Evaluation of Iraqi Hot Asphalt Mixture Properties

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Abstract

In this study, the properties of Iraqi hot asphalt mixture which is used in highway pavement construction in Iraq are evaluated by depending on the specification requirements of Asphalt Institute 1997(USA). Marshall mix design method is used to determine the optimum asphalt content. Seven specimens of hot asphalt mixture were prepared at different asphalt contents at 1% increments from specimen to another. The results show that the hot asphalt mixture does not meet the specification requirements of Asphalt Institute 1997. Therefore, this mixture need to adjust the properties or redesign by using new amount and type of aggregate and asphalt.

Keywords: Aggregate, Asphalt mixture, Asphalt properties, Marshal test, Mineral filler, Pavements.

الخلاصة

في هذه الدراسة تم تقييم خواص الخلطة الإسفلتية الحارة العراقية المستخدمة في تبليط الطرق في العراق بالاعتماد على متطلبات المواصفة الأمريكية(Asphalt Institute 1997). طريقة مارشال لتصميم الخلطات الاسفلتية استخدمت لحساب نسبة الاسفلت المثالية. سبعة نماذج من الخلطات الاسفلتية حضرت ذات محتوى اسفلتي مختلف بنسبة ١% زيادة من نموذج الى آخر. إن النتائج بينت بأن الخلطة الإسفلتية غير مطابقة لمتطلبات المواصفة الأمريكية، لذلك فان هذه الخلطة بحاجة إلى تحسين الخواص أو إعادة تصميم، باستخدام مقادير وأنواع جديدة من الحصى والإسفلت.

الكلمات الدالة: الركام، الخلطة الإسفلتية، خواص الإسفلت، فحص مارشال، المالئات المعدنية، التبليط

Introduction

A compacted bituminous mixture is a combination of bituminous material(such as tar or asphalt), properly graded aggregate, additives and air. Tar is rarely used in bituminous mixtures in recent years. Asphalt is the predominant binder material used , and the term asphalt mixture is now more commonly used to denote a combination of asphalt materials, aggregates and additives, [Roberts, *et.al*(1997)].

Hot asphalt mixture is produced in a hot asphalt mixing plant by mixing a properly controlled amount of aggregate with a properly controlled amount of asphalt at the suitable temperature. The mixing temperature has to be sufficiently high such that the asphalt is fluidic enough for proper mixing with and coating the aggregate , but not too high as to avoid excessive aging of asphalt, [Mang(2006)].

The properties of hot asphalt mixture to be determined should be good indicators of performance of the mixture in service, so that these properties can be used to determine the acceptability of the mixture and to select the optimum mixture design to be used, [Goets and Wood(1960)].

The asphalt mixture should have four requirements and these are :- [Garber and Hoel(1998)]

a- Sufficient asphalt content to ensure a durable pavement surface.
b- Sufficient mixture stability to prevent unacceptable distortion and displacement when traffic load is applied.
c- Sufficient voids in the total compacted asphalt mixture to permit a small amount of compaction when traffic load is applied without loss of stability , blushing , and bleeding.
d- Sufficient workability to facilitate placement of the mixture without segregation.

In the present study, Marshall mix design method is used to determine the optimum asphalt content , and the evaluation of hot asphalt mixture properties by using Asphalt institute specification(1997).

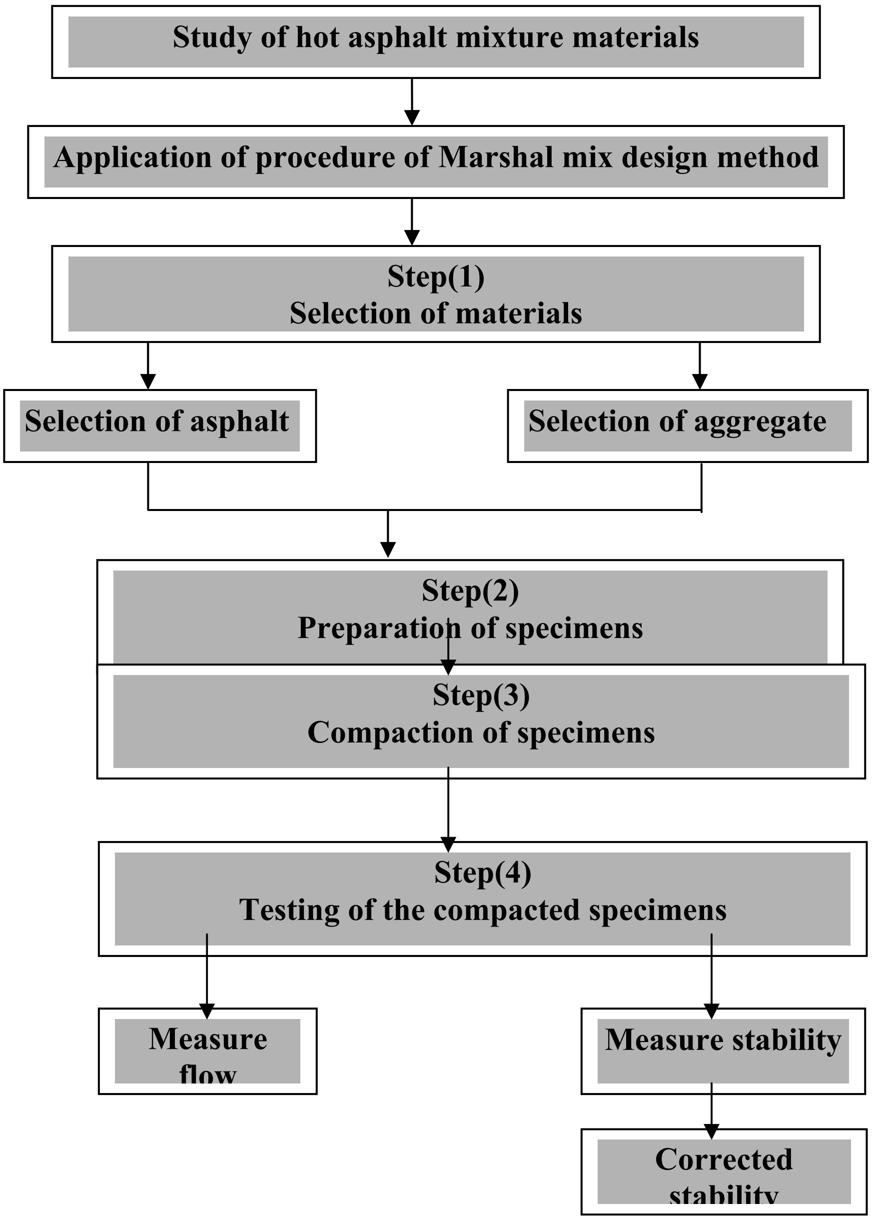
Objectives of the study

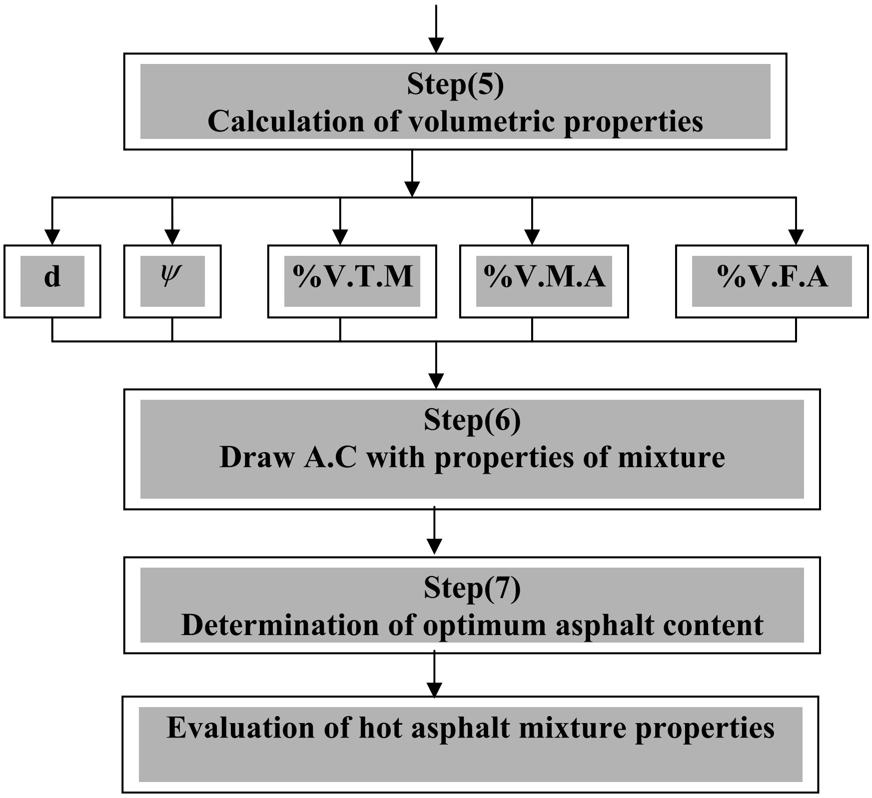
The objectives of this study are the following :

1- Determination of the optimum asphalt content for seven specimens of hot asphalt mixture by using Marshall mix design method.

2- Evaluation of hot asphalt mixture properties by using Asphalt Institute specification(1997).

Methodology of the study





Figure(1) Methodology of the study

Materials of hot asphalt Mixture

Hot asphalt mixture consists of aggregate, asphalt and air These materials can be shown in Figure(2).

1- Aggregate :

The amount of aggregate in asphalt mixture is generally 90 – 95 percent by weight and 75 – 85 percent by volume of most asphalt mixture. Aggregate provides most of the load bearing capacity of the asphalt mixture. Therefore, the properties of an asphalt mixture is greatly influenced by the properties of the aggregate used, [Garber and Hoel(1998)]

The aggregate content of asphalt mixture is composed of coarse aggregate, fine aggregate and mineral filler. [AASHTO(1997)].

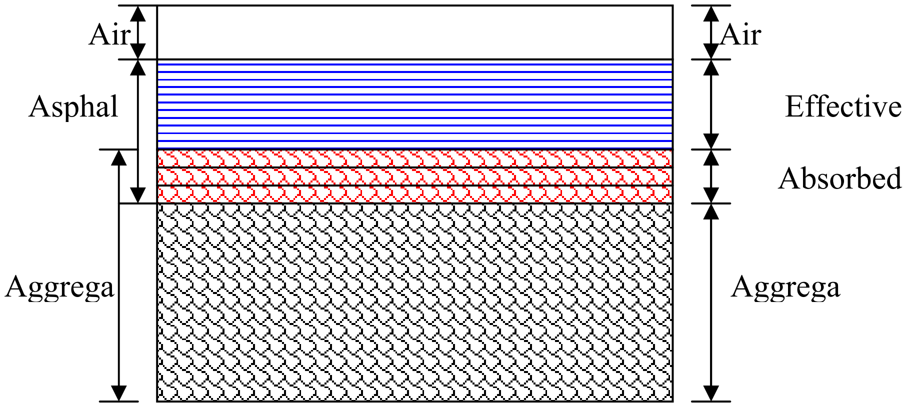
a- Coarse aggregate : is that which passes from sieve No.(3/4") and retained on the sieve No.(4). This type of aggregate includes crushed rock , slag , or gravel.

b- Fine aggregate : is that which passes from sieve No.(16) and retained on sieve No.(100). This type is usually composed of angular and natural sand particles.

c- Mineral filler : is that which passes from sieve No.(200). It is most usually composed of crushed limestone dust, cement and lime.

2- Asphalt :

Asphalt is a viscous liquid or solid materials, black or dark brown in color and having adhesive properties. Asphalt composed of penetration – grade asphalt or high – viscosity road tars. The amount of asphalt in asphalt mixture is 5% - 10% by weight and 15% - 25% by volume. Generally, there are two types of asphalt materials. The first type is which occur naturally in natural rock asphalt or Trinidad lake asphalt. Whereas, the second type is obtained from the fractional distillation of petroleum at a refinery, [Department of Building and Construction(2002)].



Figure(2) The materials of asphalt mixture, [Department of Building and Construction(2002)].

Procedure of Marshall mix design method and results

The concept of the Marshall method of mix design was originally formulated by Mr. Bruce Marshall, formerly a bituminous engineer with the Mississippi State Highway Department. The Marshall mix design method is used to determine the optimum asphalt content in asphalt mixture. This method is the most commonly used mix design method in United States and it is still the most commonly used mix design methods in the world, [Asphalt Institute(1997)].

In this study, Marshall mix design method is used and it consists of the following steps :

Step one : Selection of hot asphalt mixture materials

a- Selection of asphalt :

The asphalt of mixture must meet the specification requirements as set by the local highway agency. In this study, asphalt material which is used in hot asphalt mixture is brought from Al-Dora refinery. Table(1) shows the properties for 60 / 70 and 85 / 100 penetration grade asphalt cements. In this study, asphalt cement 65 – penetration grade is used. The properties of asphalt used in this study is shown in Table(2).The weight of asphalt(w_{asp}) can be determined by using the equation :

W_{asp} = % asphalt content * W_A -------------------- eq(1)

where :

W_{asp} = weight of asphalt(gm)

W_A = total weight of mixture(gm)

Table(1) Properties for 60 / 70 and 85 / 100 penetration asphalt cement [ASTMO(1997)].

Test	Penetration grade			
	60 / 70		85 / 100	
	Min	Max	Min	Max
Penetration at 25 ºc , 0.1mm	60	70	85	100
Flash point ºc	232	-	232	-
Ductility at 25 ºc , cm	100	-	100	-
Solubility in trichloroethylene %	99	-	99	-
Retained penetration after TFOT	52	-	47	-
Ductility at 25ºc after				
TFOT , cm	50	-	75	-

Table(2) The properties of asphalt using in the study[Laboratory of Highway Engineering(2005)]

Properties	value
Penetration at 25 ºc ,(0.1 mm)	65
Flash point ºc	251
Ductility at 25 ºc ,(cm)	100
Viscosity at 60 ºc,(poises)	1120

b- Selection of aggregate :

The aggregate of mixture must meet all the requirements as specified by the local highway agency. Table(3) shows the percentage of weights for aggregate components which is used in this study. The weights of aggregate components can be determined by using the following equations :

$W_{agg} = W_A - W_{asp}$ ---------------------------------- eq(2)

$W_c = \% 50 * W_{agg}$ --------------------------------- eq(3)

$W_f = \% 40 * W_{agg}$ --------------------------------- eq(4)

$W_{mf} = \% 10 * W_{agg}$ -------------------------------- eq(5)

where:

W_{agg} = total weight of aggregate(gm).

W_A = total weight of mixture in air(gm).

W_{asp} = weight of asphalt.

W_c = weight of coarse aggregate(gm).

W_f = weight of fine aggregate(gm).

W_{mf} = weight of mineral filter(gm).

Table(3) The percents of weights for aggregate components.

Aggregate components	Sieve size	% passing	% Retained	Percent of aggregate components
Coarse Aggregate	3/4"	100	0	% 50
	1/2"	85	15	
	3/8"	70	15	
	No. 4	50	20	
Fine Aggregate	No. 16	37.5	12.5	% 40
	No.52	17.5	20	
	No. 100	10	7.5	
Mineral filler	No. 200	5	5	% 10
	pan	0	5	

Table(4) The weights of compacted asphalt mixtures components

Specimen number	W_A (gm)	W_W (gm)	V (cm^3)	% asphalt content	Weight of asphalt(gm)	Total weight of aggregate (gm)	W_C (gm)	W_F (gm)	W_{mf} (gm)	d (gm/cm^3)	Ψ (gm/cm^3)
1	1200	652	548	4	48	1152	576	460.8	115.2	2.18	2.50
2	1200	632	568	5	60	1140	570	456	114	2.11	2.46
3	1200	627	573	6	72	1128	564	451.2	112.8	2.09	2.43
4	1200	617	583	7	84	1116	558	446.4	111.6	2.05	2.39
5	1200	667	533	8	96	1104	552	441.6	110.4	2.25	2.36
6	1200	647	553	9	108	1092	546	436.8	109.2	2.16	2.32
7	1200	637	563	10	120	1080	540	432	108	2.13	2.29

Step two : Preparation of hot asphalt mixture specimens :

The Marshall test uses a standard cylindrical mold test specimen that is 101.6 mm diameter by about 63.5 mm high. Specimens of asphalt mixtures of seven different asphalt contents with three replicates per asphalt content are prepared. The asphalt contents are selected at 1% increments, the aggregate and asphalt are mixed at temperature 110 ºc. In the mix process, the weight of asphalt and aggregate components for each specimen are used from Table(4). All specimens wear tested in the laboratory of Building and Construction Engineering Department – Branch of Highway and Airport Engineering in the University of Technology through July – 2005.

Step three : Compaction of the asphalt mixtures specimens :

The asphalt mixture is compacted in a standard cylindrical mold by using Marshall compaction hammer, which is 6.5 kg in weight and dropped from a height of 457 mm. The number of blows to be applied per side is 50 blows.

Step four : Testing of the compacted specimens :

The test to be run on the Marshall specimens includes Marshall stability test, which measures the Marshall stability and Marshall flow according to ASTM D1559 [ASTM(2001)].

The stability test is a type of unconfined compressive strength in which the test specimen is compressed radially at a constant rate of strain at 50 mm per minute at 60 ºc. The Marshall stability of each test specimen is the maximum load resistance in Newton. The stability is related to the tensile strength of the asphalt mixture [Mang(2006)].

The Marshall flow is the total vertical movement or strain(deformation) occurring in the specimen between no load and maximum load during the Marshall stability test [Roberts, et.al(1997].

The values of measured stability is corrected when the specimens have height not 63.5 mm. The following equation is used to determine the corrected stability :

Corrected stability = measured stability * R ----------------eq(6)

where :

R = Correction ratio from Table(5).

The values of Marshall stability and flow are shown in Table(6), and the Marshall stability test is shown in the Figure(3).

Step five : Determination of volumetric properties of the specimen :

a- Determine the bulk density(d) of each specimen :

$$d = \frac{W_A}{V} = \frac{W_A}{W_A - W_W} \text{------------------------} \; eq\ (7)$$

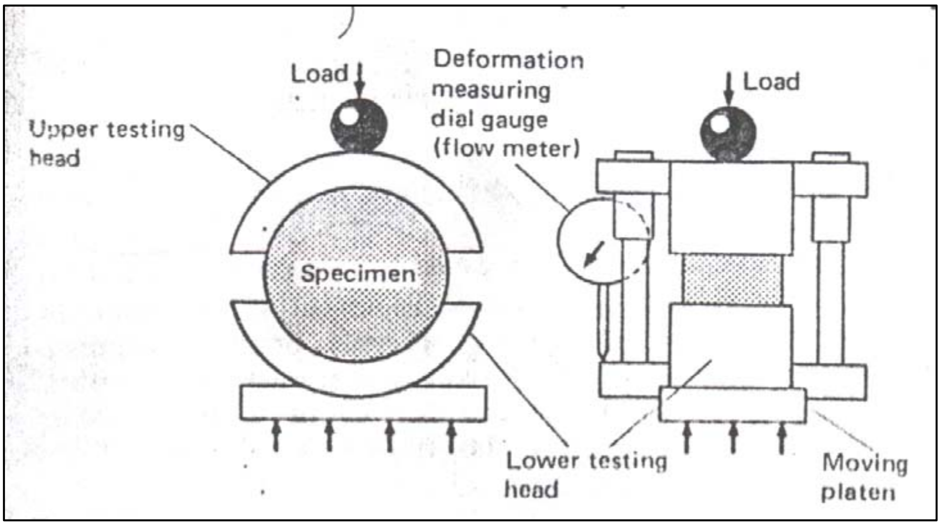
where :
d = bulk density of the compacted specimen(gm / cm^3).
W_A= weight of the specimen in air(gm).
V = volume of the specimen(cm^3).
W_W = weight of the specimen in water(gm).
b- Determine the maximum theoretical density(ψ) :

$$\Psi = \frac{W_A}{\frac{W_{asp}}{G_{asp}} + \frac{W_c}{G_c} + \frac{W_f}{G_f} + \frac{W_{mf}}{G_{mf}}} \text{------------------} \; eq\ (8)$$

where :
Ψ = maximum theoretical density of the compacted specimen(gm / cm^3).
W_A = weight of the specimen in air(gm).
W_{asp} = weight of asphalt in mixture(gm).
W_c = weight of coarse aggregate in mixture(gm).
W_f = weight of fine aggregate in mixture(gm).
W_{mf} = weight of mineral filler in mixture(gm).
G_{asp} = specific gravity of asphalt(gm / cm^3).
G_c = specific gravity of coarse aggregate(gm / cm^3).
G_f = specific gravity of fine aggregate(gm / cm^3).
G_{mf} = specific gravity of mineral filler(gm / cm^3).

Table(5) Marshall stability correlation ratio values [Roberts, et.al(1997].

Volume of specimen(cm^3)	R
432 – 443	1.32
444 – 456	1.25
457 – 470	1.19
471 – 482	1.14
483 – 495	1.09
496 – 508	1.04
509 – 522	1.00
523 – 535	0.96
536 – 546	0.93
547 – 559	0.89
560 – 573	0.86
574 – 585	0.83
586 – 596	0.81
597 - 610	0.78



Figure(3) The Marshall Stability Test[Roberts, et.al(1997)]

In this study the values of specific gravity for all materials of mixture($G_{asp,}$ G_c, G_f, and G_{mf}) were taken from the results of Laboratory of Highways and Airports Engineering Branch in Building and Construction Engineering Department. These values are: $G_{asp} = 1.02$, $G_c = 2.64$, $G_f = 2.66$ and $G_{mf} = 2.85$.

c- Determine the air voids in the total mixture(V.T.M) :

$$\% V.T.M = \frac{\Psi - d}{\Psi} * 100 ------------------- eq\ (9)$$

where :

% V.T.M = percent of air voids in the total mixture.

Ψ = maximum theoretical density(gm / cm^3).

d = bulk density(gm / cm^3).

d- Determine the voids filled with asphalt(V.F.b) :

$$\% V.F.b = \frac{\% V.M.A - \% V.T.M}{\% V.M.A} ----------------- eq\ (10)$$

$$\% V.M.A = \frac{V.M.A}{V} * 100 ------------------------ eq\ (11)$$

$$V.M.A = V - V_c - V_f - V_{mf} -- eq(12)$$

where :

% V.F.b = percent of voids filled with asphalt.

% V.T.M = percent of air voids in the total mixture.

% V.M.A = percent of voids in mineral aggregate.

V.M.A = volume of voids in mineral aggregate(cm^3).

V = volume of specimen(cm^3).

V_c = volume of coarse aggregate(cm^3).

V_f = volume of fine aggregate(cm^3).

V_{mf} = Volume of mineral filler(cm^3).

The results of volumetric properties and Marshall stability and flow are shown in Table(6).

Table(6) The values of volumetric properties stability and flow

Specimen No.	% asphalt content	% V.T.M	% V.F.b	Measured flow(mm)	Measured flow (kN)	R*	Corrected stability kN	d gm/cm^3
1	4	12.80	40.46	1.39	4.76	0.89	4.23	2.18
2	5	14.22	42.42	1.60	6.07	0.86	5.22	2.11
3	6	13.99	46.88	2.50	5.08	0.86	4.36	2.09
4	7	14.22	50.14	3.61	4.53	0.83	3.75	2.05
5	8	4.66	79.15	4.13	4.45	0.96	4.27	2.25
6	9	6.89	73.75	4.64	3.79	0.89	3.37	2.16
7	10	6.98	75.16	5.15	3.53	0.86	3.03	2.13

* From Table(5)

Step six : Draw five plots of asphalt content with :

a- Average corrected stability(Figure(4)).

b- Average flow(Figure(5)).

c- Average air voids(% V.T.M)(Figure(6)).
d- Average bulk density(d)(Figure(7)).
e- Average voids filled with asphalt(V.F.b)(Figure(8)).

To determine the optimum asphalt content, Figures(4 , 6 and 7) are used.
Asphalt content at maximum stability = 7.3 %.
Asphalt content at maximum bulk density = 5%.
Asphalt content providing 4% V.T.M(median of 3-5 % range. for surfacing) cannot be found because the 4% is out of the curve. Therefore, the average asphalt content is determined by using the average asphalt content for maximum stability and maximum bulk density.

$$\therefore asphalt\ content = \frac{7.3\% + 5\%}{2} = 6.15\%$$

To check that the optimum asphalt content gives a mixture which will meet the requirements in Table(7), reentering the curves of Figures(4, 5, 6, 7 and 8) with the average asphalt content(6.15), the following values are determined :
a-Stability= 4.2 kN
b-Flow= 2.65 mm
c-% V.T.M= 9.1%
d-Bulk density= 2.24
e-% V.F.b= 48%

Table(7) Marshall compacted asphalt requirements for stability flow, air voids and V.M.A. [Asphalt Institute(1997)].

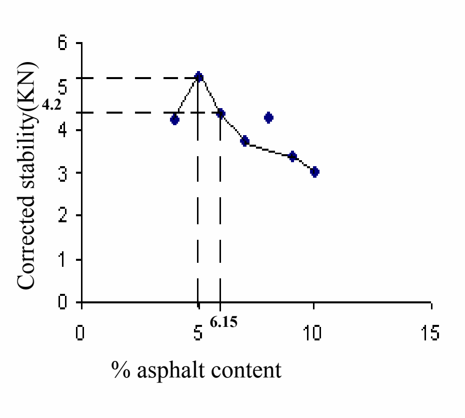
Traffic category	Light		Medium		Heavy	
	35		50		75	
	Min	Max	Min	Max	Min	Max
Stability(1b)	750	-	1200	-	1800	-
N	3333	-	5333	-	8000	-
KN	3.333	-	5.333	-	8	-
Flow , 0.01 mm	8	18	8	16	8	14
	2	4.5	2	4	2	3.5
Air voids %	3	5	3	5	3	5
V.F.A %	65	75	65	78	70	80

6- Evaluation of results :

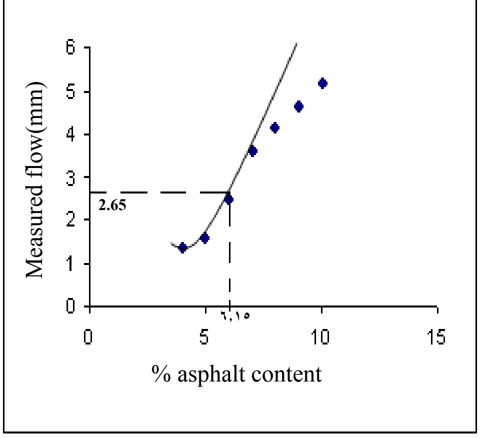
Table(7) shows the requirements for stability, flow, percent of voids in total mixture(% V.T.M) , and percent of voids filled with asphalt(% V.F.b). This table is used to evaluate the hot asphalt mixture properties according to Asphalt Institute requirements(1997). From this table, the values under medium traffic and 50 blows are taken to compare with the values of mixture properties.

The value of stability(4.22 kN) is less than the limiting value of requirements(5.333 kN). Therefore, this mixture has low value of stability because of the asphalt in mixture have no sufficient viscosity and the filler content is low and the aggregate have smooth surfaces. The value of flow(2.65 mm) is within the limiting range(2-4 mm). Therefore, this mixture is good according to the flow requirements

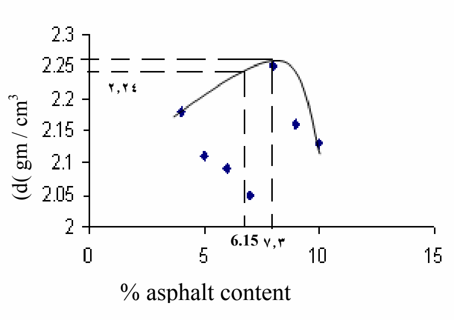
Figure(4)



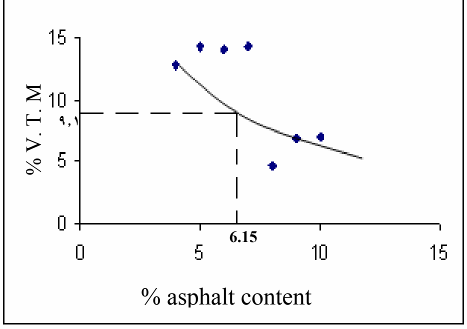
Figure(5)



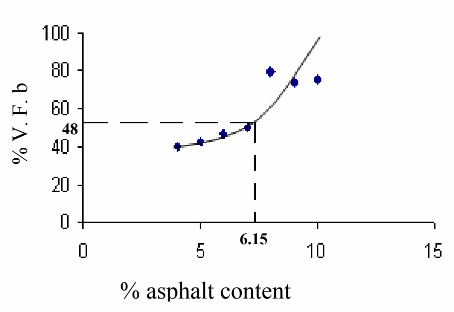
Figure(7)



Figure(6)



Figure(8)



The percentage of voids in total mixture(% V.T.M = 9.1 %) is above the limiting range(3% - 5%). Therefore, this mixture has high voids and this leads to the permeability of the mixture(pavement) being high and allowing water and air to circulate through the mixture(pavement). The percentage of voids filled with asphalt(% V.F.b = 48 %) is less than the limiting range(65% - 78%). Therefore, this mixture has low voids being filled with asphalt due to the amount of asphalt being not sufficient and the mixing process of the mixture being unsuitable.

In this study the hot asphalt mixture does not meet the requirements given in the Table(7) for stability, percent of voids in total mixture and percent of voids filled with asphalt, except the value of flow which is within the limiting range. Therefore, this mixture needs adjustment of the grading of the original aggregate blend and the use of asphalt has sufficient viscosity, and increasing the amount of mineral dust filler. All steps of Marshall mix design method are returned for design of new mixture.

Conclusions and Recommendations

Conclusion

This research was designed to evaluate the properties of Iraqi hot asphalt mixture by taking the requirements of Asphalt Institute 1997. Marshall mix design method was used to determine the optimum asphalt content by using seven specimens at different asphalt contents. The value of optimum asphalt content is 6.15 % and the values of mixture properties are as follows :

Stability = 4.22 kN
Flow = 2.65 %
% V.T.M = 9.1 %
% V.F.b = 48 %
d = 2.24 % gm / cm^3

According to these results, the mixture does not meet the requirements in Table(7) for stability, percent of air voids in total mixture and percent of voids filled with asphalt except the flow value which was within the limiting range. Therefore, this mixture is not suitable for use in pavement construction.

Recommendations :

1- Improving this mixture by using sufficient amount of asphalt with suitable viscosity , and increasing the amount of mineral dust filler to reduce the voids in mixture.
2- Redesign of mixture by using new aggregate type and new aggregate gradation with new asphalt type.

References

American Association of State Highway and Transportation Officials, " Standard Specifications for Transportation Materials and Methods of Sampling and Testing", AASHTO, Washington, D.C , 1997.

American Society for Testing and Materials," Standard Specification for Penetration – Graded Asphalt Cement for Use in Pavement Construction ", ASTM O 946, volume 04.03, pp. 91 – 92 , Philadelphia, Pennsylvania, 1994.

American Society for Testing and Materials, Annual Book of ASTM Standard, Philadelphia, Pennsylvania, U.S.A, ASTM, 2001.

Asphalt Institute, " Mix Design Methods for Asphalt Concrete and Other Hot – Mix Types", Lexington , Kentucky , U.S.A, Manual series No. 1 , 1997.

Department of Building and Construction Engineering, Branch of Highway Engineering, " Asphalt Material Notes ", University of Technology, Baghdad , 2002.

Garber, N.J. and Hoel, L.A. , Traffic and Highway Engineering , PWS publishing company , 1997.

Goetz, W. and Wood, L.E, Bituminous Materials and Mixtures , Mc Graw – Hill Book company , New York , 1960.

Laboratory of Highway Engineering Branch Tests of Asphalt Mixture Materials , University of Technology , Baghdad , 2005.

Mang , Tia , Bituminous Materials and Mixtures , Internet , 2006.

Roberts , F.L. , Kandhal , P.S. , Brown , E.R. , Lee , D.Y. and Kennedy , T.W. , Hot Mix Asphalt materials , Mixture design and Construction , NAPA Educational Foundation , Lanhom , Maryland , U.S.A, 1997.