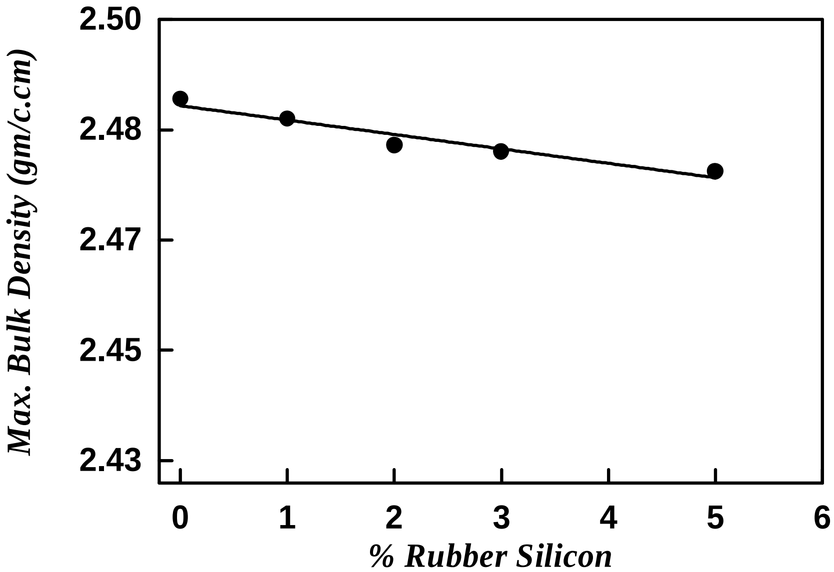

Fig.(5) Effect of Rubber Silicon Additive on Max. Bulk Density of Asphalt Mixture

Figure (6) show the effect of rubber silicon on bulk density of mixture. Increase the rubber silicon content decrease the bulk density of mixture because rubber silicon is less density than asphalt cement.

Figure (7) show the effect of rubber silicon on percent of air voids in mixture. Increase the air voids with increasing in rubber silicon content because the decrease in the bulk density of mixture with increasing rubber silicon , while the maximum bulk density remains the same nearly for all mixes.

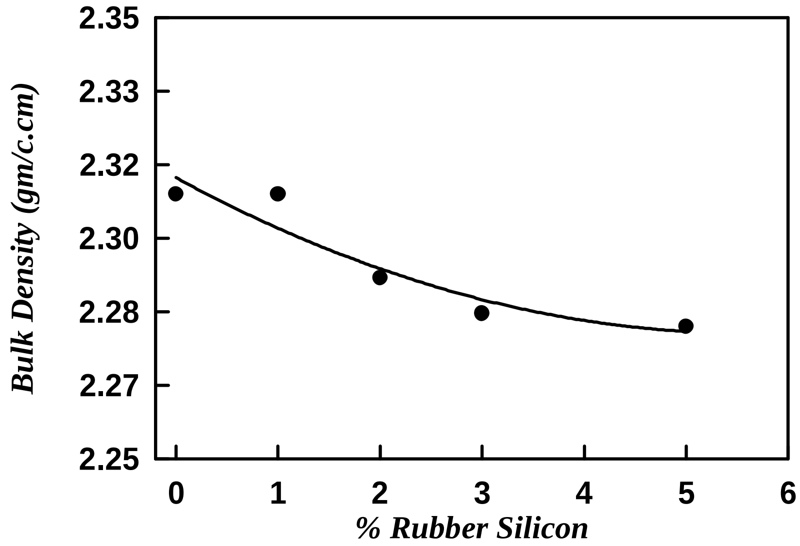

Fig.(6) Effect of Rubber Silicon Additive on Bulk Density of Asphalt Mixture

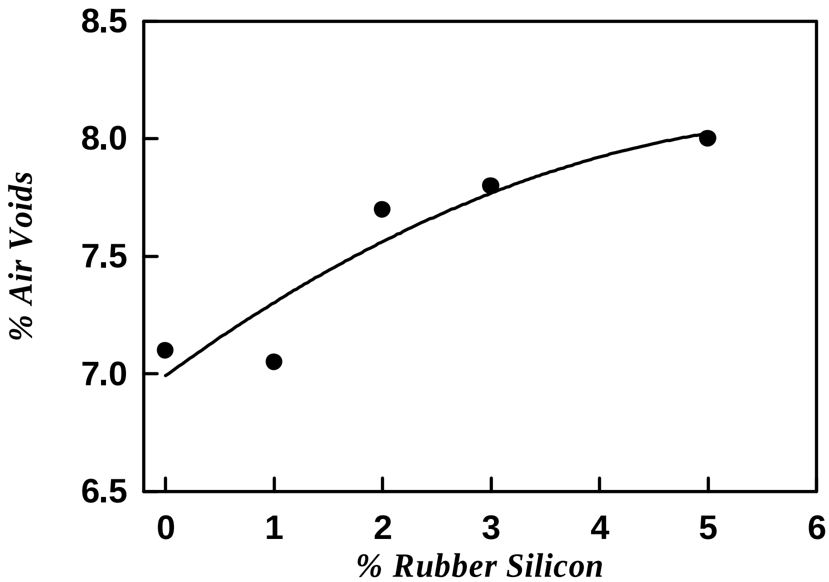

Fig.(7) Effect of Rubber Silicon Additive on Percentage Marshall Air Voids of Asphalt Mixture

Figure (8) show the effect of rubber silicon contain on diametric indirect tensile creep test under constant static load (0.1 MPa) at temperature of test (60C). increasing of rubber silicon contain reducing the rate of deformation ,and the percent of (2 and 3) have the same effect on rate of deformation.

Figure (9) show the effect of rubber silicon contain on permanent deformation at (60C) and the present of reduction is about (30 to 70)% . This induct that the rubber silicon increase the flexibility properties of the asphalt mixture.

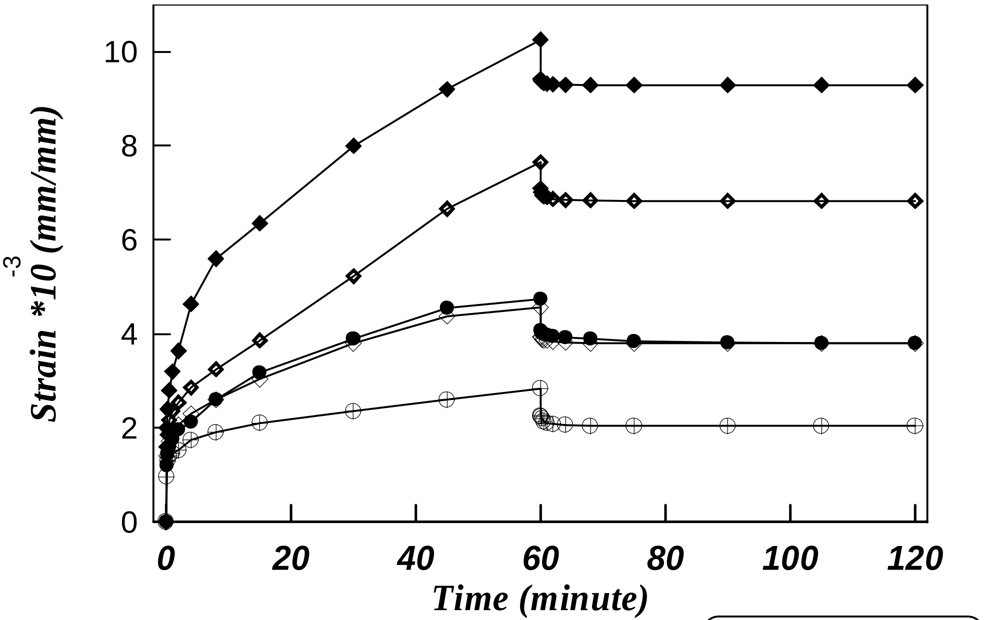

Fig.(8) Effect of Rubber Silicon on Greep Test at 60 C

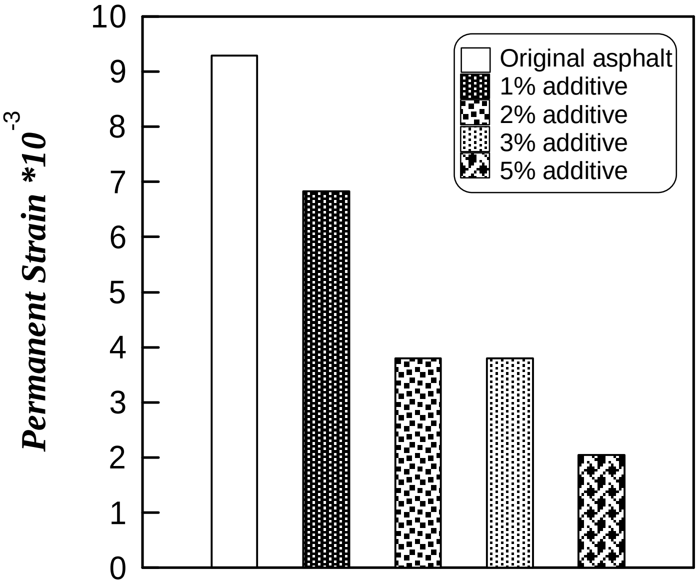

Fig.(9) Effect of Rubber Silicon Content on Permanent deformation at (60C)

Figure (10) show the effect of rubber silicon contain on stiffness modulus of asphalt mixture at (60C). the rubber silicon increasing the stiffness modulus of asphalt mixture and for that the rigidity of the mix at high temperature increasing therefore the permanent deformation was reducing**.**

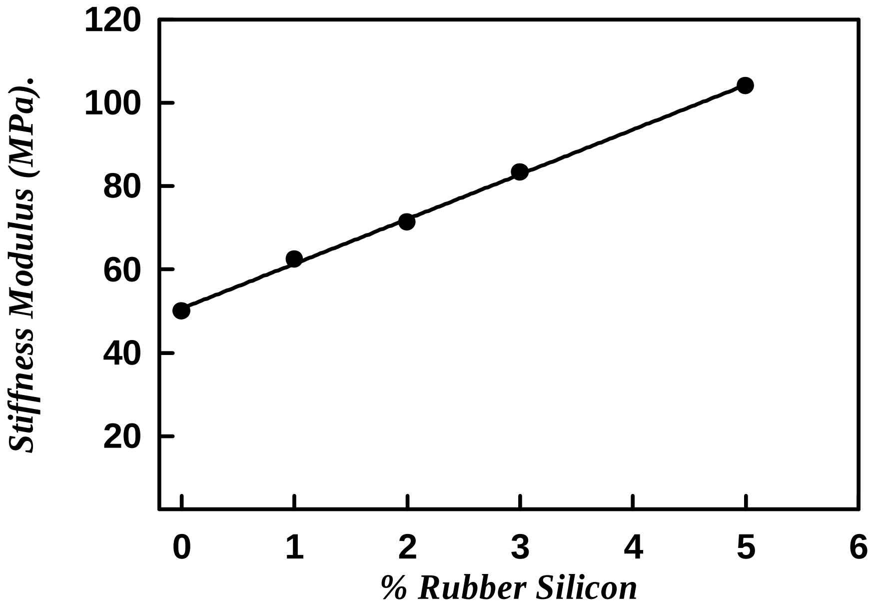

Fig.(10) Effect of Rubber Silicon Additive on Stiffness Modulus (Mo) of Asphalt Mixture at (60C)

4.Conclusion and Recommendations

Conclusion:-

The study shown that the Rubber-Silicone has the following effect on the performance of asphalt mixture:-

1- increasing the marshal stability, air voids, and reducing the flow and bulk density compared with the original mix.

2- Increase the flexibility properties of the mix and this appear from reducing the permeate deformation at test temperature (60C), the reduction percent is about (30 to 70)%.

Recommendations

Study the effect of Rubber-Silicone on the performance of asphalt mixture at low temperature..

6.References

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Effect of Wind Pressure on Horizontal Alignment of Highways

Ahmed H. Farhan
Assistant Teacher – Collage of Engineering –Anbar University

الخلاصة:

يتضمن التصميم الهندسي للطريق تصميم التخطيط الأفقي والعمودي. إن العامل الحاكم في تصميم التخطيط الأفقي هو إيجاد نصف القطر التصميمي للطريق والذي يتلاءم والمتطلبات التصميمية، لهذا فان المعادلة المستخدمة في إيجاد نصف القطر اشتقت بفرضية ان المركبة على الطريق تتعرض إلى قوة طاردة مركزية تدفع المركبة خارج مسار الطريق. في نفس الوقت توجد قوى تحاول تثبيت المركبة وهذه تشمل قوة الاحتكاك بين إطارات المركبة والطريق إضافة إلى القوى الناتجة من إمالة مقطع الطريق. عند سير المركبة على الطريق فان ضغط الرياح سيلعب دورا" مهما" في نظام القوى المؤثرة على المركبة وخصوصا" الكبيرة منها والتي تكون فيها مساحة التعرض للريح كبيرة، كما ان سير المركبة على الطرق الخارجية ذات السداد العالية خصوصا سيزيد من سرعة الريح وبالتالي ضغط الريح. الهدف من البحث الحالي هو لاستحداث معادلة جديدة لإيجاد نصف القطر التصميمي للمنحنيات الأفقية والتي تأخذ بنظر الاعتبار ضغط الرياح المؤثر على المركبة. المعادلة التي تم اشتقاقها تربط بين طول المركبة، ارتفاع المركبة،وزن المركبة، وضغط الريح المؤثر بالإضافة إلى بقية المتغيرات في المعادلة المعتمدة. وقد تم دراسة تأثير كل متغير على نصف القطر التصميمي وتم اخذ الحالة التي يكون فيها اتجاه الريح مع اتجاه القوة الطاردة المركزية التي تدفع المركبة خارج مسارها ووجد بان اقل نصف قطر مطلوب للمنحني يزداد مع نقصان وزن المركبة (نوع الحمولة) أي بتعبير أخر فان السرعة المسموحة للمركبة تتناقص مع نقصان وزن المركبة. من جهة أخرى، فان نصف القطر التصميمي المطلوب يزداد مع زيادة ارتفاع المركبة (ارتفاع الحمولة). بناءا" على ما سبق، فان ارتفاع الحمولة المسموح للمركبة يرتبط مع نوع الحمولة.يمكن اعتماد المعادلة الجديدة في تخمين السرعة المسموحة للمركبات الكبيرة على الطرق الحالية وذلك في الأجواء السيئة او العاصفة. المقارنة بين المعادلة التي اشتقت والمعادلة المعتمدة حاليا" بينت بان أعظم فرق هو بحدود 160% والذي يحصل عند ضغط الريح العالي بينما يكون الفرق لحد 20 % عند ضغط الرياح الواطيء

Abstract

The geometric design of highway alignment consists mainly of the design of horizontal alignment and Vertical alignment. The more important step in horizontal alignment design is the curve radius determination. The equation used for horizontal curve radius determination is developed with assumption that when vehicle run on curved section, there are an acting force on it. This force include the centrifugal force that try to push vehicle out off its path , on the other hand there are resisting forces try to keep the vehicle on its path. Those include the friction between road surface and tires and forces resulting from sloping the highway cross section. When a vehicle on rural highway with high embankment the wind Pressure will play an important role in force system acting on vehicle because of increasing in wind pressure intensity at these conditions (rural highway, i.e open areas, high embankment). The purpose of this paper is to present a new equation for horizontal curve radius determination taking in to account the wind force effect in addition to other forces acting on vehicle

The resulting equation relates vehicle length, height and weight and the wind pressure as well as the other factors in traditional equation. Effect of each parameter on design radius was investigated for the case

where the wind direction is acted with the same centrifugal force direction. It has been found that the required minimum radius increase with the decreasing of vehicle weight or in the other words the vehicle permitted speed decrease with the decreasing of vehicle weight. On the other hand, the required curve radius increases with vehicle height increasing. Consequently, permitted height of bags loaded on a truck is related to the type of loads. Derived equation can also be used for estimation of the permitted truck speed on existing roads especially in case of bad weathers

The comparison between the traditional and suggested equation showed that maximum difference is about 160 % which results at high wind pressure while the difference is up to 20 % for low wind pressure

Introduction:

Geometric design of highway alignments consists mainly of the design of horizontal and vertical alignments. Horizontal alignments of highway are made of striaght sections called Tangents connected by smooth horizontal curves. In fact, the design of horizontal curves entails the determination of minimum raduis, determination the length of curve, and then the computations of horizontal offsets from the tangent to the curve to facilitate the setting out of curve (1)

Many studies were conducted to investigate the effect of horizontal alignment design on highway safety. Raff and Smith (2) showed the relationship between curvature and small radii to high accident rate. Raff (2) argued that a high rate of accidents could be found on roads with a sharp horizontal curve following long tangents. The purpose of this paper is to present the new equation for horizontal curve radius determination for rural highways with high embankments subjected to high percentage of large trucks. This equation considers the effect of wind pressure as an additional force as well as the other forces acting on the vehicle. On the other hand, present paper try to identifying the effect of each parameter in the derived equation on the design radius. Finally, a comparison between the new equation and the traditional design equation is also presented.

Current Design Practice

When vehicle passing from straight sections to curved path, a vehicle is forced radially outward by the centrifugal force. This force try to push the vehicle out off its path and always acts in the horizontal direction (3). The centrifugal force is resisted by the frictional effect between the tires and the roadway surface. At high speed and/or bad weather, the frictional force is considered not sufficient to balance the centrifugal force. For this reason, it is customary to superelevate or slope the highway cross-section (3).The relationship between the superelevation rate, radius of horizontal curve, and design speed is given by the following equation (1,3):

$$R = \frac{v^2}{g(e+f)} \text{.........(8)}$$

Where:
v=design speed, m/sec.
g=acceleration, m/sec^2

The metric units equation usually used is

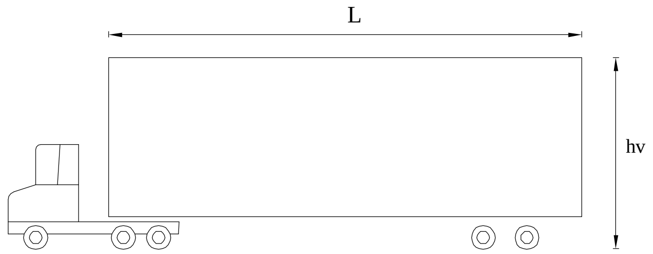
$$R = \frac{V^2}{127(e+f)} \text{...........(9)}$$

Where the V is the design speed in Km/h, e is the rate of superelevation, f is the side friction factor, and R is the radius of curve in meters. Values of (f) vary with the design speed and its values are shown in AASHTO Policy (3)

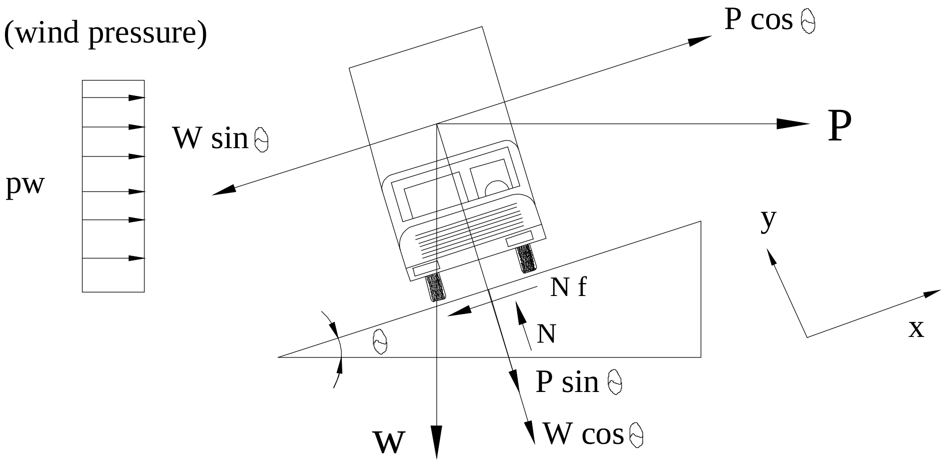
Maximum rate of superelevation are limited by the need to prevent slow-moving vehicle from sliding to the inside of the curve and , in urban areas, by the need to keep parking lanes relatively level and to keep the difference in slope between the roadway streets or driveways that intersect within reasonable bound. AASHTO Policy (3) recommends that maximum superelevation rate be limited to 12% for rural roadways, 8% for rural highways with snow or ice , and 4% or 6% for urban streets

Suggested Equation:

When a truck of given height and length on rural highway the wind pressure will play an important role in force system. In fact, pressure intensity in case of open areas (rural areas) will be greater than that on urban areas as well as this intensity increase also with elevation increasing. Moreover, the resulting wind force acting on vehicle is primarily related to exposed area i.e., vehicle length and height as shown in Figure (2) (since Force = Pressure x area). The current equation is derived assuming that there is a truck vehicle on rural highway with high embankment. It considers the effect of wind pressure (in addition to the other forces acting on vehicle as stated earlier) that may be acting toward the center of curve i.e., with the opposite direction of centrifugal force (or wind in) or acting outward the center of curve i.e., with the same direction of centrifugal force (or wind out).Actually the case in which the wind force act in the same direction of centrifugal force is more critical than this in which wind force act in the opposite direction of centrifugal force since the first case require more curve radius. Figure (2) also represent the forces acting on the truck in case of wind out

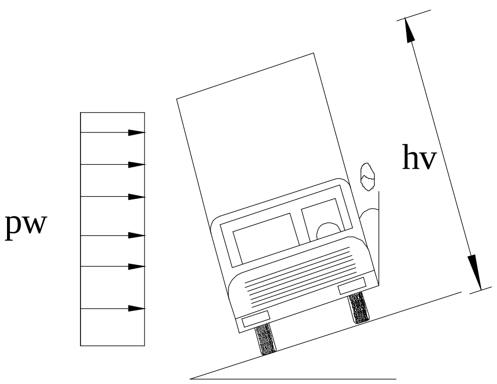


a. Vehicle Dimensions

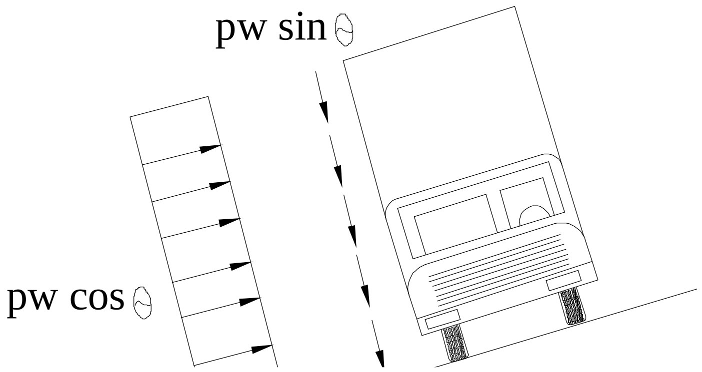


b. Forces acting on Vehicle

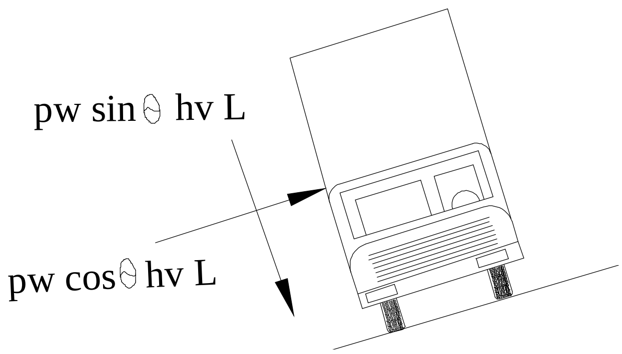
FIGURE (2): Vehicle Dimensions, Acting and Resisting Forces



a. Wind Pressure acting with the same Direction of Centrifugal Force



b. Resolving the Wind Pressure



c. Wind force acting on Vehicle

FIGURE (3): Analysis of Wind Pressure and Wind Force Determination

From equilibrium principles

$$\sum Fx = 0$$

$$P\cos q - W\sin q - Nf + p_w \cos q.hv.L = 0....(10)$$

$$\sum Fy = 0$$

$$N = P\sin q + W\cos q + p_w.\sin q.hv.L.........(11)$$

Substituting equation (11) in (10) results,

$$P\cos q - W\sin q - (P\sin q.f + W\cos q.f + p_w \sin q.h_v.L.f) + p_w \cos q.h_v.L = 0$$

Dividing by W $\cos q$ results,

$$\frac{v^2}{gR} - \tan q - \frac{v^2}{gR}.\tan q.f - f - \frac{p_w}{W}\tan q.h_v.L.f + \frac{p_w}{W}.h_v.L = 0$$

But, $\tan q$ = e =superelevation rate, simplifying more results,

$$\frac{V^2}{127R}(1 - e.f) + \frac{p_w.hv.L}{W}(1 - e.f) = e + f......(12)$$

In Equation (12) the term $e.f$ is small as compared with one, so it can be neglected and the above equation becomes:

$$\frac{V^2}{127R} + \frac{p_w.hv.L}{W} = e + f.......(13)$$

Using the same manner, the following equation represents the case where the wind pressure acts in opposite centrifugal force direction:

$$\frac{V^2}{127R} - \frac{p_w.hv.L}{W} = e + f.......(13)$$

In the above equations V=design speed (Km/h), p_w= the wind pressure (KN/m^2), and W= the weight of vehicle (KN), L=Length of vehicle (m), while the other terms are as specified earlier.

Parametric study and Comparison with Current Design Equation:

In this section, we will investigate the effect of each parameter on minimum design radius then a comparison between the current and suggested equation is presented. Table (2) present the input parameters used for these purposes.

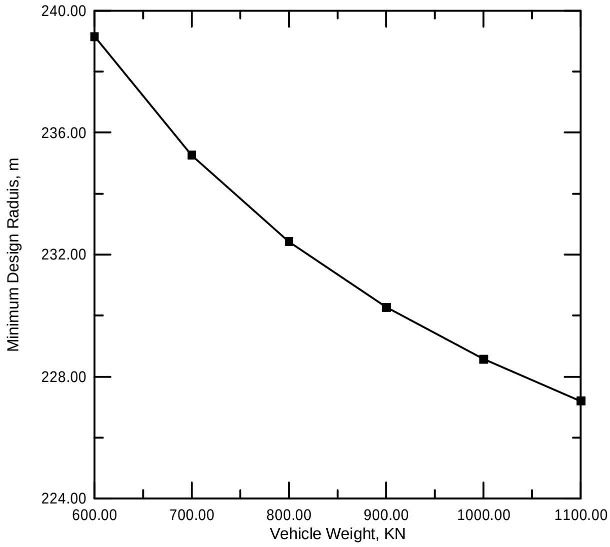
TABLE (2): Input Parameters Used in Parametric Study and Comparison

Parameters	Design Speed, Km/h	Wind[(1)] Pressure,(p_w) KN/m^2	Vehicle Weight,(W), KN [(5)]	Vehicle Height(hv), m	Vehicle length (L),m	Superelevation Rate(e),%,
Fixed Value	60	0.2[(2)]	600	4	12-22	4
Range values	20-120	0.01892[(3)]-1.2[(4)]	400-1100	3-5	16	2-12

(1) q or p_w=K V^2 where K=constant=0.0000473, V= design wind speed (km/h), Ref.(4)
(2) corresponds 65 km/h design wind speed
(3) corresponds 20 km/h design wind speed
(4) corresponds 160 km/h design wind speed
(5) 10 KN = 1 Tons.

Figure (4) shows the change in minimum radius of curve with the vehicle weight. It obvious that the required curve radius decrease with vehicle weight increasing. This because of increasing in vehicle weight will increase the resisting force (keeping in mind that there are two forces try to push vehicle out off its path which are centrifugal and wind force). Effect of vehicle height and length on minimum curve radius is shown in Figure (5) and Figure (9). It should be notice that the required radius will increase with increasing of vehicle height and / or length since the more vehicle height and/or length will generate more wind force. This because of increasing in height and/or length will increase the exposed area which in turn increase wind force. Therefore the radius of curve must be increase to decrease the effect of centrifugal force so the combined effect of acting forces (wind force plus centrifugal force) will decrease. Figure (6) illustrate the effect of wind pressure on the required minimum radius. Its clearly shows that the required radius will increased as wind pressure increase since the wind pressure will represent force that try to push vehicle out off curve. It can also be notice from Figure (7) that the required radius will increase with design speed increasing because of centrifugal force increasing. Finally, the value of curve radius decrease with superelevation increasing as represented in Figure (8).

Figure (10 to 15) represents also comparison between the derived and traditional equations. It can be conclude that the maximum difference is about 160 % which results at high wind pressure while the difference is up to 20 % for low wind pressure; the typical wind speed distribution in Iraq is shown in Appendix III



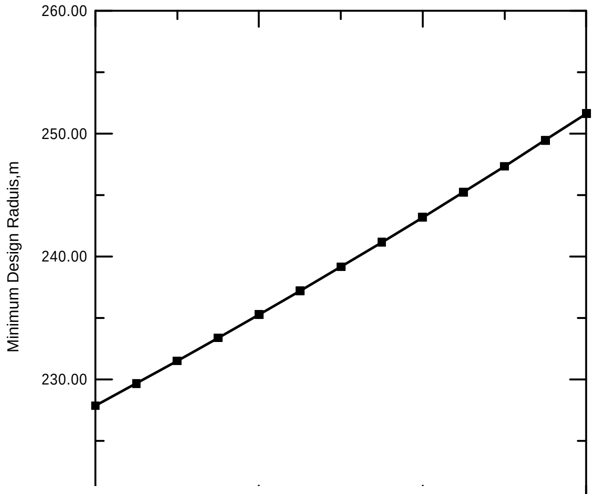


FIGURE (4): Min. Curve Radius with Various Vehicle weights

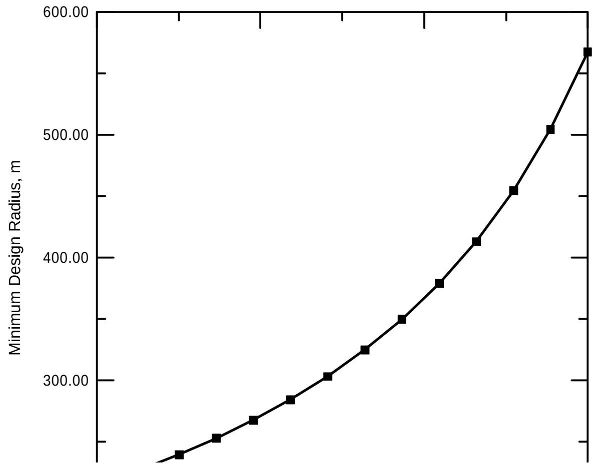


FIGURE (6): Min. Curve Radius with Various Wind Pressure

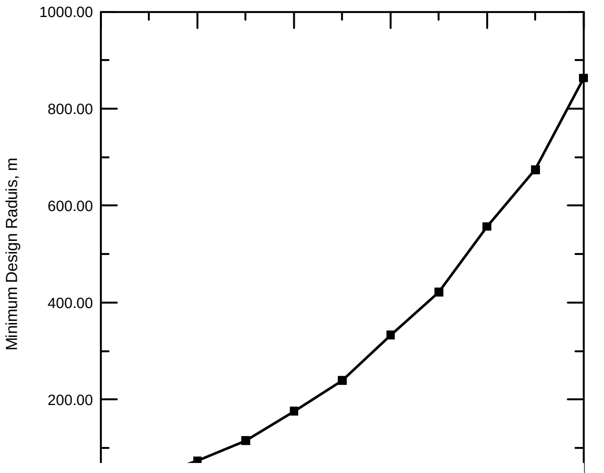
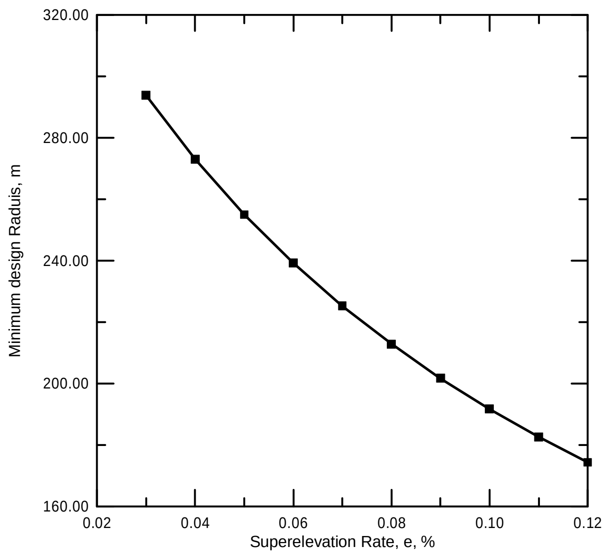


FIGURE (7): Curve Radius with Various Design Speeds



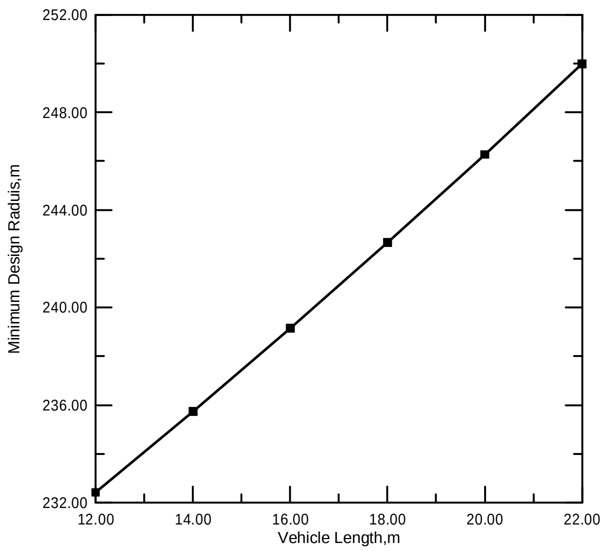


FIGURE (8): Curve Radius with Various Superelevation rates

FIGURE (9): Curve Radius with Various Vehicle Lengths

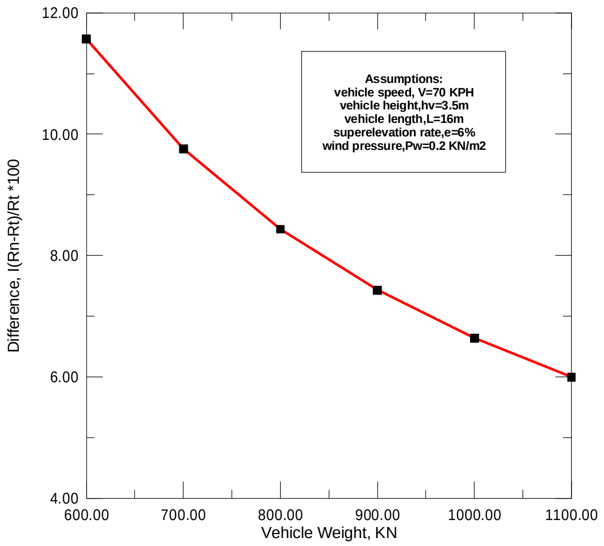


FIGURE (10): Difference between Derived and Traditional equations for various vehicle weights

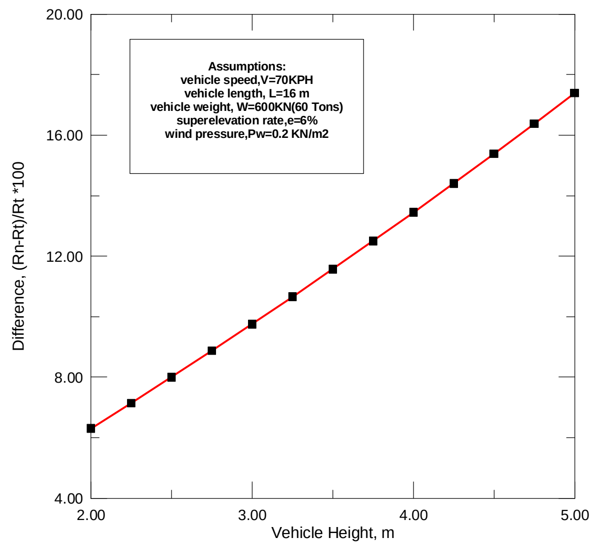
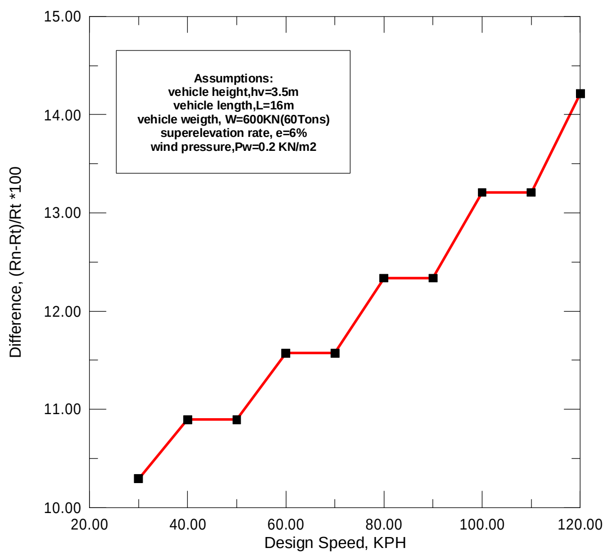


FIGURE (11): Difference between Derived and Traditional equations for various vehicle heights



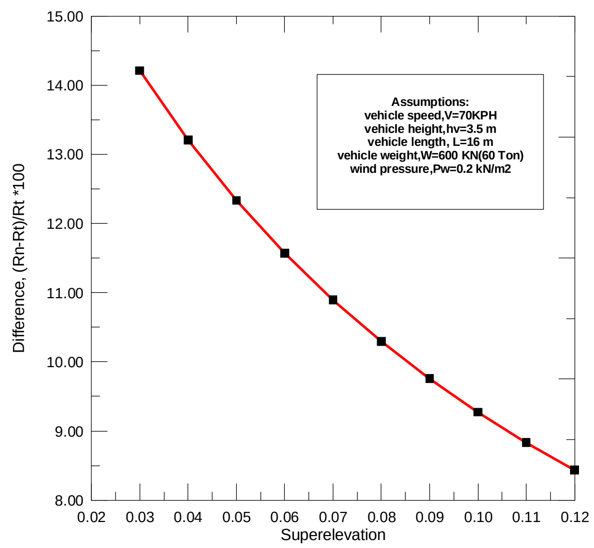


FIGURE (12): Difference between Derived and Traditional equations for various design speeds

FIGURE (13): Difference between Derived and Traditional equations for various superelevation rates

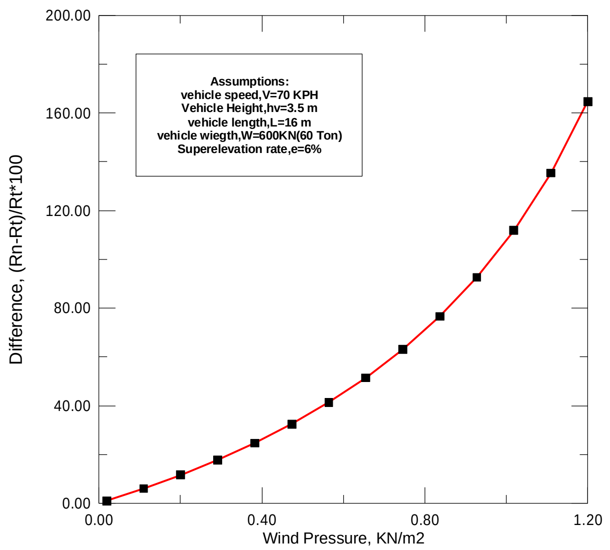


FIGURE (14): Difference between Derived and Traditional equations for various wind pressures

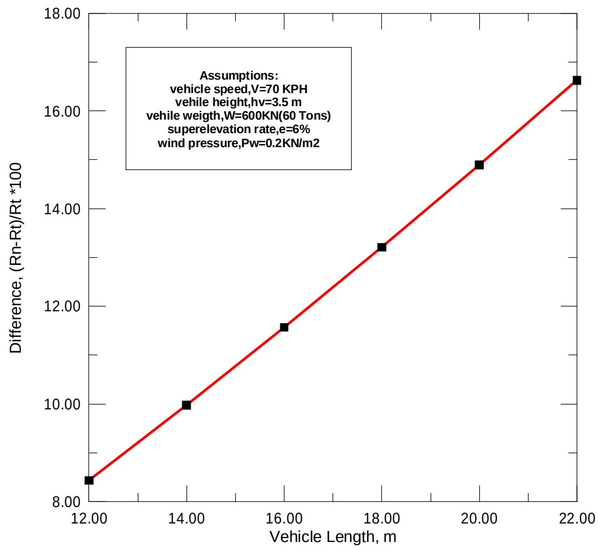


FIGURE (15): Difference between Derived and Traditional equations for various vehicle lengths

Conclusions and Recommendations:

There are several conclusions and recommendation drawn from the present study which are:

1. The developed equation introduces the effect of wind pressure, vehicle weight, length and height. Therefore it can be used to compute the minimum horizontal curve on rural highways with high embankment subjected to high percentage of large trucks
2. Required radius increase with increasing in height and/or length of vehicle or in the other words, increasing in vehicle height and/or length will reduce the design speed on curve. Therefore when truck carry a light loads such as wood or other light materials with high height the driver must reduce the speed of vehicle to balance the forces and keep his vehicle in its path.

3. From previewing the derived equation ,the effect of wind force when act in the same direction of centrifugal force is critical than the case where wind force act in opposite direction of centrifugal force since the first stated case will require more curve radius
4. It is recommended to study the effect of wind pressure on highway with compound alignment considering the dynamic effect.
5. The derived equation can be used to evaluate the permitted truck vehicle speed on highways in case of bad weather

APPENDIX I: REFERENCES

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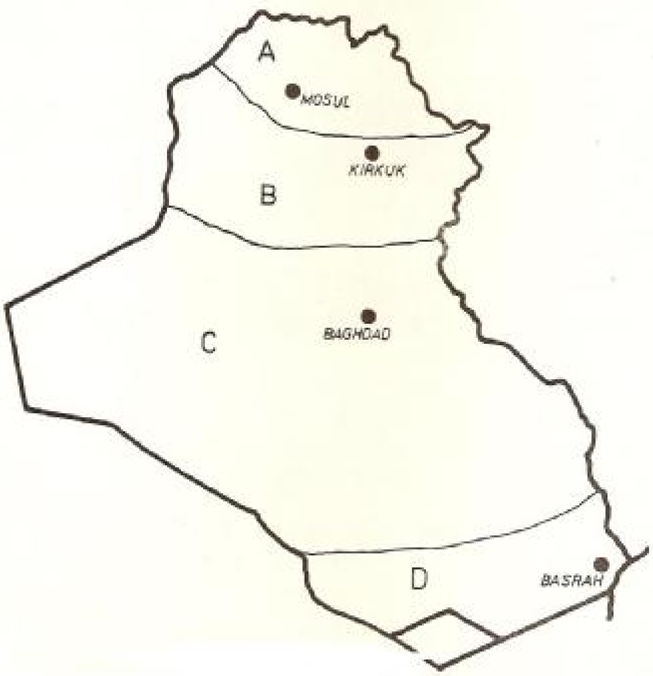
APPENDIX II: NOTATIONS

V= Design speed. Km/h
$R_{min.}$ =Minimum Curve Radius, m
f = Side Friction Factor
e= Superelevation rate, m/m
h_v= Height of Vehicle, m
p_w= Wind pressure, KN/m^2
L= Length of Vehicle, m
W=Weight of vehicle, KN
g= acceleration, m/sec^2

APPENDIX III: Wind Speed Zones in Iraq (Ref.5)

Zone	Wind Speed(KPH)
A	108
B	126
C	144
D	162



Modification Asphalt Mixture Performance By Rubber Silicon Additive

Taher M.A. Al-ani
Al-Anbar University/ Engineering College
Civil Dept.

Asmiet Ramizy Abd-Alghafour
Al-Anbar University/ Sciences College
Physics Dept.

Abstract :-

This study is the second stage of the paper “Study the Effect of Rubber Silicon on Physical Properties of Asphalt Cement”. This study took the effect of additives on asphalt mixture performance.

Asphalt mixture has been designed by Marshall method for determining the optimum asphalt content and geophysics properties of mix according to ASTM (D-1559). Rubber silicon at different percentage (1%, 2%, 3% and 5%) was added to asphalt binder and three specimens of asphalt rubber silicon mixture (ARSM) are prepared and evaluating according to Marshall method. Diametric tensile creep test ASTM (D-1075) at 60 Co used to evaluating permanent deformation and modulus of elasticity for ARSM.

The study shown that the Rubber-Silicon has more effects increasing the marshal stability, air voids, and reducing the flow and bulk density compared with the original mix.. Increase the flexibility properties of the mix and this appear from reducing the permeate deformation at test temperature (60C), the reduction percent is about (30 to 70)%.

1.Introduction:-

Polymer modified asphalt binder (PMBs) are becoming more wide speared in road building to meet today’s high traffic loading (1) . Many efforts are directed towards modifying the asphalt or paving mixture properties to get superior performance and serviceability under local conditions and to economize the construction of pavement(1).

There have been many investigations on polymer modified asphalt binders as counter measure to prevent plastic flow (2). Modification of bitumen with polymers decreases it’s temperature susceptibility chiefly by increasing its ring and ball softening point, increases its cohesion and modifies its rheological characteristics (3). The purposes of modification is also increase the viscosity at the high temperature, increase the flexibility and elasticity of binders at the low temperature, improve the adhesion to aggregates and many improve high thermostability and aging resistance (4).

The aim of this paper is studying the effect of rubber silicon on the performance of asphalt mixture for different percent of added (1%, 2% 3% and 5%). For this purposes the performance changes were evaluated by Marshall tests and diametric tensile creep test at 60C^o .

2.Review of Literature :-

The properties of asphalt important for its consideration as a paving material are its rheological properties, adhesion, and durability (3asal). Since the highway engineer is usually limited to his choice of asphalt source, there is need for a practical way to improve asphalt quality by the addition of modifying ingredients. In this regard it is believed that PMBs may proved durability and wear resistance(6).

Reclaind rubber obtained from used tiers, polyethylene in the form of low density (LDPE), styrene-butadiene-styrene copolymer, latex are used for modification of asphalt cement and test sections were found to perform satisfactorily (5).

During world war II a number of synthetic elastomers were developed and since then several of these also have been used as additives for asphaltic materials in road construction. The data show that the properties of an asphalt-rubberized with natural rubber latex can be varied not only by the amount of rubber but also by using different amounts of sulfur. Also it show that the properties of asphalt-rubberized with natural rubber latex containing small amounts of sulfur compare quite favorably with the properties of asphalt-rubberized with synthetic rubbers (7).

During the end of fiftieth there has been more interest in using rubber with asphaltic materials for surface treatments and seal coat construction. It has been observed that rubberized binders used in this type of construction were tougher, reduced the tendency of the surface to crack and bleed, and improved aggregate retention. (7).

In Sweden size of rubber particles in asphaltic pavement were evaluated. Large rubber particles (1/16 in to ¼ in) were used into an asphalt pavement. It was determined that using (3-4)% by weight of rubber is sufficient to increase skid resistance and, durability as well as reducing noises level.(8).

Battelle was investigating the use of scrap tiers as an additive in black top dressings for driveways and parking lots. Improved durability, resistance to abrasion , and resiliency are said to be possible with minor cost increases. Also reclaimed rubber is being used in asphalt patching and under foundations as a cushioning agent in Tucson, Arizona. (9)

M.J.. Fernando and H.R. Guirguis found that natural rubber with its inherent chemical constitution, is an excellent organic polymer for incorporation into asphalt in order to produce a superior form of road binder. The resultant binder is more viscous at high temperature, more flexible at low temperature, more resistance to distortion and more durable (10).

Hugo and Nachenius (11) described three test methods which may be usefully employed to study the properties of bitumen-rubber binders and asphalt, sliding plate rheometer tests for binder-rubber blinders and indirect tensile strain measurement and freeze-thaw test for bitumen-rubber asphalt.

Mahabir Panda and Magajit Muzumdar (11) were used reclained low density polyethylene (LDPE) from carry bags of goods for modification asphalt mixture performance as fatigue life, resilient modulus, resistance to moisture susceptibility in addition to marshal characteristics.

Wlodyslaw Milkowski (13) used polyethylene as an additive to achieve asphalt concrete of much higher stability and lower thermal susceptibility. Adding polyethylene (PE) in small percent reduce penetration, raised the softening point and increased the shear strength of asphalt joints.

Lee, Morrison and Hesp (14) found that the additive of polyethylene and chlorinated polyethylene to asphalt binders does significantly increase their low temperature fracture toughness and fracture energy.

Taher. M.A (15) shown that Increasing in the law density polyethylene (LDPE) percentage decreasing the susceptibility of asphalt cement for temperature**.**

3.Materials and Tests :-

1. *Asphalt Cement:-*

One binder of asphalt cement was tested, from Daurah Refinery with a grade of (40-50) penetration. The physical properties of this type are illustrated in table (1)

Table (1). Physical Properties of Asphalt Cement.

Test	Unite	*Daurah (40-50)*
Pentration @ 25 C^o	*0.1 mm*	*45*
Ductility @ 25 C^o	*Centimeter*	*+100*
Softening Point	*C^o*	*50*
Flash Point	*C^o*	*351*
Specific Gravity	*---*	*1.033*
Kinematic Viscosity	*cst.*	*270*

2. *Additive:-*

Rubber-Silicone was used with asphalt binder , it is available in the local market. Rubber-Silicone was added to binder at different percent (1% ,2% ,3% and 5%). The method of adding Rubber-Silicon to binder at temperature (150) C^0 with stirrer for (20) minute.

3. Aggregate (coarse and fine materials):-

Crushed aggregate are used in this work with a fixed dense gradation for all the specimens and from Al-Jaraishe source. The mid limits of the (19 mm) size dense gradation has been selected as a basic gradation in accordance with (ASTM D-3515) as shown in figure (1)

4. Mineral Filler:-

One type of filler is used in this work which was Limestone dust (Karbala Factory).

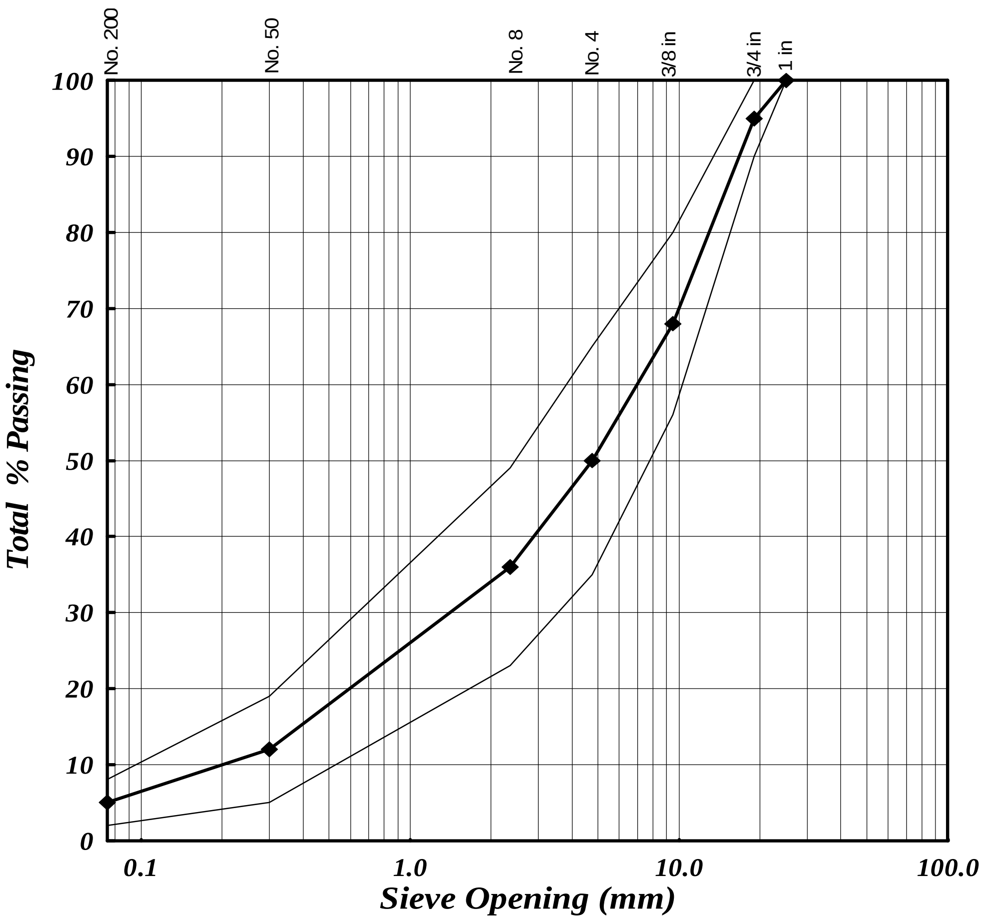


Figure (1):- Specification Limits and Selected Gradation of Aggregate Maximum Size (19 mm)

5. Test Methods:-

The following tests were used in this work to evaluate the asphalt concrete mixture.

1- resistance to plastic flow (Marshall Stiffness)
2- Permanent Deformation (diametric tensile creep test)

5.1. Preparation of Mixtures:-

The aggregate are first dried to constant weight at (110 C^0), separated into the desired sizes and recombined with mineral filler in order to meet the required gradation for each specimen. The aggregate are then heated to temperature off (155C^0) before mixing with asphalt cement. The asphalt cement is heated to the temperature , which produce a kinematic viscosity of (170±20) centistokes up to (163C^0) as an upper limit. Then, asphalt cement is weighed to desired amount and added to the heated aggregates, and mixed thoroughly until all aggregate particles are coated with asphalt.

5.2. Resistance to Plastic Flow (Marshall Method):-

This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus according to (ASTM D-1559). The test specimens were compacted using one comparative effort, which is (75) blows/end.

The bulk specific gravity density (ASTM D-2726), theoretical (maximum) specific gravity (ASTM D-2041) and percent air voids (ASTM D-3203) are determined for each specimen.

Marshall stability and flow test are performed on each specimen according to the method described by (ASTM D-1559). The cylindrical specimen (2.5" (62.5 mm) height * 4" (101.6 mm) diameter) is compressed on lateral surface with a constant rate of (50.8 mm/min) until the maximum load is reached. The maximum load resistance and corresponding flow values are recorded. Three specimens for each combination are prepared and the average results are reported.

5.3. Creep Test:-

The diametric indirect tensile creep test has been used for testing asphalt mixture to determine the permanent deformation and the stiffness of asphalt mixture by measuring the strain – time value. The same Marshall specimens have been used in this test. The specimens are then left to cool at room temperature for (24) hrs. and, placed in water bath at the specific test temperature of (60C^0) for (30) minutes before the test is conducted. The strain (deformation) was recorded at a strain time of loading and unloading (0.1, 0.25, 0.5, 1, 2, 4, 8, 15, 30, 45, and 60 minutes). The test was conducted while the specimen was submerged in water bath maintained at the test temperatures (60C^0) with a static constant stress of (14.5 psi = 0.1 Mpa). The vertical strain calculated from the measured deformation is determined as follows:-

$$\varepsilon = \Delta H / H_o \quad \text{mm/mm}$$

where:-

ΔH = the total measured vertical deformation at a certain loading time,

H_o = the original diameter of the specimen.

The stiffness modulus of the mixture is calculated by:-

$$(S_{creep})t = \sigma / \varepsilon \quad \text{N/mm}^2$$

σ = stress of test (14.5 psi (0.1 Mpa)

4.Result and Discussions :

The first result of this work was selecting the optimum asphalt content depending on marshal stability ,stiffness, and flow, bulk density, theoretical gravity density, and air voids. This optimum percentage (4.3%) was used with different percent of Rubber silicon for preparing asphalt rubber silicon mixture (ARSM).

The data of study effect of Rubber-Silicon on asphalt mixture are evaluated laboratory and arranged in table (2).

Table (2). Properties of Asphalt Rubber Silicone Mixture (ARSM)

No	% Rubber-Silicone	Marshall Properties					
		Stability Kn	Flow mm	Stiffness Kn/mm	% Air voids	Theoretical Density	Bulk density gm/cm^3
1.	0	9.2	**2.8**	3.286	7.1	2.488	2.31
2.	1	11.1	2.7	4.111	7.05	2.485	2.31
3.	2	12.01	2.4	5.004	7.7	2.481	2.291
4.	3	11.2	2.4	4.667	7.8	2.48	2.283
5.	5	10.8	2.1	5.143	8	2.477	2.28

4.1. Properties of ARSM.:-

Data of table (2) are presented in the following figures:

Figure (2) show the effect of rubber silicon on Marshall stability. Stability increase rapidly with increasing rubber silicon content until (2%) after that there are slowing in redaction. The stability increase about (30)% compared with original mixing.

Figure (3) show the effect of rubber silicon on Marshall flow. Flow decrease with increasing the rubber silicon contents.

Figure (4) show the effect of rubber silicon on Marshall stiffness.

Marshall Stiffness = (Marshall Stability / Marshall Flow) (Kn/mm)

Marshall stiffness increase with increasing the rubber silicon contents. The rate of increasing is very speed as shown in figure(4)

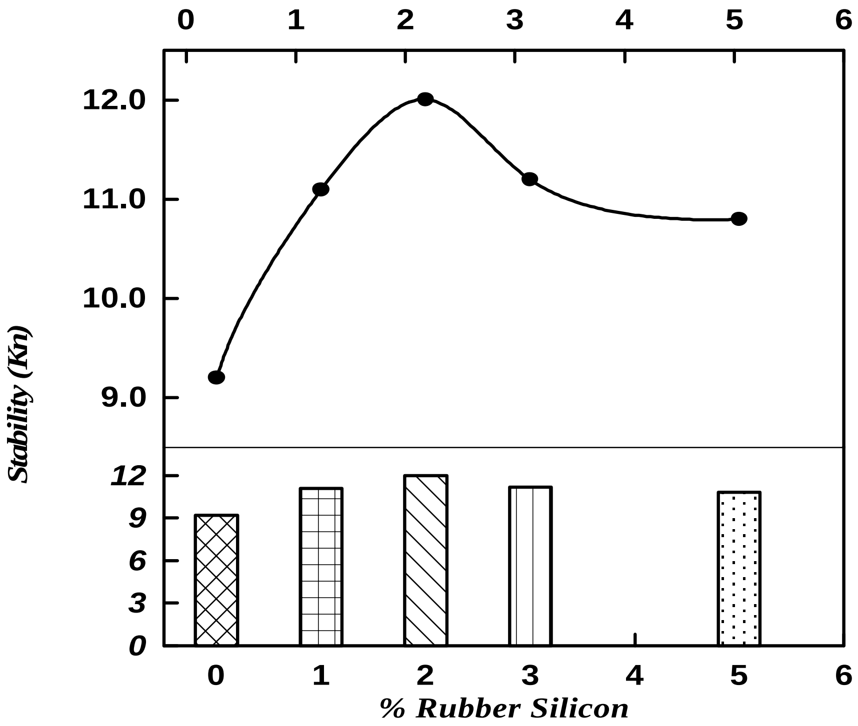


Fig.(2) Effect of Rubber Silicon Additive on Marshall Stability of Asphalt Mixture

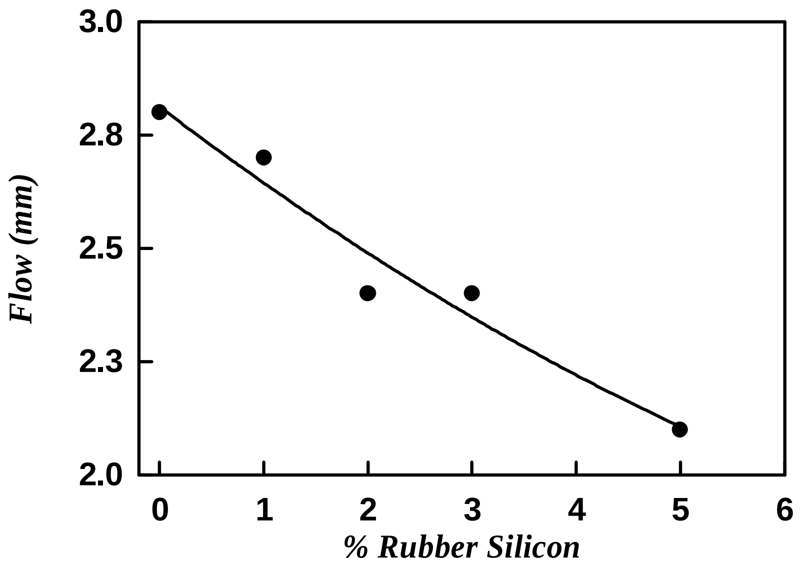


Fig.(3) Effect of Rubber Silicon Additive on Marshall Flow of Asphalt Mixture

Figure (5) show the effect of rubber silicon on Maximum bulk density. The rubber silicon content insignificant effect on maximum bulk density.

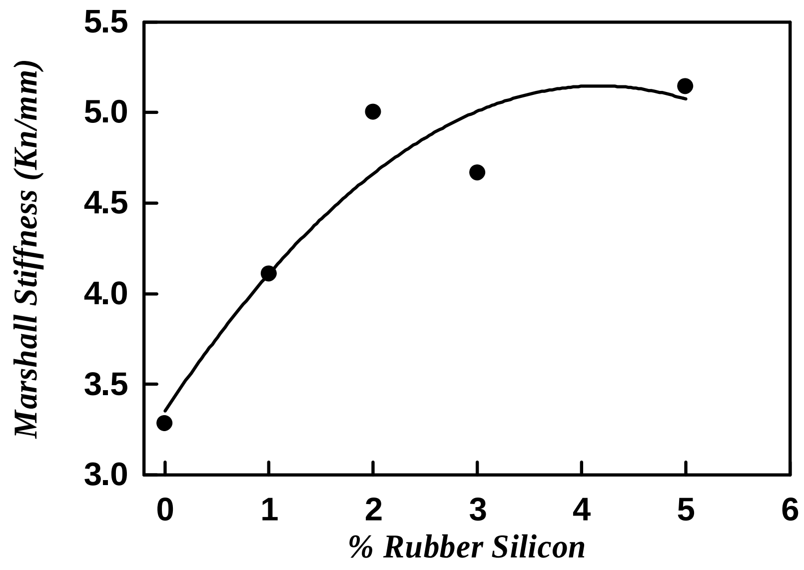


Fig.(4) Effect of Rubber Silicon Additive on Marshall Stiffness of Asphalt Mixture

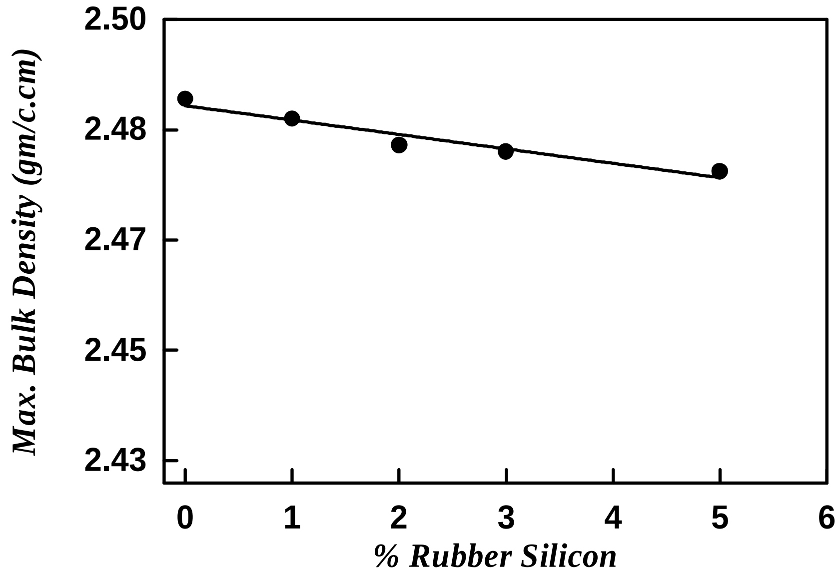


Fig.(5) Effect of Rubber Silicon Additive on Max. Bulk Density of Asphalt Mixture

Figure (6) show the effect of rubber silicon on bulk density of mixture. Increase the rubber silicon content decrease the bulk density of mixture because rubber silicon is less density than asphalt cement.

Figure (7) show the effect of rubber silicon on percent of air voids in mixture. Increase the air voids with increasing in rubber silicon content because the decrease in the bulk density of mixture with increasing rubber silicon , while the maximum bulk density remains the same nearly for all mixes.

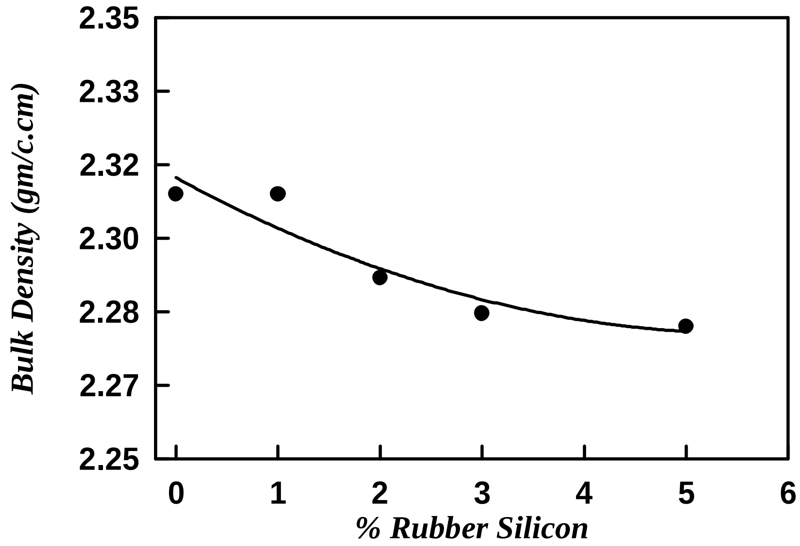


Fig.(6) Effect of Rubber Silicon Additive on Bulk Density of Asphalt Mixture

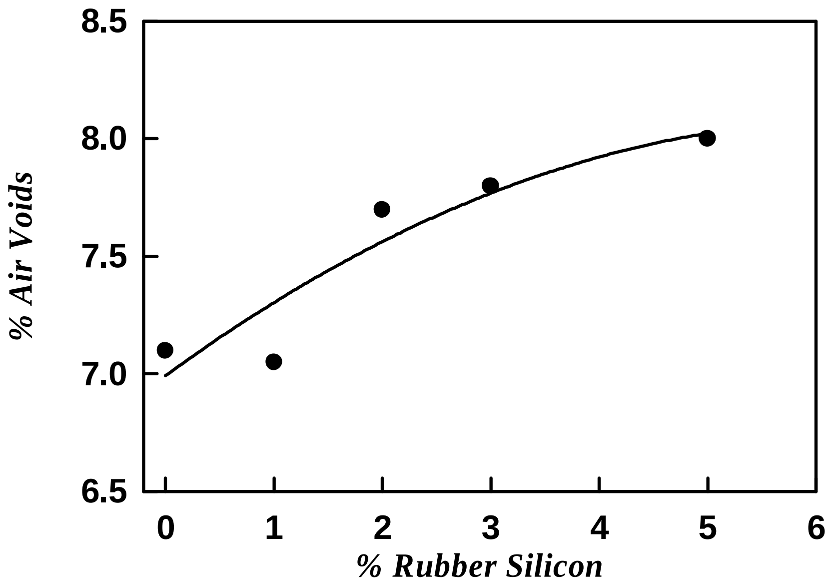


Fig.(7) Effect of Rubber Silicon Additive on Percentage Marshall Air Voids of Asphalt Mixture

Figure (8) show the effect of rubber silicon contain on diametric indirect tensile creep test under constant static load (0.1 MPa) at temperature of test (60C). increasing of rubber silicon contain reducing the rate of deformation ,and the percent of (2 and 3) have the same effect on rate of deformation.

Figure (9) show the effect of rubber silicon contain on permanent deformation at (60C) and the present of reduction is about (30 to 70)% . This induct that the rubber silicon increase the flexibility properties of the asphalt mixture.

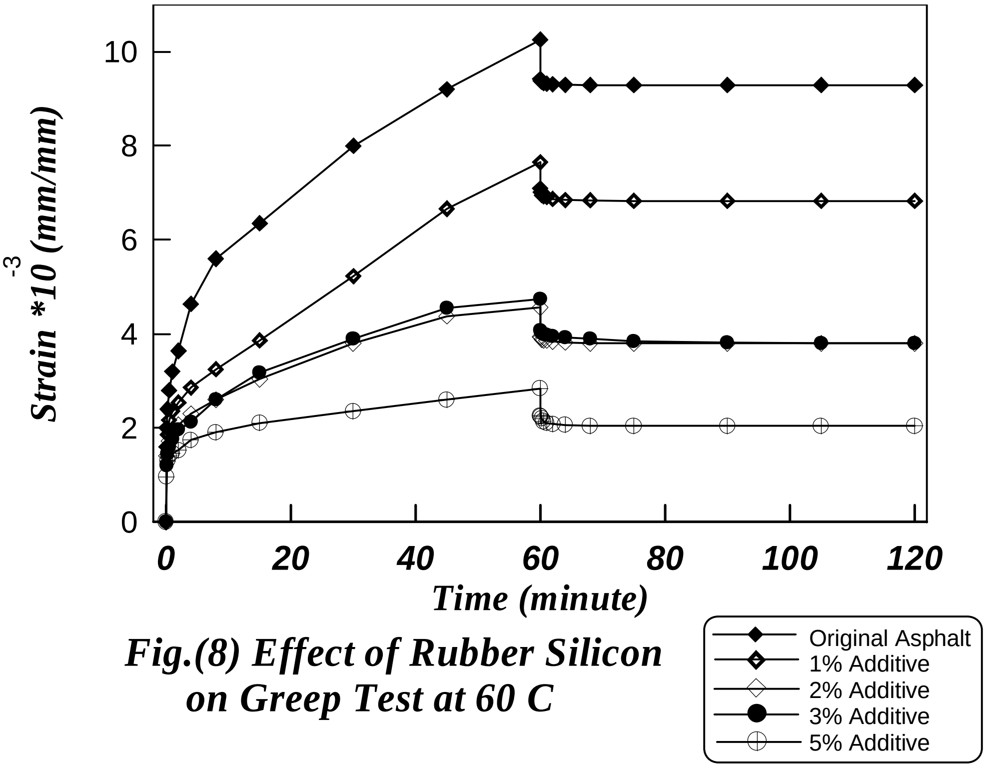


Fig.(8) Effect of Rubber Silicon on Greep Test at 60 C

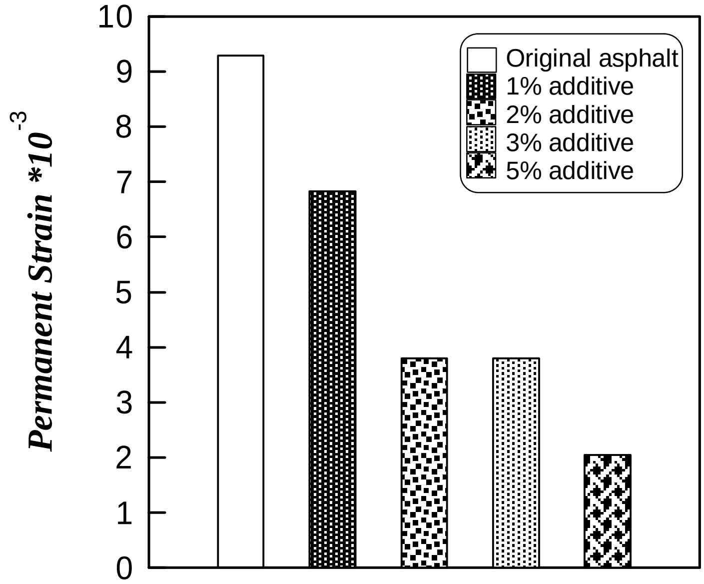


Fig.(9) Effect of Rubber Silicon Content on Permanent deformation at (60C)

Figure (10) show the effect of rubber silicon contain on stiffness modulus of asphalt mixture at (60C). the rubber silicon increasing the stiffness modulus of asphalt mixture and for that the rigidity of the mix at high temperature increasing therefore the permanent deformation was reducing**.**

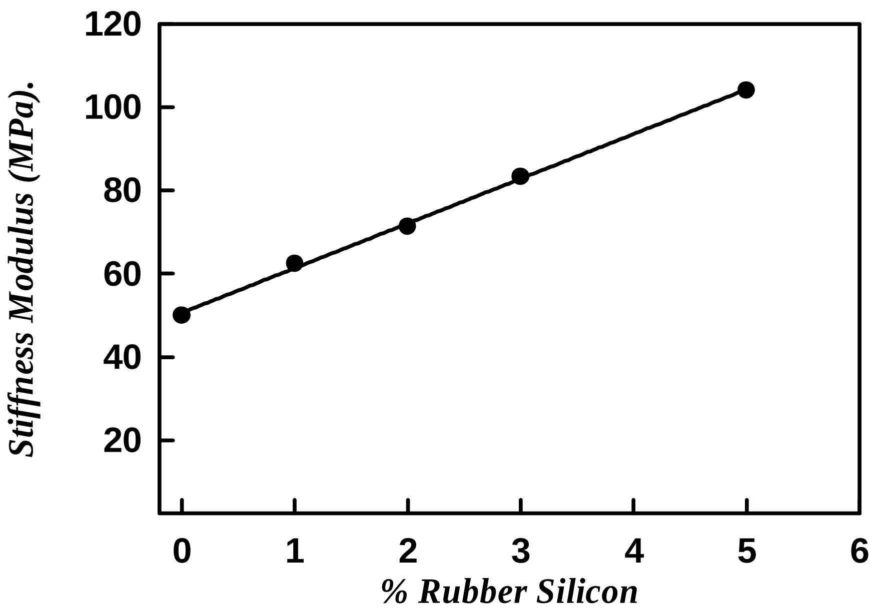


Fig.(10) Effect of Rubber Silicon Additive on Stiffness Modulus (Mo) of Asphalt Mixture at (60C)

4.Conclusion and Recommendations

Conclusion:-

The study shown that the Rubber-Silicone has the following effect on the performance of asphalt mixture:-

1- increasing the marshal stability, air voids, and reducing the flow and bulk density compared with the original mix.

2- Increase the flexibility properties of the mix and this appear from reducing the permeate deformation at test temperature (60C), the reduction percent is about (30 to 70)%.

Recommendations

Study the effect of Rubber-Silicone on the performance of asphalt mixture at low temperature..

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