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EFFECT OF AGGREGATE GRADATION AND TYPE ON HOT ASPHALT CONCRETE MIX PROPERTIES

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ABSTRACT

Mineral aggregates make up 90 to 96% of a HMA mix by weight or approximately 75 to 85% by volume. The properties of the mineral aggregates have significant affects in performance of our roadways which offers the possibility of investment in these properties towards resisting different ranges of external applied loads and environmental conditions. Therefore, aggregate characteristics deeply affect the performance of asphalt pavements. Gradation is one of the important characteristics of aggregates affecting permanent deformation of hot mix asphalt. The objective of this research is to investigate the impact of aggregate gradation variations on various properties of asphalt concrete mixtures. Fine, medium and coarse gradation mixtures for different aggregate types were tested to investigate the effects of variation in the aggregate types and gradation on mix properties. The asphalt contents of the mixes were maintained at the job mix design contents.

Properties investigated were, Marshall Stability, Marshall Flow, unit weight, air voids, and voids in mineral aggregate. Analysis of the considering different aggregate type data revealed that the fine-coarse and coarse-fine gradation variations had the greatest impact on mix.

The research program concentrated on the Marshall Design criteria for bituminous mixes. The results indicated that optimum asphalt content (OAC) is different due to aggregate type A coarse grading with 25 mm maximum size is found to give the most satisfactory result from the stand point of stability, stiffness, and voids characteristics. Test results reveal that the bituminous concrete with WCA can give satisfactory results when they are constructed using coarse gradation.

Keywords: Bituminous concrete, Gradation of aggregate, Marshall Design criteria**.**

1. Introduction

Asphalt concrete (AC) is a heterogeneous material that consists of asphalt cement, natural or artificial aggregate, mineral filler, additives and air voids. Aggregate comprise the vast bulk of paving mixture and therefore, exert significant influence on the resulting engineering properties of the structure. Coarse aggregate is the material, which is substantially retained on No. 4 sieve (2.365 mm). Generally, the asphalt concrete mixture contains from 35-65 percent of coarse aggregate for a nominal maximum size of 19.0 mm. This content normally gives a suitable texture for a heavily trafficked road (ASTM, 2003). [1]

Aggregate properties can affect mix properties in different ways. For example, if the aggregates used are weak they may disintegrated easily under the action of Marshall hammer during the mix design process. Consequently, fines and filler content in the mix are increased leading possibly, to a Marshall stability being higher than usual [2].

The factor that is usually noticed as the most effective parameter causing rutting is the characteristics of aggregates. Ahlrich [3] also mentioned that HMA properties are highly affected by their aggregate characteristics. Button et al. [4] have found nine possible factors cause rutting, but stated that the aggregate characteristics is the primary material quality factor influencing rut susceptibility. Stakston and Bahia [5] also have indicated that rut resistance is "highly dependent on aggregate grading", and that mixes made with the best possible materials would fail without a proper gradation.

Gandhi and Lytton [6] investigated large number of aggregate tests and whether these tests can be used as indicators of performance of asphalt concrete mixes.

Bissada [7] reported that, resistances to compaction of bituminous mixes are affected by mix variables (filler content, binder content and type of asphalt binder). Higher the resistance of the mix to compaction, higher it's measured stiffness value and consequently better resistance to permanent deformation performance is expected in the pavement. Higher the percent of fines in the mix, higher is the measured stiffness of mix at a lower value of resistance to compaction.

Bose [8] reported that, permanent strain decreased with increased aggregate size in large stone mixes. Large size aggregate has led to lower binder content, high density, satisfying voids in mineral aggregate. However, no correlation of aggregate properties with asphalt concrete was attempted [9]. El-Basyouny and Mamlouk in 1999 evaluated the effect of aggregate gradation on the rutting potential [10]. They found that both the aggregate gradation and aggregate nominal size affected the rut depth for pavement section. Mixtures prepared using aggregate gradation passing below the restricted zone (on the Super pave gradation chart) had better resistance to rutting as compared to those made from aggregates with gradation passing through or above the restricted zone [10,11]. This means that coarser gradations are expected to perform better than finer gradation.

Therefore, this study focuses on the effect of aggregate type and gradation more in detail and investigates the effect of coarse and fine gradation for different aggregate on Marshal properties by dividing the gradation limits into different parts (upper, middle and lower gradation).

Fine, medium and coarse gradation mixtures were tested and the effects of variation in the aggregate gradation on mix properties were investigated.

2. Objective and test plan

The objective of this study was to evaluate the effect of aggregate type and gradation on Marshall Properties for HMA mixture (specific gravity, stability, flow, and air voids). To accomplish this, various mixtures were compacted with optimum asphalt content and three different gradation types.

The same compactive effort 50 blows/face as a medium traffic loading was used to determine their volumetric and performance-related properties. In order to consider a range of mixtures, three blends of fine, medium and coarse gradations limited by the ASTM specification for gradation were used and shown in Figure 1.

3. Laboratory study and test results

3.1. Materials

3.1.1. Bitumen properties

The binder material of 60-70 penetration grade bitumen which commonly used in the region was selected for this research. The bitumen properties were evaluated by various laboratory tests, which are demonstrated in the Table 1.

Table 1.
Binder Properties

Experiment	Value	Standard No.
Penetration Grade at 25^{o} C, 1/10 mm	66	ASTM D5
Softening point (°C)	62	ASTM D 36
Specific Gravity	1.012	ASTM D70
Flash & Fire point (°C)	295/320	ASTM D 92
ductility value (cm)	100	ASTM D 113
Kinematic Viscosity (centi Stokes) 60°C	425	ASTM D2170

3.1.2. Aggregates

Aggregate is the major structural framework of asphalt mixture to absorb and control different stresses on the pavement. The aggregates used were subjected to a number of tests. These tests were as follows:

1) Specific gravity (ASTM C 127, 128-84).
2) Water absorption (ASTM C 127, 128-84).
3) Los Angeles abrasion test (ASTM C 535-81).
4) Sand equivalent (ASTM D 2419-79).
5) Soundness (using sodium sulphate) (ASTM C 88-83).
6) Crushing value (B.S. 812: Part 3, 1975).

Table 2 shows different properties of these aggregates which are crushed limestone. The sieve diagram for wearing course is also presented in Figure 1.

Table 2.
Aggregate properties

Experiment	**Value**			**Standard No.**
	Lime stone	**Dolomite**	**Basalt**	
Water Absorption %	1.61	1.48	0.27	(ASTM C 127, 128-84).
specific gravity	25	2.74	2.92	(ASTM D 2419-79).
Soundness %	4.03	6.5	9.85	(ASTM C 88-83).
Apparent specific gravity	2.57	2.68	2.72	(ASTM C 127, 128-84).
LA Abrasion loss	29.5	18.7	14.5	(ASTM DC-131)

3.1.2 .1. Aggregate Gradation

Aggregate gradations were selected with a nominal size of 19mm based on The Asphalt Institute Manual Series "Principles of Construction of Hot-Mix Asphalt Pavements "No.22 MS-22 (1983). According to the failure mechanisms (Rutting), the gradations should be limited between upper limit and lower limit based on the 19 mm nominal maximum aggregate size. In this study the gradation range divided into three variations that form a band (Fig. 1).

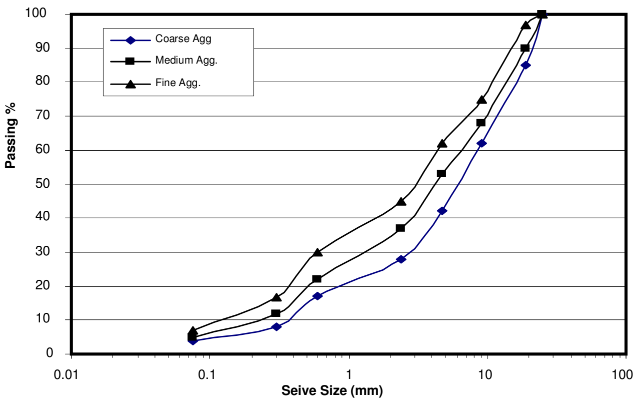

Fig. 1. Three blends of fine, medium and coarse gradations

In order to compare each of variations, the medium gradation of each variation were chosen from sieve diagram. Table 3 shows the percentage of passing for each variation (fine gradation, medium gradation and coarse gradation bands).

Table 3.
Passing Percentage for fine, medium and coarse gradations blends

Sieve size Mm	**Percent passing**			
	coarse gradation	medium gradation	fine gradation	specification
25 mm (1 in.)	100	100	100	100
19 mm (0.75 in.)	85	90	97	80-100
9 mm (0.375 in.)	62	68	75	
4.75 mm (# 4)	42	53	62	
2.36 mm (# 8)	28	37	45	
0.60(# 25)	17	22	30	
0.3 mm (# 50)	8	12	16.7	
0.075 mm (# 200)	4	5	7	

3.2. Marshall test

At each gradation and aggregate type, Marshall test specimens of 101.6 mm diameter and 63.5 mm thick were prepared as per AASHTO T245-82 by varying bitumen content to study the effect of aggregate type and gradation on the behavior of bituminous mixes. The specimens were then subjected to specific gravity, stability, and flow tests as Marshall mix design procedure. For determination of optimum bitumen content (OBC), the variations of bulk density, Marshall stability flow values and voids in total mix with bitumen contents were plotted and shown in Fig. 2, Fig.3, Fig.4 and Fig.5 respectively. At optimum bitumen content, the values of bulk density, Marshall stability, flow, percentage of voids in total mix (Va, %), percentage of voids in mineral aggregates (VMA, %), percentage of voids filled with bitumen and Marshall stiffness for different gradation types using are shown in Table (4-a, 4-b, and 4-c).

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Table 4. a.
Properties of mixes at optimum bitumen content for lime stone aggregate

PROPERTY OF ASPHALT CONCERT MIXTURES	AGGTRGATE GRADATION TYPE		
	Fine gradation	Medium gradation	Coarse gradation
Optimum binder content (%)	*5.4*	*5.2*	*5.0*
Marshall stability (kgf)	*1150*	*1380*	*1440*
Specific gravity (gm/c^3)	*2.384*	*2.399*	*2.413*
Air voids (%)	*4.5*	*4.0*	*3.5*
Marshall flow (mm)	*3.65*	*3.88*	*3.94*
Voids in mineral aggregates (%)	*14.7*	*14.2*	*13.45*
VFB, %	*74.2*	*74.1*	*72.2*
Marshall stiffness, kgf/mm	*308.21*	*355.67*	*365.48*

Table 4. b.
Properties of mixes at optimum bitumen content for dolomite aggregate

PROPERTY OF ASPHALT CONCERT MIXTURES	AGGTRGATE GRADATION TYPE		
	Fine Agg. gradation	Medium Agg. gradation	Coarse Agg. gradation
Optimum binder content (%)	*5.2*	*5.0*	*4.80*
Marshall stability (kgf) (	*1480*	*1420*	*1407*
Specific gravity (gm/c^3)	*2.46*	*2.47*	*2.45*
Air voids (%)	*3.8*	*3.8*	*4.1*
Marshall flow (mm)	*3.65*	*3.6*	*3.3*
Voids in mineral aggregates (% V.M.A)	*15.5*	*14.8*	*15.8*
VFB, %	*74.2*	*74.1*	*72.2*
Marshall stiffness, kf/mm	*405*	*394*	*426*

Table 4. c.
Properties of mixes at optimum bitumen content for basalt aggregate

PROPERTY OF ASPHALT CONCERT MIXTURES	AGGTRGATE GRADATION TYPE		
	Fine Agg. gradation	Medium Agg. gradation	Coarse Agg. gradation
Optimum binder content (%)	*5.0*	*4.8*	*4.6*
Marshall stability (kgf)	*1400*	*1380*	*1330*
Specific gravity (gm/c^3)	*2.384*	*2.399*	*2.413*
Air voids (%)	*4.5*	*4.0*	*3.5*
Marshall flow (mm)	*3.65*	*3.48*	*3.01*
Voids in mineral aggregates (%)	*14.7*	*14.2*	*13.45*
VFB, %	*74.2*	*74.1*	*72.2*
Marshall stiffness, kf/mm	*383*	*397*	*441*

4. Results and discussions

4.1. Analysis of Marshall test results

The test data from Marshal Test were analyzed to identify the effect of aggregate type and gradation variation. Analysis examines the variation of the different mixture parameter (i.e., air voids, VMA, stability, flow, density, and Marshall Stiffness). Tables (4-a), (4-b), (4-c) were prepared to compare the results of mixture parameters for all three gradation bands.

The mixture with fine gradation band has the highest stability and the coarse one has the lowest. Also asphalt mixture with fine gradation band has the highest flow parameter and also the coarse one has the minimum of flow parameter in three gradation bands. Furthermore, the mixture with coarse gradation band has the lowest special gravity but it has the highest amount of air voids and VMA. The middle gradation mixture has the lowest air voids percentage and VMA but it has the highest special gravity.

Considering aggregate type, it’s found that Marshall Stability is higher for lime stone while the basalt one is the lower, while Marshall Stiffness is higher for basalt and lower for lime stone aggregate.

5. Conclusions

Experimental program was designed and conducted on common asphalt paving mixtures of different aggregate types and gradations.

On the basis of experimental results of this investigation the following conclusions are drawn:

1. The effects of Course aggregate gradation, on the behavior of bituminous mixes is reasonably good from the considerations of Marshall test properties.
2. For better stiffness and to deformation of the bituminous mix at higher temperatures, Course gradation can be used as coarse aggregates in bituminous mixes.
3. The highest value of stability was achieved by Limestone aggregate with gradation 4C and the lowest value was achieved by Basalt aggregate of gradation 2C. Basalt mix of coarse gradation had the highest value of flow and lime stone of gradation fine had the lowest value
4. Course gradation of asphalt mixture design shows the best performance against flow while fine one has the highest amount of deformation.

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تأثير تدرج الركام على اداء الخلطة الاسفلتية الساخنة

الملخص العربى

يشكل الركام حوالي % 75 الى % 85 من حجم الخلطة الاسفلتية الحارة و 90 الى % 95 من وزن الخلطة . ونوعية الركام المعدني,وتدرجه له تاثير كبير على اداء طرقنا المحلية، والذي يوفر امكانية استثمار هذه الخواص باتجاه مقاومة مختلف القوى الخارجية والظروف البيئية .لهذا السبب اصبح من الضروري تقييم تأتأثير الخواص الادائية للخلطة الاسفلتية نتيجة التغيير في تدرج الركام ونوعيته ، باستعمال مجال واسع من التدرجات الناعمة والمتوسطة النعومة الكثيفة والخشنة .وفي هذه الدراسة تم تقييم التدرج الجبيبى ونوعية الركام . اظهرت نتائج الدراسة بان الخلطة الاسفلتية ذات التدرج الناعم تتأثر بشكل اكبر بتغيير خواص الركام من ناحية ثباتية مارشال .اما الخلطة الاسفلتية ذات التدرج الخشن فقد اظهرت تاثرية اكبر عند تغيير خواص الركام من ناحية خواص مارشال ، كما أن نوعية الركام لها أثر كبير على ثبات مارشال حيث اثبتت التجارب أن الركام من الحجر الجيرى له ثبات أكثر منه من البازلت أو الدولومايت.