Determination of Optimum Asphalt Cement (Binder) Content in Asphalt Concrete Pavement

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Abstract
Flexible asphalt concrete pavement constructions are most commonly used all over the world, particularly in Nigeria. The optimum asphalt cement content on asphalt concrete pavement was determined using the control mixes which consisted of asphalt cement and aggregates were experimented. Several experiments on the physical properties were carried out on the asphalt cement, Standard penetration, Softening point and Marshall Stability test. The prepared marshall samples were; (i) the mixtures of asphalt cement to aggregates (control mix) at percentage ratios of 4.0:96, 4.5:95.5, 5.0:95, 5.5:94.5, 6.0:94 or in gramme ratios of 48:1152, 54:1146, 60:1140, 66:1134 and 72:1128. In conclusion, the OBC was found to be 5.25% or 63g. It was found that the asphalt cement content in asphalt concrete pavement had a good performance on its unit weight, stability, flow, air void, VFB and VMA. This study has contributed immensely to the society by using the required quantity of asphalt cement (binder) in an asphalt pavement construction.

Keywords: *Asphalt Cement, Asphalt Concrete Pavement, Aggregates and Marshall Stability.*

1.0 Introduction

Flexible, rigid and composite pavements are the three typical types of pavements. Commonly, flexible pavement is used especially in municipal, state and federal road in Nigeria. Flexible pavement typically consists of asphalt mixture placed over granular base or subbase layers which is supported by the compacted soil referred to as the subgrade. Flexible pavement structure consists of subgrade, subbase, base, base course and wearing course. In addition, the main structural function of pavement is to support the vehicles wheel load applied to the road and distribute to the subgrade. The best design of wearing course is by the selection of materials, gradation and asphalt content able to form good skid resistance, desirable stability, durability and good workability. It also allows the rapid drainage of surface water, minimize traffic noise, resistance to cracking, withstand traffic turning and braking force, protect underlying road structure.

Subina et al., (2009) evaluated the performance of waste plastic/polymer modified bituminous mix and observed that the results of Marshall stability and retained stability of polythene modified bituminous concrete mix increases 1.21 and 1.18 times higher than that of conventional mix by using 8% and 15% (by weight of bitumen) polythene with respect to 60/70 penetration grade of bitumen. But modified mix with 15% polyethylene showed slightly decreased values for Marshall Stability than that of the mix with 8% modifier in their results.
According to another visco-elastic behaviour of polymer modified bitumen depend on the concentration of polymer, mixing temperature, mixing technique, solvating power of base bitumen and molecular structure of polymer used and pp offer better blend in comparison to

HDPE and LLDPE. Punith and Veeraragavan (2012) studied behaviour of Asphalt concrete mixtures with reclaimed polyethylene as additive. Sui and Chen (2011) studied application and performance of polyethylene as modifying additive in asphalt mixture. They added polyethylene as additive to hot mineral aggregate for few minutes, and then added the asphalt mixing together which simplifies the construction process and reduces the cost of construction.

2.0 Materials and Methods

2.1 Research Design

The aggregates retained on 4.75 mm sieve are called coarse aggregates. Coarse aggregate used was screened crushed rock, angular in shape, free from dust particles, clay, vegetation and organic matters which offered good interlocking properties. In this study, granite stones were used as coarse aggregate with a high abrasion resistance. Fine aggregate used was clean screened quarry dust and free from clay, loam, vegetation or organic matter. Their fractions passed 4.75 mm and retained on 0.075 mm in BS 410 sieve. It filled the voids in the coarse aggregate and stiffened the binder. Asphalt cement acts as a binding agent to the aggregates, fines and modifier in asphalt cement mixtures. Asphalt cement must be treated as a visco-elastic material as it exhibits both viscous as well as elastic properties at the normal pavement temperature. At low temperature it behaves like an elastic material and at high temperatures its behaviour was like a viscous fluid. Asphalt cement of 60/70 penetration was used in this work. The grade of asphalt cement used in the pavements was selected on the basis of climatic conditions and their performance in the past. It fills the voids, cause particle adhesion and offers impermeability.

In order to determine the effect of modified binder on the properties of asphalt concrete, it was necessary to carry out mix design to determine the optimum asphalt cement (binder) content (OBC); in achieving this, trial mix of five (5) samples at 0% proportion of solidified waste sachet by weight of asphalt concrete was used. The control mix was used in the Marshall Mix design method for designing hot asphalt concrete. It was designated as ASTM (D6927 – 06) using manual compaction.

2.2 Nature/ Source of Data

This was a primary data obtained from different natural sources such as glacial deposits or mines for aggregates and asphalt cement was gotten from petroleum products.

2.3 Methods of Data Collection/ Instrumentation

Laboratory experiment methods were used in collection of data. The methods and instruments are explained below.

Particle Size Distribution Analysis test was used to determine the percentage of individual particle sizes present in the mix. This was carried out with the aid of BS 410 sieves with screens of graded mesh. The procedure consists of sieving a measured quantity of aggregate through a series of successively smaller sieves. This was performed by a manual shaker with the sieve sizes between 0.075mm to 19mm. The weight retained on each sieve was then expressed as percentage of the total sample. The percentage passing was calculated as the cumulative of the percentage retained. Graph of percentage weight passing against sieve sizes was plotted to see if the selected aggregates fall within the specified job mix. Trial mixes were made and Ruthfuch's graphical method was used to combine the coarse and fine aggregates to obtain an all-in combined grading satisfying the specification.

Penetration Test of an asphalt cement could be defined as the distance in tenths of a millimeter that a standard needle will penetrate into the bitumen under a load of 100g applied for five seconds at 25^{o}c (77^{o}F). Other conditions of load, time and temperature may be used for special purposes. It was noticed in my work that the higher the penetration, the softer is the asphalt cement. The penetration is often abbreviated to "pen".

The asphalt cement was heated and mixed thoroughly in a small tin, allowed to cool in air and then transferred to a water bath maintained at a precisely 25^{o}c for 1 to 1hour 30 minute. The preliminary heating sequence was important as some asphalt cement develop a physical structure which affects the result unless treatment was always identical. A needle was then allowed to penetrate into the surface for 5 seconds under the correct loading. This was done by means of an instrument known as penetrometer which was manually operated. The test was carried out in transfer dish containing water because it was important that the temperature should remain unchanged during the actual measurement. Three or four penetrations were made and the average value was reported. The penetration test was used for classifying asphaltic cement into standard grades. Penetration values below 20mm have been associated with bad cracking but this rarely occurs when the penetration exceeds 30mm. For road surfacing using penetration grades, the following measures are recommended as shown Table 2.1

2.4 Preparation of Marshall Samples

Performance of an asphalt concrete mixture was based on the determination of the correct proportion of aggregate and asphalt cement. To determine the optimum asphalt cement content that would produce asphalt concrete mixtures with strength and durability properties that meet the standard specifications. Five (5) samples each of 1200gram in weight of asphalt concrete were prepared according to the mix design of 4.0, 4.5, 5.0, 5.5 and 6.0%. All examined asphalt concrete mixtures were prepared in accordance with the standard 50-blows. The Marshall Stability and flow test was done to determine the Marshall stability and flow values of asphalt cement mixture. The mixes were prepared according to the Marshall procedure specified in ASTM D1559. The coarse and fine aggregates were mixed with asphalt cement. Optimum Binder Content (OBC) was found by Marshall Test.

The penetration test of an asphalt cement is the distance in tenths of a millimeter that a standard needle penetrated into the asphalt cement under a load of 100g applied for 5 seconds at a temperature of 25^{o}c (77^{o}F).

3.0 Results and Findings

Table 3.1: Penetration Test (Source: Laboratory Experiment)

TEST PARAMETERS	TEST 1	TEST 2	TEST 3	AVERAGE
Test Temperature	25	25	25	25
Time in second(s)	5	5	5	5
Penetration (Pen)	69	68	68.7	68.57

The trial mix materials for five samples were recorded in percentages in Table 2.2.

Table 3.2: Percentages of Trial Mix Materials (Source: Laboratory Experiment)

Asphalt cement content (%)	Fine Aggregate Content(%)	Coarse Aggregate Content(%)	Asphalt Cement Content (%)
4.0	55.68	40.32	100
4.5	555.39	40.11	100
5.0	55.10	39.90	100
5.5	54.81	39.69	100
6.0	54.52	39.48	100

The trial mix materials for five samples were recorded in gammes in Table 2.3.

Table 3.3: Weights of Trial Mix Materials (Source: Laboratory Experiment)

Asphalt Cement Content (g)	Fine Aggregate Content(g)	Coarse Aggregate Content(g)	Asphalt Concrete Content (g)
48	668.16	483.84	1200
54	664.68	481.32	1200
60	661.20	478.80	1200
66	657.72	476.28	1200
72	654.24	473.78	1200

Asphalt concrete mixture of without waste sachet as trial were used in Table 2.4.

Table 3.4: Asphalt Concrete Mixture (Trial Mix)

Asphalt Cement Content (%)	Stability (KN)	VFB (%)	Unit Weight gm/cc	Air Void(%)	Flow Values (mm)	VMA(%)
4.0	8.0	70	2.300	4.2	3.25	13.5
4.5	9.0	72	2.390	4.0	3.50	14.7
5.0	11.0	75	2.425	3.7	3.75	15.5
5.5	10.0	82	2.400	3.5	3.80	15.7
6.0	8.8	90	2.390	3.0	3.85	16.0

The constituent materials are given in percentages in Table 2.5.

Table 3.5 Percentages of Constituent Materials

Asphalt Cement Content (%)	Fine Aggregate Content (%)	Coarse Aggregate Content (%)	Asphalt Concrete Content (%)
5.25	54.955	39.795	100

The constituent materials are given in grammes in Table 2.6.

Table 3.6 Weights of Constituent Materials

Asphalt Cement Content (g)	Fine Aggregate Content (g)	Coarse Aggregate Content (g)	Asphalt Concrete Content (g)
63	659.46	477.54	1200

The constituent materials are given in percentages in Table 2.7.

Table 3.7 Percentages of Constituent Materials

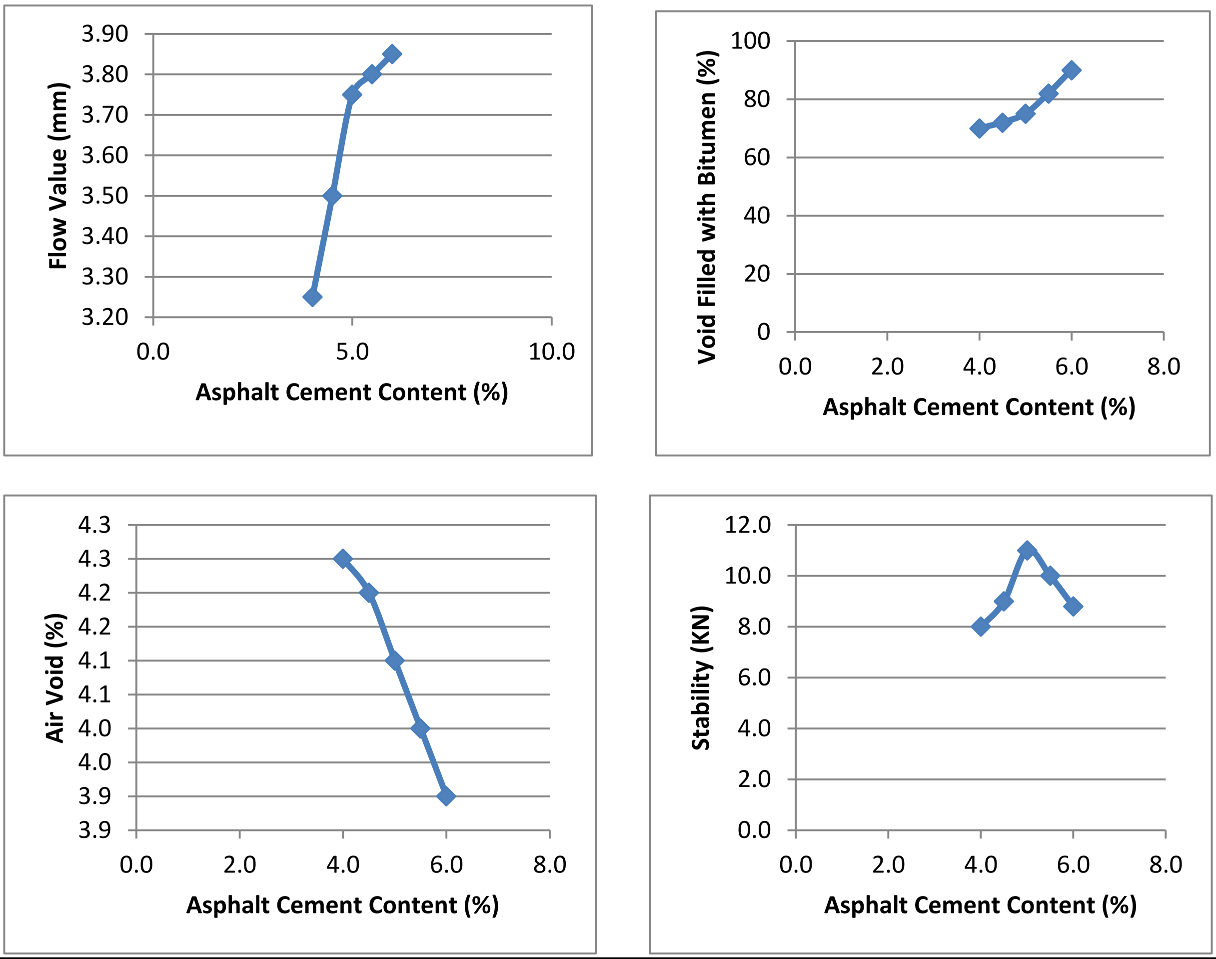
Asphalt Cement Content (%)	Fine Aggregate Content (%)	Coarse Aggregate Content (%)	Asphalt Concrete Content (%)
5.25	54.955	39.795	100

The constituent materials are given in grammes in Table 2.8.

Table 3.8 Weights of Constituent Materials

Asphalt Cement Content (g)	Fine Aggregate Content (g)	Coarse Aggregate Content (g)	Asphalt Concrete Content (g)
63	659.46	477.54	1200

The trial concrete mix is presented in figure 2.1



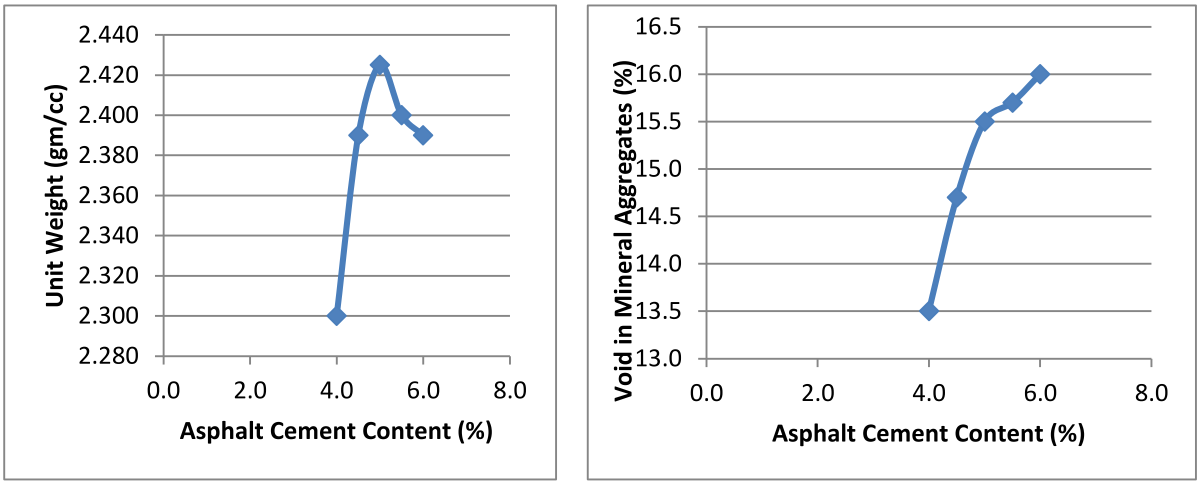


Fig 3.1 Graph for Trial Concrete Mix

3.1 Data Analysis

3.1.1 Calculation for the Optimum Binder Content

From figure 2.1,

Asphalt cement content at maximum stability = 5.0%

Asphalt cement content at 80% VFB = 5.5%

Asphalt cement content at max unit weight = 5.0%

Asphalt cement content at 4% Air Void = 5.5%

Asphalt cement content = $\frac{5+5.5+5+5.5}{4}$ = 5.25%

4.0 Conclusion

1. The optimum asphalt cement content in the mix was found to be 5.25% or 63g.
2. This study has contributed immensely to the society by using the required quantity of asphalt cement (bitumen) in an asphalt pavement construction.

References

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