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THE QUALITY CONTROL MEASURE OF ASPHALT MIX DESIGN AS SOLUTION TO PAVEMENT FAILURE

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ABSTRACT

This paper covered major aspect of asphalt mix design analysis, as the quality control measure of asphalt production, using British Method of Asphalt mix design procedure. It is aimed in highlighting the important of designed Asphalts as compared to ordinary mixed Asphalt in Asphalt production, for any pavement structural work. This is to analysis the merit of designed and control Asphalt product as required by BS 594, T49 and BS 4691, in Asphalt and Bitumen requirement. It equally include the whole laboratory test analysis, to determine the physical and geotechnical properties of the materials needed for the mix design, in order to attain the required data for the design procedure, in accordance to the parent material types and location and to control specific density of the designed Asphalt, that will be suitable, adoptable, durable, economical, workable and generally safe for the pavement structural design objective of the weather condition in any specified locality. This is equally aimed at controlling the rate of structure pavement failure in Nigeria as a Nation before the design age, on this note, major factors that may lead to structural pavement failure, were generally treated. The design covered both Asphaltic Binder course of 60mm thick and Asphaltic wearing course of 40mm as flexible pavement with Bitumen viscosity of 60/70. Basically the extraction of the design to determine, the Bitumen content (B.C), sieve analysis, stability, flow and void Ratio were equally include in accordance with British stand as the control measure. All individual result of the design mix were adequately presented. These have shown that generally Asphalt mix design is necessary, as measure of quality control of Asphalt both on Binder course and wearing course. Also it is very important to note, that in any pavement structure as part of Civil Engineering Project on road Transportation, either surface dressing and any other classis of flexible pavement, for Government and Individual, Design and Control should be applicable to maintain standard and control pavement failure.

INTRODUCTION

Generally, the design requirement of any structural Asphalt, flexible pavement project to be achieved. Close supervision and adequate mix design and control should be done by the civil Engineer involved. In recent year, we have witness allot of flexible pavement failure as part of structural failure on road either during construction, after the construction or few years of the project completion, without satisfying pavement design age of the project, life span. Although the likely cause pavement failure were very enormous, failure of pavement from sub-base layer to base course and from base course to binder course, before it get to the wearing course of the flexible pavement structure, might be as a result of the following

Construction Factor are as follow

1. Poor or none Application of Asphalt mix design

2. Poor Asphalt production
3. In adequate field compaction on structural pavement layer and Asphalt laying
4. Placing material and laying of Asphalt during raining period.
5. Production of Burn Asphalt, due high temperature of the bitumen and dryer.
6. Lack of production plant calibration professional personnel
7. Use of in compactable material for structural pavement layer and asphalt production
8. Lack of efficient supervisor
9. In adequate preparation of laying platform
10. Inadequate application of codes of practices
11. General corruption of client representative, consultant and contractors
12. Lack of required equipment for construction
13. Absence of Quality control personnel
14. Absence of professional Civil Engineer
15. Absence of Drainage channel to evaluate pounded water

Local Factor are as follows

1. Constant oil for instance petrol, engine oil, kerosene and diesel spillage on pavement due to accidental cases, tank leakage, break down of vehicle on pavement with engine oil spillage can cause pavement failure
2. Burning on the pavement during political uproar (the heat emitted by burning, affect the Asphalt layers
3. Placing of service duck without efficient treatment of the locations (this will affect the sub-base, base course , binder and wearing course layer
4. Dumping of refuse on pavement (this will decay and degenerate to gases that affect and dissolve the Asphalt component to separation)
5. Deposition of refuse on drainage channel to block the channel from continuous flow, therefore affecting some section of the pavement due water stagnation or pounding within alignment
6. Lack of maintenance of road by constant removal of weed on shoulder and evacuation of Drainage channel that may negatively affect the section of the pavement by flooding.

Naturally its is physical that even after critical design and supervision, there are still more to control, during the serviceability of the flexible pavement as explained above

CONSIDERATION OF DESIGN

Considering Road project, that include the use of flexible pavement, as the structural layer of carriage way, it involve the use Asphalt and required that all the material needed for the Asphalt, be tested to determine the physical and Geotechnical properties of such materials.
These are, Bitumen (60/70), fine Aggregate (sand or quarry dust) coarse Aggregate, diesel, S125 (tack coat) and Mc 1 The value of the physical properties obtained will be used for the basis of all the design consideration for the asphalt mix design. These will on the long run assist in preventing failure in the design of pavement structure and the design of Asphalt Mix needed for the road. If this project is well supervised and maintained, the design age of the

project will be adequately achieved. Therefore it is necessary that in every individual road project, there should be a qualified quality Civil Engineering for the design, control and maintenance of the project

CONDITION OF DESIGN

It should be understood that Asphalt mix design and Asphalt production. Must achieve the specified requirement, and also that the physical properties of materials obtainable might very from one location to another. It is a common practice to produce a trial Asphalt mix design at a location of any state, take for instance Kaduna State with Kaduna soil, rock aggregate and quarry dust of specific company in Kaduna. Although, Bitumen depend on the Brand, either 40/50, 60/70, 20/100 at 25 degree centigrade in accordance with any selected viscosity and use the Asphalt in another state, if the January distance in kilometer is with the specifying requirement, with out resulting to cooled asphalt to be laid on site it generally accepted.

The most important factor on the condition of Asphalt design and production were as follow

1. The soil and aggregate material used for the design most conform with the required limitation.
2. The Brand of Bitumen used on the design must be maintained and should conformed with the required specification
3. The batching plant should be calibrated and control before production
4. The production temperature should be within the required limitation, should be maintained and controlled
5. The procedure for transportation of Asphalt should strictly followed In accordance general specification
6. The required bitumen content for a specific asphalt production should be within range of specification
7. The design and production asphalt for extracted, sieve analysis of the Aggregate should be within the specify range and envelop respectively
8. The produce bitumen content as binder content, should be equal to the design binder content and should be within the limit of specification
9. Job mix formula, which highlighted the Bulk density, voids in total mix, flow, stability, and voids fill with Bitumen, should form the bases of control and should be within the specified requirement
10. The Asphalt laying temperature should be continuous monitored, to control the bleeding, creeping and washing out of Bitumen, from the laid Asphalt.
11. At every five hundred meter of laid Asphalt, there should be control sample for analysis as itemized above from (1-9) and if any alteration, deviation of the control test result were found not within the required specified limitation, such production should be rejected, until it is Generally corrected and controlled to normal, before it will be accepted on site for laying

Quality control of Asphalt mix design (as applicable to binder and wearing course). It should be cleared that all the Asphalt mix designed quality control are considered as Trial Mix design, until it is checked and approved by consultant in conjunction with the client, Representative approval, before Asphalt production to site, can take effect. All the materials for Asphalt production have there specific code of practice to access the physical and geotechnical properties of the materials. These are the codes of practice

(1) Aggregate test and BS 812 and 882
(2) Bitumen test BS 4691 AASHHTO T 49
(3) Asphalt test BS 594

The codes of practice serve as bases for checks and balances of the material physical and geotechnical performance. In order word, Quality Control personnel duty is to make sure that the Asphaltic design parameter achieved are within the required limitation in order to achieve the serviceability requirement of the road.

Major factors affecting Asphalt mix design as a measure of the quality control procedure. According with BS 594 and BS 469, the design of Asphalt should be on the following bases, in every region of the world.

1. Types of pavement
2. Types of Asphalt
3. Choice of Aggregate size
4. Choice of Bitumen (Viscosity) /Grade
5. Range of Binder content, percentage of asphalt
6. Thickness of Asphalt mm

i. Flow range in mm
ii. Percentage void in mix
iii. Limit of Asphalt Bulk density g/ m^3
iv. Stability condition of asphalt in KN

TYPES OF PAVEMENT

This could be concrete pavement constructed mainly with concrete material of a high grade, for instance concrete grade 40N//mm^2 or flexible pavement, which is dense Bitumen macadam with specific percentage aggregate requirement design for Asphaltic Binder and wearing courses of their specified thickness. Rather it could be composite pavement of specific requirement of concrete and Asphalt layers to obtain a durable composite pavements

Types of Asphalt: These are classified under dense Macadam Asphalt Base. It could be Binder and wearing course Asphalt of an individual thickness, which varies with client demand in accordance with the requirements of the BRITISH STANDERD[BS],AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS [AASHTO] and AMERICAN SOCIETY FOR TESTING AND MATERIAL [ASTM] . These are clearly followed in accordance with the individual code of choice to achieve the require objectives of durability, safety, serviceability and economy.

The Choice of Aggregate size depend on the availability of aggregate in that locality which must be tested to determine the suitability of it for the Asphaltic mix design analysis. The choice of aggregate, equally depend on the type of asphalt to be design, for instance either Binder course and wearing course have different types of aggregate selection as may be present in mix design example in Appendix A:

Choice of Bitumen Viscosity grade; This could be 40/50, 60/70 and 20/100 viscosity grade of bitumen brand. Selecting of any grade of Bitumen depends on the individual and client choice.

Range of Bitumen quantity or Binder Content; Depends on the Nature of Asphalt, because wearing course Asphalt needed more Binder content than Binder course Asphalt. This is due to the fine Nature of Aggregate mostly consumed on wearing course Asphalt than the binder course Asphalt. The more the fine Aggregate component on Asphalt mix design, the greater the consumption of Bitumen within the require limit of the Binder content percentage specification. Because excess consumption of bitumen causes the following:

(a)Bleeding (b) cracking (c) Shifting (d) Bumping or local action

[a] **Bleeding**; is the seeping of excess Bitumen from the laid asphalt due to increase in temperature during compaction process and during high sunshine of the day.

(b) **Cracking**: this occur during compaction period of Asphalt laying some lines of pressing and separation within the line of compaction will be formed and may tense to separate after the compaction have taking effect, creating a joint that can lead to Asphalt failure. These some times can be manually removed by other natural activities on the Asphalt layer since efficient compaction is not achieved due excess Bitumen.

(c) **Shifting;** this is the moving of laid Asphalt from it original position inward or outward during compaction procedure. This may lead to excess spreading of laid asphalt without achieving the required thickness as laid for a specific type of layer as required in the specification.

(d) Bumping or local action:- This very visible at the completion of individual layer of laid Asphalt compaction, the nature super elevation compaction will not be achieved, at certain location, there will be sagging or hogging, above or below the compaction elevation respectively. These are referred to as local action or Bumping.

(e) **Thickness of Asphalt**:- This is factor that concern the client, based on the design achieved. The thickness of Asphalt as a flexible pavement Range from 100mm to 120mm, and comprise of 60mm Binder course and 40mm wearing course or both Binder and wearing courses 60mm as the case may, all depend the Dense macadam design specification which have taken care of durability safety economy and serviceability of the road project concerned.

(f) **Secondary Factor of Asphalt mix design**; To determine the secondary factor of Asphalt mix design, it include the following factures

(i) Flow Rang in mm (ii) Percentage void in mix (iii) Limit of Asphalt Bulk density in g/m^3 (iv) stability condition of the produced Asphalt in KN

All this mentions on the secondary factors must be achieved on the trial mix design within the specified limit, before the Asphalt designed mix can be considered durable, workable, safe and serviceable for use, before the approval of the asphalt trial mix design, as mix design to be use for specific road.

Texture of Asphalt: This depend on the percentage quantities of fine aggregate ratio that falls within the required design envelope, for either Binder course and wearing course Asphalt. The most important factor of Asphaltic texture on mix design is envelop no matter the ratio of Aggregate inclusive, if it is not within envelop, it is considered inadequate.

Method of Asphalt Mix Design

1. British Standard Method (BS)
2. America Association of State Highway and Transportation Officials (AASHTO)
3. American Society for testing and material (ASTM)

The above mentioned method of Asphalt mix design procedure were all same, but difference in the textural classification as required to extraction and sieve analysis, sieve arrangement differs and envelop classification differ from one another within the three method applicable for this report British standard (BS) is most applicable.

British standard Method of Asphalt Mix design, include the following steps

1. Obtain all the individual material example fine Aggregate, coarse Aggregate, and the specific viscosity brand of Bitumen 60/70
2. Subject the individual material to physical and geo-technical analysis as presented in appendix B, if the test result of whole materials ware within the limit of specification they will be kept at their specific location for instance Aggregate will be kept on the Bin and Bitumen will be kept on tanks

If for instance the Asphalt trial mix design is Binder Course the, it comprises of four Bins various range of aggregate compartment as follow:

Types of Bin	**Range of Aggregate size**	**Percentage quantities to be supplied per mix**
Bin 1	0-5mm	42%
Bin 2	5 – 12 mm	18%
Bin 3	12-19mm	24%
Bin 4	19- 25mm	16%

On the percentage quantity to be supplied per each volume of Asphalt mix can be varied at any time, if the there is change in aggregate or change in Asphalt design mix analysis for Binder Course Asphalt.
If for instance, the Asphalt trial mix design is wearing course. IT comprises of three Bin for various range of aggregate compartment as follows below

Types of Bin	**Range of Aggregate Size**	**Percentage Quantities to be supplied per mix Bin**
Bin 1	0-5mm	60%
Bin 2	5-12mm	21%
Bin 3	12-19mm	141%

For the percentage quantities of Aggregate to be supplied into the machine per 1 cubic meter of mix can varies in accordance to change in aggregate production or design analysis. The material tested and positioned will be resample, subjected to Asphalt trial mix design for either Binder and wearing course. Exert Job formula of mixing the asphalt in accordance to BS 594 will be adhered to All the method of compacting and extracting mix asphalt will applicable and the properties of the compacted Asphaltic concrete will be determined, to check and exercise the conformity to BS 594, it is expected to excise more Asphalt mix designed with different percentage of Bitumen and selected the best that is within the required Range of specification on properties of mix and compacted Asphaltic concrete as presented in appendix (A).

The importance of Quality Control

In all aspect of Asphaltic mix design procedure ware clearly excised, for good quality and achieve the design objective. On this not an experience Quality Control Engineer is needed at all cost, to run the aggregate test, trial Asphalt mix design, marshal test, extraction test analysis and subsequent control test analysis on site, if trial mix designs are considered appropriate, they will be approved for use on site. If all these procedure discussed above about Asphalt mix design and production of Asphalt are well followed failure of flexible pavement will be 80% control.

Responsibilities for quality Construction must include the following;

The client must appoint an experience consultant for design and control, and contractor must work as a team with the consultant proposer from the client and agree with any subsequent unforeseen circumstance on site with the client consultant and contractor to achieve the desired quality in flexible pavement and other construction project. Fig 2.3 highlight the major task for the three parties in the relationship needed for the successful completion of a road project with the desired quality level.

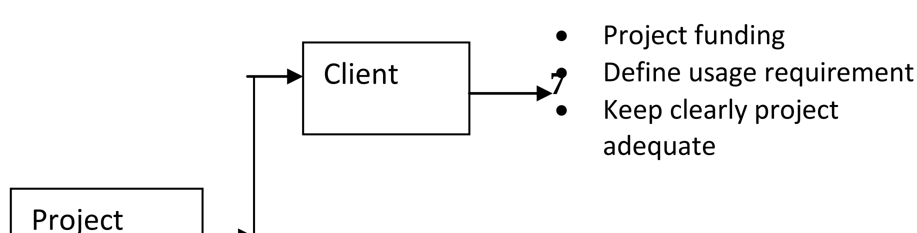

Fig 2.3 Responsibilities of the client, consultant and contractor

A sample of Asphalt mix design

A new road under construction to link Sabo road after Bridge from Eastern by-pass road as spore through U/Gibi, have reached stone base level, ready for the Asphaltic formation as the structural layer of the road, using the British method of Asphalt mix design as flexible pavement, provide trial mix design of Asphaltic Binder and wearing course, using Eksogullari Quarry aggregate and sand from chikaji river Kaduna . The recommended Bitumen viscosity Brand should be 60/70. The Binder content should be within the specified requirement for Asphalt Binder and wearing course, as represented in appendix B. For the solution of these problems, the procedure are as presented in the format below in format, 1,2,3,4,5 and 6, 7, 8, 9, 10 for Asphaltic Binder and wearing course respectively as required by the specification and as presented in Appendix A. The individual specified limitation used during the design procedure were provided in appendix B Most of the Quality control test analysis for the materials used in the Asphalt trial mix design are, provided in appendix C.

MAJOR WAYS OF CONTROLLING FLEXIBLE PAVEMENT FAILURE

1. Quality control Engineers and personnel should be duly involve in the design and control of Asphalt pavement work
2. During design, construction, production and laying of Asphalt, the three parties that form construction team, Client, Consultant and Contractor should adequately function and dedicated to their duties.
3. There should be law enacted guiding road users, transporter, oil manufacturing company and individual on road management. And violator should be punishable by law
4. There should be an agency that control and maintain road usage in all the three level of the country, like local level, state level and federal level

5. There should public awareness on radio, television and all other media on road and drainage maintenance
6. There should be security control during on carriage way to control the pavement burning, during riot, rampage or any political problems in the states and country at large.
7. In case of additional services on the carriage way or passing through the alignment, it should be directly handle by road maintenance agency.

ANALYSIS OF ASPHALT MIX DESIGN AND GRAPHS

Wearing course asphalt: The sieve analysis of the design and that of the control sample extraction were within the specified envelop. The bitumen content of the mix design and the control sample were within range of specification. Generally maximum stability, maximum density void in mix and flow rate were within the required specification for wearing asphaltic base cement.

Binder course asphalt: The sieve analysis of the design and that of the control sample extraction were within the specified envelop. The bitumen content of the mix design and the control sample were within range of specification. Generally maximum stability, maximum density void in mix and flow rate were within the required specification for binder course asphaltic base cement.

CONCLUSION

Base on the illustrations on Quality Control of Asphalt mix design, as a measure for controlling flexible pavement failure. It is clear that if all the processes discussed above are duly employed and adhered to always, the design objective and design age of flexible pavement will be achieved, for safety and durability of the road in this country.

RECOMMENDATION

In all projects that involve construction of flexible pavement, procedures above should be strictly followed at all levels of road construction in this country, without undermining the cost involved for safety, durability and serviceability of the users and the project.

- Project should not be awarded to non professionals in order to control or reduce project failure.
- There should be public awareness about the important of quality control in all sectors of production and construction industries and to the individuals in order to control or reduce failure.
- In every beginning of any asphalt production there should efficient calibration of the batching or mixing plant for adequate mix proportion.
- The control mix, laying and rolling temperature, should be adequately monitored, to avoid burned asphalt production.

- Asphalt laying should be stopped during raining period, in order to avoid cold asphalt laying and segregated asphalt base.

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APPENDIX A

Ref: 0041/34
Date;08/11/2010

Construction of Kaduna Eastern By-pass
Contract No: 5346
Kaduna /Nigeria

The Engineer's Representative
Federal Ministry of Works
Kaduna

ASPHALT WEARING COURSE MIX DESIGN

We hereby present to you the Asphalt Wearing Course Mix Design/Mix Formula, using aggregate from our new crushing machine.

Bulk Density	=	2.33g/cm^3
Maximum Stability	=	9.4KN
Voids in Mix (VIM)	=	4.0%
Flow	=	3.0mm
Optimum Bitumen Content	=	5.87%
Filter	=	5%

Bin 1	0-5mm aggregate	=	60%
Bin 2	5-12mm aggregate	=	21%
Bin 3	12-19mm aggregate	=	14%

STATEMENT OF MIX DESIGN

Mix Design at 5.0% Bitumen
Mix Design at 5.5% Bitumen
Mix Design at 6.0% Bitumen
Mix Design at 6.5% Bitumen
Mix Design at 7.0% Bitumen

Engr. Salihu A. Yunusa [NMSE]
Quality Control Chief Engineer

APPENDIX A
Construction of Kaduna Eastern By-pass Road (with spur to Rabah Road)
Contract NO. 5346

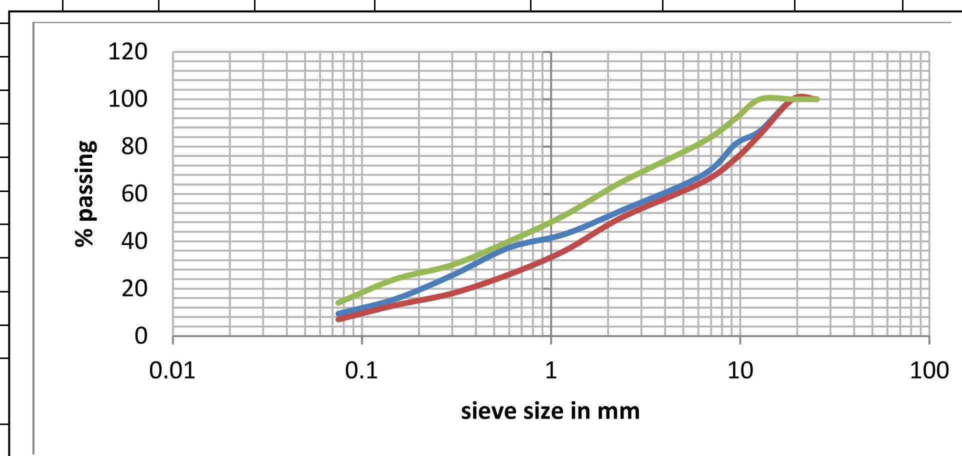
Technical:____________________ Project_____________________ Location ______________________

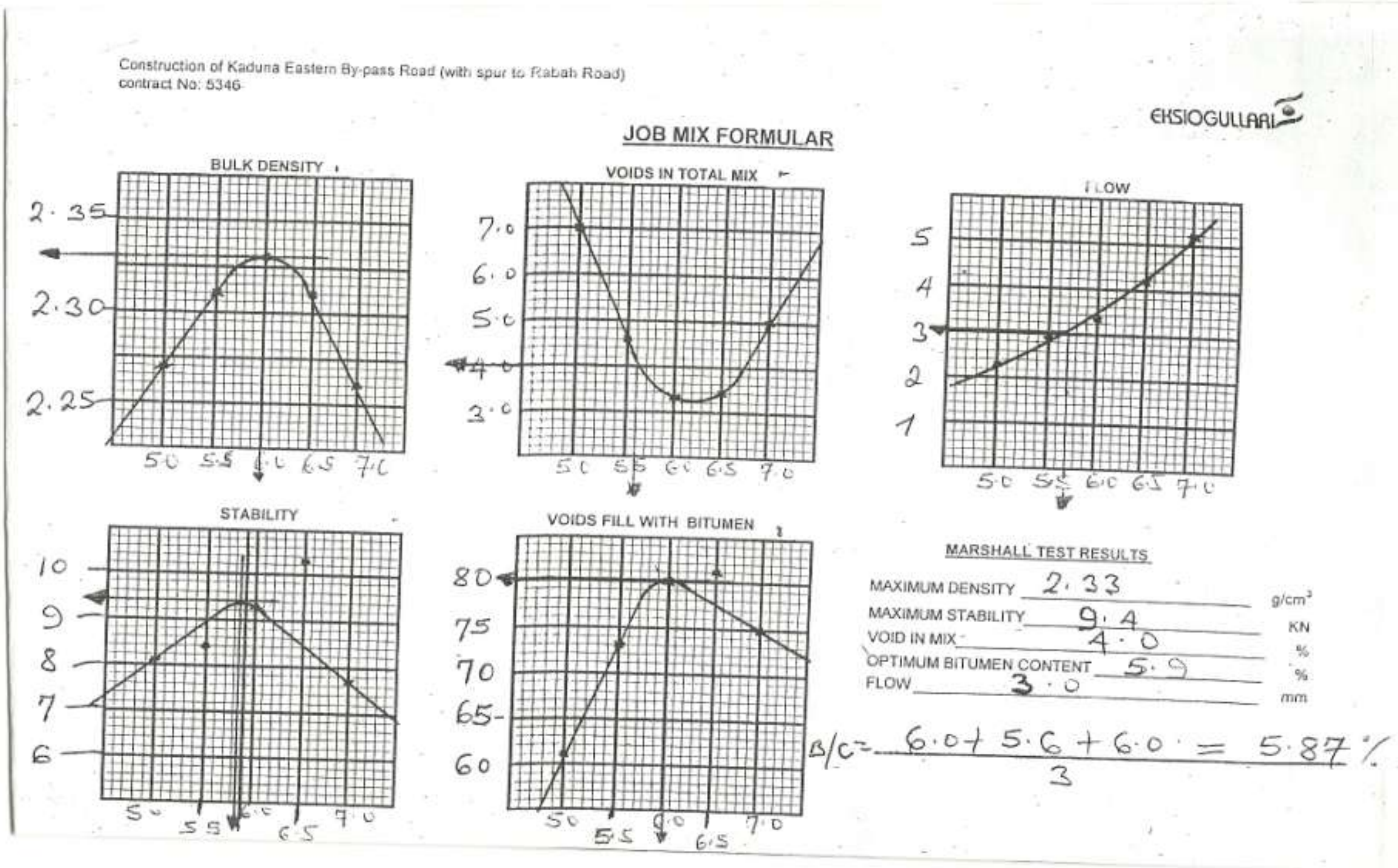
Date:________________________ Type of Asphalt; WEARING COURSE

SIEVE	**GRADING OF THE COMPONENTS % BY WEIGHT RET**							**COMPOSITION OF THE COMPONENTS % BY WEIGHT OF THE TOTAL AGGREGATE**									**GRADING OF THE TOTAL AGGREGATE % BY WEIGHT**		**SPECIFICATION**
Size								**½**	**$^3/_8$**	**$^0/_5$**	**fill**						**Retained**	**Passing**	
Mm								14	21	60	5								
1	2	3	4	5	6	7	8		9		10		11			12	13	14	15
37.5mm																			
25.4mm																			
20.0mm								14.0	21.0	60.0	5.0			100				100	100
12.5mm								2.0	20.6	60.0	5.0			87.6				87.6	85-100
10.0mm								0.1	16.5	60.0	5.0			81.6				81.6	75-92
5.0mm									1.8	59.8	3.0			66.6				66.6	65-82
2.36mm									0.1	49.2	5.0			54.3				54.3	50-65
1.18mm										38.5	5.0			43.5				43.5	36-51
600μm										32.0	5.0			37.0				37.0	26-40
300 μm										20.8	5.0			25.8				25.8	18-30
150 μm										10.9	4.8			15.7				15.7	13-24
75 μm										6.3	3.0			9.3				9.3	7-14

APPENDIX A
Construction of Kaduna Eastern By-pass Road (with spur to Rabah Road)
Contract No. 5346
CONTROL SAMPLE COMBINE AGGREGATE

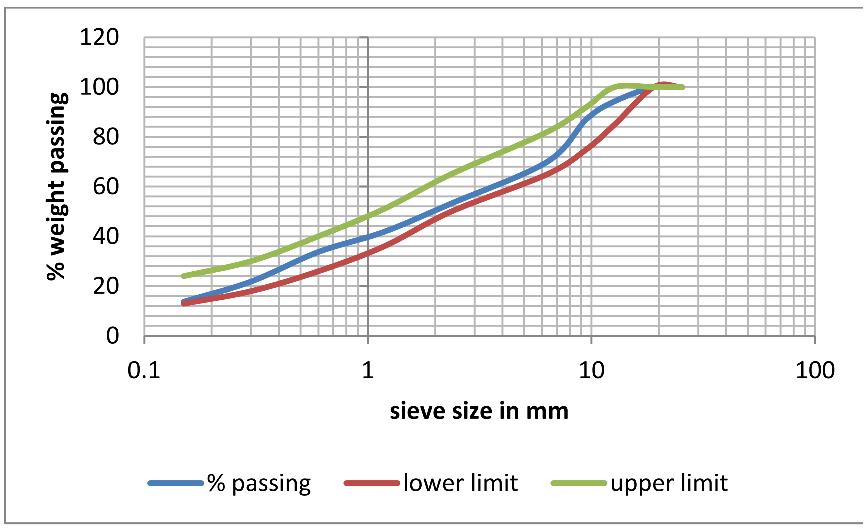
Material Testing Laboratory					**MARSHALL TEST DATA**					**Operator**								
					Wearing Course					**Date:**				**Ref:**				
					Contract					**Location**								
Mix ref. **a**	**Temperature** **b**	**Bit cont. %** **C**	**Bit Content** $\frac{Cx\,100}{100+C}$ **D**	**Weight in Air** **e**	**Weight in Air after 1hr sock** **f**	**Weight in water** **g**	**Volume f –g** **h**	**Bulk Density e/h** **i**	$\frac{S}{SGM}+\frac{B-700}{SGM}$ **J**	**Vol. of Bit d x 1 Sg Bit** **k**	**Vol of Aggre.** $\frac{100}{SG}-\frac{d\,x}{Agg}$ **L**	**Void in mix Aggt. 100 – L** **m**	**Void in Mix Vim 100x K+L** **n**	**% void filled** $100\,x\,\frac{L}{K}$ **o**	**Stability Kg** **p**	**Corr Factor** **q**	**Corr Stability Kg** **r**	**Flow0. 1mm** **s**
1			%						Gm/ml	%	%	%	%	%				
2	°C	P.H.	Wt															
3		A																
Average																		
	EXTRACTION																	
a.	Vassal + Asphalt													Sieve Analysis				
b.	Vessel Empty													25.4	-			100
c.	Asphalt a –b			394										19.0	-		100	100
d.	Vessel + Aggregate													12.7	81	13,5	86.5	85-100
e.	Aggregate d-b			361										9.5	32	5.3	81.2	75-92
f.	Filter + filler			358										6.35	79	13.2	68.0	65-82
g.	Filter Empty			349										2.36	90	15.0	53.0	50-65
h.	Filler f-g			9										1.18	60	10.0	43.0	36-51
i.	Total Aggregate e+h			370										0.60	34	5.7	37.3	26-40
j.	Binder Content c-I			24										0.300	70	11.7	25.6	18-30
k.	Binder Content % I+ex100			6.0										1.150	60	10.0	15.6	13-24
l.	Unsolve Bitumen													0.075	37	6.2	9.4	7-14
m.	Total K+L%																	




Construction of Kaduna Eastern By-pass Road (with spur to Rabah Road)
contract No: 5346
EKSIOGULLARI
JOB MIX FORMULAR
BULK DENSITY
2.35
2.30
2.25
5.0 5.5 6.0 6.5 7.0
VOIDS IN TOTAL MIX
7.0
6.0
5.0
4.0
3.0
5.0 5.5 6.0 6.5 7.0
FLOW
5
4
3
2
1
5.0 5.5 6.0 6.5 7.0
STABILITY
10
9
8
7
6
5.0 5.5 6.0 6.5 7.0
VOIDS FILL WITH BITUMEN
80
75
70
65
60
5.0 5.5 6.0 6.5 7.0
MARSHALL TEST RESULTS
MAXIMUM DENSITY 2.33 g/cm³
MAXIMUM STABILITY 9.4 KN
VOID IN MIX 4.0 %
OPTIMUM BITUMEN CONTENT 5.9 %
FLOW 3.0 mm
B/C = (6.0 + 5.6 + 6.0) / 3 = 5.87%

Material Testing Laboratory					**MARSHALL TEST DATA**					**Operator**								
					Wearing Course					**Date:**			**Ref:**					
Sample Height					**Contract**					**Location**								
Mix ref. a	**Temperature** b	C1 C2 C3 C1	**Bit Content** $\frac{Cx\,100}{100+C}$ d	**Weight in Air** e	**Weight in Air after 1hr sock** f	**Weight in water** g	**Volume f –g** h	**Bulk Density e/h** I	$\frac{S}{SGM} + \frac{B-700}{SGM}$ J	**Vol. of Bit d x 1 Sg Bit** k	**Vol of Aggre.** $\frac{100}{SG} - \frac{d}{Ag}$ L	**Void in mix Aggt. 100 – L** m	**Void in Mix Vim 100x K+L** n	**% void filled** $100\,x$ o	**Stability Kg** p	**Corr Factor** q	**Corr Stability Kg** r	**Flow 0.1mm** s
1	°C	P.H.A	% Wt						Gm/ml	%	%	%	%	%				
2																		
3																		
Average																		

	EXTRACTION	
a.	Vassal + Asphalt	
b.	Vessel Empty	
c.	Asphalt a –b	394
d.	Vessel + Aggregate	
e.	Aggregate d-b	361
f.	Filter + filler	358
g.	Filter Empty	349
h.	Filler f-g	9
i.	Total Aggregate e+h	370



SIEVE ANALYSIS				
25.4	-	-	100	
19.0	-	-	100	100
12.7	21	5.7	94.3	85-100
9.5	49	13.2	81.1	75-92
6.35	41	11.1	70.0	65-82
2.36	62	16.8	53.2	50-65
1.18	42	11.4	41.8	36-51
0.60	30	8.1	33.7	26-40

j.	Binder Content c-i	24										0.300	44	11.9	21.8	18-30
k.	Binder Content % i +ex100	6.1										1.150	30	8.1	13.7	13-24
l.	Unsolve Bitumen											0.075	16	4.3	9.4	7-14
m.	Total K+L%															

Construction of Kaduna Eastern By-pass Road (with Spur to Rabah Road)
Contract No. 5346

EKSIOGULLARI

MARSHALL STABILITY CONTROLTEST RESULTS FOR WEARING COURSE

No.	% of Bitumen W_a %	W_b %	grams	Sample Height 1 mm	2 mm	3 mm	Average mm	Wt. in Air (g) A	Weight in H_2O (g) C	Wt. after 1 hr Soaked (B)	Vol. of Spec. V = B-C	Compacted Density Dp	Theortical Density D_t	Void in Mix % V_v	VMA %	Void filled with Bit. % V_f	Flow mm	Stability KN	Corelative Radio	Corrected Stability
ASPHALT WEAEING COURSE MIX DESIGN																				
1	5		57.4	62.5	62.4	62.3	62.4	1194	667	1194	527	2.27					2.4	10.6	0.76	8.1
2	5		57.4	62.4	62.2	62.3	62.3	1195	669	1195	526	2.27					2	10.4	0.76	7.9
3	5		57.4	62.1	62.4	62.3	62.3	1195	669	1195	526	2.27					2.6	10.9	0.76	8.3
AVERAGE												2.27	2.44	6.97	17.69	60.6	2.3			8.1
4	5.5		57.8	62.2	62.3	62.4	62.3	1203	680	1203	523	2.3					2.8	9.8	0.76	7.4
5	5.5		57.8	62	62.4	62.2	62.2	1202	682	1202	520	2.31					3	12	0.76	9.1
6	5.5		57.8	62.2	62.1	62.1	62.1	1199	680	1199	519	2.31					3	11.5	0.76	8.7
AVERAGE												2.31	2.42	4.55	16.66	72.7	2.9			8.4
7	6		58	60.9	61	61	61	1192	678	1192	514	2.32					3.1	12.3	0.76	9.3
8	6		58	60.9	60.9	61.2	61	1197	683	1197	514	2.33					3.5	12.6	0.76	9.6
9	6		58	61	61.2	61	61.1	1199	684	1199	515	2.33					3.4	12	0.76	9.1
AVERAGE												2.33	2.41	3.32	1640	79.6	3.3			9.3
10	6.5		60	62	61.9	62.1	62	1200	678	1200	522	2.3					5	14.2	0.76	10.8
11	6.5		60	62	62	62.1	62	1198	679	1198	519	2.31					4.4	13	0.76	9.9
12	6.5		60	62	61.9	62	62	1199	688	1199	519	2.31					3.3	13.6	0.76	10.3
AVERAGE												2.31	2.39	3.35	17.56	80.9	4.2			10.3
13	7		66	62.4	62.4	62.5	62.4	1195	666	1195	529	2.26					5.7	10	0.76	7.6
14	7		66	62.5	62.5	62.4	62.5	1194	667	1194	527	2.27					4.1	10.2	0.76	7.8
15	7		66	62.5	62.5	62.6	62.5	1196	666	1195	529	2.26					5.8	10.3	0.76	7.8
AVERAGE												2.26	2.38	5.04	19.78	74.5	5.2			7.7

FORMULAR

$V = B - C$

$Dp = \frac{A}{V}$

$D_T = \frac{100 + W_b}{\frac{100}{G_{sf}} + \frac{W_a}{G_b}}$

$V_v = \frac{D_T - D_T}{D_T} \times 100$

$G_{sb} = \frac{100}{\frac{K\%}{G_k} + \frac{I\%}{G_i} + \frac{F\%}{G_f}}$

$VMA = 100 - D_p \frac{(100 - W_b)}{G_{sb}}$

$V_f = \frac{VMA - V_v}{VMA} \times 100$

$P_{ba} = 100 \frac{(G_{se} - G_{sb})}{(G_{eff} - G_{sb})} \times G_b$

Bit. Density = 60/70
Bit. Penetration = 60/70
Agg. Bit. =
Aggregate mix up Density = 2.62

coarse agg =35%
Fine Agg. =60%
Filler=5%
Agg. Mix density = 2.589

Coarse Agg. Vol. density = 2.535
Fine = 2.741

APPENDIX A
TEMPERATURE CONTROL

S/No	Truck Identification	Arrival Time	Department Time	Arrival Temperature	Laying Temperature	Rolling Temperature	Change Before	Cha Afte
1	XB627SNK	6:00pm	6:25pm	165^{oC}	130^{o}	100^{o}	0+990	0+9
2	XB271SNK	6:20pm	6;35pm	165^{oC}	130^{o}	100^{o}	0+957	0+9
3	XA637KRU	6:35pm	6:48pm	165^{oC}	130^{o}	100^{o}	0+997	1+0
4	XA637KRU	6:45pm	6:55pm	165^{oC}	130^{o}	100^{o}	1+027	1+0
5	XB267SNK	6:56pm	7:15pm	165^{oC}	130^{o}	100^{o}	1+057	1+0
6	XB627SNK	7:10pm	7:35pm	165^{oC}	130^{o}	100^{o}	1+067	1+0

PROPERTIES OF BITUMEN

Bitumen penetration 64mm @ 25oc for 60/70 bitumen viscosity
Specific gravity =1.02 @ 25^{oc}
Softening point = 55.65^{oc} @ 5.2minuts
Ductility = 120cm
Flash point = 93^{oc} @ 320 seconds

APPENDIX A

Ref:0041 /28
Date:08/12/2010

ASPHALT BINDER COURSE MIX DESIGN

We hereby present to you the Asphalt Binder Course Mix Design/Mix Formula, using aggregate from our new crushing machine.

Bulk Density	=	2.32g/cm^3
Maximum Stability	=	10.2KN
Voids in Mix (VIM)	=	5.2%
Flow	=	4.2mm
Optimum Bitumen Content	=	4.8%

Bin 1	0-5mm aggregate	=	42%
Bin 2	5-12mm aggregate	=	18%
Bin 3	12-19mm aggregate	=	24%
BIN 4	19-25 mm aggregate	=	16%

STATEMENT OF MIX DESIGN

Mix Design at 4.0% Bitumen
Mix Design at 4.5% Bitumen
Mix Design at 5.0% Bitumen
Mix Design at 5.5% Bitumen
Mix Design at 6.0% Bitumen

Engr. Salihu A. Yunusa [MNSE]
Quality Control Chief Engineer

APPENDIX A

Construction of Kaduna Eastern By-pass Road (with spur to Rabah Road)

Contract NO. 5346

Technical:____________________ Project_____________________ Location ______________________

Date:_________________________ Type of Asphalt BINDER COURSE

SIEVE	**GRADING OF THE COMPONENTS % BY WEIGHT RET**							**COMPOSITION OF THE COMPONENTS % BY WEIGHT OF THE TOTAL AGGREGATE**									**GRADING OF THE TOTAL AGGREGATE % BY WEIGHT**		**SPECIFICATION**
Size Mm	**25**	**20**	**12**	**Dust**				**16%**	**24 %**	**18 %**	**42%**						**Retained**	**Passing**	
								m											
37.5mm																			
25.4mm	100							16	24	18	42							100	100
20.0mm	32.2	100						5.2	24	18	42							89.2	70-90
12.5mm	0.1	17.9	100					-	4.3	18	42							64.2	55-80
10.0mm		0.8	81.5					-	0.2	14.7	42							56.9	47-70
5.0mm		0.4	3.2	100					0.1	0.6	42							42.7	40-60
2.36mm			0.4	84.2						0.1	35.4							35.5	27-45
1.18mm				63.3							26.5							26.7	20-34
600µm				46.							19.7							19.7	14-27

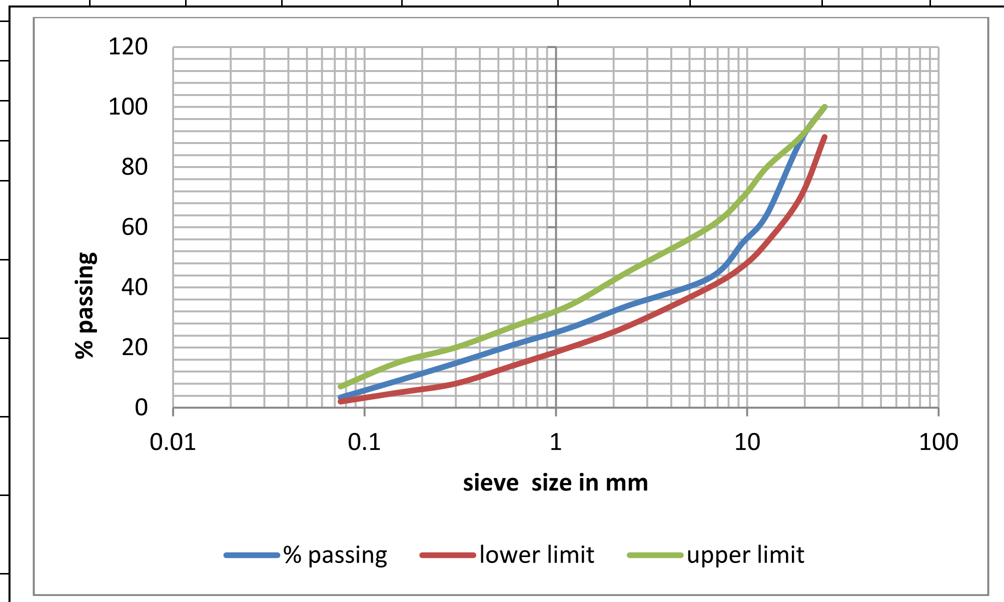
				9															
300 µm				32.2							13.5							13.5	8-20
150 µm				16.6							8.0							8.0	5-15
75 µm				9.7							4.1							4.1	2-7

APPENDIX A

Construction of Kaduna Eastern By-pass Road (with spur to Rabah Road)
Contract No. 5346
COMBINE AGGREGATE

Material Testing Laboratory					**MARSHALL TEST DATA**					**Operator**								
					Binder Course					**Date:**				**Ref:**				
Sample Height					**Contract**					**Location**								
Mix ref. A	**Temperature** b	C C C₃ C₁	**Bit Content** $\frac{Cx\,100}{100+C}$ d	**Weight in Air** e	**Weight in Air after 1hr sock** f	**Weight in water** g	**Volume f –g** H	**Bulk Density e/h** I	$\frac{S}{SGM}+\frac{B-700}{SGM}$ J	**Vol. of Bit d x 1 Sg Bit** k	**Vol of Aggre.** $\frac{100}{SG}-\frac{d}{A}$ L	**Void in mix Aggt. 100 – L** m	**Void in Mix Vim 100x K+L** n	**% void filled** $100\,x$ o	**Stability Kg** p	**Corr Factor** q	**Corr Stability Kg** r	**Flow0.1mm** s

1	°C	P.H.A	% Wt					Gm/ml	%	%	%	%	%
2												
3												
Average												



	EXTRACTION	
a.	Vassal + Asphalt	
b.	Vessel Empty	
c.	Asphalt a –b	461
d.	Vessel + Aggregate	
e.	Aggregate d-b	438
f.	Filter + filler	7
g.	Filter Empty	7
h.	Filler f-g	0
i.	Total Aggregate e+h	438
j.	Binder Content c-1	28
k.	Binder Content % 1*ex100	5.0
l.	Unsolve Bitumen	
m.	Total K+L%	

SIEVE ANALYSIS				
25.4	-	-	100	90-100
19.0	89	20.3	79.7	70-90
12.7	60	13.7	66.0	55-80
9.5	42	9.6	56.4	47-70
6.35	58	13.2	43.2	40-60
2.36	53	12.1	31.1	27-45
1.18	28	6.4	24.7	20-34
0.60	26	5.9	18.8	14-27
0.300	23	5.3	13.5	8-20
1.150	25	5.7	7.8	5-15
0.075	18	4.1	3.7	2-7

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Construction of Kaduna Eastern By-pass Road (with spur to Rabah Road)
contract No: 5346

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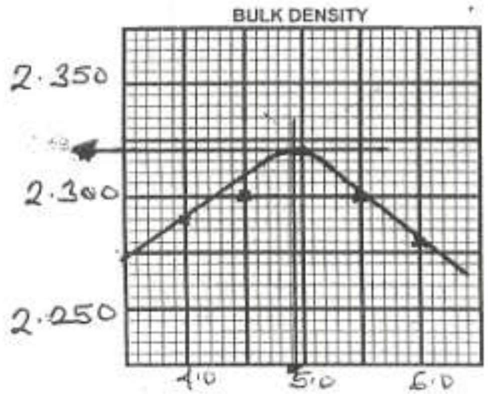
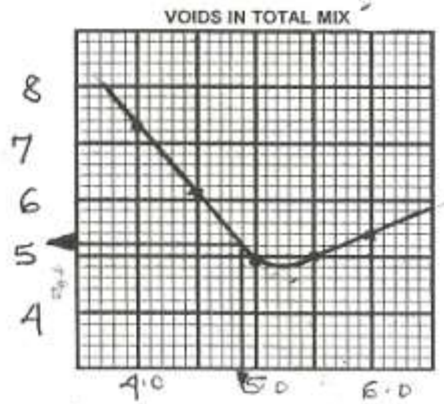
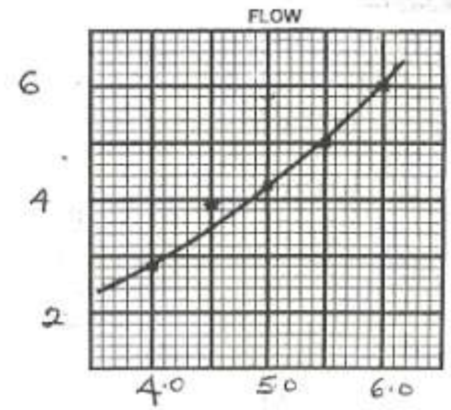
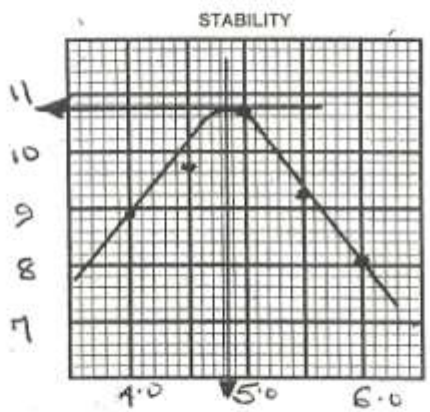
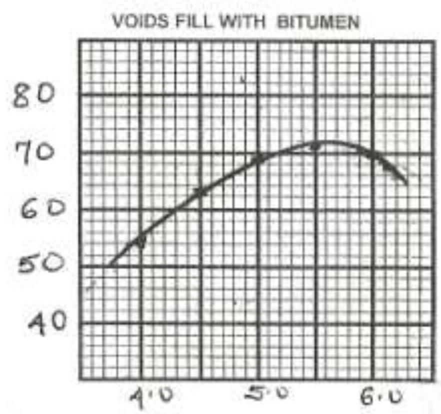
JOB MIX FORMULAR











MARSHALL TEST RESULTS

MAXIMUM DENSITY	2.32	g/cm³
MAXIMUM STABILITY	10.2	KN
VOID IN MIX	5.2	%
OPTIMUM BITUMEN CONTENT	4.8	%
FLOW	4.2	mm

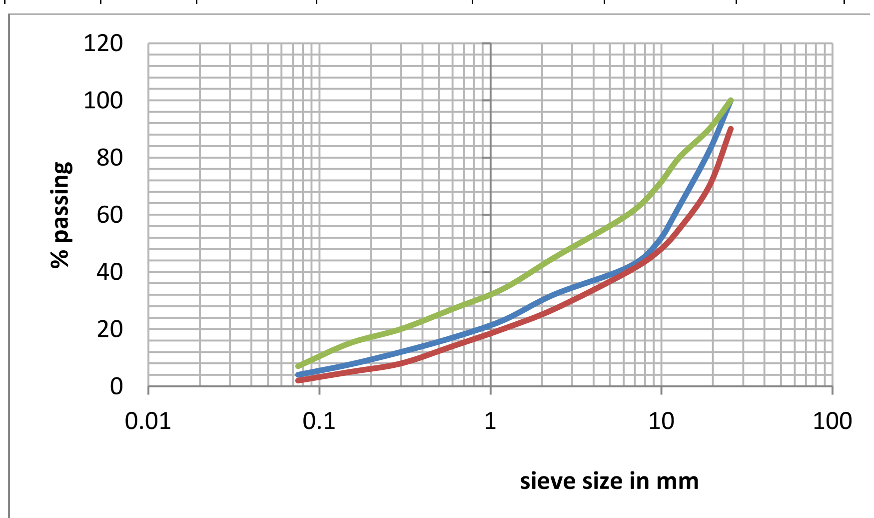
APPENDIX A

Construction of Kaduna Eastern By-pass Road (with spur to Rabah Road)
Contract No. 5346
CONTROL SAMPLE

Material Testing Laboratory	**MARSHALL TEST DATA**	**Operator**	
	Binder Course	**Date:**	**Ref:**
Sample Height	**Contract**	**Location**	

Mix ref. A	Temperature b	Sample Height (C, C, C₃, AV)	Bit Content $\frac{Cx\,100}{100+C}$ d	Weight in Air e	Weight in Air after 1hr sock f	Weight in water g	Volume f −g h	Bulk Density e/h I	$\frac{S}{SGM}+\frac{B-700}{SGM}$ J	Vol. of Bit d x 1 Sg Bit k	Vol of Aggre. $\frac{100}{SG}-\frac{d}{A}$ L	Void in mix Aggt. 100 – L m	Void in Mix Vim 100x K+L n	% void filled 100 x o	Stability Kg p	Corr Factor q	Corr Stability Kg r	Flow 0.1mm s
1	°C	P.H.A	% Wt						Gm/ml	%	%	%	%	%				
2																		
3																		
Average																		

	EXTRACTION	
a.	Vassal + Asphalt	
b.	Vessel Empty	
c.	Asphalt a –b	885
d.	Vessel + Aggregate	



SIEVE ANALYSIS				
25.4	-	-	100	90-100
19.0	95	11.3	88.7	70-90
12.7	20 5	24.4	64.3	55-80

e.	Aggregate d-b	837										9.5	79	9.4	54.9	47-70
f.	Filter + filler	11										6.35	99	11.8	43.1	40-60
g.	Filter Empty	7										2.36	78	9.3	33.8	27-45
h.	Filler f-g	4										1.18	61	7.3	26.6	20-34
i.	Total Aggregate e+h	841										0.60	47	5.6	20.9	14-27
j.	Binder Content c-1	44										0.300	51	6.1	14.8	8-20
k.	Binder Content % 1*ex100	5.0										1.150	49	5.8	9.0	5-15
l.	Unsolve Bitumen											0.075	47	5.6	3.4	2-7
m.	Total K+L%															

Construction of Kaduna Eastern By-pass Road (with Spur to Rabah Road)
Contract No. 5346

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MARSHALL STABILITY CONTROLTEST RESULTS FOR BINDER COURSE

No.	% of Bitumen W_a %	W_b %	grams	Sample Height 1 mm	2 mm	3 mm	Average mm	Wt. in Air (g) A	Weight in H_2O (g) C	Wt. after 1 hr Soaked (B)	Vol. of Spec. V=B-C	Compacted Density Dp A/V	Theoritical Density D_T	Void in Mix % V_v	VMA %	Void filled with Bit. % V_f	Flow mm	Stability KN	Correlative Ratio	Corrected Stability
ASPHALT BINDER COURSE MIX DESIGN																				
1	4		42	62	63	62	62.3	1194	675	1197	522	2.29					2.6	11.8	0.76	9
2	4		42	62.5	62.5	62.7	62.6	1198	680	11201	521	2.3					2.8	11.7	0.76	8.9
3	4		42	62	62.5	62.5	62.3	1198	675	1200	525	2.28					2.9	11.6	0.76	8.8
AVERAGE												2.29	2.47	7.29	15.93	54.2	2.8			8.9
4	4.5		48	62	63	62	62.3	1198	679	1198	519	2.3					3.8	12.8	0.76	9.9
5	4.5		48	62.5	62.5	62.5	62.5	1197	679	1197	518	2.31					8.8	11.9	0.76	9
6	4.5		48	62.5	62.4	62.5	62.5	1199	681	1202	521	2.3					4	13.9	0.76	10.4
AVERAGE												2.3	2.45	6.12	16	62.8	3.9			9.7
7	5		54	61	61.2	61	61.1	1199	686	1201	515	2.33					4.3	13.6	0.76	10.6
8	5		54	61	61	61.2	61.1	1198	679	1198	519	2.3					4.3	13.9	0.76	10.8
9	5		54	60.8	61	61	60.9	1194	685	1191	512	2.33					4	13.6	0.76	10.6
AVERAGE												2.32	2.44	4.92	15.72	68.7	4.2			10.7
10	5.5		60	60	60.5	61	60.5	1198	678	1199	521	2.3					4.9	12.3	0.76	9.3
11	5.5		60	59.5	60	60.5	60	1197	675	1198	523	2.29					5	11.9	0.76	9
12	5.5		60	59.8	59.7	59.9	59.9	1191	675	1193	518	2.3					5	12.1	0.76	9.2
AVERAGE												2.3	2.42	4.96	16.88	70.6	5			9.2
13	6		66	61.5	61.2	61	62.2	1198	673	1198	525	2.28					6	10.2	0.76	7.8
14	6		66	61	61.2	61	61.1	1196	670	1197	527	2.27					5.8	11.2	0.76	8.5
15	6		66	61	61.5	61	61.2	1194	671	1195	524	2.28					6.1	10.6	0.76	8
AVERAGE												2.28	2.41	5.39	18.04	70.1	6			8.1

FORMULAR

$V = B - C$

$Dp = \frac{A}{V}$

$D_T = \frac{100 + W_a}{\frac{100}{G_{sl}} + \frac{Wa}{G_b}}$

$V_v = \frac{D_T - D_T}{D_T} \times 100$

$G_{sb} = \frac{100}{\frac{K\%}{G_k} + \frac{1\%}{G_i} + \frac{F\%}{G_f}}$

$VMA = 100 - D_p \frac{(100 - W_a)}{G_{sb}}$

$V_f = \frac{VMA - V_v}{VMA} \times 100$

$P_{ba} = 100 \frac{(G_{se} - G_{sb})}{(Geff - G_{sb})} \times G_b$

Bit. Density = 60/70

Bit. Penetration = 60/70

Coarse Ag g= 58%

Fine Agg. = 42%

Agg. Mix density = 2.589

Coarse Agg. Vol. density = 2.535

Fine = 2.741

APPENDIX A
TEMPERATURE CONTROL BINDER COURSE

S/No	Truck Identification	Arrival Time	Departure Time	Arrival Temperature	Laying Temperature	Rolling Temperature	Chang Before
1	XB627SNK	12:26pm	12:40pm	150^{Oc}	125^{oC}	100^{oo}	10+005
2	XA637KRU	12.47pm	12:56pm	150^{Oc}	125^{oC}	100^{oo}	9+980
3	XA639KRU	1:12pm	1:19pm	150^{oC}	125^{oC}	100^{oo}	9+955
4	XA638KRU	1:20pm	1:37pm	150^{Oc}	125^{oC}	100^{oo}	9+930
5	XB271SNK	1:55pm	2:03pm	150^{oC}	125^{oC}	100^{oo}	9+905
6	XB267SNK	2:12pm	2:19pm	150^{oC}	125^{oC}	100^{oo}	9+880
7	XA637KRU	2:25pm	2:37pm	150^{oC}	125^{oC}	100^{oo}	9+855
8	XA639KRU	2:56pm	3:03pm	150^{oC}	125^{oC}	100^{oo}	9+830
9	XA638KRU	3:17pm	3:22pm	150^{oC}	125^{oC}	100^{oo}	9+800
10	XB671SNK	3:40pm	3:48pm	150^{oC}	125^{oC}	100^{oo}	9+775

APPENDIX B
TABLE 2 FINE AGGREGATE

BS 410 test	Percentage by weight passing BS sieves			
	Grading Zone 1	Grading Zone 2	Grading Zone 3	Grading Zone 4
mm				
10.0	100	100	100	100
5.00	90.100	90-100	90-100	95-100
2.36	60-93	75-100	85-100	95-100
1.18	30-70	55-90	75-100	90-100
µm				
600	15-34	35-59	60-79	80-100
300	5-20	8-30	12-40	15-50
150	0-10	0-10	0-10	0-15

Table VI-17 Properties of Compacted Asphaltic Concrete

Property	Base-course	Wearing-course
Optimum Bitumen Content	4.5% -6.5%	5.0%-8.0%
Stability not less than	3.5KN	3.5Kn
Flow	2mm-6mm	2mm-4mm
Void in total mixture	3%-8%	3%-5%
Voids filled with bitumen	65%-72%	75%-82%

Table VI13 Aggregate specification for Dense Bitumen Macadam, Asphaltic Base and Wearing Course

Pavement Course	Aggregate Crushing Value	Flakiness Index	Absorption Factor

Dense Bitumen Macadam Base	30	35	1.5
Dense Bitumen Macadam Wearing-course	30	35	0.5
Asphaltic Concrete Base course	30	35	0.5
Asphaltic Concrete Wearing Course	30	35	0.5

Table VI 16 Grading Envelope for Binder and Wearing Courses

Sieve Size	**% By Weight Passing**	
	40mm-65mm Binder-Course	40mm -50mm Wearing –Course
31.8mm	100	100
25mm	90-100	100
19.0mm	70-90	100
12.5mm	55-80	85-100
9.5mm	47-70	75-92
6.4mm	40-60	65-82
2.8mm	27-45	50-65
1.25mm	20-34	36-65
600µm	14-27	26-40
300µm	8-20	18-30
150µm	5-15	13-24
75µm	2-7	7-14
Bitumen Content % by weight of aggregate	4.5 – 6.5	5-8.0

BITUMINOUS MATERIAL
TABLE VI 15 QUALITY OF ASPHALTIC CEMENT

Property	**Asphalt Cement** **80-100PEN**	**60-70PEN**
Specific Gravity @ 25^{o}C	1.00-105	1.01-1.06
Softening Point R and B(^{o}C)	45-52	48-56
Penetration @ 25^{o}C – 0.1mm	80-100	60-70
Ductility @ 25oC-CM Minimum	100	100
Loss on Heating for 5 Hours at 163oC % By Weight – Max	0.5	0.5
Solubility in CS_2, % by WT-MIN	99	99
Drop in Penetration After Heating % Original – max	20	20

Flash point (Open CUP) ^{o}C Min.	225	250
ASH % by WT.Max	0.5	0.5

Table VI 18 Permissible Variation Percent by Weight of Total Mix

	Permissible variation % by Weight of Total mix
Passing sieve 9.5mm and layer	±5%
Passing sieve 9.5mm - 600µm	±4%
Passing 600µm - 150µm	±3%
Passing sieve 150µm-75µm	±0.1%
Bitumen content	±0.3%
Notes:	
Temperature of Mixture when emptied form mixer	145^{o}C± 5^{o}C
Temperature of Mixture on delivery on the road	130^{o}C + 5^{o}C

The job mix formula is liable to alteration by the Engineer throughout the progress of the work but at all times it will be within the specified limits.

APPENDIX C

TEST RESULT ON EKSIOGULLATRI AGGREGATE

AGGREGATE SIZE	**BULK DENSITY**	**SPECIFIC GRAVITY**
3/4"	1.722	2.639
1/2"	1.589	2.621
Dust	1.466	2.631
River sand	1.447	2.595
sand clay content	1.50%	
sand silt content	98.50%	
3/8	1.498	2.60

AGGREGATE SIZE	**FLAKINESS INDEX**	**ELONGATION INDEX**
3/4"	22.90%	25%
1/2"	18%	24.00%

TEST RESULT ON EKSIO QUARY AGGREGATE AS AT 18Th march 2011

Specific gravity Of filler	2.467
specific gravity of combined aggregate	2.615
finess modulus of fine aggregate	2.705
aggregate crushing value	20.78%
aggregate inpact value	12.5%

AGGREGATE CRUSHING VALUE

3/4" 22%

Nate:
The experiment is performed
on aggregate passing sieve 14.5mm
and retained on 10mm