The effect of aggregate gradation and asphalt type on Marshall Properties and permanent deformation parameters of asphalt concrete mixes

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ABSTRACT:

Rutting of flexible pavement idealizes the main problems of pavement distinguished around the world and especially in Iraq. Rutting of asphalt surface layer may be associated with plentiful reasons during structure period and service period. The main objectives of the research are to estimate the effect of asphalt type and gradation of aggregate on hot mixture asphalt (HMA) rutting potential in asphalt concrete mixes realize the effect of aggregate characteristic on Marshall Mix properties and estimate the relation between mix properties and rutting potential of HMA. Mineral aggregates characteristic have substantial influences in execution of local highway which offers the potential of development in these characteristic to resisting various domain of exterior applied loads and conditions of environmental. The substantial properties of aggregates are gradation impacting on permanent deformation of hot mix asphalt. In this study; Fine, mean and coarse gradation mixtures for different aggregate types were tested to check the influence the different aggregate types and gradation on mix properties. Properties investigated were, Stability and Flow of Marshall, unit weight, voids in mineral aggregate, air voids, and voids filled with asphalt. The results indicated that optimum asphalt content (OAC) and characteristics of Marshall are significant variation different due to aggregate gradation and asphalt type. The optimum asphalt content is minimum in mean gradation AC(60-70) and AC (40-50) ,The maximum value of stability obtained in the coarse gradation AC(60-70), The flow value obtained is minimum for the mean gradation AC(40-50). Maximum value of resilient modulus of the mixture in mean gradation AC (40-50) greater than maximum value of mixture in fine gradation AC (60-70) at rate 1.29 times. Finally, the altering of gradation of aggregate and type of asphalt significantly affected the permanent deformation parameters in flexible pavement.

Key Word: permanent deformation parameters, Marshall Properties, aggregate gradation, asphalt concrete type, Rutting.

1-INTRODUCTION

Permanently rutting can be considered as a worthwhile of hot mixture asphalt (HMA) pavements execution because of frequent loadings (17). The average and deepness of rutting be based on exterior and interior factors. Exterior of asphalt is the consequence of this retardant manner type. Amplification magnitude based on angularity, the aggregates shape and gradation. Last technique is the wastage of cohesion between bitumen and aggregate in mixes of asphalt. It is predictable that influence of every technique based on design of mix and thickness of pavement layer. For the tender pavement layer , stone-on-stone attrition and overlap inter aggregates are the essential technique versus rutting. Rising thickness pavement layer would minimize influence of attrition and overlap inter aggregate , thus characteristic of binder deformation has extreme impact on a strength versus defeat in adhesion and permanently between aggregates with bitumen (11). The interior strength of HMA is influenced immediately by characteristics of mixture. Anywise, there is a reduction of uniformity between the specification of aggregate and execution of mixture. It appears that there is an suitable interior domain of materials strength for a know maximum nominal size. Else interior strength of hot mix asphalt is incremented aggregate overlap .Interior connect between coarse aggregate is considered to the primary origin at interior strength ; so, it is urgent that the mixes is put with a skeleton of potent coarse-aggregate. Changeable volume of fine aggregate ((LSAMs) large-stone asphalt mixtures), would have factors comprise volume and load of truck traffic, temperature, pressure of tire, and structural exercises. Interior ingredients comprise height of pavement, aggregate, bitumen characteristic and mixes (25).

The ingredients is observed as the extreme influential factor causing the rutting is the aggregates properties. (3) else aforesaid that HMA characteristics are extremely influenced via their aggregate properties. (7) have get it nine potential factors reason of rutting, A state that aggregate properties is the elementary material characteristics effecting rut tendency. (22) likewise have specified that impedance of rut is “dependent on grade of aggregate” and mixtures made with the superior materials could defeat without a suitable gradation.

Empirical works and numeral designing presenting that loading of vehicle tire it causes shear stresses inserted eloquent quantity of exterior capacity to the mix which is command to the permanent deformations. These deformations it causes by three different technique. The first technique is to decrease a friction between bitumen and aggregates glazy. Friction Strength in aggregates such as all grainy materials is regard with the mineral combination, coarseness and else bitumen characteristic. Second technique is subjugation the overlap between the aggregates that it propulsion aggregates afar of each else. Rising percent of void in mixes highway Research Program (SHRP) aimed firstly asphalt binder properties and the participation to perform of asphalt pavement. Itemized realizations for contributions of aggregate to execution of asphalt pavement were removed from the platform. Moreover, Specifications in Taiwan have recommended altering flat and elongated aggregate definition from a dimensional ratio of 3:1 to 5:1. Reasonable data of engineering are demand to set up reasonably the criterion for the alter.

Aggregate properties morphological are so complicate ,cannot be distinguished sufficiently via single test. Interfering results have been mentioned on how aggregate shape effects the hot asphalt mixes quality . (21) deduced that exchanging crushed coarse material with uncrushed coarse aggregate did not vastly reform the properties of asphaltic mix. (14) observed a lineal relationship between the rutting possibility of asphalt mixes, texture and shape of coarse aggregate particles. (20) presented that the crushed coarse particles percentage had a important impact on properties of permanent deformation in laboratory. when the possibility rutting of hot asphalt mixes increased ,the crushed coarse particles percentage decreased. (10) found that 19 percent of elongated and flat particles in crushed aggregate did not inversely influence volumetric characteristic of hot influence on interior strength and load-carrying capacity of hot mix asphalt too. Connect Stone-on-stone is began whilst skeleton of aggregate is obtain by a fixed case. The results to the date have specified that tendency to the plastic deformation raised dramatically when grains of natural fine aggregate exchange crushed grains in a given gradation of aggregate.(8; 14; 7; 16).

Subsequently, this research converges on the influence of gradation more in detail and research the impact of coarse and fine aggregate gradation on rutting techniques by separating the gradation into the (coarse, mean and fine gradation).

2-BACKGROUND

Percentage of aggregate comprises about 95% of asphalt concrete mixes by total weight. Mostly the mineral aggregate is consisting of coarse aggregate. The research has exhibited that aggregate properties like shape, particle size, and texture effect on execution and employ capacity of asphalt concrete mixes (5; 12). Particles of flat and elongated resort to fracture through mixing, under compaction and traffic . Thus, the main consideration in design of mixture of asphalt pavements which that is the substantial characteristic is shape of aggregate to obviate early failure in pavement. The last Strategic processing of digital picture and analyses. The process supplies the ability of exact mensuration and rapid of aggregate particles properties. For example, (23) utilized a processing of digital image mechanics to determine the apportionment, direction, and shape of coarse aggregate. The mount consequences specified that microstructural properties of asphalt mixes could be gauged carefully utilizing a processing of digital picture mechanism. else utilized (14) three-dimensional picture analyses mechanism particles of aggregate to measure the shape, size , and diameter of particles.

The aims of the research are to determine the formalism coarse aggregate properties.

To reform the engineering properties of hot asphalt mixes made of various gradients of aggregate and to describe the tendency of aggregate through loading of traffic.

3-1 Asphalt Cement

In this research work, two asphalt cement are used (40-50) and (60-70) grade of penetration. It was gained from refinery of Al- Dura, in Baghdad. **Table.1** below shows The properties of asphalt cement.

asphalt mixes. (23) showed datum on the influence shape of aggregate, and recommended mixes of uniform grains, flat grains, and elongated particles to realize perfect force . the impact of size, crushing, shape of particle and aggregate discussed by (11) .

The researcher confirmed that asphalt employment can be decreased with rising the crushed aggregate size utilized in mixes. The opposite reports consequence firstly from the superior reduction perception of influence shape of aggregate on characteristic of engineering for asphalt concrete mixes. Visional test is utmost combined procedure of arbitrate aggregate shape. In order to boring mission for making many readability, the engineer finds the impracticable to distinguish particle shape optically. Different invention manners are obtainable to simplify the aggregate shape quantification. One of the most efficient manners is

3-MATERIAL CHARACTERZATION

In this work the materials utilized, asphalt cement, aggregate, and fillers were identified using all tests and results were compared with State Corporation for Roads and Bridges specifications (18).

Table. 1 Asphalt Cement Properties

Test	Test	ASTM	Units	Asphalt Binder

	condition	Designation		40-50	SCRB specif.	60-70	SCRB specif.
Penetration	100 gm, 25 °C , 5 sec., 0.1 mm	D5	1/10 mm	47	40-50	65	60-70
Specific Gravity	25 °C	D70	-----	1.04		1.03	
Ductility	25 °C , 5 cm/min.	D113	cm	>100	>100	>100	>100
Flash Point	----	D92	°C	238	232 min	249	232 min
Softening Point	(4±1) °C /min.	D36	°C	47		49	
After Thin Film Oven Test							
Penetration of Residue , %	100 gm, 25 °C , 5 sec., 0.1 mm	D5	1/10 mm	26	>55	42	>55
Ductility of Residue	25 °C , 5 cm/min.	D113	cm	55	>25	77	>25

course gradation as demanded by SCRB specification (18). **fig.1 and table.2** show the gradation aggregate.
Habit tests were completed on the aggregate to predestined their

Physical characteristic. **Table.3** abstracted the results together with the specification limits as set by the SCRB .The results of tests show that the selection aggregate met the SCRB specifications.

3-2 Aggregate

In this work used aggregate was crushed quartz gained from Amanat Baghdad asphalt concrete mix plant situated in Taji, north of Baghdad, from Al-Nibaie quarry. The aggregate is vastly utilized in city of Baghdad for mixtures of asphalt. In this research used the coarse and fine aggregates were sieved and recombined in the adequate characteristic to meet the wearing

Table .2 Surfaces or wearing course Type IIIA

Opening (mm)	Sieve Size (in)	passing by weight of total % aggregate + filler			Specification limits (SCRB-R9/3),type IIIA
		Coarse grade	Mid grade	Fine grade	
19	3/4	100	100	100	100
12.5	1/2	90	95	98	90-100
9.5	3/8	76	83	88	67-90
4.75	No.4	50	59	70	44-74
2.36	No.8	40	43	50	28-58
0.3	No.50	21	18	19	5-21
0.075	No.200	10	7	6	4-10
Asphalt Cement (% weight of total mix)					4-6

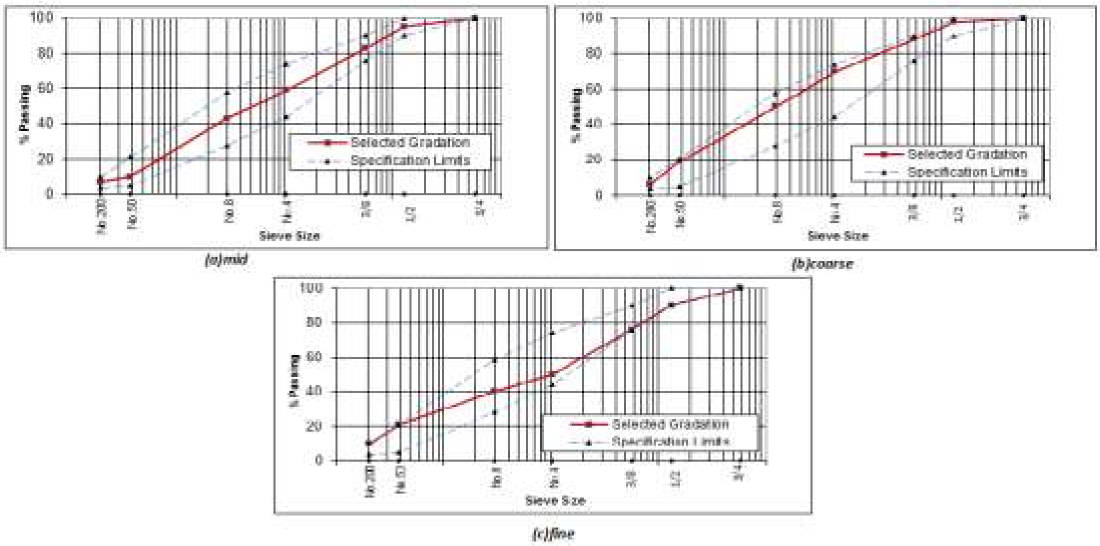


Fig.1 Aggregate Gradation type IIIA mixes of wearing course

Table. 3 Physical Properties of Aggregates

No.	Laboratory Test	ASTM Designation	Test Results	SCRB Specification
Coarse Aggregate				
1	Apparent Specific Gravity	C-127	2.683	-
2	Bulk Specific Gravity	C-127	2.605	-
3	Water Absorption,%	C-127	0.25	-
4	Fractured pieces,%	-	97	95 Min.
5	Percent Wear (Los Angeles Abrasion),%	C-131	16	30 Max.
6	Soundness Loss by Magnesium Sulfate solution, %	C-88	4.03	10 Max.
Fine Aggregate				
1	Apparent Specific Gravity	C-128	2.678	-
2	Bulk Specific Gravity	C-128	2.682	-
3	Water Absorption,%	C-128	0.5	-
4	Sand Equivalent,%	D-2419	66.29	45 Min.

3-3 Filler

The filler used in this work is limestone dust and it is a non-plastic material passing sieve No.200 (0.075mm).

Table.4 presented the physical properties of the used filler.

Table. 4 Fillers Properties

Property	Test Result
Specific Gravity	2.76
%Passing Sieve No.200 (0.075 mm)	95

4-EXPERIMENTAL WORK

The experiential work was start by calculated the optimum asphalt content for all mixes of asphalt concrete using the method of Marshall mix design. mixes of asphalt concrete were made at their optimum asphalt content and examined to rectify the engineering characteristic which involved resilient modulus, permanent deformation. These characteristic have been evaluated using uniaxial repeated loading test.

4-1 Marshall Mix Design

Standard method of Marshall as in (**4**) specifications was utilized to calculate the optimum asphalt content for asphalt concrete specimens compaction. Marshall Test was formed in a cylindrical specimen of 102 mm (4 inch) diameter by 63.5 mm (2.5 inch) height. Asphalt is heat up to 140 ^{0}C before mixing and it was put to the hot aggregate in the bowl, which was put on hot plate and two minutes mixing. Standard Marshall molds heat in an oven up to 140 ^{0}C. The aggregate perfectly mixed with asphalt was placed in the mold, 75 blows compacted on each face of the specimen, utilizing hammer of 4.53 kg (10 lb) skidding weight and a free fall of 457.2mm (18 inch) .A range of asphalt contents (4.3 to 5.5 percent) with a step of increased (0.3 percent). The optimum asphalt content of the mix was calculated as the numerical average of the values of asphalt contents corresponding to the following:

- Maximum unit weight of asphalt content .
- Maximum stability of asphalt content .
- 4% air voids of asphalt content .

To determine the optimum content, 15 Marshall specimens were prepared for each type of asphalt cement, three samples of each asphalt content were performed and the mean value was calculated a rate of (50.8 mm/min) (2"/min) until the maximum load was reached and the corresponding flow value was recorded, **Fig. 2** shows Marshall specimen while testing. Marshall stability and flow tests were prepared according to **(4)**; the specimen was put in water bath at 60°C for 30-40 minutes, and then it was pressed on the lateral surface at

Fig. 2. Marshall Specimen Test

The total deformation (εp) is calculated by applying the following equ.1:

$$\varepsilon_p = \frac{p_d \times 10^6}{h} \qquad (1)$$

where
εp= axial permanent microstrain
pd= axial permanent deformation
h= specimen height
else, during this test the resilient deflection is calculated at the load repetitive of 50 to 100, and the resilient strain (εr) and resilient modulus (Mr) are measured as follows:

$$\varepsilon_r = \frac{r_d \times 10^6}{h} \qquad (2)$$

$$M_r = \frac{\sigma}{\varepsilon_r} \qquad (3)$$

where

4-2 Uniaxial repeated loading test

The uniaxial repeated loading tests were realized for cylindrical specimens, 203.2 mm (8 inch) in height and 101.6 mm (4 inch) in diameter utilizing the pneumatic repeated load system (shown below in **fig. 3**). In these experiences , repetition compressive loading with a stress level of 0.137 mPa (20 psi) was applied in the shape of rectangular wave with a constant loading recurrence of 1 Hz (0.1 sec. load period and 0.9 sec. rest period) and the axial permanent deformation was measured under the various loading repetitions. All the uniaxial repeated loading tests were realized at 25°C. The specimen preparation method for this test can be found elsewhere (2).

(3)

form exhibited in Eqn. 4 below which is primarily proposed by (17) and (5).

$$\varepsilon_p = aN^b \qquad (4)$$

where
εp= permanent strain
N=number of stress applications
a= intercept coefficient
b= slope coefficient

εr = axial resilient microstrain
rd = axial resilient deflection
h = height of specimen
Mr= Resilient modulus
σ = repeated axial stress **(9)**

The total permanent deformation test results for this research are illustrated by the linear log-log relationship between the number of load repetitions and the permanent microstrain with the

Fig. 3 Photograph for the PRLS (Albayati, 2006)

automatic Marshall compactor on each side of the specimen which represent high tire pressure applying on roadway. Based upon this method, the optimum asphalt content is determined by averaging the three values shown below:

- Maximum unit weight of asphalt content.

5- TEST RESULTS AND DISCUSSION

5-1 Mix Design Using Marshall Method

To investigate the demands of the experiential design, Procedure of Marshall mix design were implemented stated by AI`s manual series No.2 (1) using 75 blows of the (coarse ,mid ,fine) from these Fig.s the calculated optimum asphalt content for asphalt cement grade (40-50) was(5 %) for coarse gradation,(4.8%)for fine gradation and (4.5%) for mid gradation .

For grade (60-70) the optimum asphalt content was (4.85 %) for coarse gradation,(4.74%)for fine gradation and (4.5%) for mid gradation .

. **Table.5** show the mixtures characteristics at optimum asphalt content for the design criteria of 75 Marshall blows, The data exhibited in table specified that both mixtures (i.e., containing AC (40-50) and AC (60-70) meet the Iraqi specification requirements **(18).**

- Maximum stability of asphalt content.
- 4% air voids of asphalt content.

For each asphalt cement grade, 15 Marshall Specimens were prepared with a constant increment of 0.3 percent of asphalt cement content (3 specimens for each content). The chosen asphalt contents to implement the Marshall Mix design were (4.3, 4.6, 4.9, 5.2 and 5.5) percent by weight of total mix, these values belongs to the mix type IIIA of wearing course.

Fig.4 and Fig.5 show the plots of the Marshall data for each type of asphalt cement(40-50) and (60-70) also three grades of aggregate

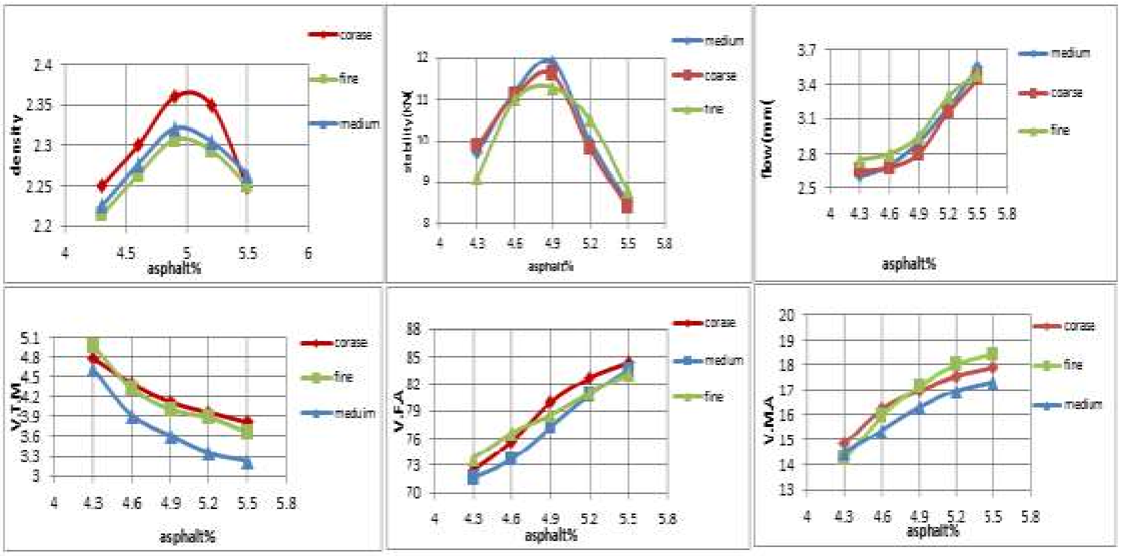


Fig. 4 Marshall plots for mixtures with AC(40-50)

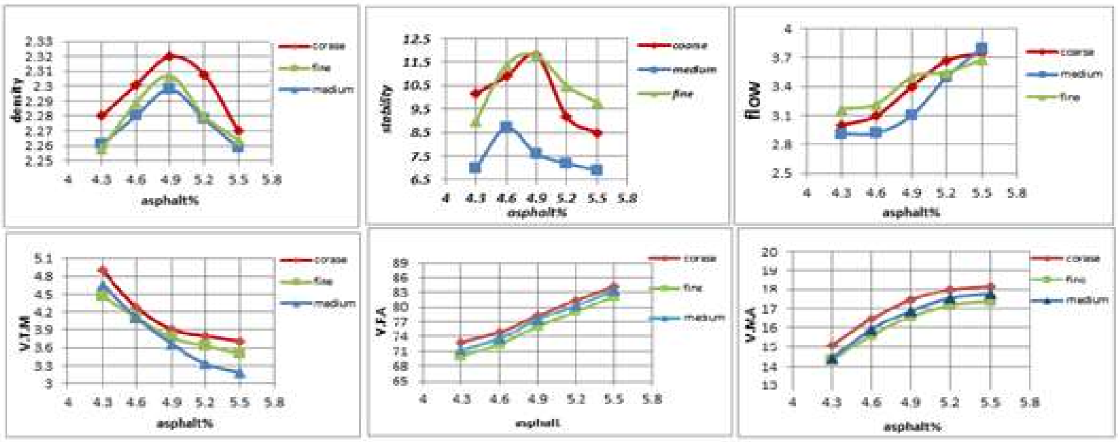


Fig. 5 Marshall plots for mixtures with AC(60-70)

Table. 5 Mix Properties at Optimum Asphalt Content and Specification Requirements

Marshall Property	Mix Type						Specification Requirements (SCRB) wearing course Type IIIA
	AC(40-50)			AC(60-70)			
	Coarse gradation	mean gradation	fine gradation	coarse gradation	mean gradation	fine gradation	
O.A.C%	5	4.5	4.8	4.85	4.5	4.74	4-6
Density Kg/cm³	2.37	2.32	2.31	2.319	2.285	2.305	
Stability , KN	11.4	11.5	11.3	11.75	8.54	11.6	8 min.
Flow,mm	2.9	2.7	2.8	3.3	2.9	3.35	2-4
A.V %	4.1	4.0	3.8	4.0	3.95	3.9	3-5
V.F.A%	81	74	78	78	75	74	(70-85)%
VMA%	17.3	15.5	14.8	17.5	16.3	15.3	14 min.

5-1-1 Stability

According to **table.4** and **fig. 6** , the asphalt cement type (60-70) coarse gradation have the highest value of Marshall stability, the asphalt cement type(40-50) fine gradation have lowest value of Marshall stability . But all stability values for three gradations of aggregate and for two type of asphalt have a values are within the range of Specification Requirements **(18).**

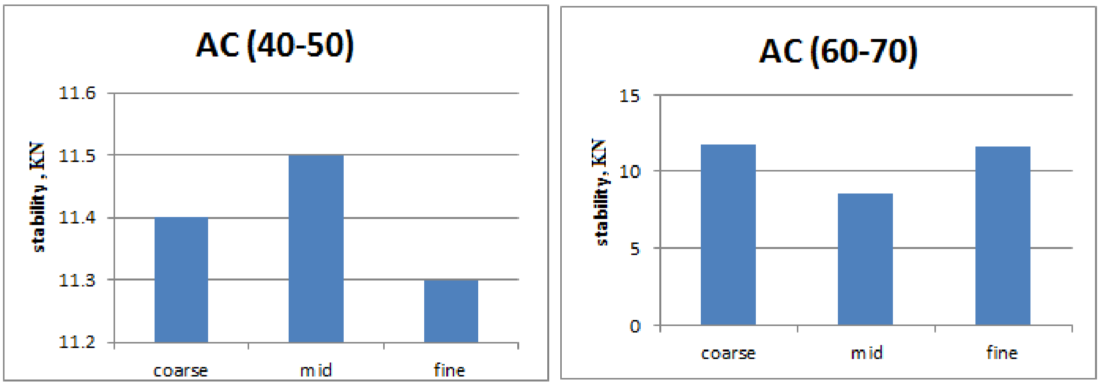


Fig. 6 Values of stability for three gradation of aggregate

5-1-2 Flow

The flow values specified in ranges of (2-4) mm according to specification requirement (SCRB) .in this study for all gradation, the flow values are in this limit. It is observed that due to increasing bitumen percent the flow value is also increasing .highest value of flow is in fine gradation of AC(60-70) and lowest in mid gradation AC(40-50) because of softening degree in AC(60-70) is greater than in AC(40-50) and viscosity is lowest that shown in **fig.7**.

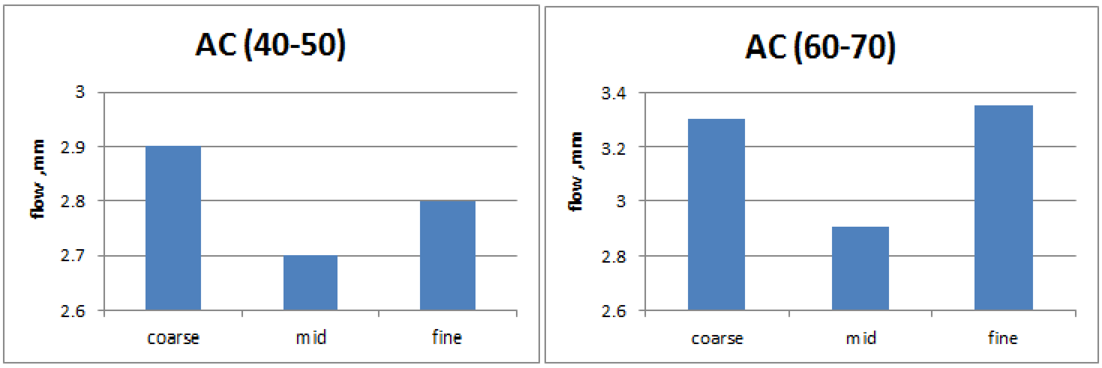


Fig. 7 values of flow for three gradation of aggregate

5-1-3 Air Voids

The value of air voids in limit of (3-5)% is specified by specification requirement (SCRB). In this study for all gradations , the air voids percent are in this range .it is observed that the lowest value of AV is in the fine gradation, and the highest value of air voids coarse gradation for two type of asphalt because of the percent of AV increasing with coarse gradation increase that shown in **fig.8**.

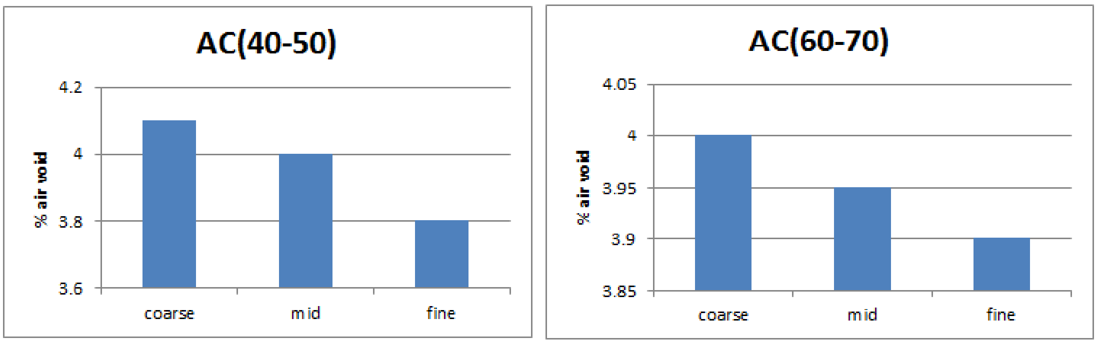


Fig. 8 Values of air voids for three gradation of aggregate

highest value of percent voids in coarse gradation and the lowest value in fine gradation ,the percent of voids in mineral aggregate in coarse aggregate is greater than voids in fine aggregate ,but all the results are within the ranges.

5-1-4 Voids in mineral aggregate

Iraqi Specification requirement (SCRB) specified the voids with mineral aggregate VMA values greater than 14% .the results is represented in **fig.9** indicated that the

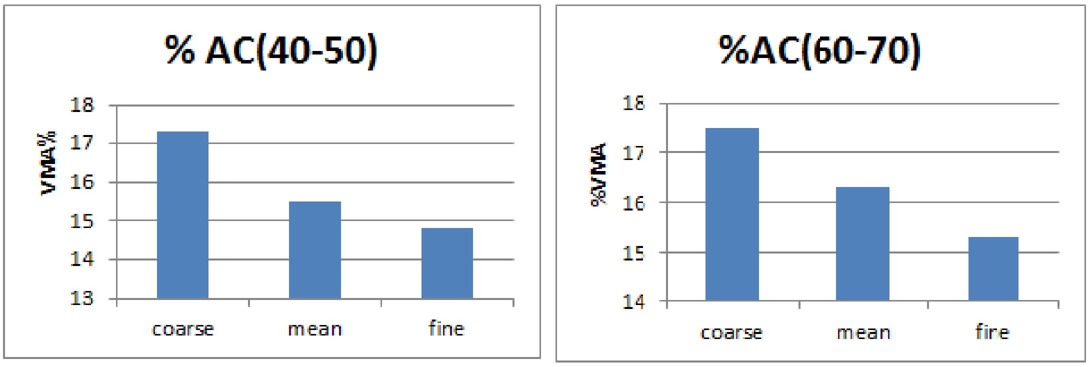


Fig. 9.values of voids in mineral aggregate for three gradation of aggregate

intercept coefficient (a) and the slope coefficient from (b)can be derived from the correlated equ.5,6 within the Fig., accordingly the permanent deformation parameter , Alpha (α) and Mu (μ) can be found as follows:

$\alpha = 1-b$ *(5)* ,

$\mu = (a \times b)/\varepsilon r$ (6)

5-2 Analysis of rutting test results

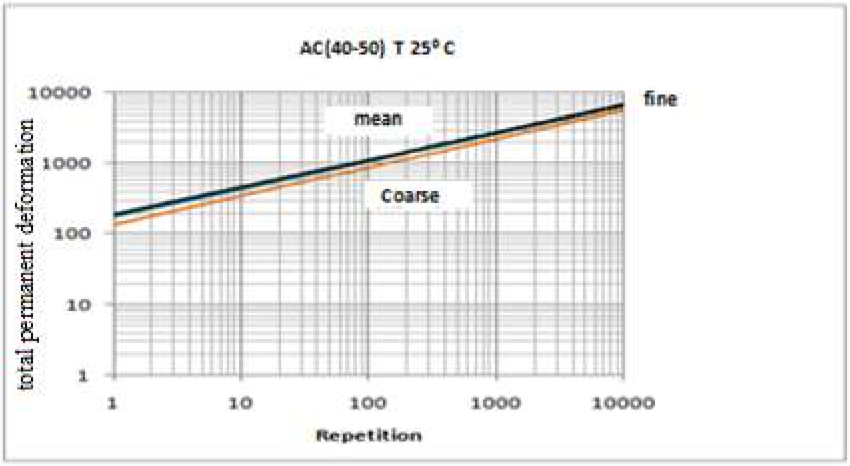
The results of rutting tests in terms of permanent strain (Ɛp) are plotted against number of repetitions(N) for each specimen to find the permanent deformation parameter . **table.5** shows the results of parameter (a,b ,α,μ and resilient modulus Mr) .**fig. 10** shows (Ɛp) versus (N) on log-log axes for the specimen at temperature 25º c and (20 psi) for AC(40-50) and AC(60-70) respectively. The

εr = resilient microstrain found after 200th recoverable repetition
εp=plasticmicrostrain. **(9)**

a = intercept coefficient from log εp vs. log N regression,
b = slope coefficient from log εp vs. log Nf regression

Table. 5 Summary of rutting test results

parameters	Coarse gradation		Mean gradation		Fine gradation	
	AC(40-50)	AC(60-70)	AC(40-50)	AC(60-70)	AC(40-50)	AC(60-70)
a	**135.6**	**137.5**	**178.1**	**185.3**	**172.7**	**323**
b	**0.385**	**0.422**	**0.367**	**0.371**	**0.354**	**0.392**
Mr(psi)	**184132**	**162242**	**233313**	**172360**	**197757**	**180200**
α	**0.633**	**0.578**	**0.615**	**0.629**	**0.646**	**0.608**
μ	**0.326**	**0.290**	**0.627**	**0.447**	**0.470**	**0.857**



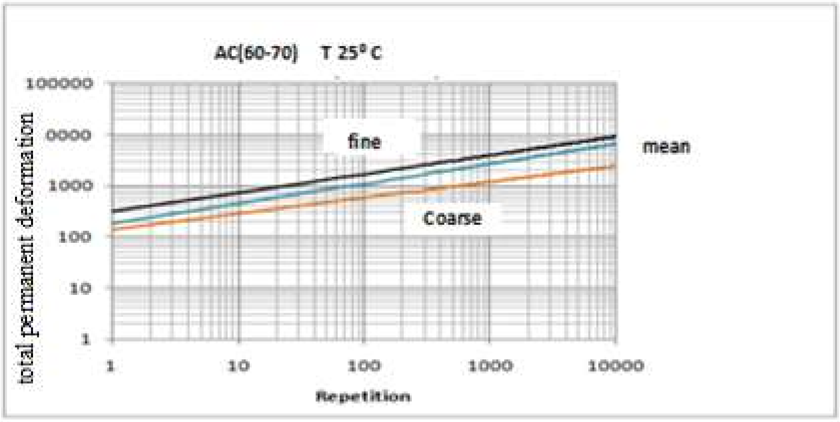


Fig.10 (εp) Versus (Nf) on log-log Axes

6- CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the laboratory tests and analysis, the following conclusions and

7. Maximum value of resilient modulus of the mixture in mid gradation AC(40-50) is 233313psi compared with maximum value of mixture in fine gradation AC(60-70) is 180200 psi ,this increasing in resilient modulus at rate 1.29 times .
8. The observation of the results all values of resilient modulus at AC(40-50) greater than values at AC(60-70).
9. The altering of gradation of aggregate and type of asphalt given the significantly effected of permanent deformation parameters, slope and intercept, the value of intercept at AC(40-50) is less than at AC(60-70) for all gradations ;also the value of intercept in coarse gradation is less than in mid and fine gradation that is caused lowest amount of permanent deformation and rutting resistance will be increased.

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recommendations are presented in this research:

1. The minimum value of optimum asphalt content (O.A.C.) is (4.5) at mid gradation of AC(40-50) and AC (60-70) which increased with coarse mixes and decreased in fine mixes because of the surface area of aggregate in coarse mixes greater then in fine aggregate.
2.The maximum value of Stability in coarse gradation AC(60-70) is (11.75KN); the value of Marshall Stability increased in coarse aggregate mixes and decrease in fine aggregate mixes.
3. The flow value is highest at fine gradation AC (60-70) and lowest value at mid gradation AC (40-50) .
4. The density is highest at coarse gradation AC (40-50) and lowest in mean gradation AC (60-70).
5. From the results of curves and tables the value of voids filled with asphalt is highest at coarse gradation AC(40-50) and lowest value in mid gradation AC(40-50) and fine gradation AC (60-70).
6. The value of air voids highest in coarse gradation AC (40-50) and lowest in mid gradation AC(40-50). According to the gradations, it is found that by decreasing the percentage of air voids, voids in mineral aggregate and void filled with asphalt to the definite value, resilient modulus of the mixture will be increased to (233313 psi) and subsequently deformation and non-recoverable strain will minimize.

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تأثير تدرج الركام ونوع الاسفلت على خواص مارشال ومعاملات التشوهات الدائمية لخلطات الخرسانة الاسفلتية

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الخلاصة :

يمثل التخدد في التبليط الاسفلتي واحد من المشاكل الرئيسية المهمة في الطرق حول العالم وخاصة العراق . وان هذا التخدد قد يتسبب من مشاكل اما في مرحلة الانشاء او مرحلة الخدمة للطريق .ان الهدف الرئيسي من هذا البحث هو لتخمين تأثير تدرج الركام ونوع الاسفلت على خلطات الخرسانة الاسفلتية وامكانية حصول التخدد في هذه الخلطات .ان خصائص الركام تملك تأثير كبير على اداء الطرق والتي توفر امكانية توظيف هذه الخصائص اتجاه مقاومة مختلف الاحمال الخارجية المسلطة على طبقة التبليط وكذلك الظروف الخارجية. يعتبر التدرج واحد من الخصائص المهمة للركام الذي يؤثر على التشوهات الدائمية لطبقة الاسفلت. في هذه الدراسة اجريت الفحوصات على التدرج الناعم ,الوسط والخشن ودراسة مدى تأثير هذا التغير على خصائص الخلطة الاسفلتية . وهذه الفحوصات هي ثبات مارشال ,الجريان, الكثافة, نسبة الفراغات الهوائية , نسبة الفراغات في الركام ونسبه الفراغات المملوءة بالإسفلت. اظهرت النتائج الى ان نسبة الاسفلت المثلى وخصائص مارشال تختلف باختلاف تدرج الركام ونوع الاسفلت المستخدم .اقل قيمة لنسبة الاسفلت المثلى هي في خلطات التدرج الوسط لنوع الاسفلت (60-70) و(40-50) واعلى قيمة لقوة الثبات في التدرج الخشن لنوع الاسفلت (60-70) ,واقل قيمة للجريان هي في التدرج الوسط لنوع الاسفلت (40-50) وكذلك اعلى قيمة لمعامل المرونة هو لخلطات التدرج الوسط لنوع الاسفلت (40-50) اكبر من اعلى قيمة لمعامل المرونة لخلطات التدرج الناعم انوع الاسفلت (60-70) بمعدل 1.29 مرة . واخيرا فأن تغيير تدرج الركام ونوع الاسفلت يعطي تأثير واضح وجلي على التشوهات الدائمية لطرق الرصف المرن.

الكلمات المفتاحية معاملات

التشوهات الدائمية ,خصائص مارشال, تدرج الركام ,نوع الاسفلت ,التخدد