Glassphalt Concrete Production Using Stone Dust as a Filler through Trial Mix Design.

Nkama Amadi E.
Civil Engineering Department
School of Engineering Technology
Transportation Laboratory
Akanu Ibiam Federal Polytechnic,
Nigeria
ekpoconstruction@gmail.com

***Abstract*-Various studies have shown that waste glass has been crushed and screen and can serve as an alternative replacement of fines and coarse aggregate when mixed with Bitumen to form a glassphalt concrete which can be used in landscaping or non-load bearing walls in a building. This researched work was intended to compare and analyze the hot mix glassphalt (HMG) and the strength of asphalt concrete using trial mix design through investigative of their performances. The mineral fillers with different percentage by total weight of the mixture used in the study were crushed igneous rock that passes from 0.075mm to 200mm sieve sizes. However, this production did not only establish the usage of glassphalt but also analysis grade of bitumen like 60/70, 30/40, 80/100, 180/200 etc, its sustainability for various road uses either for priming eg. MCI, tackcoat eg. RSI, or surface dressing e.g S125. Various tests were conducted like water absorption test, marshal stability test, void ration test etc. using bitumen grade 60/70 which has a flash point of 250°c and a melting point of 48 – 56°c. Different types of glassphalt concrete was classified: Macadam, Binder course and wearing course with experimental design to determining the maximum deformation load that will deform the glassphalt concrete to aid in predicting its design life span and equally makes necessary recommendations.**

***Keywords*: Bitumen, Glassphalt Concrete, Production, Design Life, Trial Mix,**

I. INTRODUCTION

The word "glass" described a glassy for vitreous state that is obtained when a liquid cools and becomes more viscous or has the apparent, physical properties of a solid. (Victor & et al, 2010).

For single commercial compounds, the temperature at which the formation of crystals start, is known as the freezing point, but in the case of glasses, which are not composed of a single compound. This temperature is called the liquidus temperature.

Glass is also an inorganic substance in a condition which is continuous with, and analogous to the liquid state of that substance, but which as the result of a reversible change in viscosity during cooling, has attained so huge a degree of viscosity as to be, for all practical purpose and rigid. American society of testing and materials (ASTM) defines glass as "an inorganic product of fusion that has cooled to rigid condition without crystallization"

Therefore glass can be defined as inorganic transparent hard substance with reversible change in viscosity during cooling which can be used in making windows and bottles.

II. GLASS TECHNOLOGY DEVELOPMENT

Glass technology is concerned with the engineering and technological development of glass manufacturer process to satisfy global technological and engineering needs. (Victor & et al, 2010).

Glass engineering technology (GET) deals on the following:

a. Engineering designs of glass making systems.
b. Research and development of new and better glass manufacturing methods that is cost effective.
c. Fabrication of parts and components in conjunction with other technologies for the building of glass making systems.
d. Developments of an effective operation planning and control managements mechanism to ensure that technical glass are manufactured to meet the end users standard specifications.

III. GLASSPHALT CONCRETE

Concrete comes from a Latin word "Konkretus", which means to grow together. Concrete is a composite material made up of appropriate proportions of aggregates, cement and water that after a while hardens to form a rock like mass (Elechi,2012).

Oyenuga, (2008). Defines concrete as a composite inert material comprising of a binder course (e.g. cement), mineral filler (body) or aggregates and water.

Therefore glassphalt concrete is composed of inorganic materials called aggregates such as crushed stone and glass cemented together with some cementing material (mostly bitumen or binder) which when mixed together get hardened.

IV. GLASSPHALT CONCRETE MATERIALS

a. Aggregate
b. Bitumen
a. *Coarse Aggregate:* As defined by AASTHOM 147 is a hard, durable particles or fragments of stone, gravel or slag retained on the No. 4 sieve (4.75mm). eg. Gravel, crushed stone, etc.
b. *Fine Aggregate:* This is defined by American Association of State Highway and Transportation officials (AASTHO M 147) as natural or crushed sand passing the No. 4 sieve (4.75mm) eg. Sand.

Waste glass that has been crushed and screened can serve as an alternative replacement of fines and coarse aggregate in asphalt paving mixes.

Satisfactory performance has been achieved from hot mix asphalt pavement incorporating 90-95 percent by weight crushed stones in wearing surface of a road. Thus, the term glassphalt consist of pellet of crushed glasses also known as cullet or fines or coarse aggregate and bitumen all mixed together in appropriate proportion. (Abraham, 1972).

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This glass is generally gotten from recycled product like bottles etc. these products are broken into small pieces with relatively smooth edges, the broken pieces ranges from 0.075 – 4.75 mm in size.

Glass aggregate serves as an effective alternative to traditional rock or gravel in place of aggregate used in laying asphalt in road construction, to give a light reflection ability to the pavement.

V. COMPONENTS OF GLASSPHALT CONCRETE

This chapter of the research work unveils the materials used in the production of glassphalt, its behavior properties and its suitability for usage after production. Glassphalt production is composed of two (2) components, aggregate and Bitumen.

Typically, the production of glassphalt involves mixing broken glasses sand/stone dust with bitumen which acts as the binding agent.

Nkama, (2015) defined bitumen as an oil based substance (a semi-solid hydrocarbon product) produced by removing the lighter fractions such as liquid petroleum gas, petrol and diesel from heavy crude oil during the refining process. As such, it is correctly known as refined bitumen.

The word bitumen (latin bitumen) as defined by Abraham, (1960) is a native substance of variable colour, hardness and volatile composed principally of hydrocarbons, substantially free from oxygenated bodies, sometimes associated with mineral matter, the non-mineral constituent being fisible and largely soluble in carbon disulfide, yielding water insoluble suffocation products.

Therefore, any of the various viscous or solid impure relatively non volatile hydrocarbons that occur naturally or are obtained by fractional distillation of petroleum which can be used for paving, roofing and water proofing is called bitumen (American Heritage Dictionary, 2011).

VI. GENERAL PROPERTIES OF BITUMEN

The general properties of bitumen are enumerated below:

i. They contain predominantly, with small quantities of sulphur, oxygen, nitrogen and metals.
ii. They are predominantly soluble in carbon disulphide (CS_2) the portion insoluble in CS_2 being generally less than 0.1%.
iii. Most bitumen is colloidal in nature.
iv. Bitumen is thermoplastic i.e they soften on heating and harden on cooling.
v. They have no specific melting point boiling poi
vi. nt or freezing point, though a form of softening point (Ring and Ball) is used in their characterization.
vii. Bitumen are insoluble in water
viii. They are highly impermeable to the passage of water.
ix. They are generally hydrophobia (water-repellent), but they may be made hydrophilic (water liking) by the addition of small quantity of surface active agents.
x. They are chemically inert and oxidize slowly.

For the satisfactory, performance as a road material, bitumen should have the following desirable properties:

1. It should be fluid enough at the time of mixing to coat the aggregates evenly by a thin film.
2. It should have two temperature susceptibility or in other words, it should exhibit little change in viscosity with change in temperature.
3. The bitumen should have good affinity to the aggregates and should not be stripped off in the continued presence of water.
4. The bitumen should be ductile and not brittle. (Kadiyali, 2001).

VII. BITUMEN EMULSION

For the purpose of road construction, the following types of bitumen emulsion are available.

i. MC1 – (Prime Coat): A prime coat is an initial application of a low viscocity liquid bituminous materials to an absorbent surface preparation to any super-imposed bituminouse treatment or construction.
ii. RS1 – (Tack Coat): A tack coat is an application of a bituminouse binder to an existing surface (blacktopped or otherwise) or between weaving course and binder course to ensure a bond between the new construction and the old surface.
iii. S125 – (surface dressing): Surface dressing also known as surface treatment in the USA is a process whereby a thin film of bituminous binder is sprayed on the road surface. (Road shoulders), covered by a coat of mineral aggregates and well rolled.

VIII. GRADE OF BITUMEN

Bitumen has various grades namely 30/40, 60/70, 80/0, 180/200, etc. bitumen can also be classified into modified bitumen and cutback between. The 60/70 grade is used for the design of Asphalt/glassphalt concrete (binder, wearing course or macadam) on highway in Nigeria with a softening point of 48°c – 56°c and a flash point of 200°c – 250°c (Nkama, 2015). The hardest grade of bitumen in India is 30/40, which has a softening point of 50°c – 65°c. The softest paving bitumen is 180/200 grade, having a softening point 30°c – 45°c. (Kadiyali, 2001).

Types of Glassphalt Production and Its Components

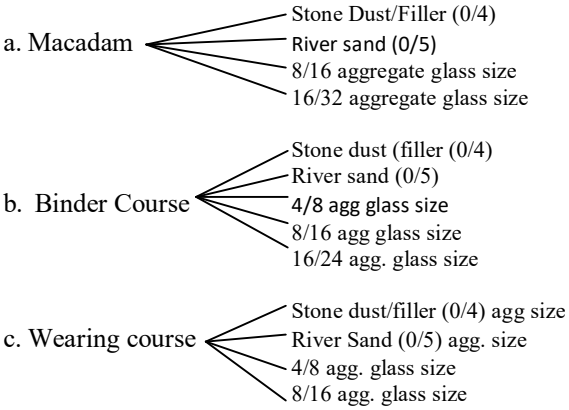

Table I. Aggregate Size and bitumen Percentage Content

Glassphalt/Asphalt	Highest Agg. Glass size	Bitumen % Content Range / Optimum	
Wearing Course	16 mm Ø	5 – 6 %	5.5 %
Binder Course	24 mm Ø	4 – 6 %	5%
Macadam Course	32 mm Ø	3.3 – 3.6	3.5%

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Table II. Aggregate Temperature and bitumen temperature range During Glassphalt Production

		Temperature Range
Glassphalt	Aggregate	130°C – 150°C
	Bitumen	135°C – 160°C

Bitumen Temperature is about 10°c difference.

IX. TESTS FOR BITUMEN

Penetration Test

An indirect measure of viscosity is the amount of penetration of a standard needle under standard conditions of load, time and temperature. The test measures the hardness or softness of bitumen in terms of penetration, expressed in units of mm/10 of the standard needle.

The standard conditions selected are:

- Temperature: 25°c (test to be performed after sample is kept for one hour in water-bath at this temperature).
- Load on needle:100gms
- Time in which penetration is recorded: 5 secs
- Penetration less than 2 and greater than 500 cannot be determined satisfactorily.

A bitumen of penetration 80/100 signifies that the range of penetration of the bitumen is 80-100, expressed in tenths of a millimeter. The lower the penetration value, the harder is the grade of bitumen (Kadiyali, 2007).

A. Softening Point

A viscous material like bitumen or tar does not have a well defined softening point.

However, a standard test determines the temperature at which a standard ball will pass through a disc of bitumen contained in a ring.

The test is known as the "ring and ball test". A brass ring containing the bitumen sample is suspended in water or glycerin at a given temperature. A steal ball is placed on the disc of bitumen. The liquid medium is then heated at the rate of 5°c increase per minute. The temperature at which the softened bituminous material below the bottom metal plate placed at a specified distance below the ring is recorded as the softening point.

Specific Gravity: Specific gravity of a binder does not influence its behavior. But all the same, its value is needed in a mix design. The property is determined at 27°c by a pycnometer or by preparing a cube of a sample. The specific gravity of road making bitumen varies from 1.02 to 1.04, tars have a higher specific gravity (1.16 – 1.28).

B. Viscosity Of Bitumen

Viscosity is the property of a fluid that determines the resistance offered by the fluid to a shearing force under laminar flow conditions. It is thus the opposite of fluidity. The determination of viscosity is generally done by efflux viscometers. They work on common principles, though they differ in detail. The liquid under test is poured to a specified level into a temperature control. At the base of the container is a small orifice with a simple valve control.

On opening the valve, the time in seconds is recorded for a stated quantity of liquid to discharge into a measuring liquid below:

The viscometers commonly used are:

1. STV (Standard Tar Viscometers) for cut-back (10mm dia orific and 50 ml of fluid to discharge).
2. Saybolt furol viscometer (for bitumen) (3mm dia orifice and 60ml of fluid to discharge).
3. Redwood Viscometer (4mm dia orifice and 50 ml of fluid).
4. Engler Viscometer (for emulsion) 3mm dia orifice and 200 ml of fluid to discharge).
5. These efflux viscometers determine viscosity in an indirect mannerly measuring the time taken for flow through the orifice. The time measured does not bear any relation to the absolutely velocity.

C. Properties Of Glass

a. *Density:* the density of glass is 2.5, which gives flat glass a mass of 2.5kg per m^2 per mm of thickness, 2500kg per m^3.

b. *Compressive Strength:* The compressive strength of glass is extremely high, 1000 N/mm^2 = 1000 mpa. This requires a load of some 10 tones.

c. *Tensile strength:* When glass is duplicated, it has one face under compression and the other in tension, whilst the resistance of glass to compressive stress is extremely high, its resistance to tensile stress is significantly lower.

d. *Elasticity:* Glass is a perfect elastic material. It does not exhibit permanent deformation, until breakage. However, it is fragile and will break without warning if subjected to excessive stress.

X. TEST RESULTS

In carrying out this research, specific and accurate information on the method chosen to arrive at a result and procedure is needed and critical for effective decision. It also involves collection of materials used in the mixture, includes coarse and fine aggregates and bitumen for glassphalt concrete production.

However, these ingredient materials were subjected to various laboratory tests in order to determine their physical properties whether they can meet common specifications limits. The test carried out on the glassphalt concrete include; penetration test, water absorption test, sieve analysis, flash point, softening point test etc. as indicated in then tables below:

Table III. Penetration Test 1/10mm/250c

DATE	TIME	TRACK NO	1	2	3	AV	REMARKS
	8am	B7424	63	63	64	63	60-70

Table IV. Softening point R + B (oc)

DATE	TIME	TRACK NO	1	2	3	AV	REMARKS
	8am	B7424	50.5	50.5	-	50.5	48-56°c

Table V. Flash point Open Cup (oc)

DATE	TIME	TRACK NO	1	2	3	AV	REMARKS
	8am	B7424	260	-	-	260	≥ 250°c

Table VI. Specific Gravity (25oc)

DATE	TIME	TRACK NO	1	2	3	AV	REMARKS
	8am	B7424	1.06	1.05	-	1.06	1.02-1.06

Grain size analysis: This test was carried out to decide the particle size distribution of sample in accordance with BS 812 Parts 103:1985

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Table VII. Sieve Analysis of Fine Aggregate (River Sand)

SIEVE NO	SIEVE SIZE	WT RTD	% WTRTD	% WT PASSING
4	4.750	0	-	100
10	2.00	0	-	100
20	0.850	18.6	3.72	96.25
40	0.425	291.6	58.32	37.96
60	0.212	112.4	22.48	15.48
100	0.150	11.7	2.34	13.14
200	0.075	0.7	0.14	13.0
PAN	-	0.5	0.10	12.90
TOTAL		498.5		

ERROR = 500.0 – 498.5 = 1.5g

ERROR % $= \frac{1.5}{500} \times \frac{100}{1} = 0.3\%$

Table VIII. Sieve Analysis of Fine Aggregate (stone dust)

SIEVE NO	SIEVE SIZE	WT RTD	% WTRTD	% WT PASSING
4	4.750	9.82	2.00	98.0
10	2.00	3.6	7.20	90.8
20	0.850	163.45	32.70	58.1
40	0.425	124.30	24.90	33.2
60	0.212	64.50	12.90	20.3
100	0.150	40.50	8.10	12.2
200	0.075	18.50	3.70	8.5
PAN	-	38.0	7.60	0.9
TOTAL		495.1		

ERROR = 500.0 – 495.1 = 4.9g

ERROR % $= \frac{4.9}{500} \times \frac{100}{1} = 1.0\%$

Table IX. Sieve Analysis of Coarse Aggregate (Broken Glass)

SIEVE NO	SIEVE SIZE	WT RTD	% WTRTD	% WT PASSING
4	4.750	497.46	55.3	33.0
10	2.00	105.30	11.7	20.0
20	0.850	112.30	12.5	9.7
40	0.425	97.10	10.8	1.5
60	0.212	73.10	8.2	0.8
100	0.150	6.70	0.7	0.8
200	0.075	0.00	0.0	0.8
PAN	-	0.0	0.0	0.8
TOTAL		892.5		

ERROR = 900 – 892.5 = 7.5g

ERROR % $= \frac{7.5}{900} \times \frac{100}{1} = 0.8\%$

XI. WATER ABSORPTION TEST

This test was carried out to measure the degree of water intake by the samples due to the presence of voids in accordance with BS 812: part 109:1990 and part 2: 1995 method of test.

Table X. Determination of Particles Density and Water Absorption (Broken Glass – 8/24 mm Aggregate)

Mass	Condition of Aggregate	Test No 1	Test No 2	Average
A	Mass of Saturated surface dry sample in air (g)	500.0	500.0	500.0
B	Vessels containing sample and filled with water (g)	1120	1100	1110
C	Mass of vessel filled with water only (g)	890.0	920.0	905.0
D	Mass of oven dry sample in air (g)	500.0	500.0	500.0
Particle density oven dry basis: D/((A-(B-C))mg/m^3		1.85	1.56	1.71
Particle density ssd: A/((A-(B-C))mg/m^2		1.85	1.56	1.71
Particle density apparent: D/(D-(B-C)mg/m^3		1.85	1.56	1.71
Water absorption 100 X (A-D)/D%		0.0	0.0	0.0

Table XI. Determination of Particles Density and Water Absorption (River Sand – 0/5 mm Aggregate)

Mass	Condition of Aggregate	Test No 1	Test No 2	Average
A	Mass of Saturated surface dry sample in air (g)	500.0	500.0	500.0
B	Vessels containing sample and filled with water (g)	1343.4	1343.7	1343.6
C	Mass of vessel filled with water only (g)	1033.7	1033.7	1033.7
D	Mass of oven dry sample in air (g)	498.2	498.6	498.4
Particle density oven dry basis: D/((A-(B-C))mg/m^3		2.618	2.624	2.622
Particle density ssd: A/((A-(B-C))mg/m^2		2.627	2.632	2.630
Particle density apparent: D/(D-(B-C)mg/m^3		2.643	2.644	2.644
Water absorption 100 X (A-D)/D%		0.361	0.280	0.321

Table XII. Aggregate Crushing Value (ACV) acc. to BS 812 Part 3 – 8/24 mmØ (Broken Glass)

	Sample	Unit	Test No 1	Test No 2	Average Value
A	Mass of cylinder + Base Plate + materials	G	600	600	600
B	Mass of cylinder + Base Plate	G	1000	1000	1000
C	Mass of surface dry materials sample size 10-14mm (A-B)	G	5000	5000	5000
D	Mass of fraction passing sieve 2.36mm	G	1000	1005	1002.5
E	Percentage fine D/C x 100	%	20.0	20.1	20.5

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Table XIII. Aggregate Crushing Value (ACV) acc. to BS 812 Part 3 – 8/24 mmØ (granite)

	Sample	Unit	Test No 1	Test No 2	Average Value
A	Mass of cylinder + Base Plate + material	G	6000	6000	6000
B	Mass of cylinder + Base Plate	G	1000	1000	1000
C	Mass of surface dry material sample size 10-14mm (A-B)	G	5000	5000	5000
D	Mass of fraction passing sieve 2.36mm	G	705.0	708.0	706.5
E	Percentage fine D/C x 100	%	14.10	14.16	14.13

A. Design Analysis of Glassphalt Concrete Production (Binder Course).

Assuming we want to design and produce a glassphalt concrete of 3.5kg

Note: Binder course has 5% bitumen content (See table 1.1)

Therefore, 5% bitumen of 3.5kg glassphalt = 5/100 x 3.5 = 0.18kg (bitumen)

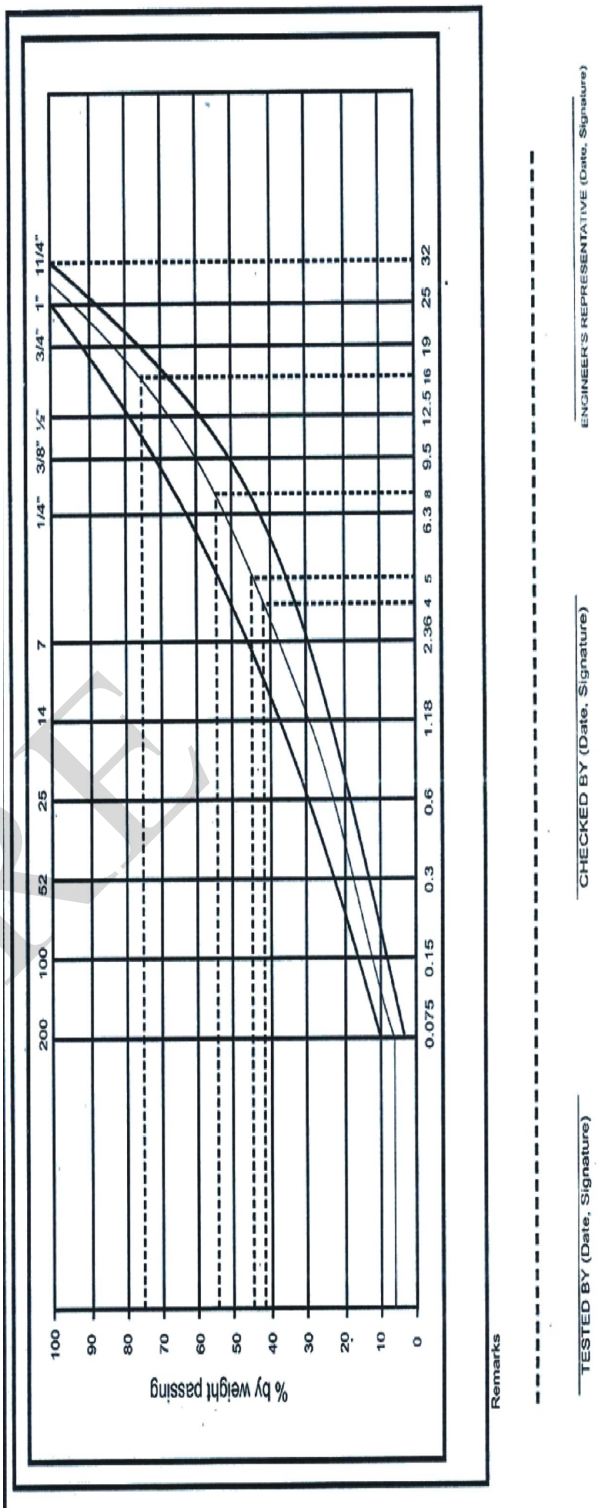
Hence, all aggregate has to be shared among the different aggregate sizes.

Which is 3.5kg (glassphalt concrete) – 0.18kg (bitumen) = 3.32kg (Aggregate)

Table XIV. Sieve analysis of various aggregate sizes

No	Aggregate size	Type of aggregate	No 200	No 100	No 52	No 25	No 14	No 7	1/4”	3/8”	½”	3/4”	1”
	0.075	Filler	80.6	97.3	99.5	100							
	0-5	River Sand	1.3	5.2	19.9	42.0	66.9	87.3	99.3	100			
	0-4	Stone Dust	11.3	17.6	28.3	43.2	60.8	81.6	100				
	4-8	Broken Glass	1.6	2.2	2.9	3.7	4.7	6.4	55.1	99.1	100		
	8-16	“	1.1	1.9	2.7	3.4	4.1	5.0	10.6	34.7	74.1	100	
	16-24	“	0.5	0.6	0.9	1.0	1.0	1.0	1.1	1.2	1.9	43.6	100

Table XV. Percentage Aggregate Used Through The Graph



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B. Analysis Through The Graph Design

Aggregate Size		%WT Passing				
0-0.07 (Filler)	=	5.5%x .32kg			=	0.18kg
0-4(Stone Dust)	=	42% - 5.5%	=	36.5%x.32kg	=	1.21kg
0-5(RiverSand)	=	45.5%-42%	=	3.5%x3.32kg	=	0.12kg
4-8(Crushed glass)	=	55.5%45.5%	=	10% x 3.32kg	=	0.33kg
8-16(Crushed glass)	=	75%-55.5%	=	19.5%x3.32kg	=	0.65kg
16-24(Crushed glass)	=	100%-75%	=	25% x 3.32kg	=	0.83kg
TOTAL					=	**3.32kg**

Hence, bitumen + crushed glass = glassphalt
0.18kg (bitumen) + 3.32kg (Crushed glass)
= 3.5kg glassphalt design

C. Marshal Stability Test Of Glassphalt Concrete

Aim: To determine the maximum load/deformation of a given asphalt

Apparatus Used: Funnel, measuring caliper, hand operated hydraulic extruder, pull out tray, scale pan, scale balance, marshal compactor, marshal mould, rag, mob, square/circular base plate, hot water, caliper etc.

Procedure:

- A fresh sample of mix glassphalt/ asphalt and bitumen was collected and poured into a measuring pan which measured 3500g each, A&B.
- The two samples were placed in an oven at a temperature of about 150°c for about 2 hours before the marshal moulds were placed in an oven to achieve a uniform temperature within the sample.
- After two hours, the samples were removed and poured into the marshal moulds (which were covered top and bottom with a thin sheet) with the help of a funnel.
- Furthermore, the mould was placed in a compaction machine and compact 50 times top and bottom each by a standard hammer which were thereafter placed in a pull out tray.
- The glassphalt concrete was allowed to cool for about 30 minutes before extruding the sample from the mould which was kept at room temperature for about 24 hours before the initial weight of the sample was immensed in hot water at a constant temperature of 60°c for 30 minutes. Each of the samples were removed from the hot water and measured with caliper to know the thickness, the samples were weighed again to know the final weight.
- Lastly, the glassphalt were inserted into the breaking head stability of the asphalt stability machine and crushed.
- Finally, the flow (deformation at maximum load) and the stability maximum load were recorded.
- Hence, the procedure was repeated for Asphalt concrete production using broken igneous rock as an aggregate.

XII. PRESENTATION OF RESULTS

Table XVI. Aggregate proportion value for broken glass

Sizes of Aggregate	Volume
0 – 0.075 mm	0.18kg (Filler)
0 – 4mm	1.21kg (Stone Dust)
0 – 5mm	0.12kg (River sand)
4 – 8mm	0.33kg (Broken glass)
8 – 16mm	0.65kg (Broken glass)
16 – 24mm	0.83kg (Broken glass)

Note: The same volumes and aggregate sizes applies for igneous rock in asphalt concrete production.

Table XVII. Crushed strength value (compressive strength result N/mm2)

Type of Specimen	Sample A	Sample B	Average (N/mm^2)
Asphalt	1.03	1.05	1.04
Glassphalt	0.85	0.87	0.86

Table XVIII. Marshal Stability using crushed igneous rock in Asphalt Concrete Production

Marshal stability			1	2	3
R	Thickness	mm	64.0	64.0	63.0
	Stability	Kp	1290	1320	1300
T	Correction = 41.5/(r-22)	-	0.988	0.988	1.012
U	Correction stability s x t	Kp	1275	1304	1316
V	Correction stability s x t average	Kp		1298	
W	Flow	mm/10	34.6	35.0	34.8
X	Average	mm/10		34.8	

Table XIX. Marshal Stability using broken glass in glassphalt concrete production.

Marshal stability			1	2
R	Thickness	mm	65	65
S	Stability	Kp	890	912
T	Correction = 41.5/(r-22)	-	0.965	0.965
U	Correction stability s x t	Kp	858.9	858.9
V	Correction stability s x t	Kp	588.9	
W	Flow	mm/10	28.4	28.9
X	Average	mm/10	28.7	

Table XX. Void Ratio And Unit Weight Asphalt Concrete

Unit Weight			A	B	C
i	Sample	g	1196.2	1196.9	1191.45
m	Sample wet	g	1199.5	1200.7	1198.5
n	Weight of sample in water	g	689.7	690.8	691.5
o	Volume of sample m-n	ml	509.8	509.9	512.7
p	Unit weight 1/0	g/ml	2.346	2.347	2.350
q	Unit weight average	g/ml		2.348	
Voids					
a	Difference k-p	g/ml		0.061	
b	Voids a x100/k	Vol.%		2.5	
Voids filled with Bitumen					
c	Bitumen Content	%		5.0	
d	Density of Bitumen	g/ml		1.03	
e	Vol. of Mineral c x q/d	%		11.39	
f	Vol. in Mineral b + e	%		13.89	
g	Voids filled bit. e x 100/f	%		82.00	

K = specific gravity = 2.409

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Table XXI. Void Ratio And Unit Weight Of Glassphalt Concrete

Unit Weight			**A**	**B**	**C**
I	Sample	G	1197.4	1198.4	1198.9
M	Sample wet	G	1203.5	1201.1	1202.6
N	Weight of sample in water	G	691.1	693.3	689.9
O	Volume of sample m-n	Ml	512.4	507.8	512.7
P	Unit weight 1/0	g/ml	2.337	2.360	2.338
Q	Unit weight average	g/ml		2.345	
Voids					
A	Difference k-p	g/ml		0.11	
B	Voids a x 100/k	Vol.%		4.5	
Voids filled with Bitumen					
C	Bitumen Content	%		5.0	
D	Density of Bitumen	g/ml		1.03	
E	Vol. of Mineral c x q/d	%		11.38	
F	Vol. in Mineral b + e	%		15.88	
G	Voids filled bit. e x 100/f	%		71.7	

K = specific gravity = 2.409

XIII. CONCLUSION

From the various quality assurance test conducted on the design of glassphalts concrete production and asphalt concrete production based on marshal stability procedures with a comparison to the supported marshal stability criteria, the comparative analysis in designing pavement construction can be drawn and concluded.

Hence, from the marshal stability result and comparative strength of the specimen shown above, which involves using broken glass as partial replacement of aggregate has a maximum load deformation of 588.9 kp to deform the glassphalt concrete.

With water absorption of 0.00%, aggregate crushing values (ACV) of 20.5% and compressive strength of 0.86 N/mm^2 while that of igneous rock (broke stones) as partial replacement of aggregate in asphalt concrete production with the results obtained has maximum load deformation of 1218 kp with maximum water absorption of 0.321%, aggregate crushing value of (ACV) 14.13% and maximum compressive strength of 1.04 N/mm^2

It is therefore, very imperative that to achieve an accurate and efficiency in glassphalt and asphalt concrete production, grade 60 – 70 bitumen must be used, competency and professionalism to guide in achieving a success in the production must also be considered.

RECOMMENDATIONS

Since the compressive strength and the Marshall stability results of the glassphalt concrete is 0.86N/mm^2 and 588.9kp respectively, and does not meet the NIS(Nigerian Industrial Standard) minimum compressive strength of 2.3 N/mm^2 and 3.5N/mm^2 for non load and load bearing walls respectively.

The following recommendations are made thus:

i. The Federal Government of Nigeria and mining industries in this nation shall establish glass manufacturing industries so as to among other benefits from recycling broken glass and industrially prepare glass aggregate for the purpose of light traffic road construction like pedestrian lane and other constructional application like land scalping in an individual compounds.

ii. Glassphalt Concrete can be a replacement for sand concrete block usage in a half walls and inner partitions in a building that doesn't bear any load on it. It can also add as an aesthetic values in a building.

iii. Government of Nigeria has to sensitized on the need not to discard broken glasses since it can be recycled for glassphalt production in which it is economical in usage for placement of igneous rock and (broken stones) in bitumen and aggregate mixture.

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