Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.8, No.3, 2016

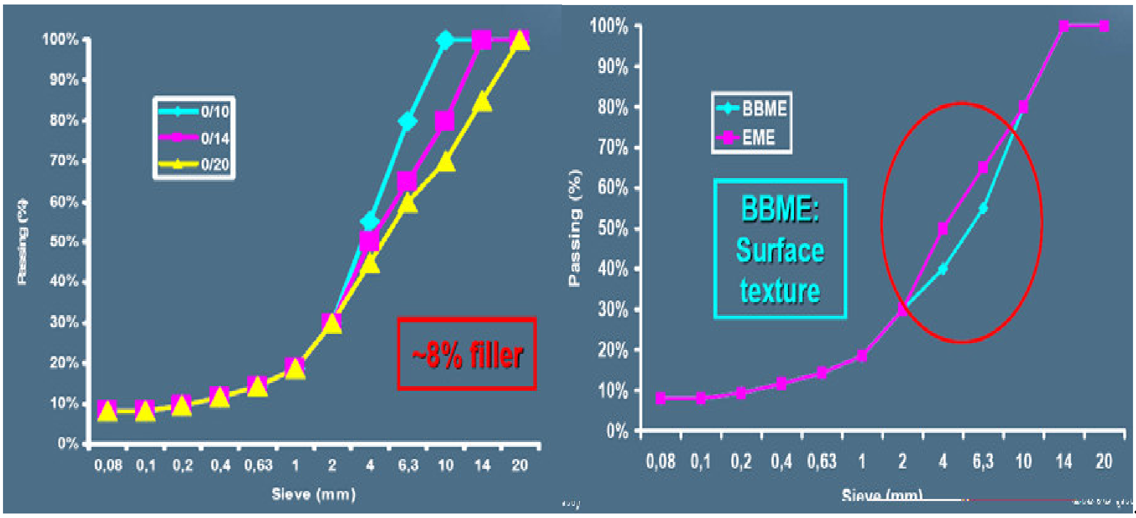
Evaluation the Using of Local Aggregate in High Modulus Asphalt Concrete Layers

Sahar Fayek Najm   Professor Dr. Nahla Y. Ahmed
Department of Civil Engineering, Babylon University, P.O Box: 4 Iraq - Babylon – Hilla

Abstract
The performance of Hot Mix Asphalt (HMA) mixtures is greatly affected by the properties of the aggregate characteristics. The aggregate properties that significantly influence the performance of HMA mixtures are gradation, shape (angularity) and texture (roughness) .In 1990, the French Road Administration (LCPC) developed asphalt mixtures with a gradient "BBME", for the purpose of this new mixtures is to get a good resistance to rutting and good fatigue behavior. in Iraq, this type of the mixture is not used yet.The main purpose of this study is to evaluate the performance of asphalt mixtures with "BBME" gradient and compare them with the conventional mixture for binder course. To achieve this aim, one type of asphalt grade (40-50) from Al-Nasiriyah refinery and two types of local aggregates were used. First type of Al-nibaie area and the second from an area of Badra and Jassan with two types of texture rounded and fully fracture. Physical tests on asphalt binder and aggregate, indirect tensile strength and wheel truck testing have been made in this work. Three asphalt contents (optimum asphalt content , optimum asphalt content ± 0.5) were used in indirect tensile strength test with one asphalt content (optimum asphalt content) in wheel truck testing under 60° temperature. The results of experimental work showed that the Marshall stability for BBME mixture were more than that for conventional(SCRB) mixture by 3, 3, 4 percent for al-nibaie half fracture, Badra and Jassan fully fracture and Badra and Jassan fully rounded aggregate mixture, respectively. The Indirect Tensile Strength resistance of the BBME mixes were approximately equal with comparison to the conventional mixes for all aggregate types, and showed that the mixes contain optimum asphalt content have a resistance to indirect tensile strength more than that mixes contain (optimum asphalt content ± 0.5) for BBME and conventional mixtures. As result, the both conventional and BBME mixes were failed at the same number of passing but less at rutting depth for the mixtures with BBME gradation.The mixtures that contain al-nibaie aggregate have an excellent resistance to Indirect Tensile Strength and permanent deformation in comparison with other types of aggregate.Based on **AFNOR** specification with using K formula and values of rutting percent, it was found that the mixture used in this study, Class III, is the type used in the roads with higher traffic.
Keywords: BBME gradation, Marshall stability, Indirect Tensile Strength**,** Wheel Truck Testing, Optimum Asphalt Content.

1. Introduction

For the last few years, the number of trucks and vehicles with their heavy traffic loading have been increased along with the impact of external factors such as air temperatures effects and moisture. Growth of these factors on the road with not enough maintenance have caused deteriorations or distresses on pavement. Enrobés à Module Elevé "EME" for base course and Beton Bitumineux a Module Eleve "BBME" for binder and wearing course can be called High- Modulus Asphalt (HiMA). Two classes of EME and three classes BBME are defined: EME class2 and BBME class3 are specified for the most heavily trafficked roads. They require higher binder contents according to aggregate gradation. The main objective of HiMA conception is to increase the stiffness and decrease thickness of asphalt layers, and thus decrease pavement structure fatigue by reducing the tensile stress in the bottom of asphalt binder layer and compression stress in the top of the base layer. Those influences reduce distress in asphalt wearing layer. In addition, HiMA was used for asphalt base layers when the pavement was newly constructed (to achieve economic effect), and the thickness of asphalt pavement layers was reduced (Vaitkus, 2013). The most commonly used aggregate grading for EME are 0/10 mm, 0/14 mm and 0/20 mm, and 0/10 mm and 0/14 mm (minimal/maximal particle size in mm, where 0 represents the 0,075mm) aggregate grading for BBME are shown in (Figure 1-1), (AFNOR, 2002).



(a) **(b)**

Figure (1-1) Typical Grading Curves for (a) EME and (b) BBME and EME Gradation (Sabita, 2006)

The benefits of high-modulus layers in HiMA concept can be summarized into two categories (1) the increased stiffness allows the section to be reduced or stresses to be reduced in the subgrade, and (2) possible higher binder contents which increase the durability by decreasing voids content **(Maupin and Brian, 2006)**.

This research presents High Modulus Asphalt (HiMA) for binder course, including the selection criteria for binder, aggregates and the choice of a grading curve. The major objective of this research is to evaluate the performance of high modulus mixture according to various types and gradation of aggregate with using locally produced asphalt. The backbone of this study is the usage of two types of aggregate and one grade (40-50) asphalt cement for binder course mixture. Two types of testing techniques were used besides the Marshall method for the determination of the optimum asphalt content of the mixtures. These tests are; indirect tensile stress to evaluate the fatigue properties, and repeated load test for evaluating rutting properties .

2. Materials and Methods

All the materials used in this study are generally available and widely employed in pavement construction works in most parts of Iraq. One type of asphalt cement , two types of aggregate and mineral filler. The properties of these materials were evaluated and compared with the **SCRB (R/9, 2003)** specification requirements and the **BBME (NF P98-141)** specification.

2.1 Asphalt Cement

One type of asphalt cement was used with (40-50) penetration grade brought from al-Nasseryia refinery. The physical properties and tests of the asphalt cement used are summarized in Table (1).

Table 1. Physical Properties of Asphalt Cement

Properties before TFOT					
Property	**Test Condition**	***ASTM Designation***	**Units**	***Test Result***	***SCRB Specification***
Penetration	25^0C, 100gm, 5sec., 0.1mm	D-5	**1/10 mm**	46	(40-50)
Kinematic viscosity	135 C^0	D-2170	cst	377	300
Ductility	25 C^0, 5 cm/min	D-113	**cm**	106	>100
Flash point	-----	D-92	**0C**	288	Min. 232
Specific gravity	-	D-70	**gm/cm3**	1.04	-----
Properties after TFOT					
Retained Penetration	**100 gm, 25 0C , 5 sec., 0.1 mm**	D5	**%**	65	Min. 55%
Ductility	**25 0C , 5 cm/min.**	D113	**cm**	79	**Min. 50**
Loss in Weight	**50 gm, 163°, 5 hours**	D1754	**%**	0.28	-

2.2 Aggregate

2.2.1 Aggregate selection

Two types of coarse aggregate were used in this stud, first half fractured aggregate from Al-nibaie quarry and second from Badra and Jassan quarry with two texture fully fractured aggregate and rounded aggregate. These types of aggregate are widely used in local asphalt pavement in Iraq. The fine aggregate brought from Karbala quarry. Routine tests were officiated on the aggregate to evaluate their physical properties. The results of testing are tabulated in Table (2) to Table (5).

Table 2. Physical Properties of fully Fractured Aggregate from Badra and Jassan quarry.

No.	Property	ASTM Designation	Test Results	**SCRB Specification**
1	Bulk specific gravity	C-127	2.567	-
2	Apparent specific gravity	C-127	2.635	-
3	% water absorption	C-127	1	-
4	Abrasion (Los Angeles)	C-131	19%	30 Max
5	%Fractured Pieces (Angularity)	D-5821	92%	90 Min

Table 3. Physical Properties of Rounded Aggregate from Badra and Jassan quarry.

No.	Property	ASTM Designation	Test Results	**SCRB Specification**
1	Bulk specific gravity	C-127	2.567	-
2	Apparent specific gravity	C-127	2.635	-
3	% water absorption	C-127	1	-
4	Abrasion (Los Angeles)	C-131	19%	30 Max
5	%Fractured Pieces (Angularity)	D-5821	2%	-

Table 4. Physical Properties of half Fractured Aggregate from Al-nibaie quarry.

No.	Property	ASTM Designation	Test Results	**SCRB Specification**
1	Bulk specific gravity	C-127	2.610	-
2	Apparent specific gravity	C-127	2.678	-
3	% water absorption	C-127	0.22	-
4	Abrasion (Los Angeles)	C-131	17.8%	30 Max
5	%Fractured Pieces (Angularity)	D-5821	52%	-

Table 5. Physical Properties of Fine Aggregate

No.	Property	ASTM Designation	Test Results	**SCRB Specification**
1	Bulk specific gravity	C-128	2.672	-
2	Apparent specific gravity	C-128	2.681	-
3	% water absorption	C-128	0.65	-

2.2.2 Developing a Grading Curve

EME shall be designated as EME 0/10, EME 0/14 or EME 0/20 and BBME shall be designated as BBME 0/10 or BBME 0/14 according to aggregate size **AFNOR (2002)**. The target grading should fall within the appropriate limits explained in Table (6).

Table 6. Limiting Values for Target Grading for EME (Sanders and Nunn,2005)

Test sieve Opening size(mm)	EME 0/20	EME 0/14	EME 0/10
31.5	100	-	-
20	90-99	100	-
14	60-90	90-99	100
10	42-27	-	90-99
6.3	-	42-65	55-80
4	20-35	-	35-65
2	18	19-42	27-45
0.25	8	8-18	8-18
0.063	5-9	5-9	5-9

For the purpose of this work, the appropriate grading for the binder course based on **SCRB (R/9, 2003)** is **BBME (0/14).** The selected gradation with specification limits of **(BBME 0/14)** and **SCRB (R/9, 2003)** are tabulated in Table (7) and figure(1) .

Table 7. Percent Pass by Weight of Selected Aggregate Gradation (19 mm Nominal Maximum Size, Binder Course)

BBME 0/14		**SCRB (R/9, 2003)**				
Sieve size (mm)	**% passing by weight**	**English Sieve.**	**Standard Sieves (mm)**	**% passing by weight**		
	Specification range			**Selected Limit**	**Specification range**	**Gradation used**
20	100	1"	25	100	100	100
14	90-99	3/4"	19	95	90-100	98
10	-	1/2"	12.5	80	70-90	88
6.3	42-65	3/8"	9.5	68	56-80	68
4	-	No.4	4.75	50	35-65	50
2	19-42	N0.8	2.36	36	23-49	35
0.25	8-18	No.50	0.3	12	5-19	14
0.063	5-9	No.200	0.075	6	3-9	7

2.3 Mineral Filler

Filler is a material passing sieve No.200 (0.075mm), in which the ordinary Portland cement (Tasluja) was used in this work. Filler is usually used
to improve mixture properties throughout reducing the volume change, reducing plasticity and increasing viscosity. The physical properties of used filler used in this study are shown in Table (8).

Table 8. Physical Properties of Filler

Property	***Test Result***
Specific gravity	3.1
Fineness, Blain, (cm^2/gm)	3200
Passing Sieve No.200	95%

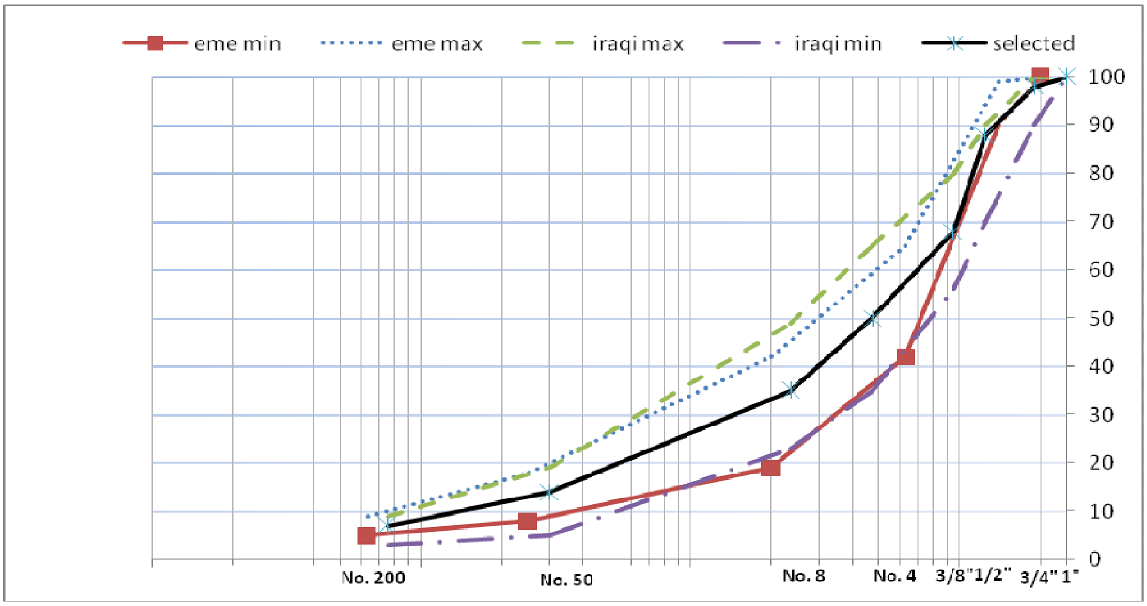


Figure 1. Gradation Curve of Aggregate Used for Binder Course

3.Test Methods

The test methods employed in this study were to evaluate the performance of different mixtures by different gradation. Here we depended on two gradation, the first one was the BBME gradation, and the second was the SCRB gradation.

3.1Marshall Design Method

The results of Marshall tests showed most of times time regular compatibility between asphalt content and the properties of Marshall mixes. The Optimum Asphalt Content (O.A.C) for each mix were evaluated using the Marshall Properties curves; (air voids, stability and bulk density), and it was 4.6 % and 4.2 % for binder and base course respectively.The results were shown in table (9).

Table 9. Volumetric Properties of asphalt concrete mixtures compacted by Marshall method

Gradation **type**	**Al-nibaie Aggregate**	**Badra and Jassan fully Fracture Aggregate**	**Badra and Jassan Rounded Aggregate**
BBME Gradation	2.377	11.6	2.4
SCRB Gradation	2.388	11.50	2.7

The Optimum Asphalt Content (O.A.C) and Marshall stability for high modulus asphalt mixture were approximately the same values compared them with the conventional mixture. However, by comparing between mixtures containing different types of aggregate (Alnibaie 50% crushed, Badra and Jassan 100% rounded and Badra and Jassan 100% crushed), it was noticed that the mixtures with Alnibaie 50% crushed aggregate utilized a higher stability than the other types, due to the high interlocking between the particles (high inter-particle friction) and high compositional structure.

The optimum asphalt content of mixtures containing 100% crushed Badra and Jassan aggregate was 4.8%, for mixture containing 50% crushed Alnibae aggregate was 4.7% and for mixture containing 100% rounded was 4.6%. Mixtures with 100% crushed Badra and Jassan aggregate achieved the highest optimum binder content due to high surface area of the fractured particles.

3.2 Indirect Tensile Strength

The indirect tensile test*, **ASTM D4123*** was used to evaluate the tensile strength of asphaltic mixtures. The climatic conditions and various traffic loading may cause tensile stresses to be developed within the pavement constriction, and as a result, two types of cracks may be displayed: one resulted from climatic conditions, called thermal cracking and the other type of cracks resulted from traffic loading and called fatigue cracking.

In order to evaluate the mix resistance to tensile stresses on pavement at temperature (20 ^{0}C). Three asphalt content (Optimum asphalt content, Optimum asphalt content ± 0.5) and three types of aggregate were used in this test. The results are shown in Figures (2), Figure (3) and Figure (5).

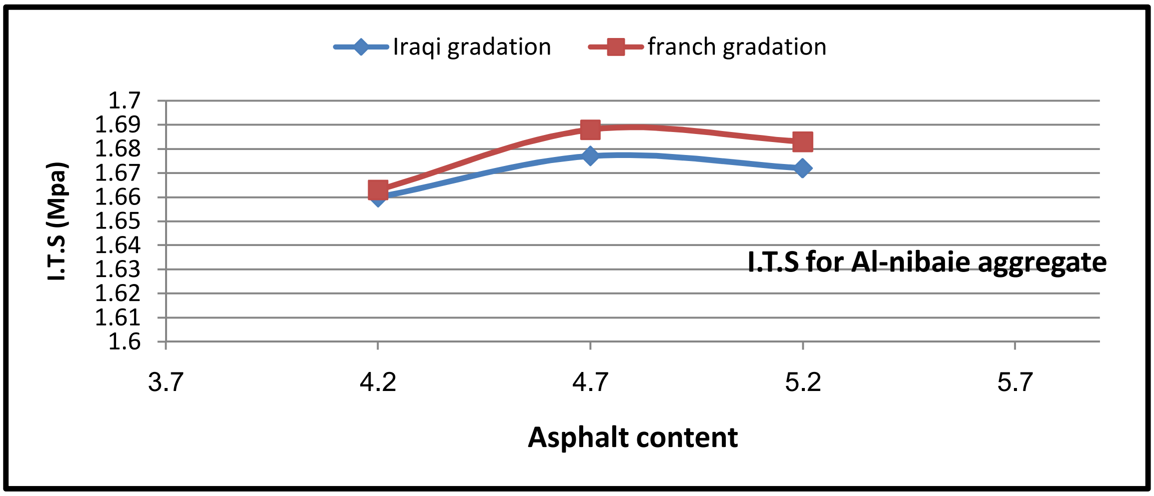


Figure 2. I.T.S for Al-nibae Aggregate.

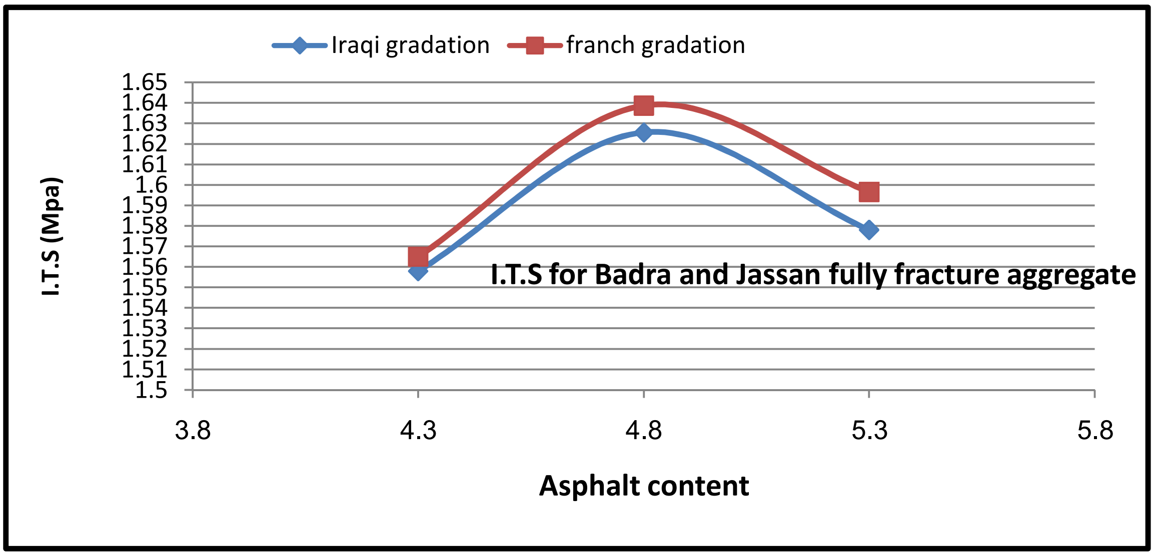


Figure 3. I.T.S for Badra and Jassan fully Fracture Aggregate

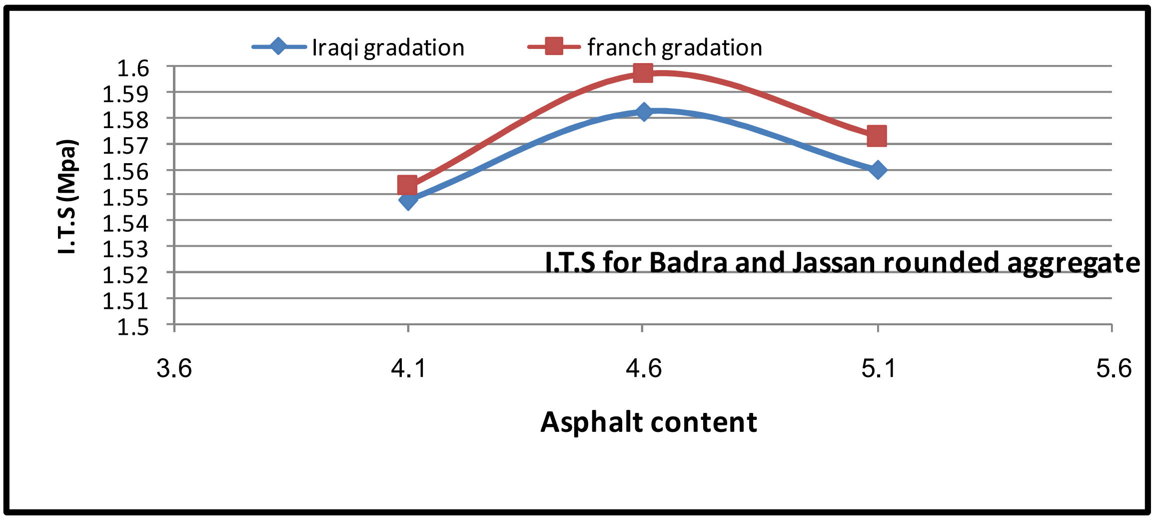


Figure 4. I.T.S for Badra and Jassan Rounded Aggregate

Figures above show the effect of two gradation on Indirect tensile strength. It was noticed that the indirect tensile strength for the mixtures containing SCRB and BBME gradation are almost equals, due to the same type of asphalt (40-50), and the effect of aggregate types on Indirect tensile strength. Asphalt mixtures with al-nibae aggregate achieved the highest values of indirect tensile strength in comparison with Badra and Jassan fully fracture and rounded aggregate, due to al-nibaie aggregate is stronger and absorption of the water is less than (0.22%) to be lesser than other types of aggregate. In addition the abrasion (17.8) is less.

3.3Wheel Track Test Results

Rutting in asphalt concrete layers is a frequent distress mode in flexible pavements. Surface rutting in a flexible pavement structure usually originates from all pavement layers and the subgrade. Flow rutting is defined as an excessive deformation of bituminous layers in the wheel paths which gradually increases with increasing the numbers of vehicle load repetitions. In Iraq, the high temperature in the summer season is considered the primary reason for the permanent deformation occurrence (Albayati, 2006).

The hot mixtures asphalt specimens were prepared in steel compaction mold, and the specimens were compacted by using standard Marshall compacter as shown in Plate (1) with various trials numbers of blows (75 , 100, 125 , 150 , 175 , 200). Bulk density (GM actual) *(ASTM D2726)* and max theoretical density (GM Max) , air voids (AV) *(ASTM D2041)*, can be calculated for each trial.

The relationship between the number of blows and air voids is plotted as shown in figures (5) to (10).The optimum number of blows corresponding to (4 % air voids) for dry case according to Standard Iraqi Specification for Roads and Bridge ***(SCRB, R/9. 2003)*** were selected.

Plate 1. Marshall Standard Compaction

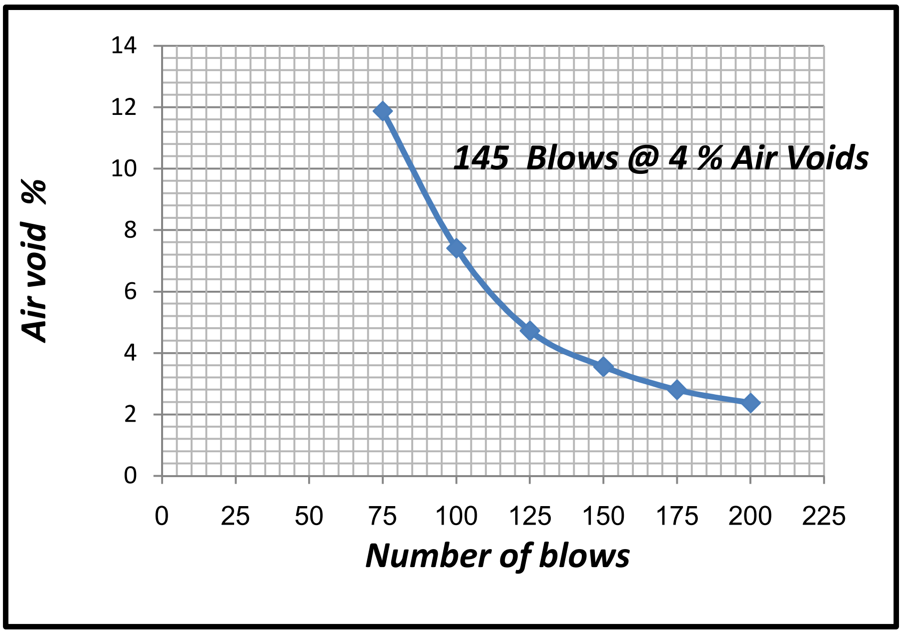


Figure 5. The Optimum Number of Blows for WTA Samples For Al-nibaie Aggregate / SCRB Gradation.

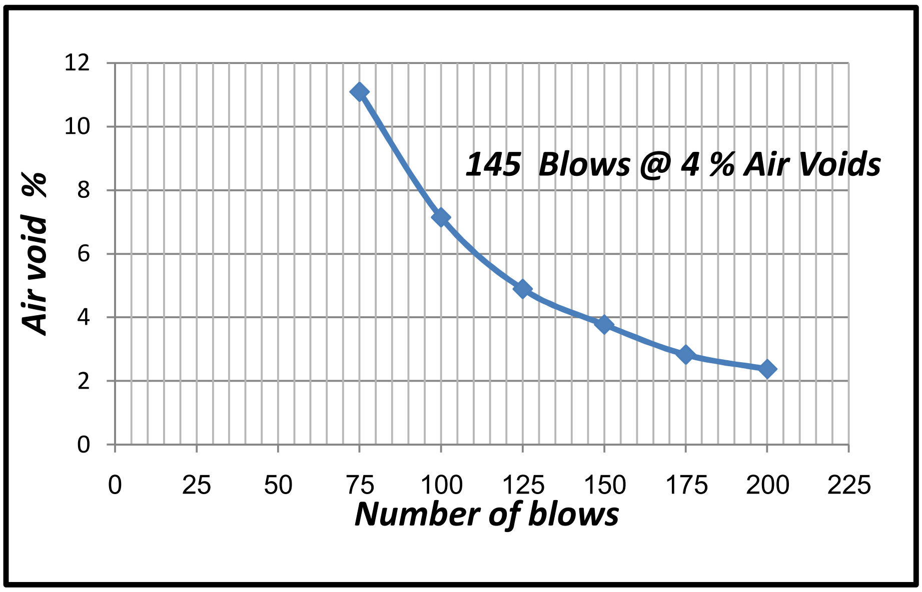


Figure 6. The Optimum Number of Blows for WTA Samples For Al-nibaie Aggregate / BBME Gradation.

Civil and Environmental Research www.iiste.org
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.8, No.3, 2016

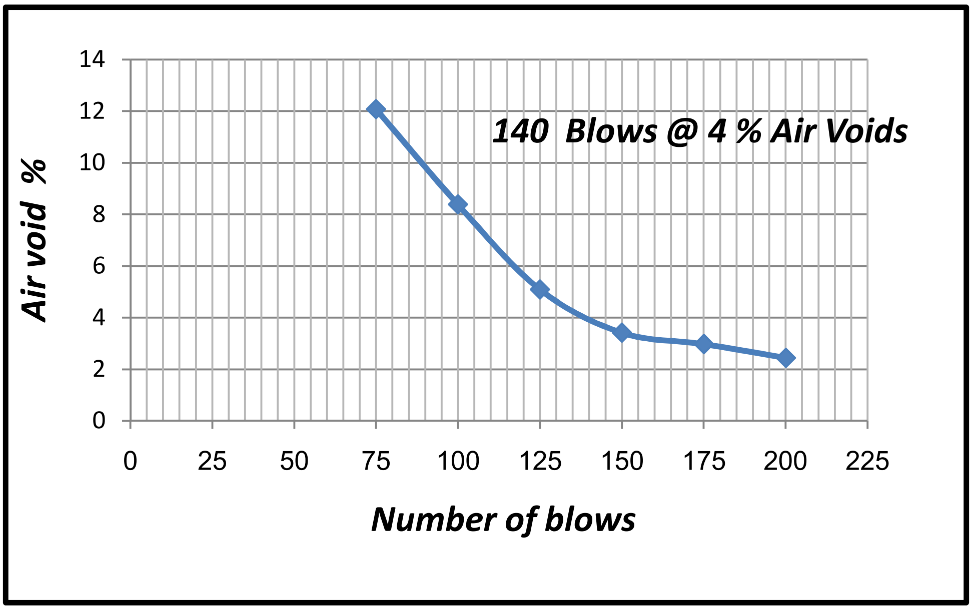


Figure 7. The Optimum Number of Blows for WTA Samples for Badra and Jassan fully Rounded Aggregate / SCRB Gradation.

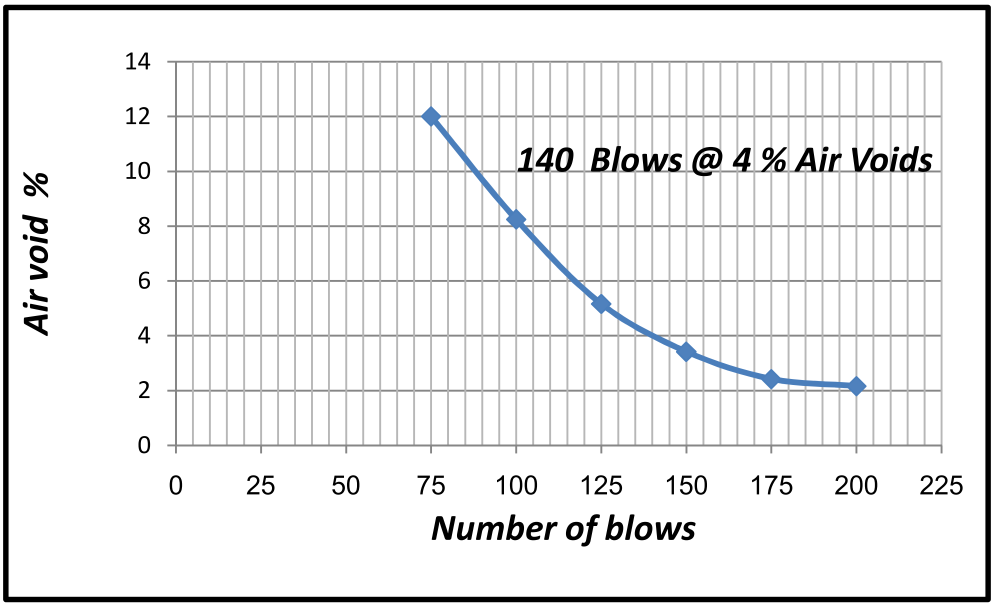


Figure 8. The Optimum Number of Blows for WTA Samples for Badra and Jassan fully Rounded Aggregate / BBME Gradation.

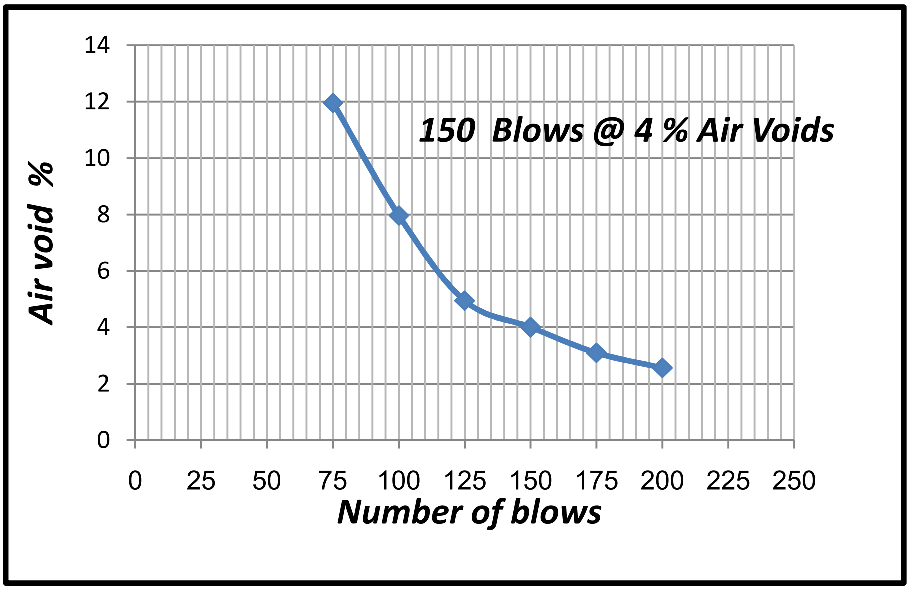


Figure 9. The Optimum Number of Blows for WTA Samples for Badra and Jassan fully Fracture Aggregate / SCRB Gradation.

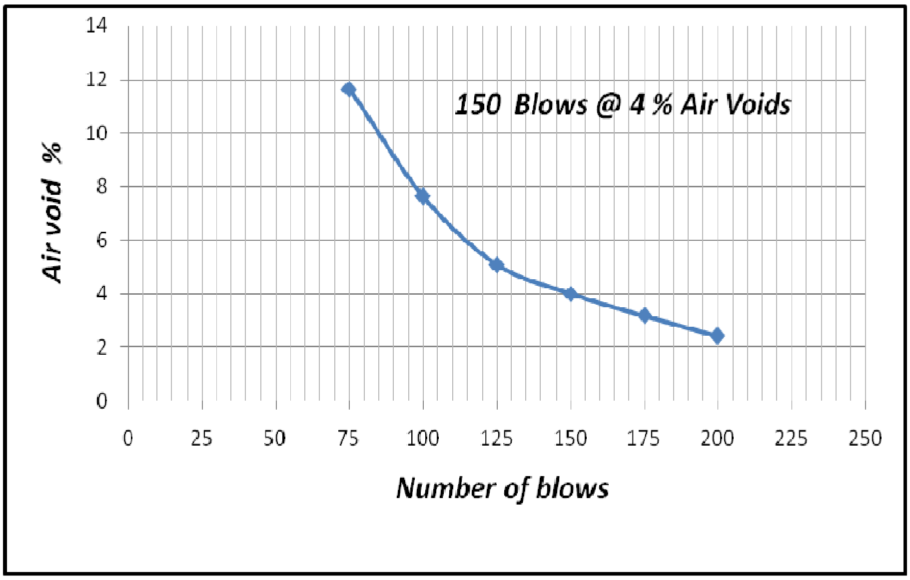


Figure 10. The Optimum Number of Blows for WTA Samples for Badra and Jassan fully Fracture Aggregate / BBME Gradation.

In this study, the comparison between the high modulus mixture (HMAC) and the conventional mixture has been quantified at temperatures 60 C. This test needed two samples to obtain the average value for each case. Two readings (at least) at the center of specimen were recorded for each case at specified number of loading cycles to calculate rut depth directly under rolling length of wheel on the sample surface to simulate the longitudinal depressions in the wheel paths of the road surface.

The analysis result based on the following variables aggregate gradation and types of aggregate. The obtained results represented the average values of the maximum rutting depth for two samples that occured at number of passes of loading to samples failure , (5000passes),(4000passes) and (4000passes) for al-nibaie, Badra and Jassan fully fracture and fully rounded aggregate respectively. The rutting depth recorded at 60C^{o} were (5000,4000,4000) passes as shown in table (10). Asphalt mixtures with Al-nibae aggregate achieved the highest number of passing (5000passes) therefore, higher resistance of permanent deformation in comparison with other types of aggregate, because the rounded particles in coarse aggregate led to reduce interlocking and internal friction as well as caused a reduction in permanent deformation resistance for mixtures.

Table 10. Wheel Track Test Results for Conventional & HMAC mix

Mix Type	Rutting Depth (mm) According To Aggregate Types		
	Al-nibae aggregate	Badra and Jassan fully fracture aggregate	Badra and Jassan fully rounded aggregate
Conventional	6.97	5.64	7.21
HMAC	6.38	5.31	6.78

From the figures (11) to (16), it can be seen that the HiMA mixtures reached to final collapse at the same number of passing compared with the conventional mixture but with less rutting depth.

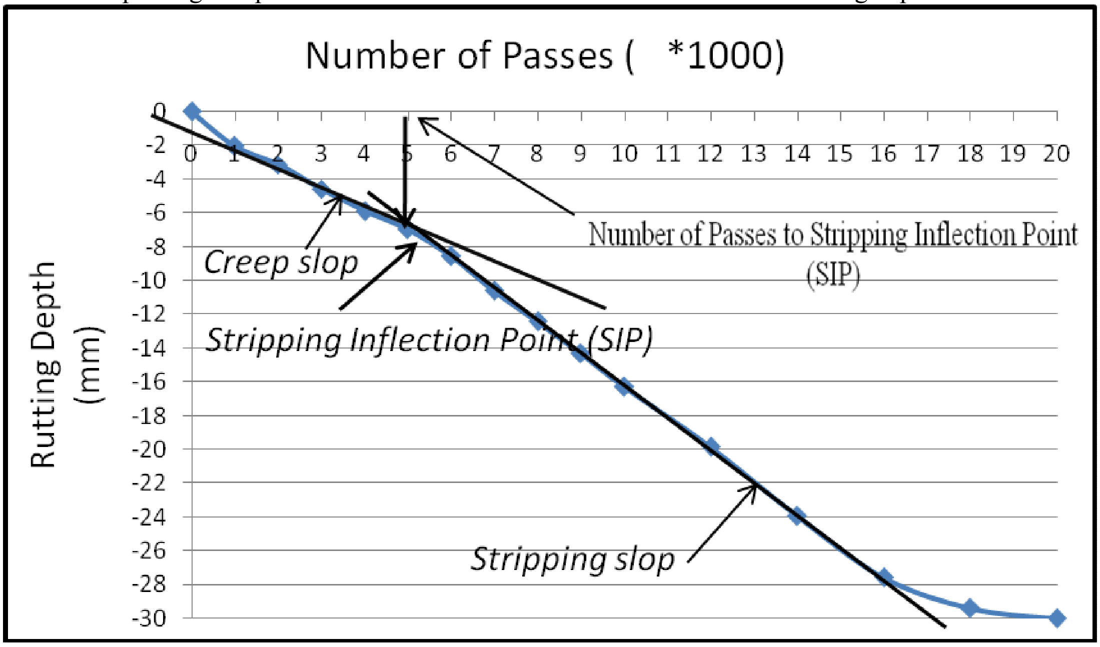


Figure 11. Wheel Track Apparatus Curve with Test Parameter (60 Cº) for Al-nibaie Aggregate / SCRB Gradation.

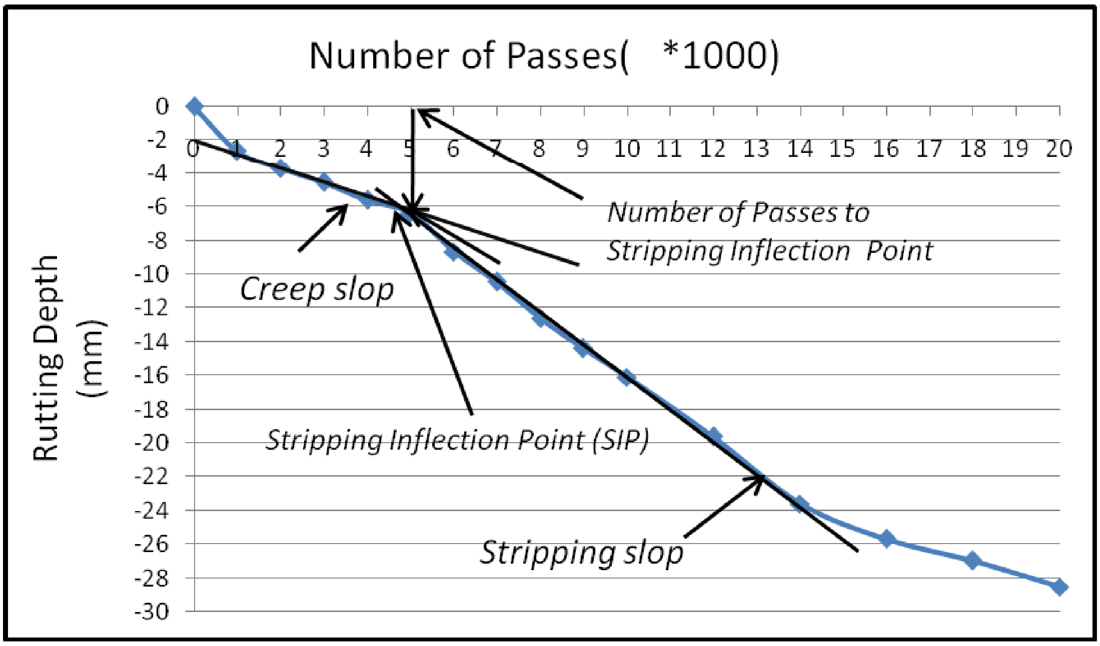


Figure 12. Wheel Track Apparatus Curve with Test Parameter (60 Cº) for Al-nibaie Aggregate / BBME Gradation.

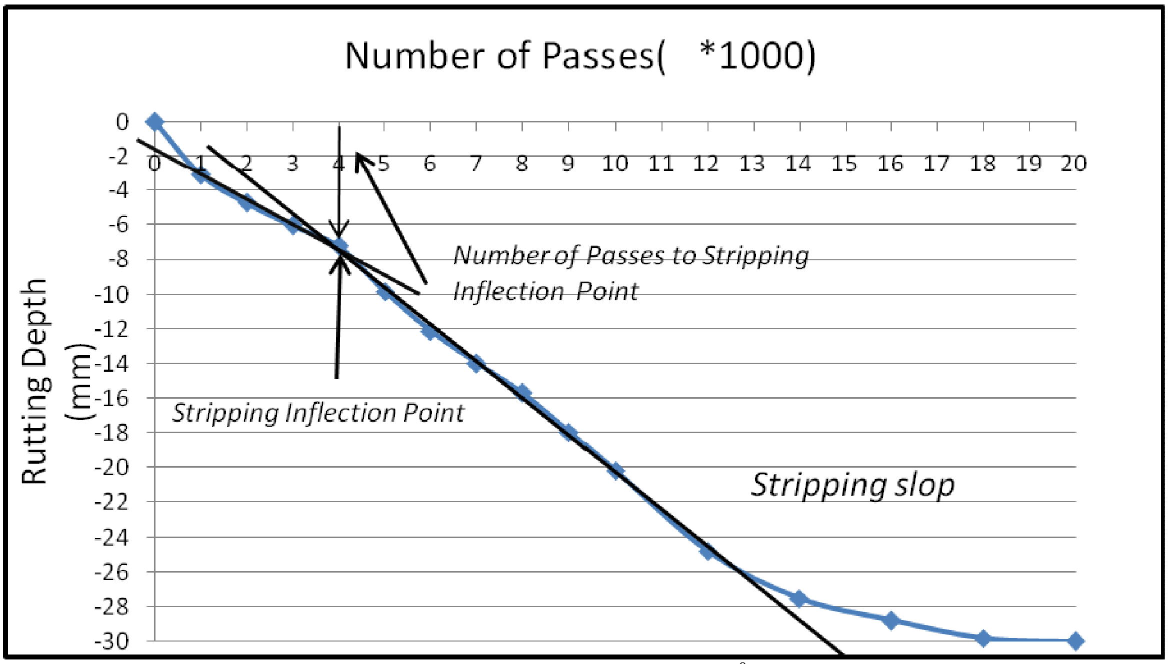


Figure 13. Wheel Track Apparatus Curve with Test Parameter at (60^0C) for Badra and Jassan fully Rounded Aggregate / SCRB Gradation.

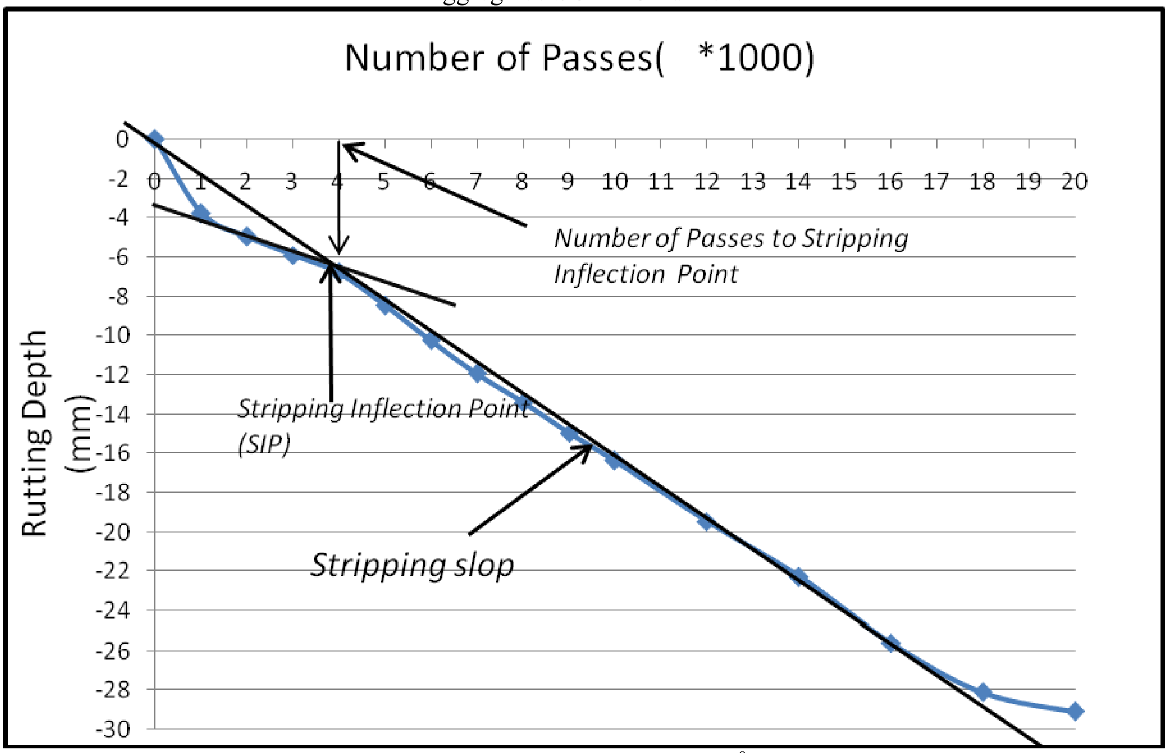


Figure 14. Wheel Track Apparatus Curve with Test Parameter at (60^0C) for Badra and Jassan fully Rounded Aggregate / BBME Gradation.

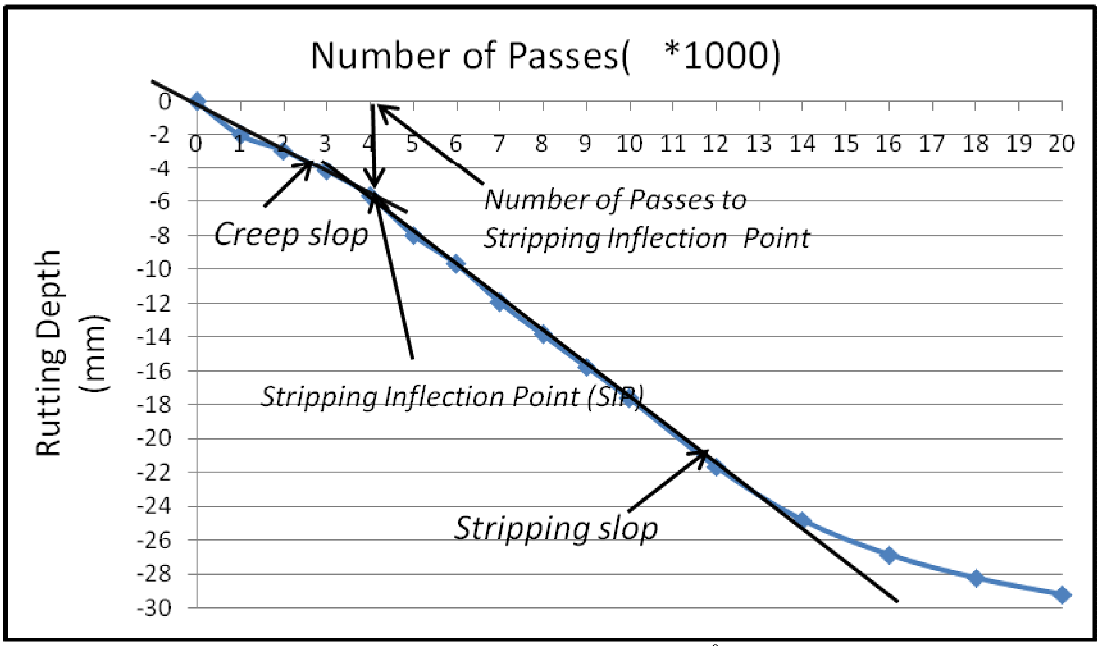


Figure 15. Wheel Track Apparatus Curve with Test Parameter at (60 ^{0}C) for Badra and Jassan fully Fracture Aggregate / SCRB Gradation.

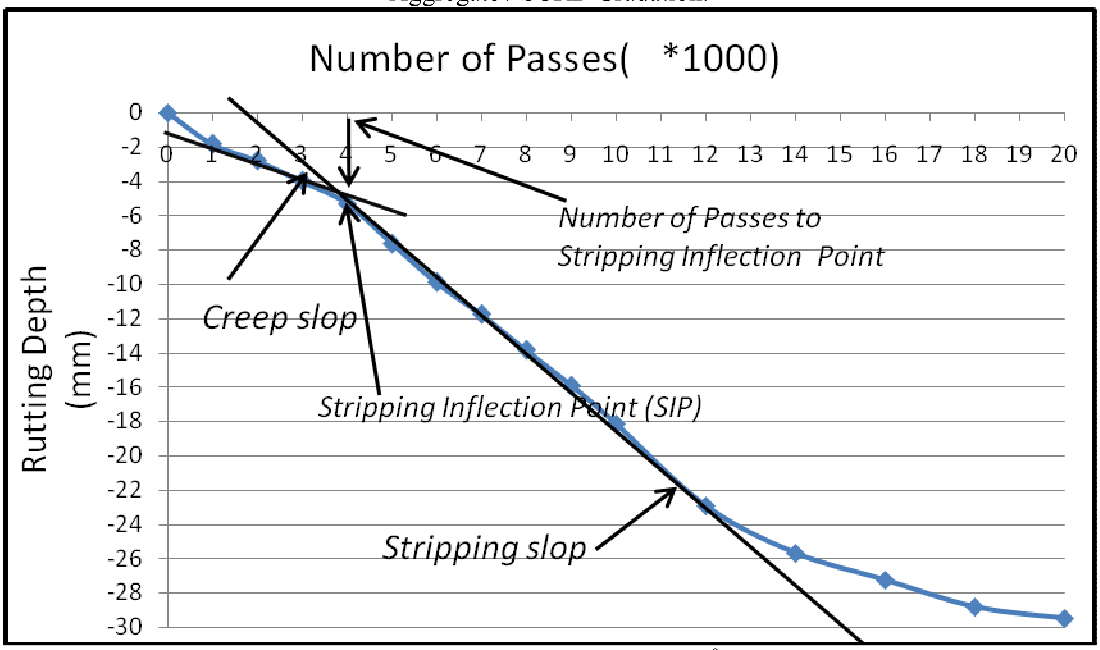


Figure 16. Wheel Track Apparatus Curve with Test Parameter at (60 ^{0}C) for Badra and Jassan fully Fracture Aggregate / BBME Gradation.

4. Conclusions

Within the limitations of testing program and materials used in this study, the following main conclusions are drawn based on the findings of the actualizations:

1- Marshall stability for BBME mixture were more than that for conventional mixture by 3, 3, 4 percent for al-nibaie, Badra and Jassan fully Fracture and Badra and Jassan fully rounded aggregate mixture, respectively.

2- The results of Indirect Tensile Strength Test showed that resistance of the BBME mixes were approximately equal to the conventional mixes for all aggregate types.

3-The mixes that contain optimum asphalt content, for the BBME and conventional mixes had the largest resistance to Indirect Tensile Strength to be more than that mixes contain (optimum asphalt content$^{\pm 0.5)}$ for all aggregate types.

4-The results of Indirect Tensile Strength Test showed that resistance of the mixes that contain al-nibaie (half fracture) aggregate achieved the highest resistance of Indirect Tensile Strength for other types of aggregate.

5- The results of Wheel Truck Testing for both the SCRB and BBME gradation both were failed at the same number of passing but less for rutting depth for the mixtures with BBME gradation.
6- The mixes that contain al-nibaie aggregate have an excellent resistance to permanent deformation in comparison with other types of aggregate.

References

AASHTO T322.(2002),"Determining the Creep Compliance and Strength of Hot-Mix Asphalt (HMA) Using the Indirect Tensile Test Device", American Association of State Highway and Transportation Officials .

AASHTO T324-04.(2004),"Hamburg Wheel-Track Testing (HWTT) for Compacted Hot-Mix Asphalt (HMA)", American Association of State Highway and Transportation Officials .

AFNOR, (2002), Enrobés Hydrocarbonés - Couches D'assises: Enrobés à Module Elevé (EME) . AFNOR, Norme Française NFP 98-140 (in French), Paris, France.

AFNOR, (2002), Couches De roulement et Couches De Liqison :Beton Bitumineux à module élevé (BBME) .

AFNOR, Norme Française NF P 98-141 (in French), Paris, France.

Albayati, A. H., (2006), "Permanent Deformation Prediction of Asphalt Concrete under Repeated Loading", Ph.D. Thesis,University of Baghdad, College of Engineering.

ASTM D-2041.(2002), "Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures" , American Society of Testing and Materials .

T Distin (Sabita),(2006), " High Modulus Asphalt: Assessment of Viability Based on Outcomes of Overseas Fact Finding Mission", L Sampson (Asphalt Academy), H Marais (Much Asphalt (Pty) Ltd) and B Verhaeghe (CSIR Built Environment).

Vaitkus, A., and Vorobjovas, V., (2013), "Use of Local Aggregates in High Modulus Asphalt Concrete Layers" , Journal of the Croatian Association of Civil Engineers (HSGI). Zagreb :HSGI. Vol. 65, PP. 353-360.

Maupin, G., W., and Brian, K., D., (2006), "Design of a High-Binder- High-Modulus Asphalt Mixture", Virginia Transportation Research Council, Final Report VTRC 07-R15.