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Stabilization Assessment of Aggregates in Asphalt Concrete Mixtures

I. Akiije, G. L. Oyekan

ABSTRACT - Aggregates particle size and gradation assessment of asphalt concrete mixtures produced in the south-western part of Nigeria have been investigated for mechanical stabilization. Samples of asphalt concrete produced were collected from three selected asphalt plants (A, B, and C) all located in the south-western part of Nigeria. Bitumen Extraction and Aggregates Sieve Analysis were carried out on the collected samples. The result of the investigation has shown that from each of the asphalt plant, the maximum aggregate size used in the production of asphalt concrete was 12.5 mm while the nominal size was 9.5 mm. However, the asphalt concrete paving materials investigated were of a dense mixture because of the presence of mineral materials that retained on sieve openings 2.36 mm, 0.3 mm, 0.15 mm and 0.075 mm. Sample from asphalt plant A was with aggregates gradings approaching the maximum amount permitted to pass the 2.36 mm sieve openings and this will result in pavement surfaces having comparatively fine texture. While samples from asphalt plants B and C were with aggregates gradings approaching the minimum amount passing the 2.36 mm sieve openings which will result in surfaces with comparatively coarse texture.

KEYWORDS: Aggregates, Asphalt Concrete, Dense Mixture, Sieve Openings, Specifications

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1 INTRODUCTION

Mechanical stabilization is the selection and combination of aggregates to obtain a gradation within the limits of any mix design of asphalt concrete. Gradation is the designed aggregate structure defined by the distribution of aggregate particle sizes for a given blend of aggregate mixture. Maximum size gradation is defined as one sieve larger than the nominal maximum size. Nominal maximum size gradation is one sieve larger than the first sieve that retains more than 10 percent of the aggregate. Maximum density gradation is obtained when the aggregate particles fit together in their densest form. Asphalt concrete is a composite material of a uniformly mixed combination of asphalt cement and aggregates. Asphalt concrete can be used in variety of ways, including the construction of highways and airport pavement and bases, parking areas, and industrial floors. Asphalt cements are solid hydrocarbons with certain physiochemical characteristics that make them cementing agents obtained after separation of the lubricating oils. They are also very viscous, and when used as a binder for aggregate in pavement construction, it is necessary to heat both the aggregate asphalt cement prior to mixing the two materials. Asphalt cements are used mainly in the manufacture of hot-mix, hot-laid asphalt concrete.

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Aggregates refer to granular mineral particles of a composite material that resists compressive stress and provides bulk to the composites. Aggregates can be sourced from natural deposits of sand and gravel, pulverized asphalt pavements, crushed stone and blast-furnace slag. Aggregates are widely used for highway base, subbase and backfill. According to Adedimila [1] aggregates are used in combination with asphalt or bitumen, a cementing material, to form base and binder courses as well as surface and levelling courses.

In Nigeria premature failure of highway pavement shortly or less than 5 years after construction or rehabilitation is a thing of concern. This is a major challenge to highway engineers, contractors and the government of Nigeria because designed life span of a road is 20 years. Substandard materials, poor design mix of highway pavement components and inadequate quality control among other factors are bane in meeting the standard stated in the specifications of roads. Ajani [2] indentified the causes of asphalt pavement failure to include; use of substandard road materials, lack of current traffic studies and analysis, insufficient hydrological data, insufficient geo-technical studies, use of inappropriate design, inadequate quality control, inadequate Supervisory/Technical Staff.

The aim of this study therefore is to determine the stability of the selected and combined aggregates used for a defined asphalt concrete whilst meeting the required standard specifications. Specifically the objectives of this study include (i) investigation into the aggregates particle size and gradation properties of some produced asphaltic concrete (ii) comparison of the results of (i) with a standard specifications (iii) Make inferences on the results and make appropriate recommendations, including areas of future research work. The scope of this research project includes the collection of asphaltic concrete samples from three different asphalt producing plants located in the south-western part of Nigeria. Also, bitumen extraction test on each of the asphaltic concrete material samples to check the sieve analysis of the constituents aggregates and checking with specified standards. The investigation reported by this paper is limited to aggregates particle size and gradation assessment of already prepared asphalt concrete mixtures after bitumen extraction. The significance of this study is that grain-size analysis results data plotted on an aggregate grading chart will serve as useful aid at determining the gradation of aggregates used for highway projects and conformance to the limits of a standard specification.

American Society for Materials and Testing Standard specification developed by an official body in the United States of America is considered here for processing and testing methodology of aggregate materials. Table 1 gives suggested grading requirements of aggregate material based on the ASTM Designation 3515 [3] and Kentucky Department of Highways [4].

Considering the total grading characteristics of a bituminous paving mixture, the amount passing the 2.36 mm sieve is a significant and convenient field control point between fine and coarse aggregate. Gradings approaching the maximum amount permitted to pass the 2.36 mm sieve will result in pavement surfaces having comparatively fine texture, while coarse gradings approaching the minimum amount passing the No.8 sieve will result in surfaces with comparatively coarse texture.

Plotting of the grain-size analysis data are usually done on an aggregate grading chart as demonstrated in Figure 1. The chart is a powerful aid to make it easy for engineers to determine a preferred aggregate gradation. The chart is necessary so that the gradation of aggregates for highway projects conforms to the limits of a standard specification band.

TABLE 1: AGGREGATE GRADING REQUIREMENTS FOR DENSE MIXTURE BITUMINOUS PAVEMENTS

Passing Sieve Designation	Percentage Passing, by weight	
	Surface Course Specification from ASTM Designation 3515*	Surface Course Specification from Kentucky Department of Highways**
19 mm	100	100
12.5 mm	90 to 100	80 to 100
9.5 mm	56 to 80	55 to 80
4.75 mm	44 to 74	35 to 60
2.36 mm	28 to 58	20 to 45
0.3 mm	5 to 21	3 to 14
0.15 mm	3 to 20	2 to 7
0.075 mm	2 to 10	

SOURCES: *Garber, N. J., and Hoel, L. A. [5]
**** Wright, P. H. [6]**

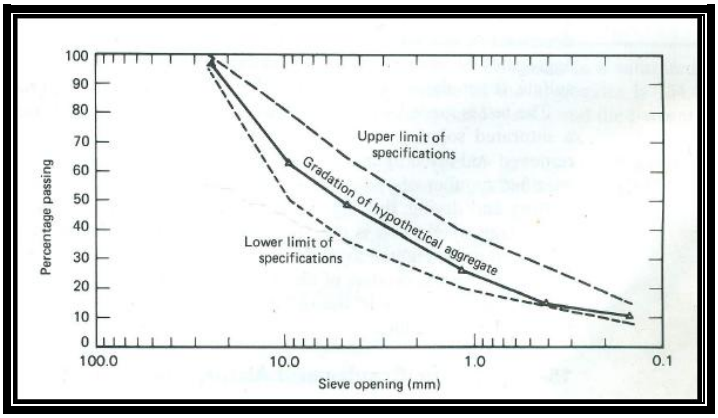

Figure 1: Aggregate Gradation Specification Chart
Sources: Wright, P. H. [6]

2 MATERIALS AND METHODOLOGY

Samples of asphalt concrete produced were collected from three (A, B, and C) selected asphalt plants all located in the south-western part of Nigeria. Bitumen Extraction and Grain-Size Analysis Experiments for gradation of aggregates were carried out on the collected asphalt concrete samples. The main objective of bitumen extraction test is to provide asphalt free aggregates for gradation analysis for this study. It is worthy of note that aggregates gradation is the blend of particle sizes in the mix which influence the density, strength, and economy of the pavement structure.

2.1 Bitumen Extraction Experiment

Bitumen extraction experiment was carried out for the purpose of separating the asphalt from the mineral aggregates in the asphaltic paving mixture obtained from the selected asphalt plants A, B, and C which are all located in the south-western part of Nigeria.

From each of the asphalt concrete sample, 1000 g of was weighed and bitumen extraction test was carried out respectively in triplicate by order of Sample A, Sample B and Sample C. The apparatus used include bitumen extracting machine, weigh balance, trowel, weighing-pan, kerosene, stove and oven capable of maintaining a temperature of 110±5^{0}C. Carbon disulfide and trichloroethylene solvent cannot be used because they may be life-threatening for they affect the nervous system, kidney, and they may cause liver damage, headaches, lung irritation, dizziness, poor coordination, and difficulty in concentrating. Also, skin contact with trichloroethylene for short periods may cause skin rashes.

In the bitumen extraction test carried out, weight of asphalt concrete (asphalt + aggregates),X, is 1000 g; weight of cleanup aggregates Y and weight of bitumen Z and therefore the percentage by weight of asphalt P% are calculated thus

$$X - Y = Z \quad (1)$$

$$(C/A) \times 100 = P\% \quad (2)$$

2.2 Grain - Size Analysis Experiment of Extracted Combined Aggregates

Grain-size analysis to determine the relative proportions of various particle sizes in the mineral aggregate mix after bitumen extraction experiment was carried out. Grain-size analysis was used to determine the relative proportions of various particle sizes in the cleanup mineral aggregates mix for samples A, B and C. To perform this analysis, the weighed cleanup aggregates sample having dried up for 24 hours was shaken over a nest of sieves having selected sizes of square openings. The sieve openings used were 19 mm, 12.5 mm, 9.5 mm, 4.75 mm, 2.36 mm, 0.3 mm, 0.15 mm and 0.075 mm. The sieves were grouped together with the one with the largest openings on top and those with successively smaller openings placed underneath. The aggregate sample was shaken with a mechanical sieve shaker, and materials retained on each sieve opening with the exception of sieve opening 19 mm were weighed. The weight of material retained on each sieve was determined and expressed as a percentage of the original sample.

3.0 RESULTS AND DISCUSSION

The test results of the bitumen extraction experiment is in Table 2 of which three samples from asphalt plants A, B and C are having bitumen content on the average of 5.4 %, 5.8 % and 6.2 % respectively. The results of gradation specification analysis of the extracted combined aggregates of asphalt samples from plants A, B, and C are in Table 3. Graphically, the results of the gradation specification analysis of the extracted combined aggregates of asphalt samples from plants A, B, and C are also plotted on an aggregate grading chart as shown by Figure 2.

TABLE 2: SUMMARY OF THE PROPERTIES OF THE ASPHALT CONCRETE SAMPLES IN COMPARISON WITH THE SPECIFICATIONS

Properties	Specification From ASTM Designation 3515	Sample A	Sample B	Sample C	Remarks
Bitumen content by weight % of total mixture	4 to 11	5.4	5.8	6.2	Each sample met the specification requirements

The results of respective bitumen extraction experiment of samples A, B and C are meeting the amount of 4 to 11 as standard values of the specifications from ASTM designation 3515 as shown in Table 2.

Considering Table 1, it is worthy of note that surface course aggregates specification from ASTM Designation 3515 used for samples A, B, and C made a useful comparison rather in this study rather than specification from Kentucky Department of Highways. This is vividly shown in Table 3. The reason is that ASTM Designation 3515 is having specification for percentage passing by weight of aggregates for sieve designation 0.075 by taking care of the available extracted aggregates of asphalt concrete paving stones samples. Whereas, specification on percentage passing of aggregates by weight for asphalt surface course, from Kentucky Department of Highways is lacking sieve openings with designation 0.075 that is very useful in this experiment. Also, it is obvious that the gradation specification analysis of the extracted combined aggregates of asphalt samples from asphalt plants A, B, and C did not conform to standard specification in particular ASTM designation 3515 as expressed in Table 3. In addition, extracted combined aggregate samples A, B, and C of Figure 2 are not in conformity with aggregates gradation specification chart of Figure 1. This is because in Figure 2 the result lines showing the gradation of samples A, B and C are not well defined

mid-way between the Lower and Upper limits of standard specifications as recommended in Figure 1

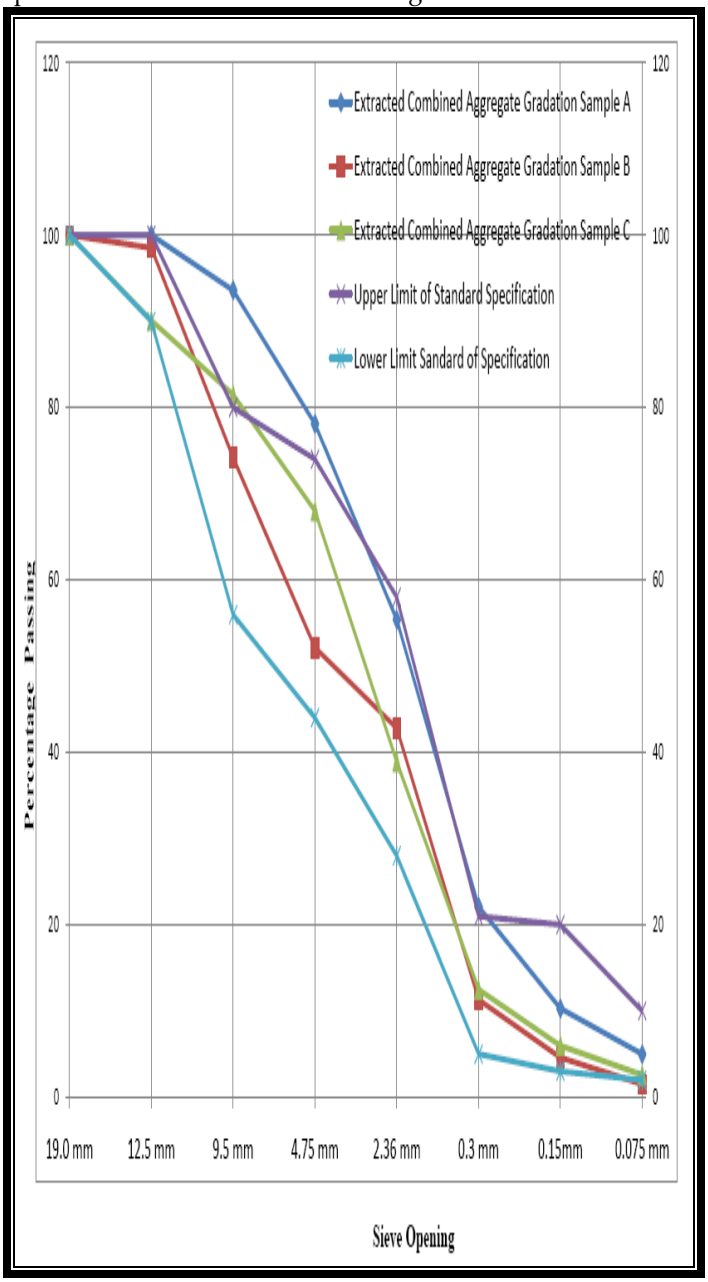

Figure 2: Gradation Specification Analysis Chart of the Extracted Combined Aggregates of Asphalt Samples from Plants A, B, and C

TABLE 3: GRADATION SPECIFICATION ANALYSIS OF THE EXTRACTED COMBINED AGGREGATES OF ASPHALT SAMPLES FROM PLANTS A, B, AND C

Passing Sieve Designation	Specification from ASTM Designation 3515	Sample A Percent By Weight	Sample B Percent By Weight	Sample C Percent By Weight
19 mm	100	100	100	100
12.5 mm	90 to 100	100	98.50	90.10
9.5 mm	56 to 80	93.60	74.20	81.50
4.75 mm	44 to 74	78.10	52.14	68.00
2.36 mm	28 to 58	55.40	42.80	38.90
0.3 mm	5 to 21	22.10	11.30	12.50
0.15 mm	3 to 20	10.30	4.60	6.00
0.075 mm	2 to 10	5	1.50	2.60

With the aid of the chart as in Figure 1, it is possible for an engineer to determine a preferred aggregate gradation for specified asphalt concrete at a glance. This is achievable in this study as in Figure 2 with the aid of Microsoft Excel where comparison of the gradation of combined aggregates extracted from already prepared asphalt concrete and the conformity to the band limits of Specification from ASTM Designation 3515 was possible easily.

4 CONCLUSIONS AND RECOMMENDATIONS

Based on the investigation carried out in this study the following conclusions and recommendations are derived as follows:

4.1 CONCLUSIONS

1. The determination of the stabilization assessment of aggregates gradation in asphalt concrete mixtures is better done by the extraction of asphalt from samples of asphalt concrete mixture for road pavement construction.
2. Better assessment aggregates gradation could be done by grain - size analysis experiment on extracted combined aggregates samples.
3. ASTM Designation 3515 Standard Specification methodology of aggregate gradation analysis has the desired ability of determining percentage passing stabilization assessment of aggregates gradation of asphalt concrete samples.
4. The three asphalt concrete paving materials investigated were of a dense mixture because of the presence of mineral materials that retained on sieve openings 2.36 mm, 0.3 mm, 0.15 mm and 0.075 mm.
5. Sample from asphalt plant A was with aggregates gradings approaching the maximum amount permitted to pass the 2.36 mm sieve openings and this will result in pavement surfaces having comparatively fine texture.
6. Samples from asphalt plants B and C were with aggregates gradings approaching the minimum amount passing the 2.36 mm sieve openings which will result in surfaces with comparatively coarse texture.
7. Supervising agencies of road pavement construction should learn from this study by ensuring the testing of the assessment of extracted aggregate stabilization of the asphalt concrete supplied for road pavement.
8. Varying cost of asphalt concrete supplied to pavement construction site could be easily determined by recognising the usefulness of this experimental investigation carried out in this study.
9. This study surely serves as prodigy towards the determination of strength and stability of asphalt concrete paving stones.

4.2 RECOMMENDATIONS

1. Stabilization assessment of extracted aggregates in asphalt concrete mixtures as carried out in this study must be done on samples of asphalt concrete from an asphalt plant yard before purchase and during the laying of asphalt concrete for road pavement.
2. The gradation of sample aggregate for standard stabilization assessment of extracted aggregates should have a graphic line result lying mid-way between upper and lower limits of standard specifications similarly as in Figure 1 and not necessarily like ones in Figure 2 so that the asphalt concrete paving stones produced is of good strength, durable and cost effective.

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