Assessing the Impact of Aggregate Quality on Flexible Pavement Perfotmance

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Abstract
The construction of cost-effective flexible road pavements is depend on appropriate design and using quality materials for pavement construction. Road Flexible pavements are intended to limit the stress created at the subgrade level by the traffic traveling on the pavement surface, so that the subgrade is not subject to significant deformations. At the same time, the pavement materials themselves should not deteriorate to such an extent as to affect the riding quality and functionality of the pavement. These goals must be achieved throughout a specific design period. Pavements do deteriorate, however, due to, several factors can affect the pavement performance. Among these factors quality of materials and its deviation from specification. The objective of this research is, to assess the effects of aggregate quality on pavement performance in Jimma zone; this was achieved by conducting laboratory tests which were started visiting quarry sites and pavement aggregate production sites, then samples was extracted and brought to Ethiopian Road Construction Corporation laboratory, where qualities of aggregates investigated and finally marshal mix design were taken place.There are two source of aggregates for wearing course and one source also for base course aggregate. Aggregates from both sources each have its own deficiency in size distribution (gradation), in some basic properties of an aggregate supposed to be and with sever temperature the hot mix asphaltnot strong enough to resist the upcoming traffic loads, and these problems leads to the pavement not perform with expected durability, skid resistance and fatigue resistance, impose their impact on pavement performance or durability of the pavement.
Keywords: - Absorption; Particle Shapes; Pavement Performance; Size Distribution; Strength.

1. Introduction

Road Flexible pavements are intended to limit the stress created at the subgrade level by the traffic traveling on the pavement surface, so that the subgrade is not subject to significant deformations. In effect, the concentrated loads of the vehicle wheels are spread over a sufficiently larger area at subgrade level. At the same time, the pavement materials themselves should not deteriorate to such an extent as to affect the riding quality and functionality of the pavement. These goals must be achieved throughout a specific design period[1]. Pavements do deteriorate, however, due to time, climate and traffic. Therefore, the goal of the pavement design is to limit, during the period considered, deteriorations which affect the riding quality, such as, in the case of flexible pavements, cracking, rutting, potholes and other such surface distresses to acceptable levels. The design method aims at producing a pavement which will reach a relatively low level of deterioration at the end of the design period, assuming that routine and periodic maintenance are performed during that period[1].

1.1. Objectives

- To identify the sources of aggregates and their engineering properties;
- To determine the quality of aggregates and compare with standard specification;
- To determine Marshall mix design using the aggregates and assess the effects on pavement performance;

1.2. Scope and limitation of the study

The paper was focused on aggregates used in base courses and wearing courses of flexible pavement roads in Jimma zone, for aggregates used in flexible pavement construction in another area than stated area, may not applicable but it may be used as reference.

1.3. Significance of the research

These research provides important answer for controversies, about the materials, especial aggregates used in road pavements in study area. And knowing the effects of quality of aggregates on pavement performance, enable pavement specialist to build smooth, cost effective, and long-lasting pavement that requires little maintenance and satisfies user needs. To have an understanding or awareness about the qualities of aggregate around Jimma zone.

2. MATERIALS AND METHODOLOGY

2.1. Sampling procedure and data analysis

Aggregate sampling has been conducted according the sampling methods of (ASTM D 75) and(AASHTO T 2). The following laboratory tests has been taken place in Ethiopian Road Constriction Corporation material and testing laboratory. After conducting the tests listed below data was analyzed for further investigation the results (data analysis, see appendix (1-5))

Table 3-1laboratory tests taken place

A} Tests on Aggregates	Reference to test methods
Flakiness Index (FI)	[16]
Aggregate Crushing Value (ACV)	[7]
Aggregate Impact Value (AIV)	[17]
Los Angeles Abrasion Test (LAA)	AASHTO T 96
Specific Gravity and Absorption of Fine Aggregate	AASHTO T 84
Specific Gravity and Absorption of Coarse Aggregate	AASHTO T 85:
Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates	AASHTO T 84[18]
B} Asphalt concrete mix tests	Reference to test methods
Marshall Mix Design	ASTM D1559-89
Bulk Density of Saturated Surface Dry Asphalt Mix Samples	ASTM D2726-96
Calculation of Void Content in Bituminous Mixes	ASTM D3203
Marshall Test	ASTM D1559-89

3 Analysis and Discussion

3.1. Aggregates from Babu's aggregate production site for wearing course

3.1.1. Sieve analysis or gradation

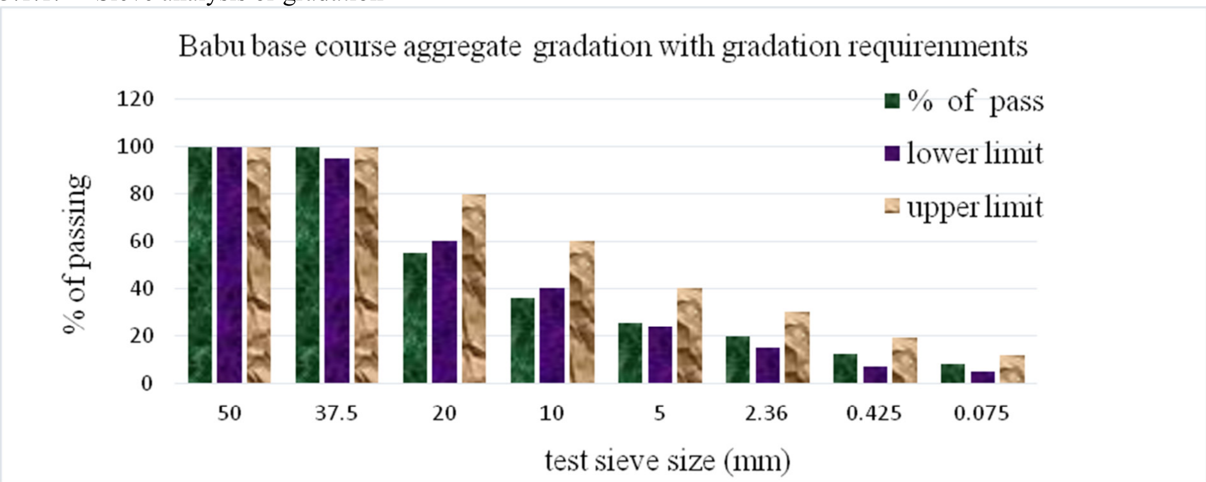

Figure 4-1 Babu base course aggregate gradation with ERA gradation requirement

Figure 4-1, figure 4-2 and table 4-6 shows that the size distribution of within the requirement (except sieve 10mm & 20mm this means base course aggregate has a deficiency coarse aggregate or coarser aggregates are not sufficient, because it is clearly indicates that the gradation requirement of for special higher sieve sizes or coarser aggregates are lower than the lower limit).

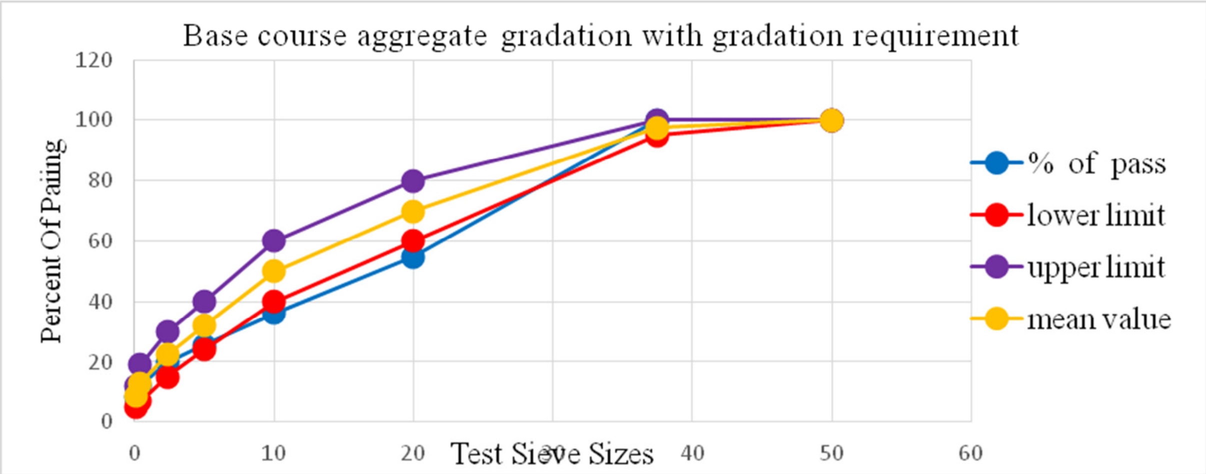

Figure 4-2Babu base course aggregate gradation with ERA gradation requirement

Whereas the amount of aggregate particles (the fine aggregates of base course aggregate fulfills the requirements it needs necessarily) that able passing the sieve size 0.425mm is sufficient because meeting the grading requirement of the size.

3.1.1.1. Summary of basic properties of Babu Aggregates for base course

No	Property	Babu aggregate for base course aggregate	ERA specification	Remarks
1	Particle shape Flakiness index	34%	< 35per cent <30% preferably	ok but not in a preferably position
2	ACV	36%	< 25 or <29	Not good in strength
3	AIV	13%	< 25	Ok
4	Hardness/toughness or abrasion	19%		

3.1.2. Aggregates from Enkulu's aggregate production site for wearing course

3.1.2.1. Sieve analysis or gradation

Table 4-1 sieve analysis of (3/4) aggregate which Enkulu aggregate production site.

Sieve size mm	Retained gm.	% of Retained	wt. of pass	% of Pass	Specification limit
25	0	0	5050	100	100
19	151.5	3	4898.5	97	85-100
13.2	2833.05	56.1	2065.45	40.9	71-84
9.5	1338.25	26.5	727.2	14.4	62-76
4.75	671.65	13.3	55.55	1.1	42-60
2.36	15.15	0.3	40.4	0.8	30-48
1.18	5.05	0.1	35.35	0.7	22-38
0.6	5.05	0.1	30.3	0.6	16-28
0.3	0	0	30.3	0.6	12--20
0.15	0	0	30.3	0.6	8--15
0.075	5.05	0.1	25.25	0.5	4--10
pan	25.25	0.5			

3.1.2.2. Summary of Enkulu's aggregate properties with respect to ERA wearing course aggregate specifications

Table 4-2 summary of Enkulu's aggregate properties with respect to ERA wearing course aggregate specifications

No	Property	Enkulu aggregate Coarse aggregates (3/4 and 3/8)	ERA specification	Remarks
1	Cleanliness	0.56%[19]	< 5 per cent passing	Ok
2	Particle shape Flakiness test	22%	< 45 per cent	Ok
3	Strength			
	1 ACV	16%	< 25%	Ok
	2 AIV	16%	< 25%	Ok
	3 LAAV	15%	< 30%	Ok
4	Hardness/toughness or abrasion	15%	<15 or <12 for heavy traffic	Ok
5	Polishing	Not tested because no polishing machine in the lab	Not less than 50-75 (depending on location	
6	Durability	Not tested because unavailability of sodium sulphate or magsium sulphate solution and economic limitation, even though for wearing course the aggregate temperature during Marshall mix is high(170ºc) no room for thawing and freeze.	< 12 per cent < 18 per cent	Not necessary for wearing course
7	Water absorption	1. for 3/4 Enkulu aggregate is 1.89 2. for 3/8 Enkulu aggregate is 2.09	< 2 per cent	3/4 ok but 3/8 not ok

3.2. Hot mix asphalt results and discussion

3.2.1. Aggregate blending for mix design

Table 4-3 proportioning or blending Babu Aggregate for marshal mix design

Materials used	3/4 aggregate		3/8 aggregate		fine aggregate		filler material				
	Proportioning or blending Babu aggregate for marshal mix design										
	25%		20%		20%		35%				
sieve mm	% pass	% blend	% pass	% blend	% pass	% blend	% pass	% blend	total blend	target value	design range
25	100	25	100	20	100	20	100	35	100	100	100
19	96.08	24.02	100	20	100	20	100.00	35	99.02	92	85-100
13.2	25.78	6.45	100	20	100	20	100.00	35	81.45	77	71-84
9.5	3.95	0.99	69.83	13.97	100	20	100.00	35	69.95	69	62-76
4.75	2.46	0.62	5.25	1.05	97.95	19.59	100.00	35	56.26	51	42-60
2.36	2.31	0.58	2.27	0.45	60.30	12.06	87.65	30.68	43.77	34	30-48
1.18	2.25	0.56	2.21	0.44	31.57	6.314	56.65	19.83	27.15	30	22-38
0.6	2.23	0.56	2.17	0.43	17.13	3.426	37.51	13.13	17.55	22	16-28
0.3	2.22	0.56	2.14	0.43	10.12	2.024	25.73	9.01	12.01	16	12--20
0.15	1.23	0.31	2.12	0.42	7.13	1.426	18.50	6.47	8.63	12	8--15
0.075	1.11	0.28	2.10	0.42	5.71	1.142	13.76	4.82	6.66	7	4--10

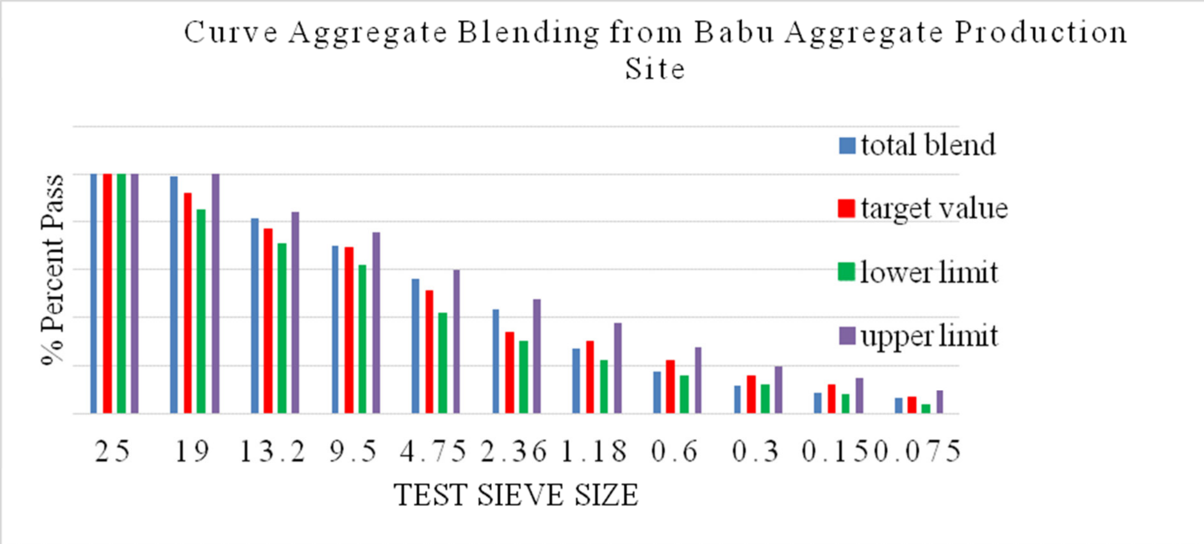

Figure 4-3Gradation of total aggregate blend with respect to lower and upper limit

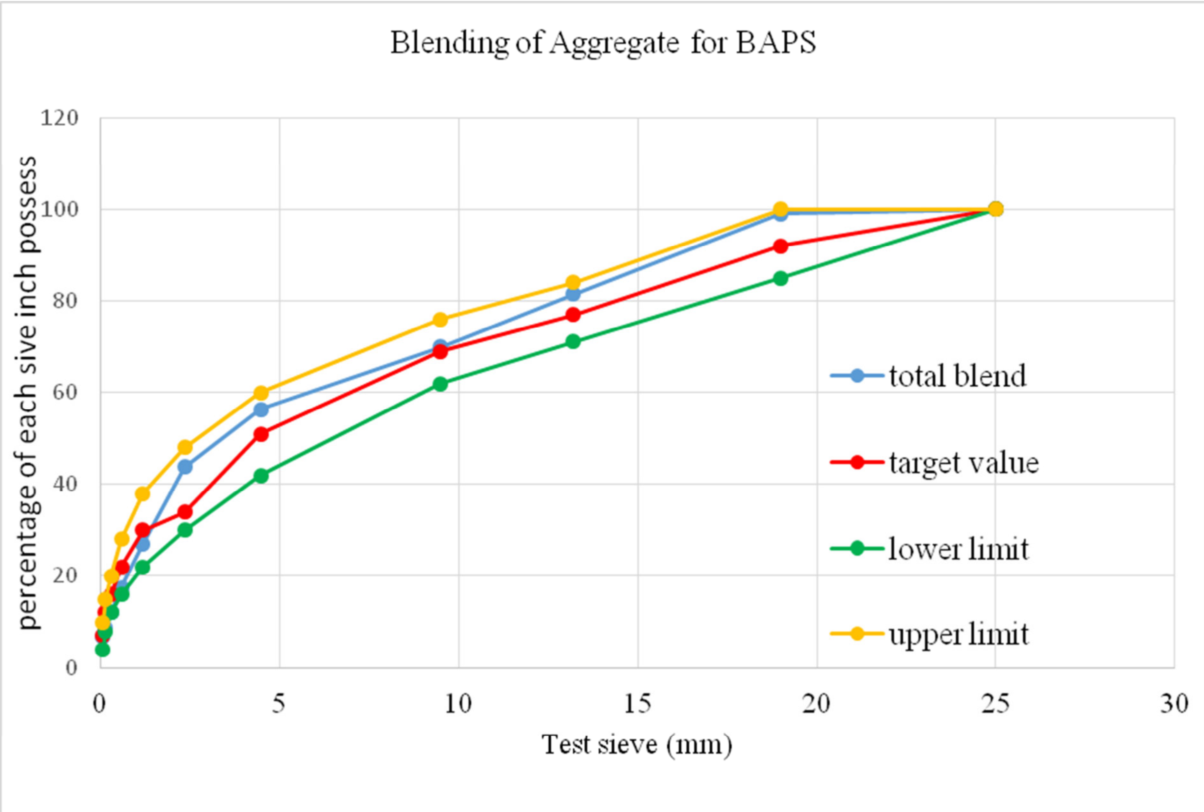

Figure 4-4 Gradation of total aggregate blend with respect to lower and upper limit

Figure 4-4 and 4-5, shows that size distribution of blending Babu Aggregate, it shows the gradation of Babu aggregate looks like with comparing with lower, target value and upper limit gradation requirements.

3.2.2. Enkulusources of aggregate

3.2.2.1. Aggregate blending for mix design

Table 4-4proportioning or blending Enkulu aggregate for marshal mix design

Materials used	3/4 aggregate		3/8 aggregate		fine aggregate		filler material				
	proportioning or blending Enkulu aggregate for marshal mix design										
	22%		20%		20%		38%				100%
sieve mm	% pass	% blend	% pass	% blend	% pass	% blend	% pass	% blend	total blend	Target value	design range
25	100	22	100	20	100	20	100	38	100	100	100
19	97.0	21.34	100	20	100	20	100.00	38	99.34	92	85-100
13.2	40.9	9.00	100	20	100	20	100.00	38	87.00	77	71-84
9.5	14.4	3.17	99.6	19.92	100	20	100.00	38	81.09	69	62-76
4.47	1.10	0.24	22.0	4.4	89.60	17.92	100.00	38	60.56	51	42-60
2.36	0.80	0.18	10.8	2.16	45.60	9.12	87.65	33.31	44.76	34	30-48
1.18	0.70	0.15	7.30	1.46	28.90	5.78	56.65	21.53	28.92	30	22-38
0.6	0.60	0.13	5.30	1.06	19.50	3.9	37.51	14.26	19.35	22	16-28
0.3	0.60	0.13	4.00	0.8	13.30	2.66	25.73	9.78	13.37	16	12--20
0.15	0.60	0.13	3.20	0.64	9.80	1.96	18.50	7.03	9.76	12	8--15
0.07	0.50	0.11	2.50	0.5	7.50	1.5	13.76	5.23	7.34	7	4--10

Table 4-18 shows that, blending Enkulu Aggregates based on sieve analysis of each type of the crushing plant products (3/4, 3/8, fine and filler aggregates) using their percentage of pass.

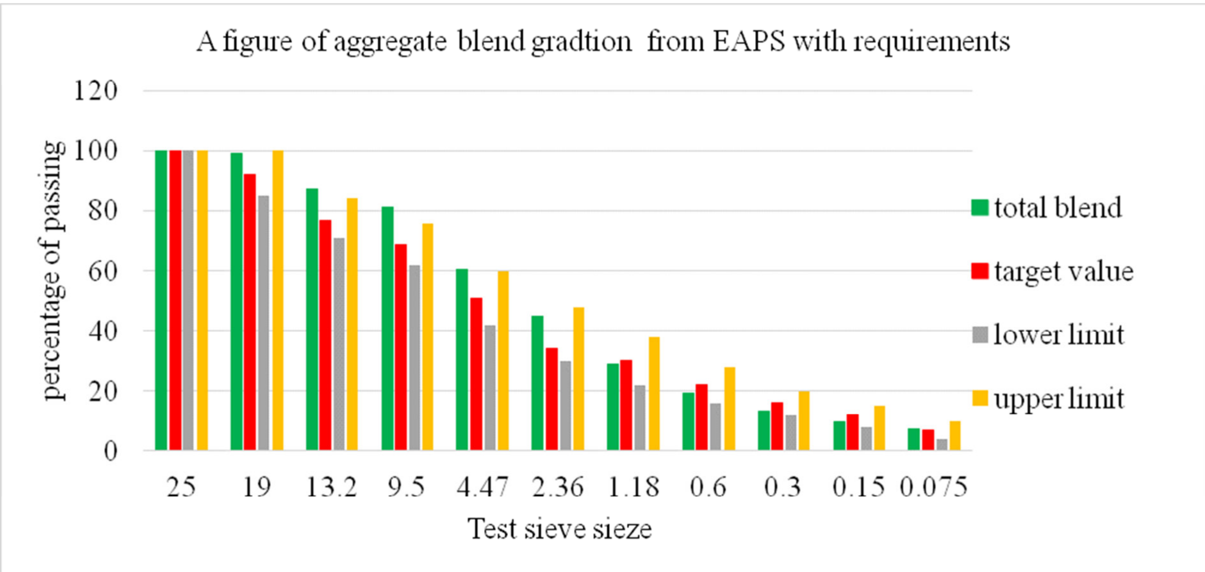

Figure 4-5Gradation of total aggregate blend with respect to lower and upper limit

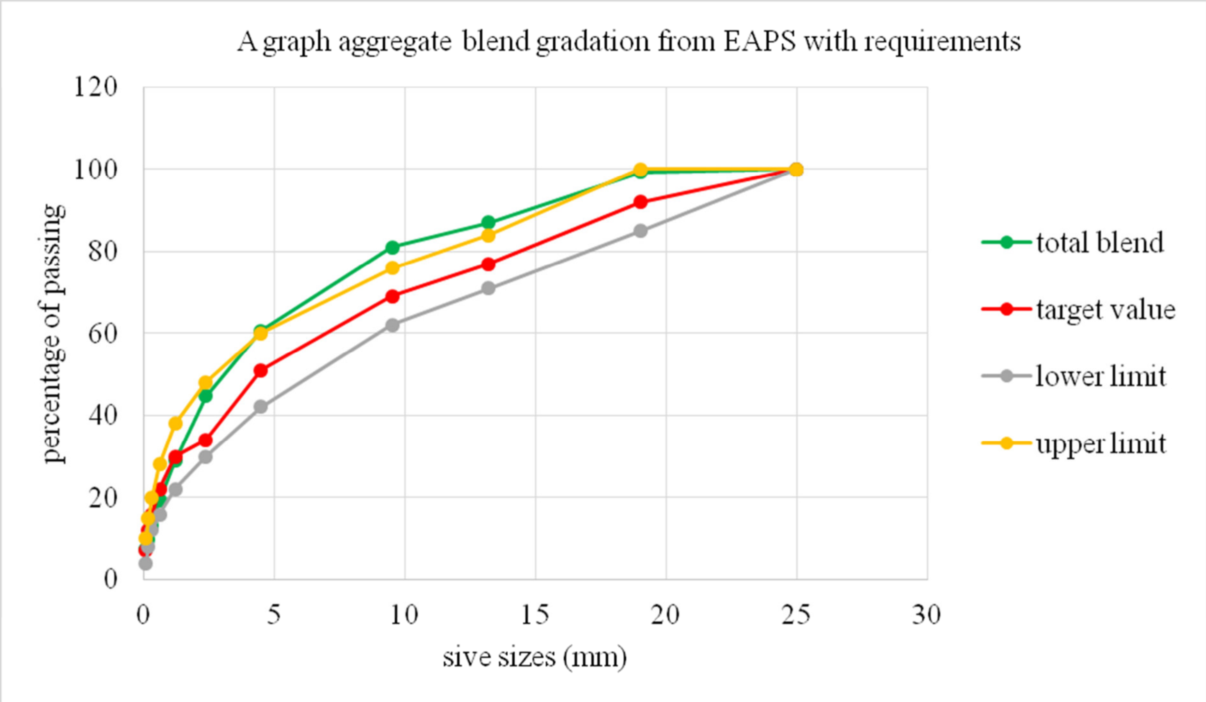

Figure 4-6 Gradation of total aggregate blend with lower and upper limit

Figure 4-6 and 4-7, shows that size distribution of blending Enkulu Aggregate, to see how it looks like while comparing with lower and upper limit of gradation requirements and in the blending the sieves with higher sizes have high amount of passage,

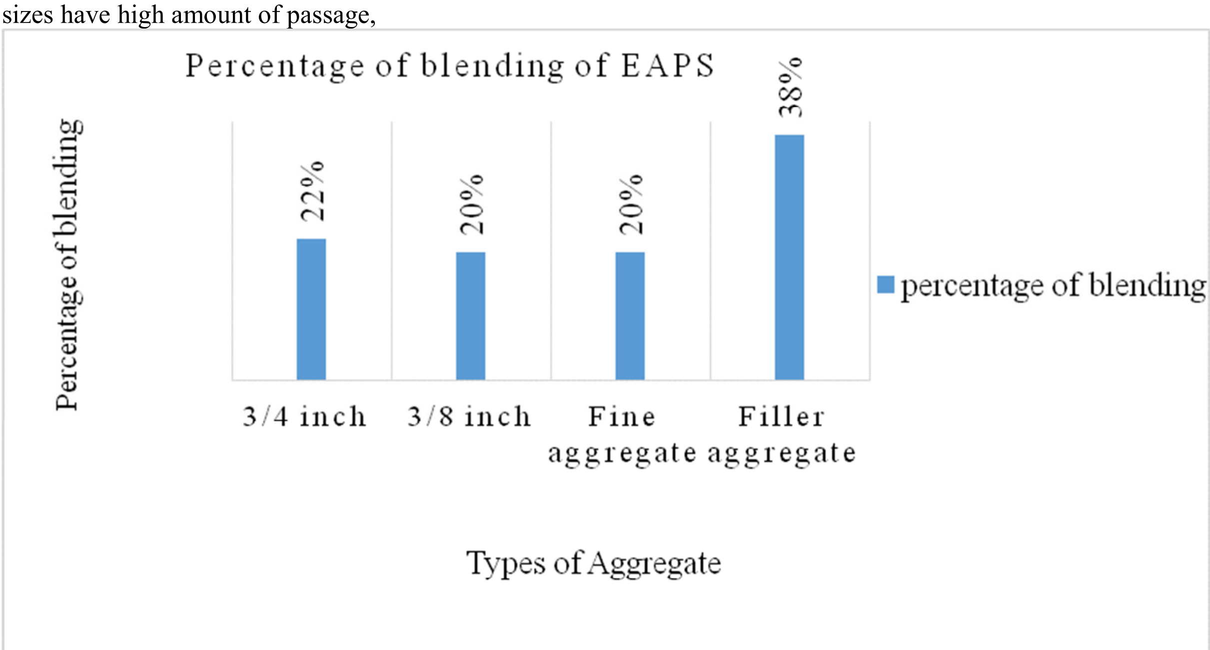

Figure 4-7 Percentage of each types of aggregate blending graphical

Table 4-5 proportioning or blending Enkulu aggregate retained

Materials used	3/4 aggregate		3/8 aggregate		fine aggregate		filler material				
	proportioning or blending Enkulu aggregate for marshal mix design										
	22%		20%		20%		38%				100%
sieve mm	% retained	% blend	% retained	% blend	% retained	% blend	% retained	% blend	total blend gm.	target value	design range
25	0	0	0	0	0	0	0	0	0	100	100
19	3.00	0.66	0.00	0	0.00	0	0.00	0	7.92	92	85-100
13.2	56.1	12.3	0.00	0	0.00	0	0.00	0	148	77	71-84
9.5	26.5	5.83	0.40	0.08	0.00	0	0.00	0	70.9	69	62-76
4.47	13.3	2.92	77.6	15.5	10.40	2.08	0.00	0	246	51	42-60
2.36	0.30	0.06	11.2	2.24	44.00	8.8	12.4	4.69	189.6	34	30-48
1.18	0.10	0.02	3.50	0.7	16.70	3.34	31.00	11.78	190.1	30	22-38
0.6	0.10	0.02	2.00	0.4	9.40	1.88	19.14	7.27	114.8	22	16-28
0.3	0.00	0	1.30	0.26	6.20	1.24	11.79	4.47	71.74	16	12--20
0.15	0.00	0	0.80	0.16	3.50	0.7	7.23	2.74	43.29	12	8--15
0.075	0.10	0.022	0.70	0.14	2.30	0.46	4.73	1.79	29.05	7	4--10
pan									88		

Table 4-19, shows percentage of for each type of aggregate for each sieve size and the blend value shows that the percent retained multiplied by the 1200gm of weight of aggregates for the Marshall Mix specimen.

3.2.2.2. Summary of volumetric analysis Marshall Mix design of Enkulu Materials

Table 4-6summary of volumetric analysis Marshall Mix design of Enkulu Materials.

Specimens	Gsb	Gmb	Gmm	% VA	% VB	VBA	VBE	Pbe	Pba	% VMA	% VFA
Sample A	2.60	2.297	2.481	7.4	11.37	2.6	8.7	3.9	1.2	16.2	54.06
Sample C	2.60	2.278	2.481	8.2	11.28	2.6	8.7	3.9	1.2	16.9	51.45
Average	2.60	2.29	2.48	7.81	11.33	2.62	8.71	3.92	1.18	16.51	52.76

Table 4-22 shows the summary of HMA volumetric analysis or void analysis by using EAPS.It indicates Percent void of air the specimen using Enkulu's aggregate and is higher than the specification ERA provides (3%-5%) and which will be permeable to air and water, resulting in significant moisture damage and rapid age hardening (which means the HMA pavement have a problem in durability resulting to performance the pavement earlier than design period) and it is 45.96% of VMA, (supposed to be 18%-30.9%).

The value of voids in the mineral aggregate (VMA) which within the limit of minimum requirement (minimum VMA is 14, ERA), but VFA is not within the requirements (VFA of high traffic 65% to 75%), which means the voids between aggregate particles is large.

3.2.2.3. Marshall Stability and flow

Table 4-7marshall Stability criteria of ERA versus Enkulu's aggregate

Marshall test criteria	HMA of EAPS	ERA specification	Remarks
Stability (KN) at 60°c	1.249	7.0	Not good
Flow value (mm)	3.175	2	ok

Table 4-23 shows that, one of the major feature of Marshall Method of designing mixes,

stability test and flow test; with ERA specification with maximum applied load at sever temperature (60°c); the ability of that the asphalt concrete will not withstand the applied traffic load, will leads to deformation and deflectionand result in making shorting the pavement performance and durability (due to problems gradation and particle shapes (means the aggregate has large or high surface area that needs filler and binder material to be effective in interlocking, voids of air with the particle is higher)),

Whereas in flexibility (flow value plastic flow of specimen at material failure) which shows that is good plastic flow.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusions

From the research made on the effects quality of aggregate on the pavement performance, the following conclusions are drawn.

- Source for base course aggregate is Babuaggregate production site.
- Base course aggregates are not sufficiently durable, even though able resist any sudden action without difficulty and good in its particle shapes.
- Size distribution of base course aggregates are not well graded with the gradation requirement but pass sufficient passing of test sieve .0425mm.
- Sources for wearing course aggregates, are both BAPS and EAPS.
- Wearing course aggregates are well adequate in strength and hard/ tough, able resist any sudden action without difficulty and good in its particle shapes hard enough from any abrasion. But have water absorption problem.
- Size distribution of blended aggregate from BAPS comparing with gradation requirements is well graded

or dense graded since it lies within the ranges, but with target value, is argumentative to say well graded.

5.2. Recommendations

- ✓ It is important if it able review the aggregates quality periodical to as per quality specification to protect the public asset from an early deteriorate and maintenance cost.
- ✓ Base course aggregates seemsthat (not exactly), it meets the requirement specified it supposed to achieve in base course construction but it has a strength problem (due to this not sufficiently durable) in carrying the imposed loads and needed to be checked.
- ✓ As the one who work for the client, consultants should determine any material quality related activities, in accordance with the intention of client without compromise, in professional way.
- ✓ Since roads are one of the public asset and needs protection from all nation, with their point of view, therefore, all Highway Engineers,' Material Engineers, Construction Engineers and Structural Engineerhave the duty to do the research, provide important feedback on the quality of aggregates and its impact on the pavement performance to the officials.

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