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Effect Of Effective Specific Gravity On Vma Of Asphalt Concrete (Case Study Of Lolioge Materials Of Palu City)

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ABSTRACT

In the analysis and design of asphalt mixtures, consideration of the contributions of the three material components to the total volume of compacted mixtures has been recognized as a significant factor. The study of this component make up of asphalt mixtures has come to be known as “volumetrics.” The combined volume of entrapped air and the asphalt binder external to the aggregate, which is referred to as the voids in the mineral aggregate (VMA). The purpose of this study are: (1) To find out which of quarry has an aggregate with the best technical quality among the four quarries in the city of Palu, namely; the Suluri river, the Wuno river, the Matampondo river, and the Lolioge river, (2) To analyze the effect of specific gravity and composition of each of aggregate fraction on the Gse of combined aggregates, (3) to analyse the influence of the value of effective specific gravity (Gse) of mixed aggregate of the VMA dense asphalt mixture AC-WC at several levels of asphalt mixture , and (4) To determine effect of the level of asphalt mixture on VMA value at each of Gse value. To achieve these purpose, technical quality test comprises of bulk specific gravity, absorption, abrasion values and CBR of unbound base layer must be done. Aggregate Technical and Quality Testing, which includes testing of coarse aggregate, fine aggregate, dust, sand and asphaltic material were carried out based on AASHTO and ASTM specification. Mechanical testing of materials was done by using the Abrasion Test Machine Los Angelos. The abration value indicates abrasion resistance against the destruction of the coarse aggregate (degradation) due to mechanical loading. Determination of mixed aggregat gradation is carried out using by portion method under trial mix analysis. In this concern, for performing research speciments of asphalt concrete mixtures, the performance-based specification that applying the black area or restricted zone was used as developed by SHRP (Strategic Highway Research Program) to prevent obtaining soft of asphalt mixture. In this research five types of Superpave gradation were designed under the trial mix method yielding 5 different types of Gse ie 2.757, 2.733, 2738, 2.731, and 2.734. From analysis it was known that at some value of Gse, increasing level of asphalt mixture causes decreasing value of the VMA, while on other Gse values, increased levels of bitumen initially is lowering the value of the VMA but yet slowly increased with increasing of binder content.

Key Words: *Trial Mix, Effective Specific Gravity (Gse), VMA, Asphalt Content.*

1. INTRODUCTION

Palu Bay coastal area consists of 26 villages / sub-villages included in the administrative area Donggala and Palu with natural resources fairly large (Andrean, 2012). Lolioge River, located in the Village Watusampu, West Palu District, within 12 Km north of Palu. Its quarry comes from river and mount of Lolioge. Its materials quality touted as one of the best in Central Sulawesi, even in Indonesia. All bituminous mixes have three basic components; aggregate, binder and air. The mechanical properties of the mix are strongly dependent on their relative volumetric proportions, S.F, Brown et al (1982).

From the results of a survey of several companies carried out by B.D. Prowell, et al (2005) , he reported that the Superpave method specifies the use of the dry bulk aggregate specific gravity for the calculation of VMA. Of the responding agencies, 89% use dry bulk specific gravity to calculate VMA. Four agencies (9%) use the aggregate effective specific gravity to calculate VMA. The effective gravity is determined by using the HMA maximum specific gravity or rice value, asphalt content, and binder specific gravity. The effective specific gravity is always larger than the bulk specific gravity and, therefore, results in a larger calculated VMA. The use of the effective aggregate specific gravity to calculate VMA includes the volume of absorbed asphalt as part ofthe void volume between particles. One agency uses the apparent specific gravity to calculate VMA. This would result in a larger calculated VMA then would be determined using either the bulk or effective aggregate gravities. In addition to using the dry bulk specific gravity, Gse can also be used to calculate the VMA even during the production process of asphalt mixture. In the calculation of the VMA, Gse first calculated using the maximum specific gravity, asphalt binder content, and specific gravity. Moreover, by using a correction factor applied to the Gse can be used to determine bulk specific gravity mix.

LITERATURE REVIEW

Aggregate and Asphalt Specifications Tests

Aggregate plays an important role in performance of asphalt mixtures. The amount of mineral aggregate in asphalt paving mixtures is generally 90 to 95 percent by weight and comprise of 75 to 85 percent of the volume (Robert et al, 1996). In the Table-1 is presented testing aggregate specification used in this research.

Table-1, Aggregate Specifications Tests

No.	Item	Testing Methods	Unit	Specification Min.	Specification Max
	Coarse Aggregate				
1.	Gradation/Sieve Analysis	AASHTO T-27	-	-	-
2.	Absoption	AASHTO T 85	%	-	3
3.	Bulk Specific gravity	AASHTO T 85/ASTM C127	-	2.5	-
4.	Apparent Specific gravity		-	-	-
5.	Effective Specific gravity		-	-	-
6.	Abration	AASHTO T-96/ASTM C131			
7.	Angularity	AASHTO T326/ BS-812	%	-	-
8.	*Soundness*	AASHTO T-104/ASTM C88	%	-	18
	Fine Aggregate				
1.	Gradation	AASHTO T-27	-	-	-
2.	Absorption	AASHTO T-84	%	-	3
3.	Bulk Specific gravity	AASHTO T-84/ ASTM C128	-	2.5	-
4.	Apparent Specific gravity		-	-	-
5.	Effective Specific gravity		-	-	-
	Filler				
1.	Specific Gravity	AASHTO M-17/ASTM C120	-	-	-

Aggregate are expected to provide a strong stone skeleton to resist the repeated traffic load applications. When a mass of aggregate is subjected to excessively high loads, a shear plane develops resulting in the aggregate particles sliding or shearing with respect of each others. This behavior produces what is called permanent deformation in asphalt pavement (Asphalt Institute SP-2, 1989). Along this shear plane, the applied shear stress exceeds the shear strength of the asphalt mixture.

In the table-2 is listed testing methods for asphalt 60/70 used in laboratory during conducting this research. Jackson, MS (1949) reported that Marshall Mix Design approach did not have a VMA requirement. Marshall himself believed "no limits can be established for VMA, for universal application, because of the versatile application of bituminous materials to many types and gradations of aggregate".

Table-2, Bitumen Specification (Pen 60/70)

No.	Item	Testing Method	Specifications Min	Specifications Maks	unit
1.	Penetration of Bituminous Materials (25°C, 5 sec)	AASHTO T-49	60	79	0,1 mm
2.	Softening point (*Ringball*)	ASTM D 36	48	58	°C
3.	Flash and Fire Points by Cleveland Open Cup	AASHTO T-48	200	-	°C
4.	Loosing Weight (163 °C, 5 hr)	AASHTO T-240	-	0,8	% weight
5.	Ductility of Bituminous Materials (25°C, 5 cm/min)	AASHTO T-51	100	-	Cm
6.	Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures (25°C)	AASHT0 T-209/ ASTM D 2041	1	-	Gram/cc

Bulk Specific Gravity of Total Aggregate

Total aggregate consisting of fractions coarse aggregate, fine aggregat, and fillers, each having a different specific gravity . For the bulk specific gravity (Gsb) the aggregate total can be calculated as follows :

$$\mathrm{Gsb} = \frac{P_1 + P_2 + \cdots + P_n}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \cdots + \frac{P_n}{G_n}} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where:

G_{sb} = Bulk specific gravity of Total Aggregate

P1, P2, Pn = The percentage of each fraction of aggregate

G1, G2, Gn = Specific Gravity of each fraction of aggregate, Sukirman (2010)

Effective Specific Gravity of Total Aggregate

When the maximum specific gravity of the mixture (Gmm) measured by AASHTO T - 209-90, the effective specific gravity of the mixture (Gse) including all the voids in the aggregate particles (except the absorbing asphalt) can be determined by the formula :

$$G_{se} = \frac{W_{agg}}{V_{eff}} \quad \ldots\ldots\ldots \quad (2)$$

Because the effective volume of the aggregate is aggregate volume (+) void of the outer aggregate (-) outside the inner void filled with asphalt aggregate, so that:

$$G_{se} = \frac{W_{total} - P_{bt} \cdot W_{total}}{V_{TV} - V_{bt}} \text{ ....(3)}$$

The simplification of the above formula can be drown as:

$$G_{se} = \frac{1 - P_{bt}}{\frac{1}{G_{mm}} - \frac{P_{bt}}{G_b}} \text{ ....(4)}$$

where:

Gse = *Effective Specific Gravity of Total Aggregate*
Gmm = Maximum Specific Gravity of Total, zero air void (AASHTO T-09-90 or ASTM 2041)
Pbt = Asphalt content based on the maximum specific gravity testing tested with AASHTO T-209-90 or ASTM 2041, percent of the total weight of the mixture
Gb = Asphalt Specific Gravity

Asphalt Specific Gravity

In the calculation of asphalt concrete mixtures, the apparent specific gravity is usually calculated as the mean between the bulk specific gravity and density effectively. Therefore, the apparent specific gravity can be calculated: S.Sukirman (2010)

$$G_{app} = \frac{G_{sb} + G_{se}}{2} \text{ ....(5)}$$

Unit Volume of Compacted Mix

In the analysis and design of asphalt mixtures, consideration of the contributions of the three material components to the total volume of compacted mixtures has been recognized as a significant factor (Brian J. Coree, 2000).

The study of the component volumetric make-up of asphalt mixtures has come to be known as "volumetrics." In the simplest approach, a compacted asphalt mixture may be resolved to the individual volumes of the mineral aggregate, Va, the asphalt binder, Vb, and the entrapped air, Vv. However, because of the inevitable characteristic of aggregate absorption by which a portion of the asphalt binder is taken into the body of the aggregate, the sum of the individual component volumes exceeds the total volume of a compacted asphalt mixture. As a result, two secondary volumetric parameters are conventionally used: (1) the combined volume of entrapped air and the asphalt binder external to the aggregate, which is referred to as the voids in the mineral aggregate (VMA) and (2) the degree to which the external binder saturates the VMA volume (voids filled with asphalt, VFA). Both VMA and VFA have been identified as significant indicators of performance. The component diagram shown in Figure-1 is commonly used to model the mass and volumetric properties of asphalt mixtures (S.F, Brown et al, 1982). He states that proportions by volume and two particular parameters will need to be determined to evaluate the mechanical properties of mixes of significance for design. These are V_B, the proportion of binder by volume, and void in mineral aggregate will be calculated under formula (6). Given the binder content by mass and the void content of a mix as usual starting points, V_B is calculated from equation (7). If the various portions of aggregate have different specific gravities, then an effective GSe for the mixed aggregate can be calculated from equation (8). where X, Y, etc, are the percentages by mass of each aggregate fraction having specific gravities G_X, G_Y, etc, or a number of M_A/Ga terms may be included in the denominator of equation (1) so long as all the mass proportions total 100%. If it is necessary to calculate void content from measured density, the equation (9) is applicable, in which γmax is the theoretical maximum density which corresponds to zerovoid content, it is determined as follows:

$$VMA = V_B + V_V, \text{.......................................(6)}$$

VMA = the voids in mix aggregate

$$V_B = \frac{(100 - V_V)(M_B/G_b)}{(M_B/G_b) + (M_A/G_{se})} \text{ .... (7)}$$

$$GSe = \frac{100}{(X/G_X) + (Y/G_Y) + \cdots} \text{ ....(8)}$$

$$V_V = \frac{(\gamma_{max} - \gamma_m)}{\gamma_{max}} \, x \, 100 \text{ ....(9)}$$

$$\gamma_{max} = \frac{100\gamma_w}{(M_B/G_b) + (M_A/G_{se})} \text{ ....(10)}$$

Some mix designers combined VMA, air voids, and experience to determine the best asphalt content and others using approach combined air voids, the product of surface area and optimum film thickness, and experience to determine the best asphalt content. Usually, the aggregate gradation was determined by specification, by locally available materials, or by theoretically "idealized" gradations, (Brian J. Coree, 2000).

Generally stone crusher in Indonesia producing size fraction with a diameter of 19 mm, and the limitation of material through sieve No. 200 maximum of 15%, then gradation AC-WC used in this research as presented in Table-3. In general, materials to be used in asphalt concrete mixture consisting of coarse aggregate, fine aggregate, filler and bitumen as a binder. The use of aggregate and asphalt material in principle should be limited in proportion, based on the principles and experience of empirical or analytical calculation. In a performance-based specifications HMA mixture, mix performance was analyzed based on the response of pavement to load. The essential thing in this specification is the gradation requirements using the black areas, namely restricted zone is developed to prevent obtaining the asphalt mixture is soft and susceptible to deformation.

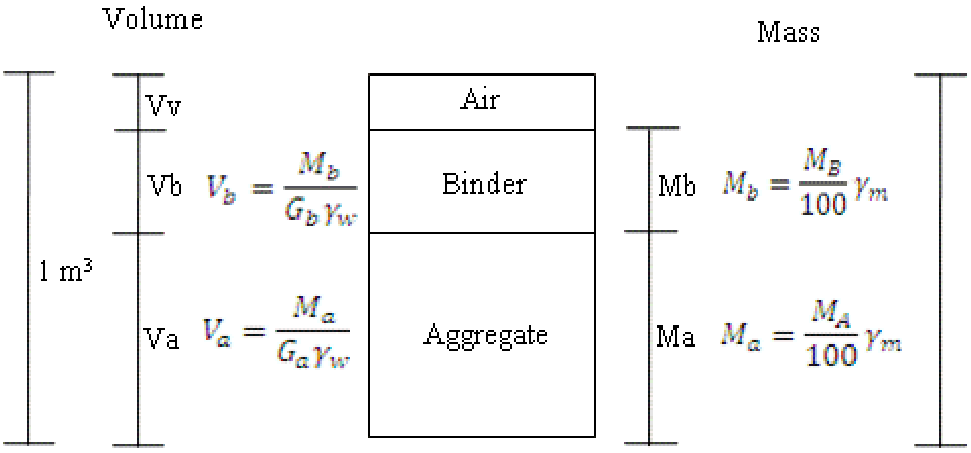

Figure-1, The Volume and Mass Components of a Unit Volume of Compacted Mix, (S.F, Brown et al, 1982).

Where:

V_a = Volume of Aggregate, m^3
V_b = Volume of binder, m^3,
V_B = Volume of binder as %
V_v = Volume of voids, m^3
$V_a + V_b + V_v = 1$ m^3
M_B = Binder content per cent by mass of total mix
M_A = Aggregate content per cent by mass of total mix
$M_A + M_B = 100\%$

M_a = Mass of aggregate, kg
M_b = Mass of binder, kg
G_b = Specific Gravity of Binder
G_{se} = Specific Gravity of Mixed Aggregate
γ_m = Density of compacted mix, kg/m^3
γ_w = Density of water, kg/m^3
V_A = Volume of aggregate as %
V_B = Volume of binder as %
V_V = Volume of air voids as %

Table-3, Aggregate Gradation Specification (R.A Yamin, 2002)

Sieve size		HRSS	HRSS	HRS	HRS	AC	BC	AC
(mm)	(Inc.#)	A	B	W/C	B/C	W/C	B/C	Base
37,5	1,5							100
25	1							
19	3/4	100	100	100	100	100	90-100	Max. 90
12,5	1/2			90-100	90-100	90-100	Max. 90	-
9,5	3/8	90-100		75-85	65-55	Max. 90	-	-
2,36	#8		75-95	50-72	35-55	28-58	23-49	19-45
0,600	#30			35-60	15-35			
0,075	#200	10-15	8-13	6-12	2-9	4-10	4-8	3-7

The essential thing in this specification is the gradation requirements using the black areas, namely restricted zone is developed to prevent obtaining the asphalt mixture is soft and susceptible to deformation.

With these requirements, the percentage of fine sand to the total usage is limited, The restricted zone gradation for a number types of mixture is listed in Table-4 and can be observed in figure-2.

Table-4, Restricted Zone Gradation
(Kennedy et al, 1991, Mahboub et al, 1990, Hopman et al, 1992, and Oliver, 1994).

Sieve Size		AC	AC	*AC*
(mm)	(inc.#)	W/C	B/C	Base
4,75	No.4			39,5
2,36	No.8	39,1	34,6	26,8-30,8
1,16	No.16	25,6-31,6	22,3-28,3	18,1-24,1
0,600	No.30	19,1-23,1	16,7-20,7	13,6-17,6
0,300	No.50	15,5	13,7	11,4

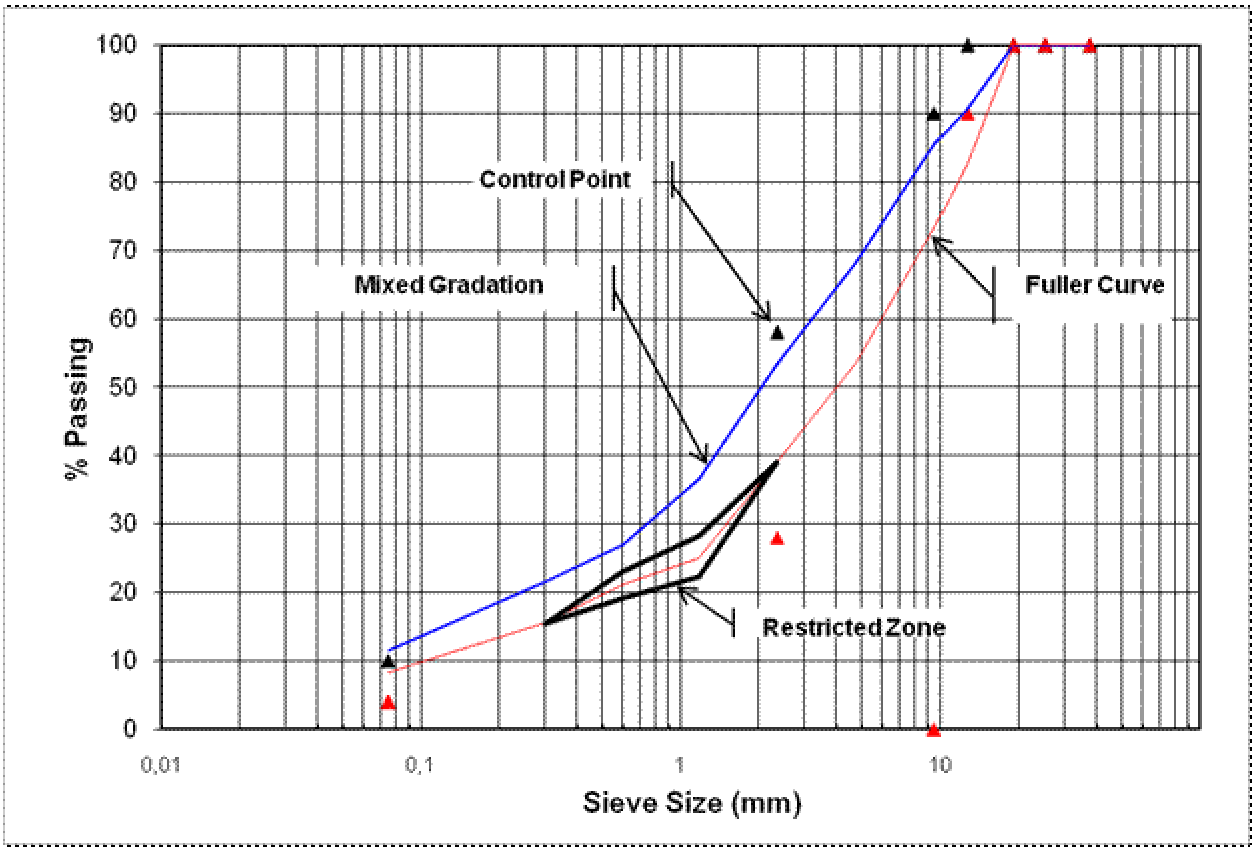

Figure-2, Mix Gradation of Total Aggregat Contains 5% of Sand Fraction (Analysis results)

In the specification of asphalt concrete mixtures performance-based, envelope or gradation tape is not applied as the outer gradation boundary. In this specification the black area or restricted zone is used as developed by SHRP (Strategic Highway Research Program) to prevent obtaining soft of asphalt mixture which is susceptible to plastic deformation, (B. Al-Mistarehi, 2014). For practical reasons, proportions by mass are used to specify a mix for a particular job. Hence, conversions from mass to volume and vice versa are frequently needed and a sound grasp of the important mix parameters is required.

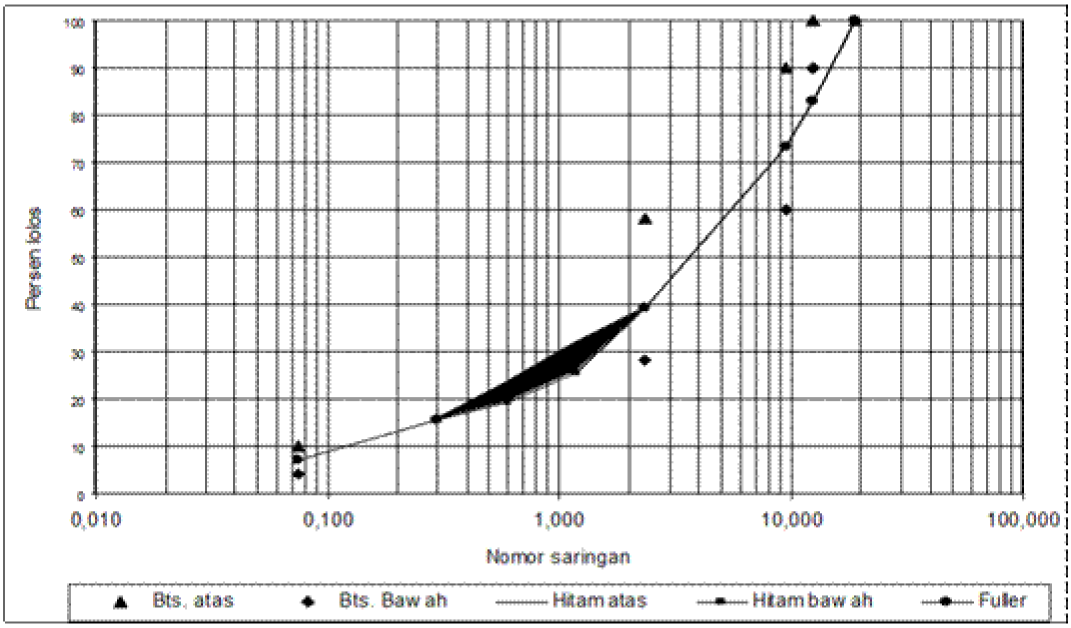

Figure-3, Black Area and Fuller Curve

The volume and mass components of a unit volume of compacted mix are shown in Figure-1. Mistarehi argument did not explicitly mention durability; he concerned that specifications with requirements on both air voids and VFA were too restrictive at higher asphalt contents.

Table-5, Corps of Engineers Marshall Mix Design Criteria

Test Property	Requirement
Stability	500 pounds (min)
Flow	20 (max)
Air voids, total mix	3-5 percent
VFA	75-85 percent
Unit Weight	-

He showed for absorptive aggregates that computed VMA and VFA would be wrong unless the bulk specific gravity was used in the calculations.

McFadden and Ricketts (1948) presented the Corps of Engineers (COE) version of the Marshall method for design and field control of paving, which used the five parameters shown in Table 5 to determine the design asphalt content. The peak values of all parameters except flow were averaged to determine the design asphalt content. The shift towards a minimum VMA requirement began in the mid-1950s. McLeod (1955) presented his initial analysis on “the voids properties of compacted paving mixtures,” in which he laid out the basic principles of a minimum VMA requirement.

Table-6, Asphalt Concrete Mixture Specification

Item	Heavy Vehicle (2x75 blows)		Moderate Vehicle (2x50 blows)		Light Vehicle (2x35 blows)	
	Min	Max	Min	Max	Min	Max
Stability (kg)	550	-	450	-	350	-
Flow (mm)	2	4	2	4,5	2	5
VIM (%)	3,0 – 5,0					
Marshall Quatient (kg/mm)	200 – 350					
Density (gr/cm^3)	2	-	2	-	2	-
VFA (%)	75	82	75	85	75	85
VMA (%)	Presented in Table-7					
Soaked Index	75	-	75	-	75	-

In recent years, some researchers have presented concerns that these minimum VMA requirements are too restrictive and may rule out economical mixes with acceptable performance properties. Others point out that evaluating and selecting the aggregate gradation to achieve a minimum VMA is the most difficult and time-consuming step in the Superpave mix design process. Others suggest it is not applicable to all asphalt mixtures and propose refinements to it (Kandhal, P.S et al (1996, 1998), Mallick, R.B et al (2000).

Table-7, Minimum Values of VMA, (H.N.Atkins, 1997)

Maximum Nominal Aggregate Size		Minimum Values of VMA (%)
Diameter (mm)	Sieve Size	
1.18	No.16	23,5
2,36	No.8	21
4,75	No.4	18
9,52	3/8 inch	16
12,7	1/2 inch	15
19,1	3/4 inch	14
25,4	1 inch	13
38,1	1 1/2 inch	12
50	2 inch	11,5
63	2 1/2 inch	11

Because experience was usually the critical factor, regardless of approach, they usually resulted in similar mix designs. Usually, the aggregate gradation was determined by specification, by locally available materials, or by theoretically “idealized” gradations Brian J. Coree (2000). VMA is the area between the combined aggregate particles and the air filled with asphalt effective . VMA value needs to be known in order to guarantee the availability of the thickness of the asphalt mixture blanketed aggregate so durability is achieved . Transmitted by Hmoud (2011) emphasized the importance of maintaining the value VMA asphalt mixture is a combination of air cavities and content of asphalt.

Coree BJ (2000) conducted a mixture of asphalt mix design in the laboratory using three aggregate maximum size 19 , 12.5 and 9.5 mm for the minimum VMA values that meet the specifications , as well as the bulk specific gravity (G_{mb}) and the theoretical maximum specific gravity (G_{mm}). It is known that the condition of volumetric HMA is influenced by the maximum size of aggregate, gradation, shape and texture of the aggregate .

J.W. Nelson (2005) compared the effect of the use of 9.5 mm maximum aggregate and sand (according to him, would affect the effective density gradation and aggregate mixture , Gse) in a mixture of Superpave and Marshall mix , the result is higher VMA Superpave mix , but otherwise VMA greater in Marshall mixture of sand when the percentage of 13 %. Zanariah (2006) stated that in addition to asphalt and VFA levels , VMA is an important factor that determines the nature - the volumetric properties of asphalt mixture . VMA parameters have been used in the mix design Supervape to reduce the possibility of bad performance .

RESEARCH METHOD

Prior to the main research, laboratory tests have been done on aggregates of several quarries, namely; Suluri, Wuno, Matampondo, and Lolioge river to determine the material of the highest quality in terms of specific gravity and absorption, abrasion, and the bearing capacity of the unbound base material. It was proved that the material of Lolioge river has been the best quality.

To determine the performance of asphalt concrete mix using Lolioge materials, it is necessary to include the methods of analysis;

1. Aggregate Technical and Quality Testing, which includes testing of coarse aggregate, fine aggregate, dust, sand and asphalt as well are presented in table-1 and table-2.
2. Mechanical Testing of Materials is the mechanical properties of the material, which showed resistance to plastic deformation. Coarse aggregate in particular, is expected to have a resistance to the destruction or breakdown due to mechanical processes that occur during the execution of road construction (piling, spreading and compacting), the traffic load and chemical processes, such as the influence of moisture, heat, and temperature changes throughout the day. Mechanical testing of coarse aggregate is done by using the Abrasion Test Machine Los Angelos. Its value is the value that indicates abrasion resistance against the destruction of the coarse aggregate (degradation) due to mechanical loading.
3. Determiming mixed aggregat gradation

Table-8, Weight of Aggregate Fractions and Asphalt at Each of Sand Variations

Weight of Aggregate Fractions and Asphalt (gram)						
Sand (0 %)						
Asphalt Content (%)		5	5,5	6	6,5	7
Fraksi ¾	15	165	165	165	165	165
Fraksi 3/8	45	495	495	495	495	495
Dust	40	440	440	440	440	440
Sand	0	0.0	0.0	0.0	0.0	0.0
Aspal		57.9	69.8	76.6	83.4	88.4
Sand (5 %)						
Asphalt Content (%)		5	5,5	6	6,5	7
Fraksi ¾	10	110	110	110	110	110
Fraksi 3/8	35	385	385	385	385	385
Dust	50	550	550	550	550	550
Sand	5	55	55	55	55	55
Aspal		57.9	69.8	76.6	83.4	88.4
Sand 10 %						
Asphalt Content (%)		5	5,5	6	6,5	7
Fraksi ¾	5	55	55	55	55	55
Fraksi 3/8	40	440	440	440	440	440
Dust	45	495	495	495	495	495
Sand	10	110	110	110	110	110
Aspal		57.9	69.8	76.6	83.4	88.4
Sand 15 %						
Asphalt Content (%)		5	5,5	6	6,5	7
Fraksi ¾	1	11	11	11	11	11
Fraksi 3/8	38	418	418	418	418	418
Dust	46	440	440	440	440	440
Sand	15	165	165	165	165	165
Aspal		57.9	69.8	76.6	83.4	88.4
Sand 18 %						
Asphalt Content (%)		5	5,5	6	6,5	7
Fraksi ¾	0	0.0	0.0	0.0	0.0	0.0
Fraksi 3/8	40	440	440	440	440	440
Dust	42	440	440	440	440	440
Sand	18	220	220	220	220	220
Aspal		57.9	69.8	76.6	83.4	88.4

R.A Yamin, (2002) reported that in the determination of the composition of the asphalt mixture using the Trial and error Method, starting with the filtering each aggregate fraction using a set of sieves according to the specification, when the composition of every size is known, then the composition of aggregate is determined and the result is compared with the required gradation. If the aggregate composition has met specifications, followed by determination of the weight of each fraction, including asphalt content of each speciment.

According to T.P. Teng, (2001) that the determination of the proportion based on By Portion Method is recommended due to difficulty in establishing asphalt concrete mixtures in the field to provide each of aggregate diameter as listed in the specification. Freddy J et al, (2007) review that material mixing asphalt concrete aggregate fraction based on availability at the stone crusher, such as the fraction ¾ ", the fraction ½", the fraction 3/8" dust fraction and filler. Accoding to him that mix design procedure is used to determine aggregate gradation and optimum asphalt content with regard to the requirements of the gradation limit and air void to be achieved. Asphalt content in the mixture between 4% - 7%. Initial estimates of the optimum bitumen content can be obtained by using the following empirical formula as equation (11). where: Pb = Asphalt Content, CA = Coarse Aggregate, FA = Fine Aggregate, constant value of C has a value of 0.5 – 1.0 for Asphalt Concrete is of 0.5% - 1%. Once estimated asphalt content obtained, its variation with a range of values above and below 2 levels is adjusted to ± 0.5%. (R.A Yamin, 2002).

$$Pb = 0{,}035\ (\%CA) + (0{,}045\ (\%FA)) + 0{,}18\ (\%\ Filler) + C \quad \text{............... ....}(11)$$

RESULT AND DISCUSSION

Superiority of Lolioge Aggregates Proportis

The pavement distress depends on the characteristics of pavement layer such as thickness and quality of the material, the traffic load and the environmental conditions. Several factors affect the aggregates quality of an quarry is; gravity and absorption, abrasion value, and carrying capacity (L.A Khateeb et al, 2011). Hence, based on the above statement, specific gravity and absorption, as well as abrasion testing were conducted to determine the quality of an individual aggregate, while the CBR test was intended to determine the bearing capacity of material mixture of coarse aggregate, fine aggregate, and filler from the four sources of the material. Laboratory test results are presented in Table-9.

Table-9, Values of Specific Gravity and Absorption, Abrasion, and CBR of Several Quarries

No	Quarry Material	Type of Aggregate	Bulk Specific Gravity	Absorption (%)	Abrasion Values (%)	CBR of Unbound Base Layer (%)
1	Suluri River	Coarse	2,203	1,411	36.79	87.195
		Fine	2,403	2,166		
2	Wuno (Tulo) River	Coarse	2,408	0,959	35.38	88.51
		Fine	2,470	1,574		
3	Matampo ndo River	Coarse	2.621	0.86	35.86	90.265
		Fine	2,630	0,878		
4	Loli Oge River	Coarse	2,770	0,575	20.44	96.835
		Fine	2,714	0,806		

It can be observed from the above table that the specific gravity of coarse aggregate and fine aggregate taken from the Lolioge River is the highest. This illustrates that this river material is denser, and fewer air void compared to material from three other sources. With lower air void means that rate of absorption of water or other liquid material is low.

In Table-10 the results of laboratory tests showed that the highest specific gravity is a fraction of CA 3/8 ", which is greater in average of 2.9 % than the density of CA 3/4" fraction, while the dust and sand fractions as fine aggregate fractions have lower specific gravity.

By trial and error method, mixing of the four aggregate fractions in Table-10 (where the percentage of sand fraction is 0%, 5%, 10%, 15% and 18% respectively) to perform gradations of asphalt concrete that fulfill; specification as in the Table-3, restricted zone gradation in the Table-4, and the Figure-3, it was resulted in specific gravity of aggregate mixtures as listed in the Table-11.

Table-10, Specific Gravity of Loli Oge Aggregates and Sand

Agg. Fractions	Bulk	SSD	App
CA, 3/4"	2,743	2,762	2,797
CA, 3/8"	2,824	2,843	2,878
Dust	2,558	2,628	2,751
Sand	2,626	2,671	2,737

Based on the five types of planned aggregate mixtures in this study, by using equations 4 and 7, mixture with sand content of 0% yielded a Gse with the largest value ie 2.757 and the smallest of 2.731 was 15% of sand content. Value of all Gse mixtures are presented in Table-11. Analysing the Gse values on this table, it was observed that the amount of Gse value was strongly determined by the percentage of the aggregate fraction with the largest specific gravity ie the of 3/8" and of 3/4" fractions. If one or sum of these two fractions resulted in the biggest percentage (ie when percentage sand of 0 %, the sum of the fraction 3/8" and 3/4" was 60%), it was ascertained that the resulting value of Gse will be the biggest, and vice versa.

Table-11, Specific Gravity of Mixed Aggregates at Each of Sand Composition

Agg. Fractions	Sand Composition in Mixture				
	0%	5%	10%	15%	18%
Fraksi ¾	15	10	5	1	0
Fraksi 3/8	45	35	40	38	40
Dust	40	50	45	46	42
Sand	0	5	10	15	18
Total	100	100	100	100	100
CA, FA, and FF Composition					
CA, %	52,77	46,62	49,70	49,34	52,33
FA, %	36,93	41,83	39,38	39,67	37,30
FF,%	10,30	11,55	10,93	10,99	10,37
Specific Gravity of Mixed Aggregates					
Gsb	2,700	2,667	2,675	2,666	2,671
Gsa	2,814	2,798	2,801	2,796	2,798
Gse	2,757	2,733	2,738	2,731	2,734

After completing the design of mixed aggregate gradation of AC-WC mixture using trial and error method that fulfilling the specifications requirement in Table 3 and Table-4 then the Gse values as in Table-11 were resulted. Further mixing these aggregates with binder, heating, compacting, and analysing their volumetric based on equation-6 and the AASHTO PP19-93 (Practice for Volumetric Analysis of Compacted Hot Mix Asphalt). From this the VMA values are known at every level of the asphalt mixture as shown in Table-12 .

Table-12, Test Result of VMA at Each of Gse values and Asphalt Variations

Sand Variation	Gse	Asphalt Content (%)				
		5	5,5	6	6,5	7
0%	2,757	20,536	19,833	19,166	18,907	18,982
5%	2,733	20,712	20,291	20,166	20,185	20,714
10%	2,738	21,670	20,761	20,227	19,048	19,735
15%	2,731	21,323	20,827	20,638	19,596	20,066
20%	2,734	20,882	20,315	20,568	20,657	20,848

Source : Result analysis

Effect of Gse on VMA

Gse value of aggregate mixture is determined not only by the bulk specific gravity and apparent specific gravity, but also influenced by composition of each fraction of the aggregate mixture. Five percentage variations of sand ie 0%, 5%, 10%, 15%, and 18% have been used in the mixed aggregate resulted in five different Gse value as presented in Table-11. Effect of the Gse value on VMA of dense asphalt mixture at each of asphalt content are summarized in the figure-4:

Based on Figure-3 some important notes were recorded below:

1. For all levels of bitumen content there was a tendency for impairment of VMA with increasing of Gse value.
2. The VMA values were correlated with the values of the Gse in two types, (i) the relationship was strong marked with a coefficient of determination (R^2) nearly 1, and (ii) the relationship weaker if the coefficient of determination was far away from 1.

3. The strongest correlation was seen at 6% of bitumen content with R2 = 0.907, while the weakest one was occurred at 6,5% of bitumen content with R2 = 0,42.

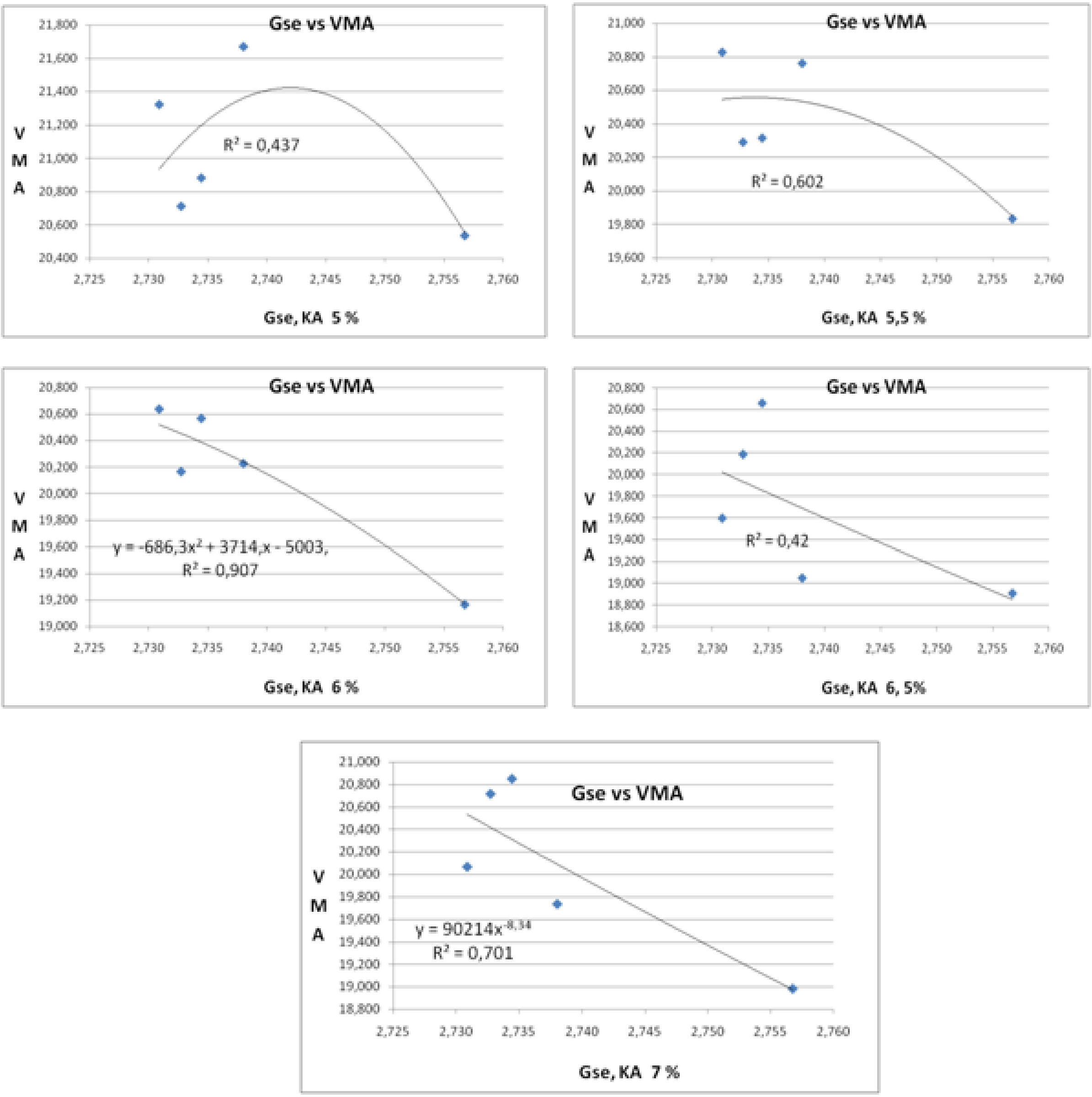

Figure-4, Correlation between VMA and Gse at each of Asphalt Content

Effect of Asphalt Content on VMA at Each of Gse

Five different aggregate mixture gradations have been determined through the method of trial mix. Later, by using equation-13, on the basis of these gradations 5 Gse values obtained. Soon after hot mixing of the combined aggregat with appropriate asphalt, laboratory compaction and volumetric analysis of the asphaltic materials are carried out in such away the VMA value at every level of asphalt content determined using the equation-6. VMA relationship with bitumen content at each of Gse presented in figure-5. As a result of observation on the Figure-5, a number of remarks may be noticed ie;

1. At each value of Gse , the change of asphalt content causes change in the value of VMA asphaltic mixture.
2. At some values of Gse (ie 2.757, 2.738, and 2.731) in case of asphalt content is increasing will result in decreasing of the VMA values.

At the value of Gse = 2.734 and 2.733, VMA are initially decreasing in line with increasing the level of asphalt. However, by continuous increase of bitument content the VMA values will increase as well.

DISCUSSION

Based on the several laboratory experiments and research analysis, some important issues may be featured as:

1) Excellence of Lolioge materials of Palu city compared to aggregate material from other quarries are based on

measurements of engineering properties ie bulk specific gravity, absorption (%), abrasion values (%) and CBR of unbound base layer (%) as presented in tabel-9.

2) The highest specific gravity was a fraction of CA 3/8 ", which was greater in average of 2.9 % than the density of CA 3/4" fraction, while the dust and sand fractions as fine aggregate fractions had lower specific gravity.

3) The Gse was strongly determined by the percentage of the aggregate fraction with the largest specific gravity ie the of 3/8" and of 3/4" fractions. If one or sum of these two fractions resulted in the biggest percentage (ie when percentage sand of 0 %, the sum of the fraction 3/8" and 3/4" was 60%), it was ascertained that the resulting value of Gse will be the biggest, and vice versa.

4) For all levels of bitumen content there was a tendency for impairment of VMA with increasing of Gse value.

5) At each value of Gse, the change of asphalt content causes change in the value of asphaltic mixtures VMA.

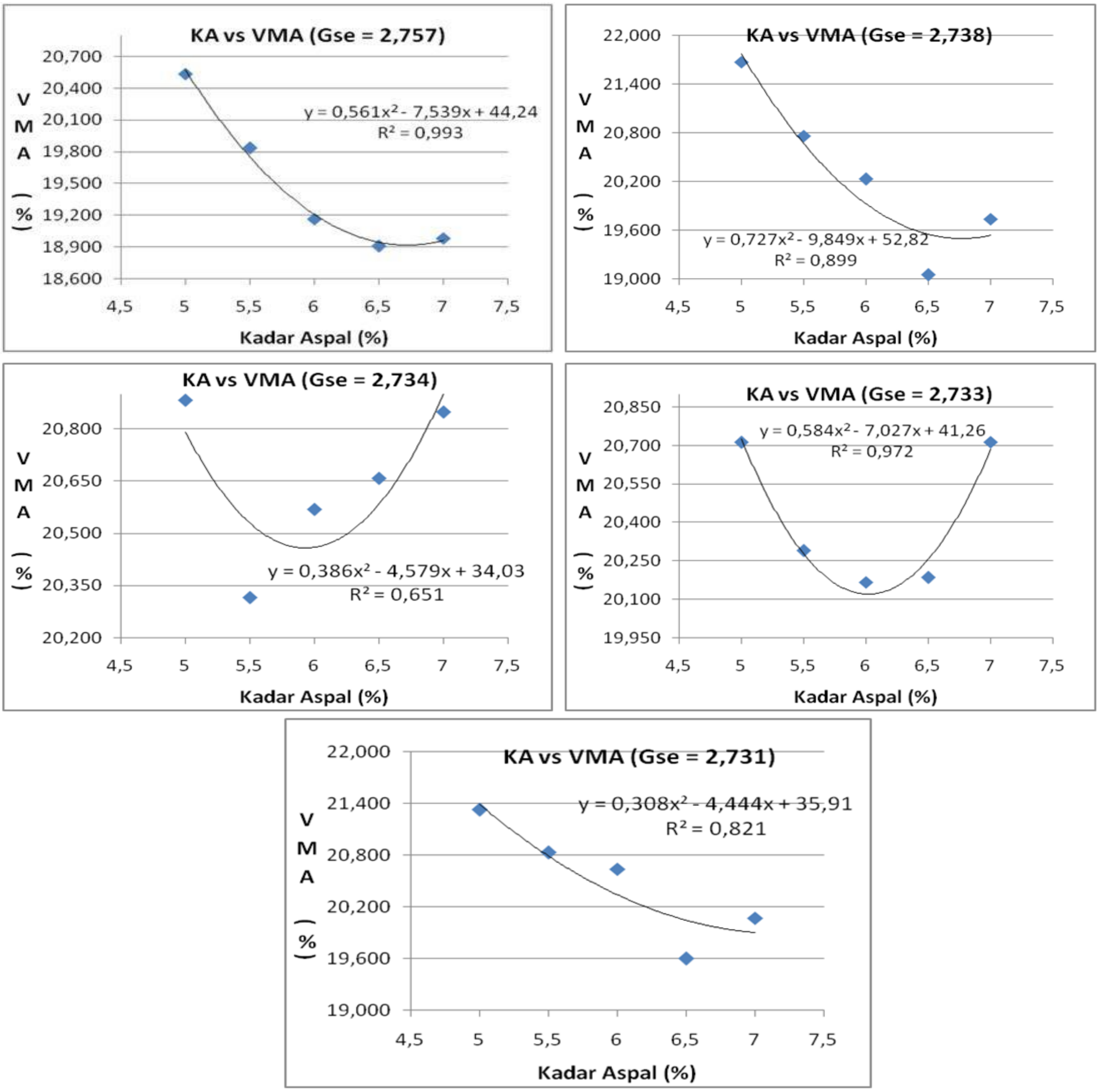

Figure - 5, Correlation between asphalt Content and VMA at each of Gse

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