

RECENT ADVANCES AND INNOVATION IN PAVEMENT CONSTRUCTION WITH CASE STUDIES AND FUTURE PLANS

PROFESSOR SAMSON DUNA
DIRECTOR/GENERAL CHIEF EXECUIVE OFFICER
NIGERIAN BUILDING AND ROAD RESEARCH INSTITUTE (NBRRI)

JUNE 2024

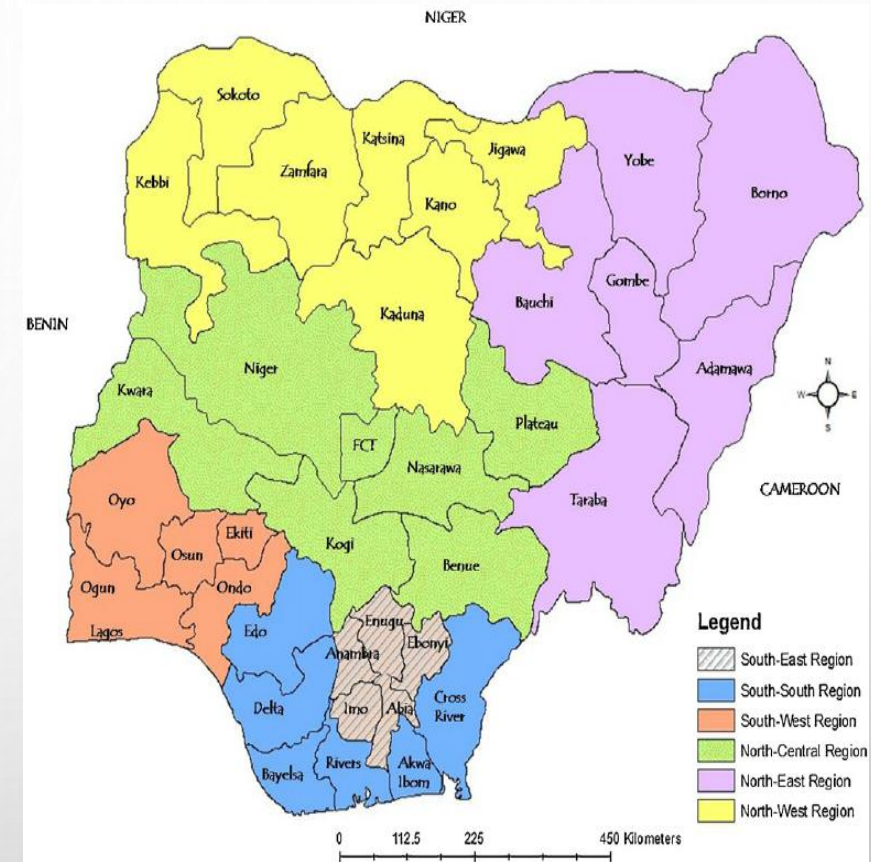


Background

- NIGERIA HAS A POPULATION OF OVER 200 MILLION PEOPLE WITH OVER 250 ETHNIC TRIBES AND 500 INDIGENOUS LANGUAGES.
- THE COUNTRY IS DIVIDED INTO SIX (6) GEOGRAPHICAL ZONES WITH DIFFERING CLIMATE
- ITS STATES ARE LINKED TOGETHER WITH VARIOUS ROAD NETWORKS DEVELOPED OVER MANY YEARS.

Category	Federal Roads	State Roads	Local Govt. Roads	Total	Percentage
Paved main roads	26,500	10,400		36,900	19%
Unpaved main roads	5,600	20,1000		25,700	13%
Urban roads			21,900	21,900	11%
Main rural roads			72,800	72,800	38%
Village access roads			35,900	35,900	19%
Total	32,100	30,500	130,600	193,200	100%
Percentage	17%	16%	67%	100%	

Source: Central Bank of Nigeria 2010





Penetration grading system



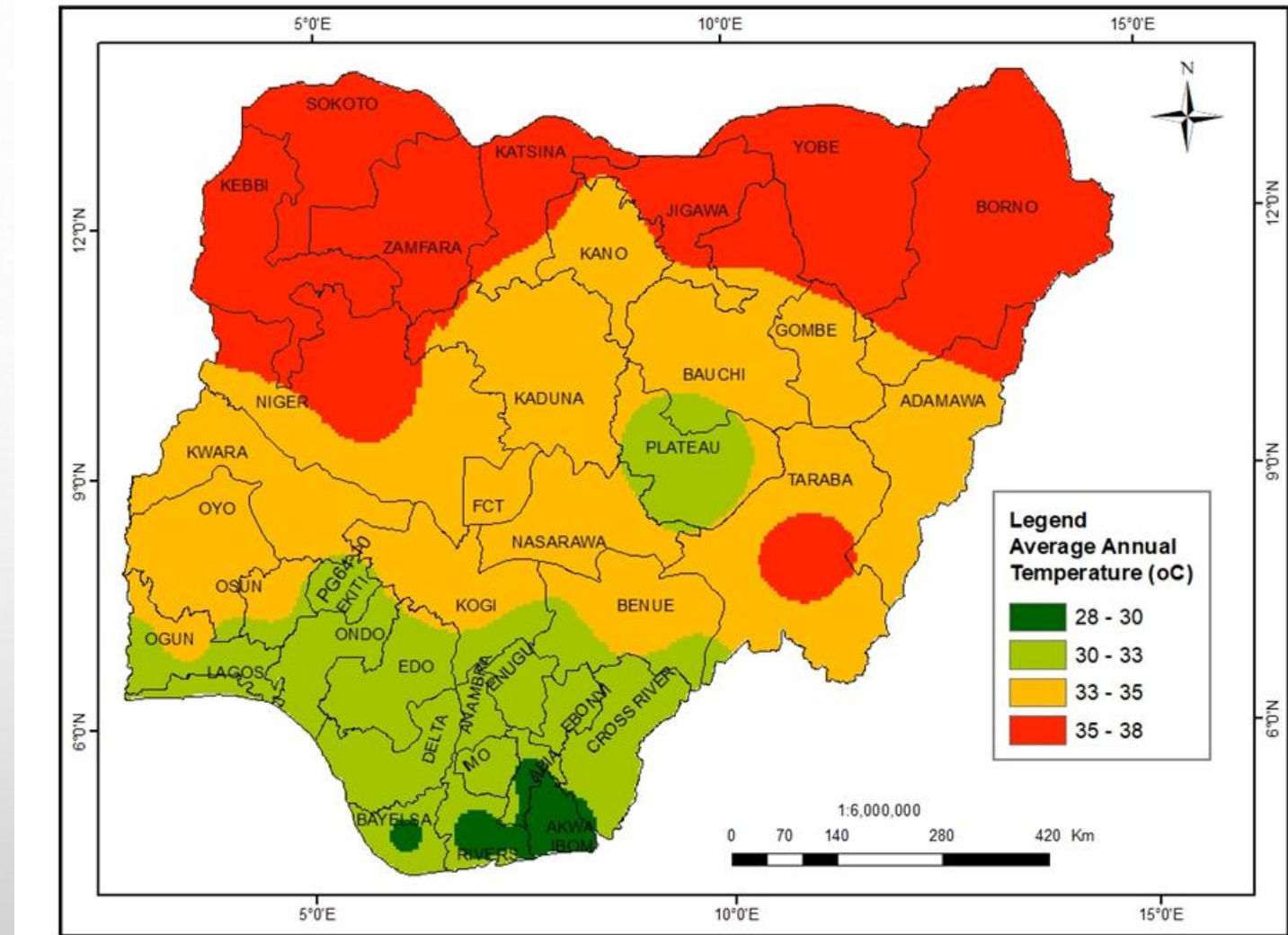
SUPERPAVE MIX DESIGN



Performance grading system

Why do we need to shift

- TRAFFIC VOLUMES AND SPEED
- CLIMATE (MAX AND MIN TEMPERATURES)
- BINDER DURABILITY
- TRAFFIC LOADING
- CLIMATE CHANGE
- SUSTAINABILITY



Average Temperature for each states.

- ❖ A sustainable pavement refers to a type of road or pathway that is designed, constructed, and maintained with considerations for environmental, economic, and social impacts throughout its life cycle.



❖ Bitumen is the most important material in pavement construction therefore it is important to evaluate its sustainability in pavement construction

Bitumen



Aggregate



Pavement Construction

❖ Bitumen Sustainability



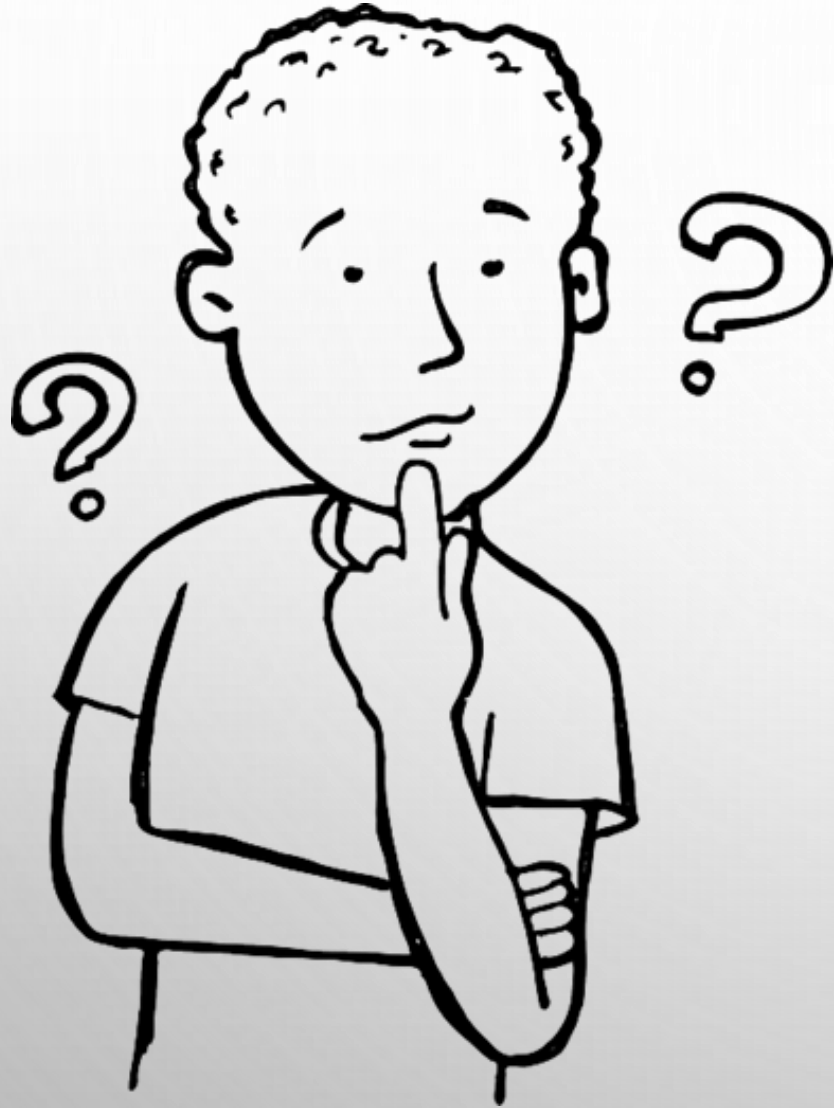
Greenhouse Gas Emission



High Cost Bitumen



Global Crude Oil
Depletion



❖ HOW DO WE ACHIEVE SUSTAINABILITY IN PAVEMENT CONSTRUCTION



Seeking an alternative material for road construction to partially or fully replace conventional bitumen is vital for a sustainable road infrastructure[6].

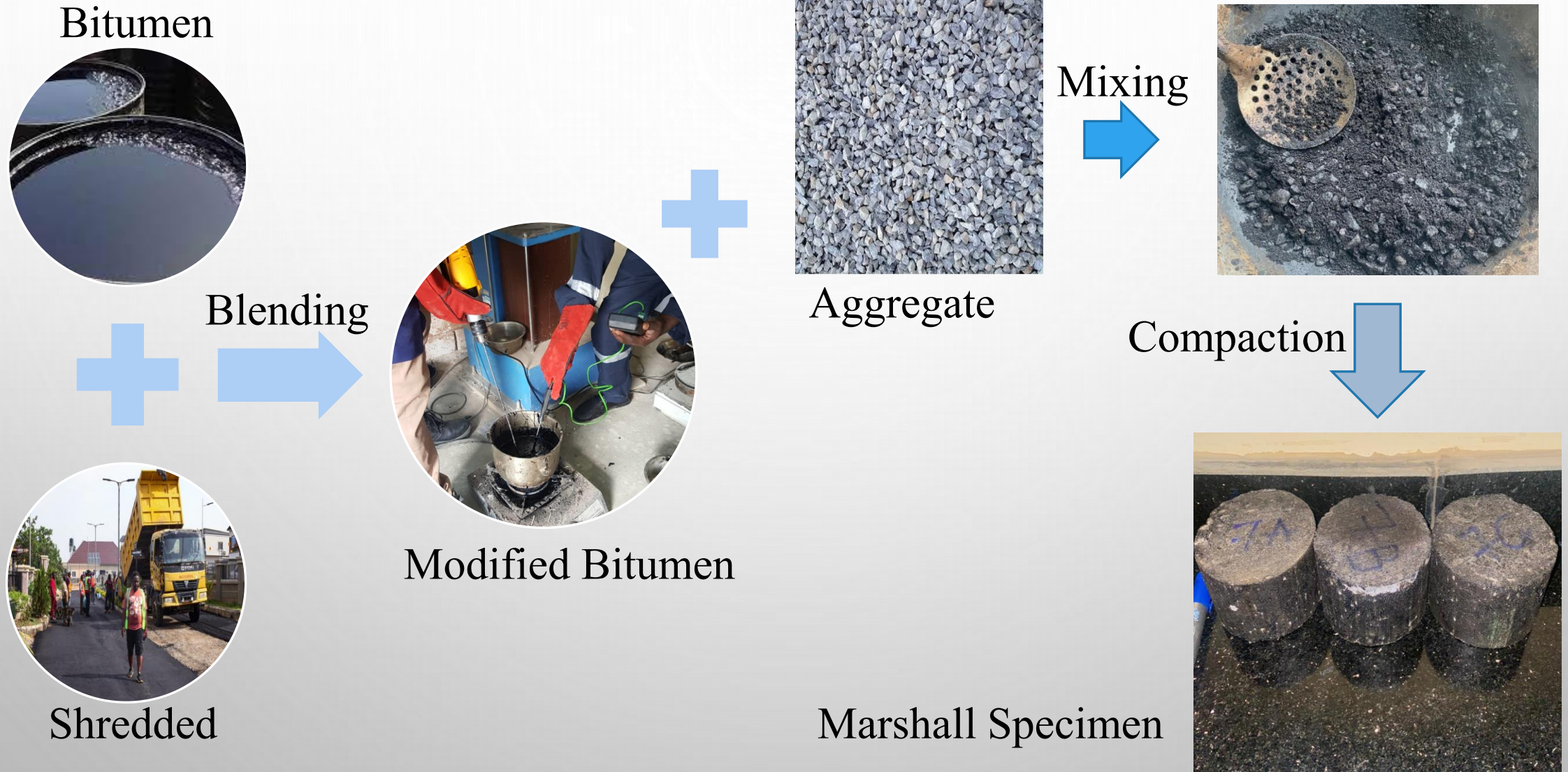
The use of waste plastic in the pavement is seen as a sustainable way of utilizing waste in road construction-related activities; however, this is not new. studies have shown that 5-10% by weight of plastics added into bituminous mixtures would improve pavement stability, strength and durability[7]



Table below presents the test conducted on the materials

S/N	Material	Test	Standard
1	Bitumen	Penetration	ASTM
		Softening (Ring and Ball)	ASTM
2	PET Plastic	Melting Point	IEC
3	Mineral Aggregate	Gradation	AASHTO T 27 ASTM C 136
		Aggregate Impact Value	IS 2386
		Aggregate Crushing Value	ASTM D5821
		Specific Gravity	ASTM D792
		Water absorption	ASTM C127
4	Filler (Lime)	Gradation	ASTM C136

METHODOLOGY



FINDINGS

- The optimum plastic content for 60/70 penetration grade bitumen was found to be 10% by weight of the bitumen
- Waste Plastic modified bitumen increase stability up to 14% in comparison with the unmodified bitumen (Conventional)

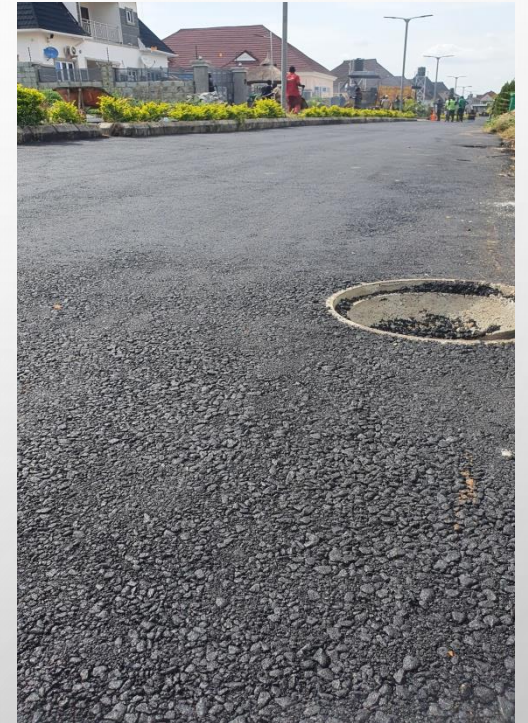
FIELD APPLICATION OF WASTE PLASTIC IN ROAD CONSTRUCTION



CONSTRUCTION SITE



NBRRI TEAM



PAVED ROAD

RUBBERIZED ASPHALT MAT FOR ROAD MAINTENANCE

- About 300 million scrap tyres are discarded annually from USA and 259 million are discarded annually from Nigeria. (Marc lallanilla. 2019).



HEAP OF DISCARDED TYRE IN NIGERIA.

Source: <https://www.TheSpruce.Com/tire-recycling-lets-burn-some-rubber-1708979>

WHAT IS RUBBERIZED ASPHALT MAT (RAM)?

Incorporating the crumb rubber into the bitumen results in modified binder that will be mixed with aggregate in the production of the rubberised asphalt mat (RAM).

BITUMEN



CRUMB RUBBER



AGGREGATE



RUBBERIZED ASPHALT MAT PRODUCTION



BITUMEN MODIFICATION



AGGREGATE AND
BINDER MIXING



RAM COMPACTION



PRODUCT (RUBBERIZED ASPHALT MAT)

FIELD APPLICATION AND INSTALLATION OF RAM

❖ IDENTIFICATION AND RESIZING OF POTHOLE



Cutting of pothole



Scarification and cleaning of pothole



Test fitting of resized pothole

❖ RAM INSTALLATION



Priming of Pothole



Placing of RAM



Sealed edges

❖ PERFORMANCE MONITORING



Patched surface during wet season



Patched surface during dry season

FINDINGS

- Based on the laboratory tests results, the following findings were drawn:
 1. The optimum crumb rubber content was determined at 15% crumb rubber modification
 2. Modification of bitumen with crumb rubber reduces the quantity of waste tyres from the environment
 3. The introduction of crumb rubber as partial replacement in bitumen exhibits better strength characteristics and can carry more traffic load as compared to conventional bitumen.
 4. At 6.0% bitumen content the binder behaves Rubber-like or more elastic and the Asphalt Mat become less temperature sensitive thereby reducing thermal cracking
 5. The Ram can be made readily available in desired dimension which saves time during road maintenance.
 6. Ram also eliminates the presence of heavy equipment on site during road maintenance.

EXPERIMENTAL STUDY OF RUBBERIZED-GLASSPHALT FOR SUSTAINABLE ROAD CONSTRUCTION



Bitumen



Glass Dust



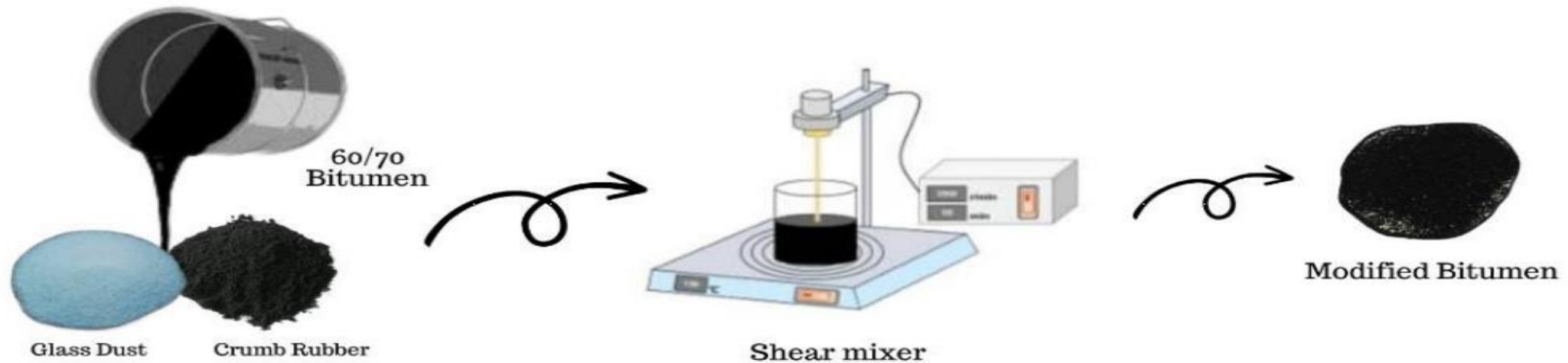
Crumb Rubber



Durable Pavement

METHODOLOGY

Glass dust is a waste generated through resizing (filing) and cutting of glass. The glass was mixed with 60/70 penetration grade bitumen at 5, 10 and 15% by weight of the bitumen and optimum percentage was obtained. Also the crumb rubber was mixed at 5, 10, 15 and 20% by weight of the bitumen and optimum percentage was also obtained. The optimum percentages of both the glass dust and crumb rubber were mixed thoroughly to produce the modified bitumen (crumb rubber glass dust modified bitumen)



METHODOLOGY

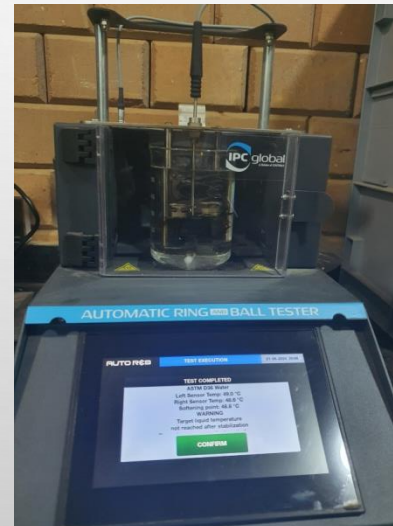


Modify &
Unmodified
bitumen

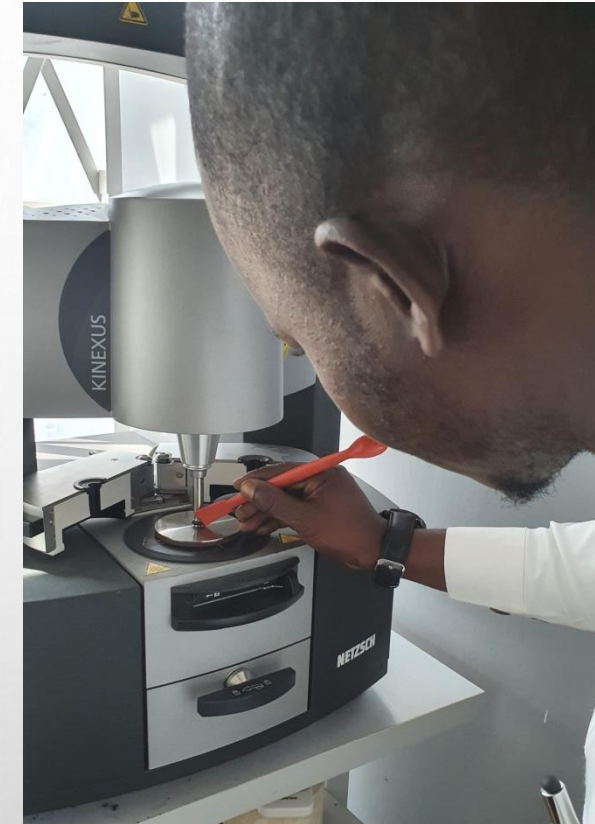
Penetration Test



Subjected to



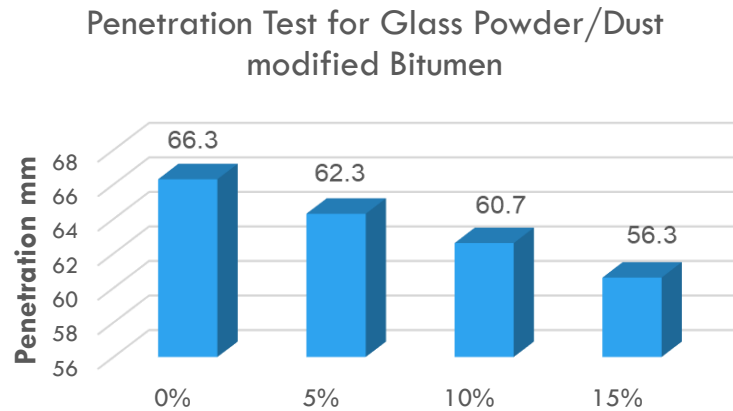
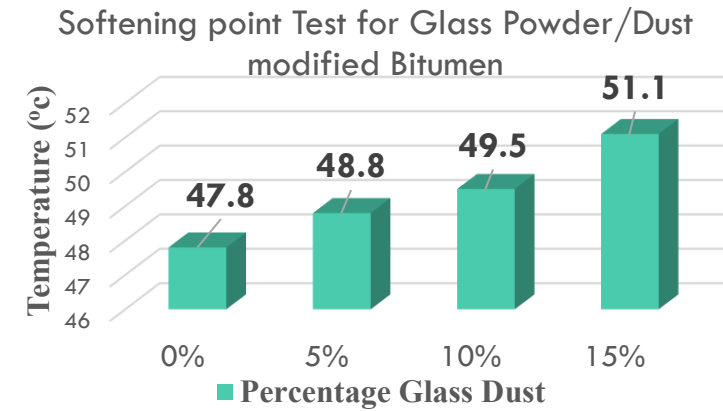
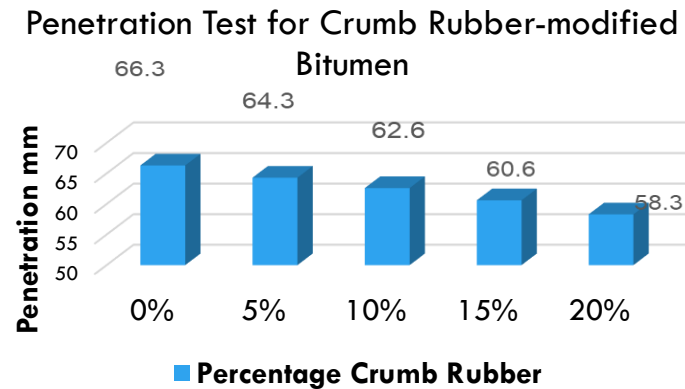
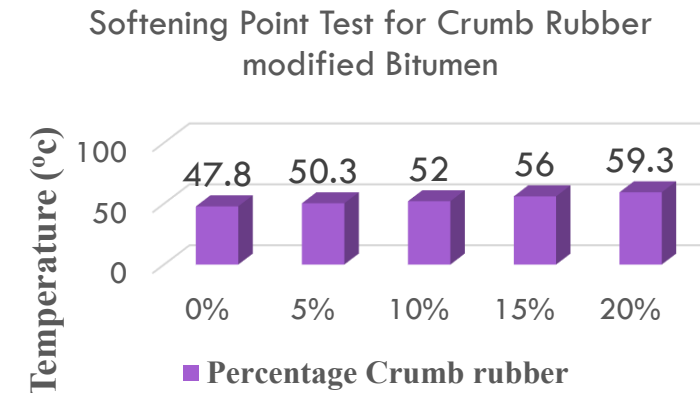
Softening Point



Dynamic Shear Rheometer

RESULTS

ASTM TEST SPECIFICATION FOR BITUMEN					
NO	Properties	Unit	Min	Max	Method
1.	Penetration @ 25°C	MM/10	60	70	ASTM D5
3.	Softening Point °C	°C	48	56	ASTM D36



RESULTS

70% Crumb Rubber mix with 30% Glass dust

Temperature	G*	δ	$\sin\delta$	G*/ $\sin\delta$	Criteria (G*/ $\sin\delta > 1000\text{pa}$)
46	1.01E+04	78.56	0.980133	10314.93	Pass
52	3.87E+03	81.08	0.987906	3914.34	Pass
58	1.61E+03	82.76	0.992027	1617.90	Pass
64	719.5	71.93	0.950678	756.83	Fail
70	353.2	83.59	0.993748	355.42	Fail
76	191.3	81.78	0.989726	193.29	Fail

60% Crumb Rubber mix with 40% Glass dust

60% CRMB + 40% GDMB					
Temperature	G*	δ	$\sin\delta$	G*/ $\sin\delta$	Criteria (G*/ $\sin\delta > 1000\text{pa}$)
46	1.38E+04	6.95E+01	0.936916	14718.49	Pass
52	5.95E+03	71.76	0.949754	6259.52	Pass
58	2.70E+03	73.29	0.957772	2821.13	Pass
64	1.31E+03	73.73	0.959952	1359.44	Pass
70	680.4	72.24	0.952343	714.45	Fail
76	389.4	68.28	0.929003	419.16	Fail

50% Crumb Rubber mix with 50% Glass dust

Temperature	G*	δ	$\sin\delta$	G*/ $\sin\delta$	Criteria (G*/ $\sin\delta > 1000\text{pa}$)
46	4.11E+04	72.37	0.953032	43083.54	Pass
52	1.73E+04	74.4	0.963163	17940.90	Pass
58	7.43E+03	74.56	0.96391	7710.27	Pass
64	3.53E+03	71.98	0.950949	3713.13	Pass
70	1.88E+03	66.74	0.918722	2047.41	Pass
76	1.14E+03	58.73	0.854731	1332.58	Pass

FINDINGS

- The optimum modification of the glass dust in the bitumen was found to be 10% by weight of the bitumen
- The optimum modification of the crumb rubber in the bitumen was found to be 15% by the weight of the bitumen
- The Glass dust mix with crumb rubber improves the rutting resistance of the bitumen at 50% crumb rubber modification and 50% glass dust modification, thereby addressing the effect of high temperature on pavement

GLASS FIBER REINFORCEMENT FOR SUSTAINABLE PAVEMENT CONSTRUCTION



Glass Fiber Reinforcement



Steel Reinforcement



Reinforced Concrete Beam



Curing of Concrete Beams

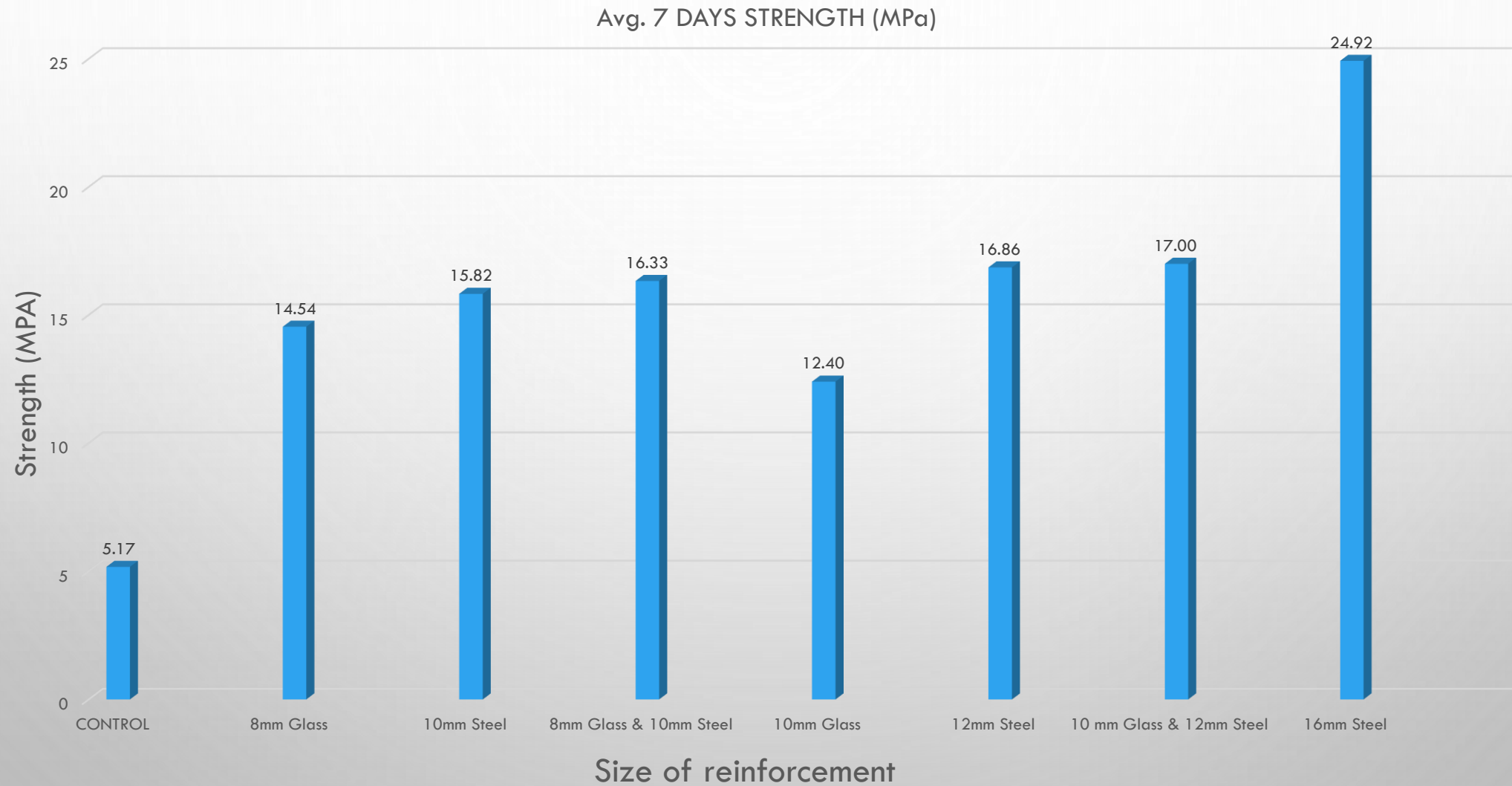


Flexural Test of Concrete Beams



Analysis of Concrete Beams

FINDINGS

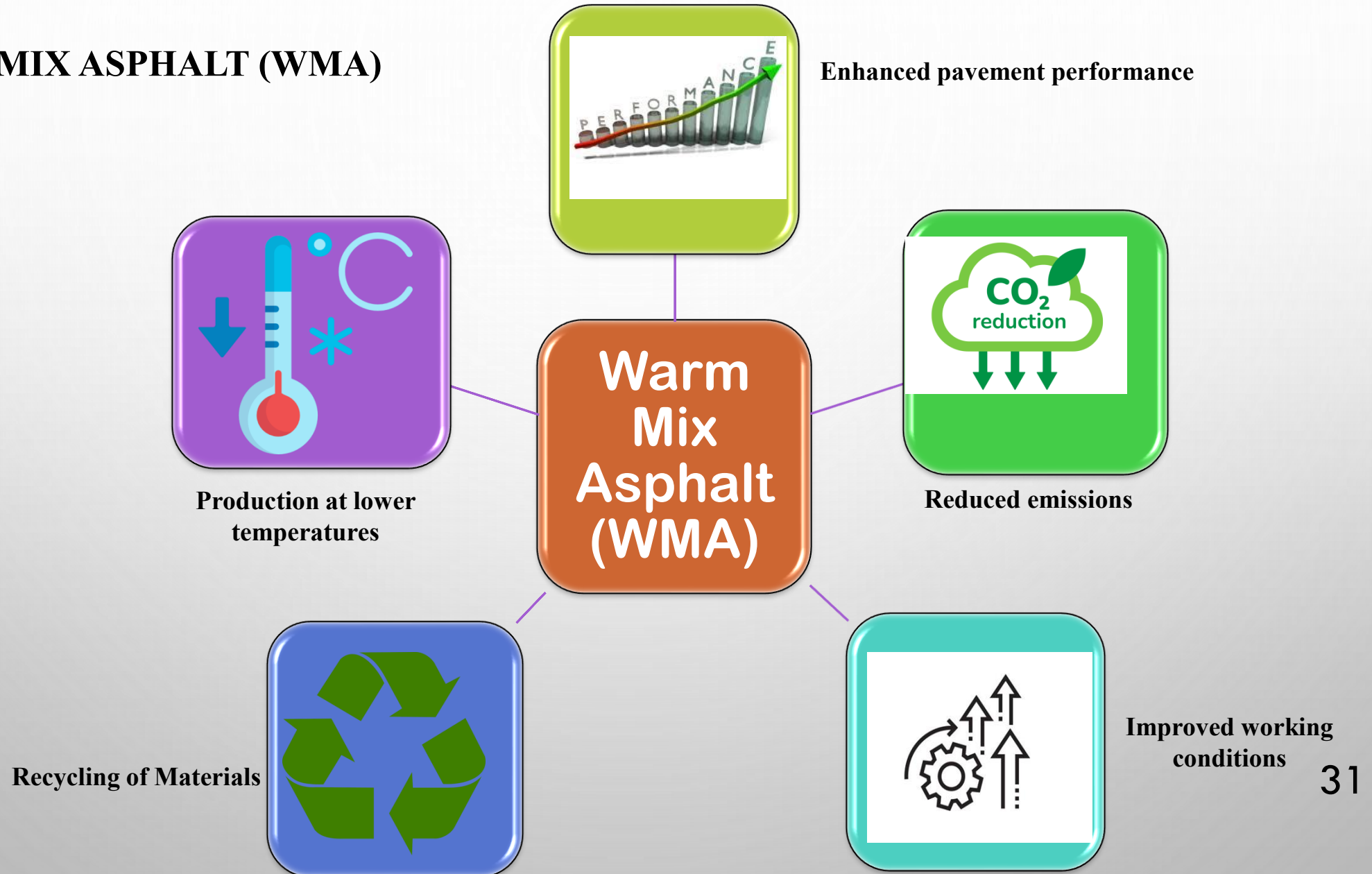


FINDINGS

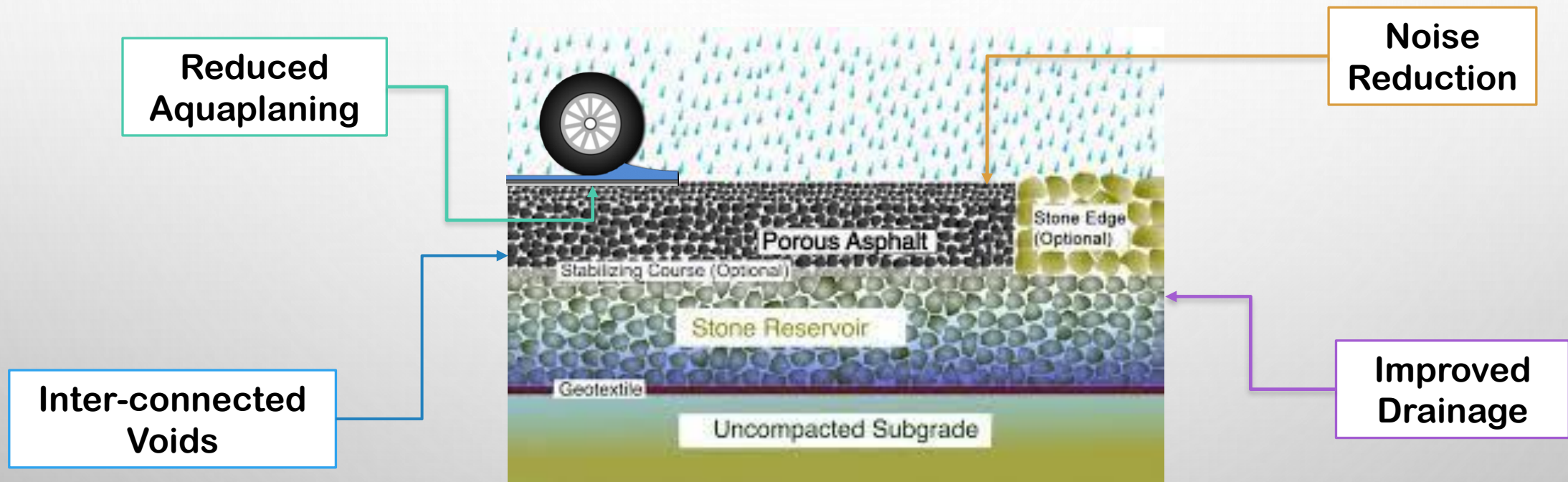
1. Based on the studies conducted, the 8mm glass fiber reinforcement have similar strength to the that of 10mm regular reinforcement
2. Combination of 8mm glass fiber reinforcement and 10mm steel reinforcement have similar strength to 12mm full steel reinforcement

FUTURE RESEARCH FOCUS FOR SUSTAINABLE ROAD PAVEMENT

❖ WARM MIX ASPHALT (WMA)



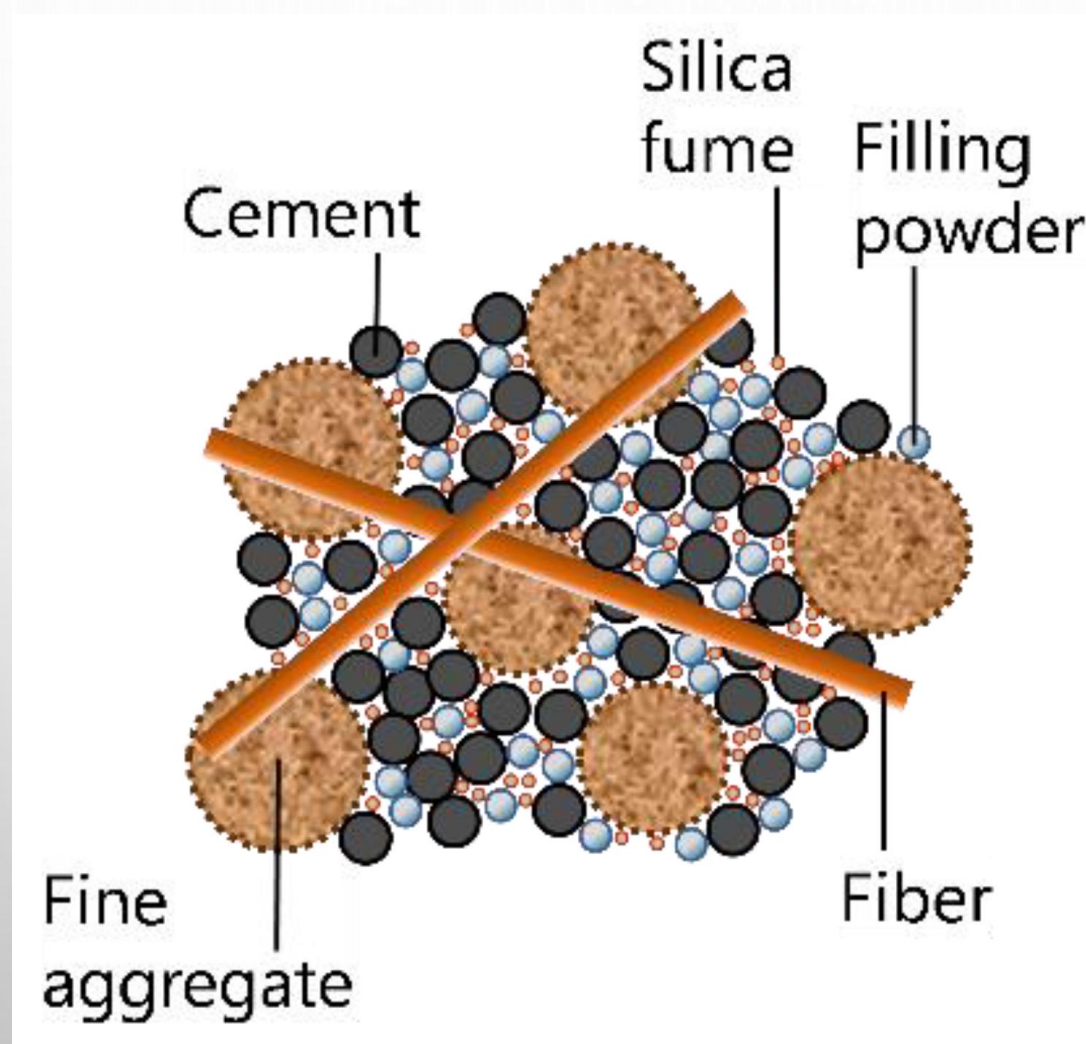
POROUS ASPHALT



HIGH-PERFORMANCE CONCRETE (HPC)

Enhanced
Strength

Durability &
Longevity



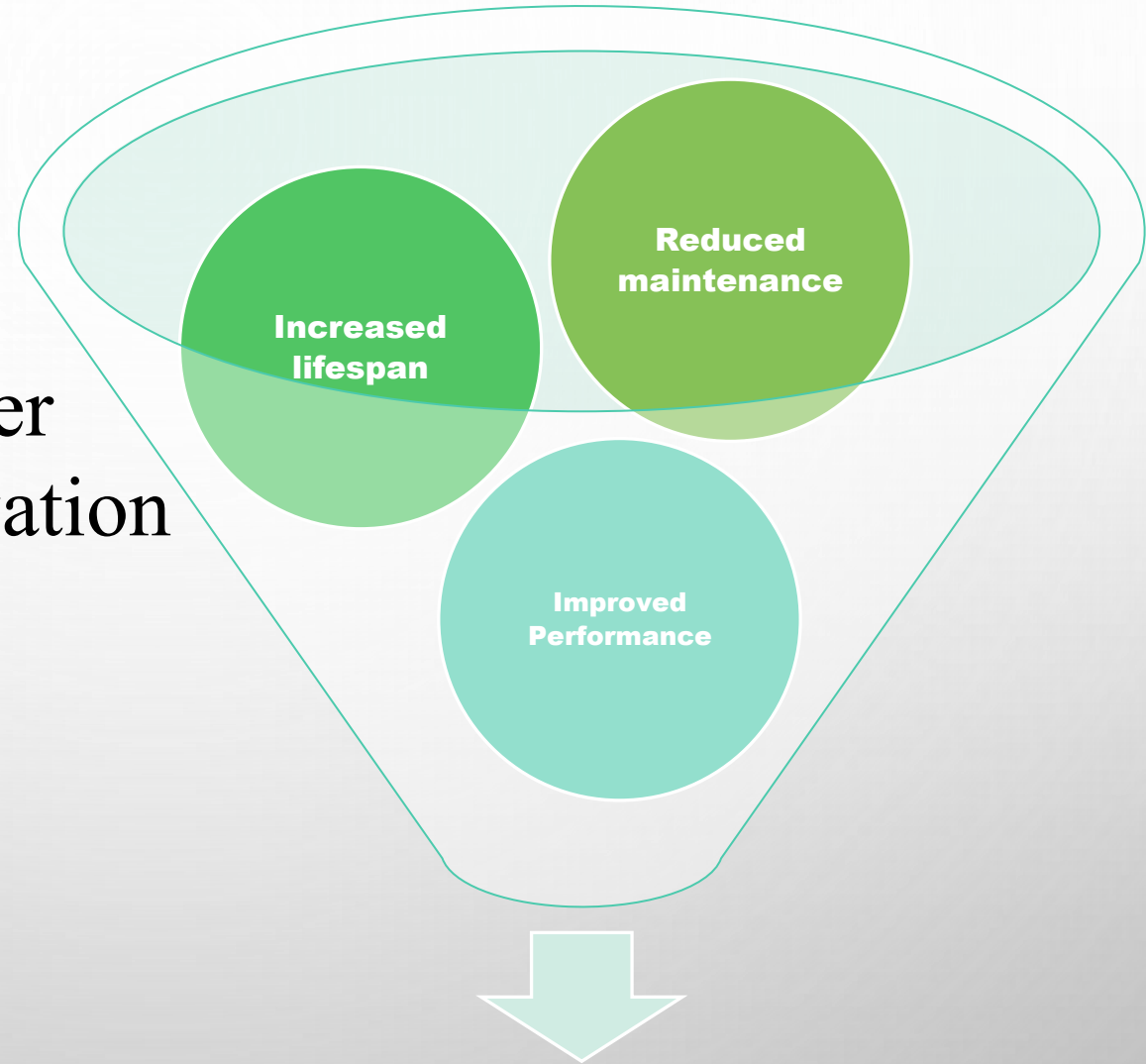
Fiber-reinforced
Concrete

Self-healing
Concrete

GEOSYNTHETICS

APPLICATIONS:

- 1) Separation of Soil Layers
- 2) Filtration/ Drainage of Water
- 3) Soil Reinforcement/stabilization



SUSTAINABLE ROADS

INTELLIGENT PAVEMENTS

BENEFITS:

- ✓ Real-time monitoring
- ✓ Predictive maintenance
- ✓ Enhanced safety
- ✓ Artificial Intelligence



CONCLUSION

1. Based on the study conducted by the Institutes, it is recommended that Nigeria should move from the generic (60/70 Penetration grade) to three (3) penetration grade across the country
2. The performance of waste bottle plastics both at laboratory and field shows that the waste plastic bottles improves both fatigue and rutting resistance of asphalt
3. The introduction of crumb rubber as partial replacement in bitumen exhibits better strength characteristics and improve waste management system
4. The utilization of glass fibre reinforcement in rigid pavement construction reduces the use of higher steel diameter in rigid pavement construction



THANK YOU FOR LISTENING