The Institute of Asphalt Technology
Irish Branch

Designing low energy sustainable asphalt mixtures based on their mechanical properties and performance characteristics.

Dimitris Michailidis (CEng MIEI)

Kilsaran Technical Manager – Road Surfacing & Operational Improvement

PhD research student at UCD

Kilsaran ROAD SURFACING & CONTRACTING

UCD DUBLIN

Research Objectives

- ❖ Global concerns over shrinking natural resources and worsening environmental conditions

- ✓ Development of novel materials and technologies to integrate greener material, waste, and recycled materials into the production cycle of asphalt mixtures
- ✓ Utilizing performance-based tests to characterize asphalt mixtures with view to extend the pavement life cycle, reduce overall costs and minimize the environmental footprint.

- ❖ The environmental burden of pavements may be reduced through the implementation of new strategies and one of these strategies is the life cycle assessment (LCA) approach.

Research Objectives

❖ The term "Sustainability" is a complex word to define.

Sustainability refers to the impacts on environment, economy, and society at all stages.

Including material selection, design, construction, as well as preservation strategies.

Research Objectives

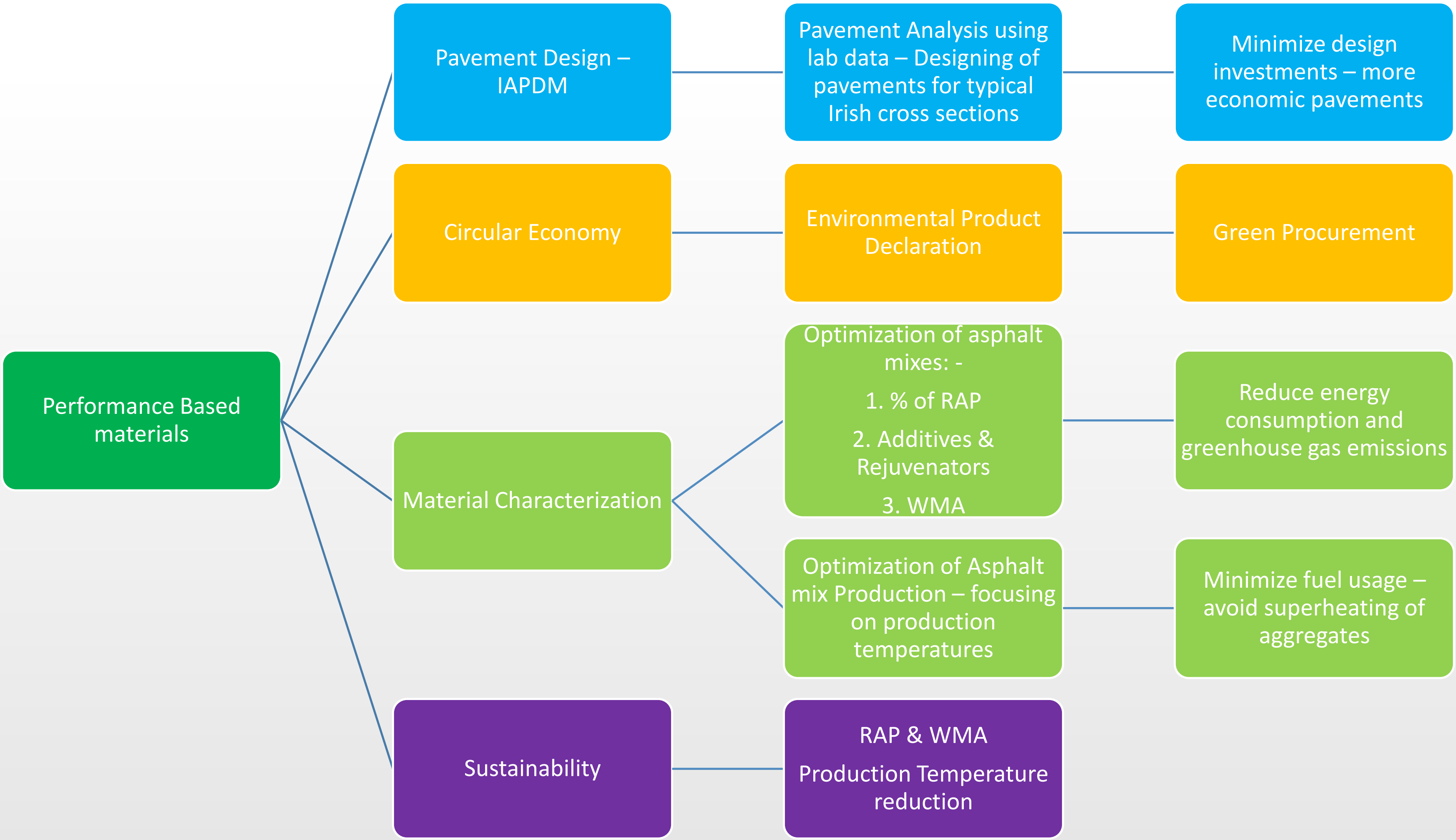
The achievement of sustainability goals with regard to pavements, becomes more difficult due to the fact that these three basic aspects are not easily measured.

Research Objectives

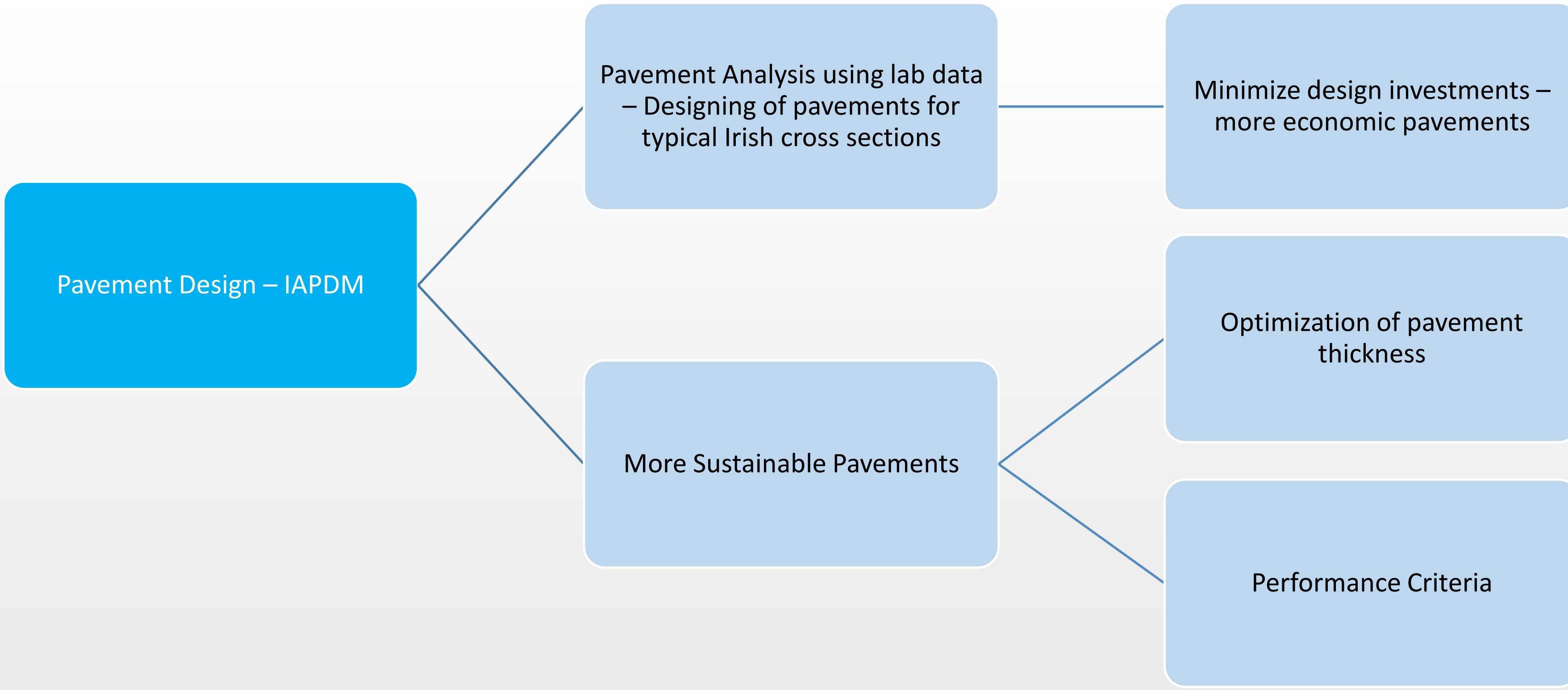
- Given that pavements are material intensive assets, a large focus in pavement sustainability has been on the use of recycled materials in road construction.

- While it may be a narrow view (since it does not consider added benefits), the most common sentiment is that alternatives must perform equal to or better than the current standard practice.

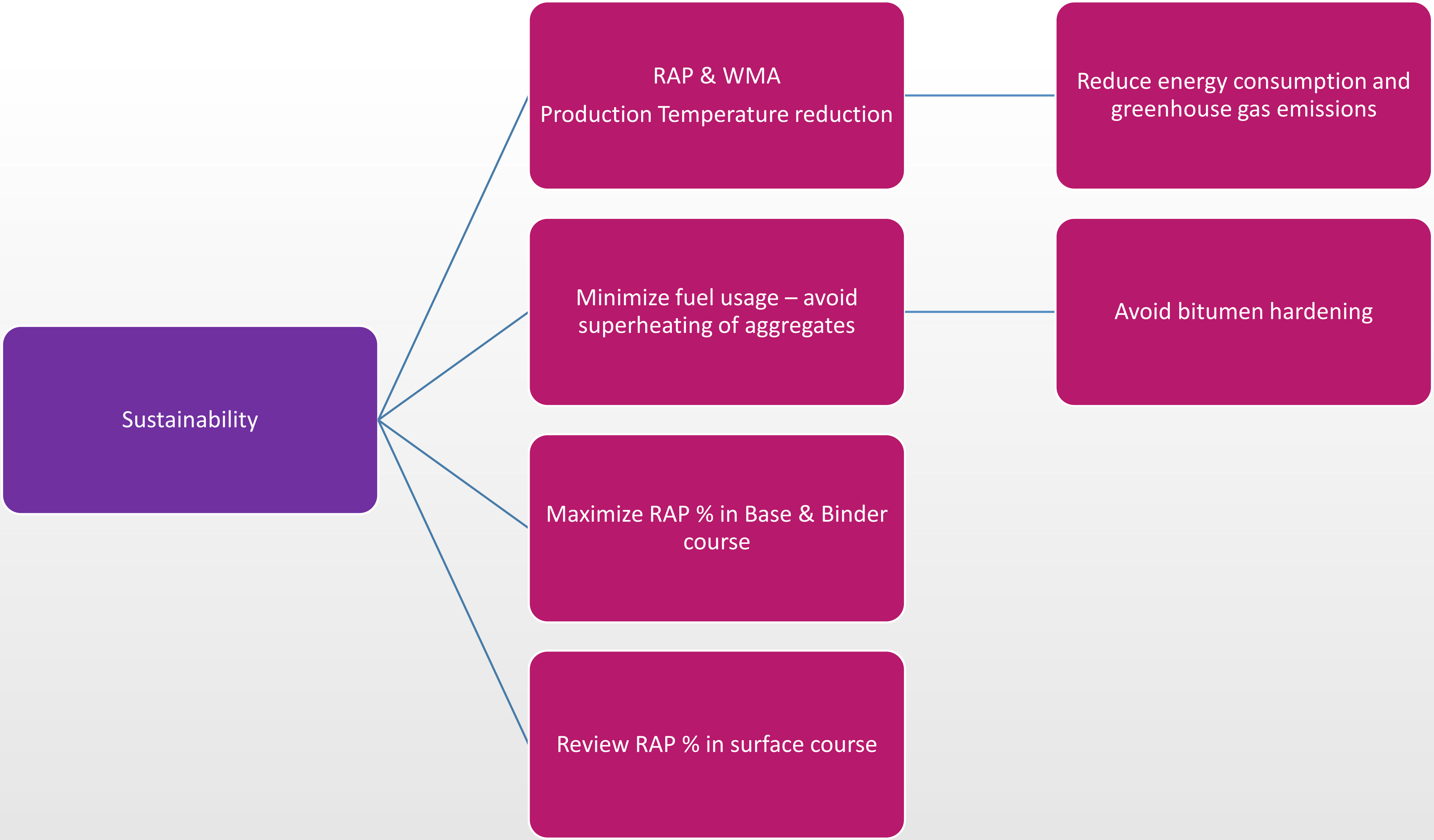
Research Objectives



Research Objectives



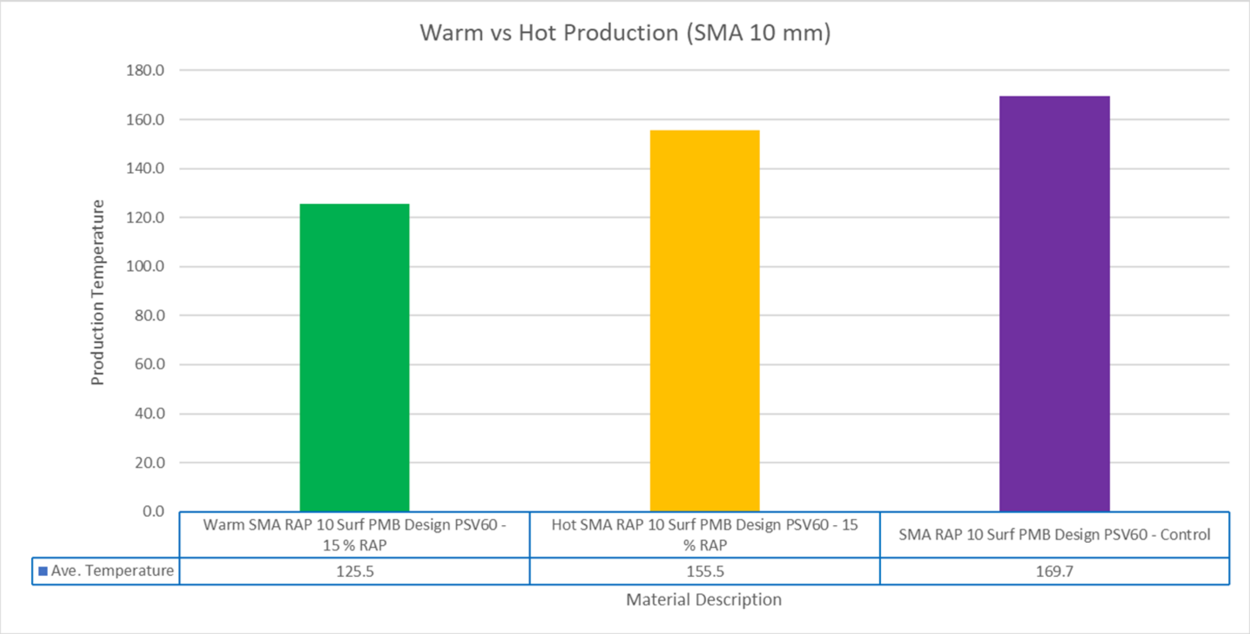
Research Objectives



Sustainability Solutions

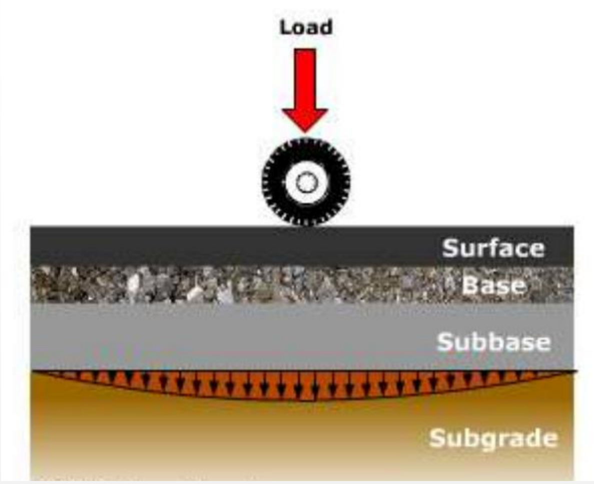
- RAP provides advantages in terms of engineering, economic, and environmental Perspectives.
- A recent evaluation of long-term performance indicated that a well-designed mix with 40% RAP could perform as satisfactorily as that produced with virgin materials to meet in-service performance Requirements.

Sustainability Solutions

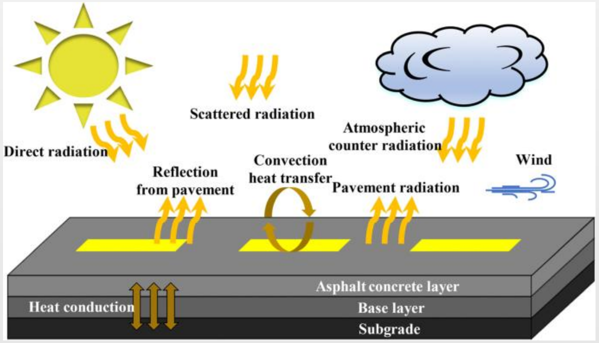


Sustainability Solutions

❖ Sustainability in road engineering can be achieved by increasing the performance of the materials against:



Traffic loads

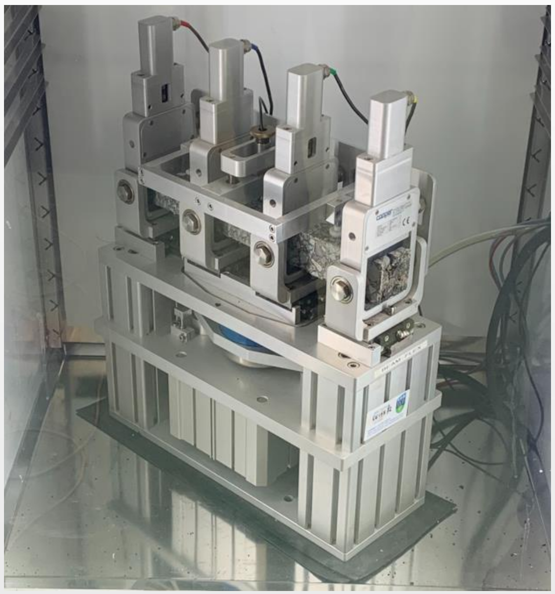


Environmental factors

Extend the durability of the whole pavement system.

Sustainability Solutions

❖ Asphalt materials should be characterized and compared in terms of their:



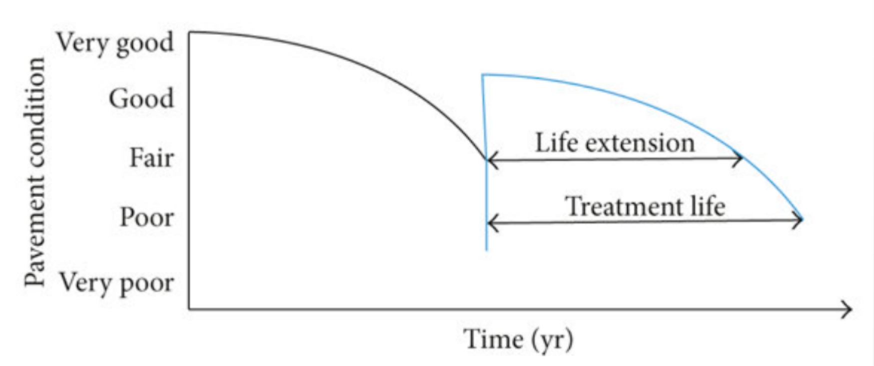
Resistance to fatigue

Stiffness modulus

Volumetric properties

Sustainability Solutions

- Performance-based tests can be used to characterize asphalt mixtures regardless of materials and technologies in use, thus allowing:



Extension of pavement life

Cost savings in pavements

Minimization of environmental footprint

Materials Performance

AC 20 – Coarse RAP 40%

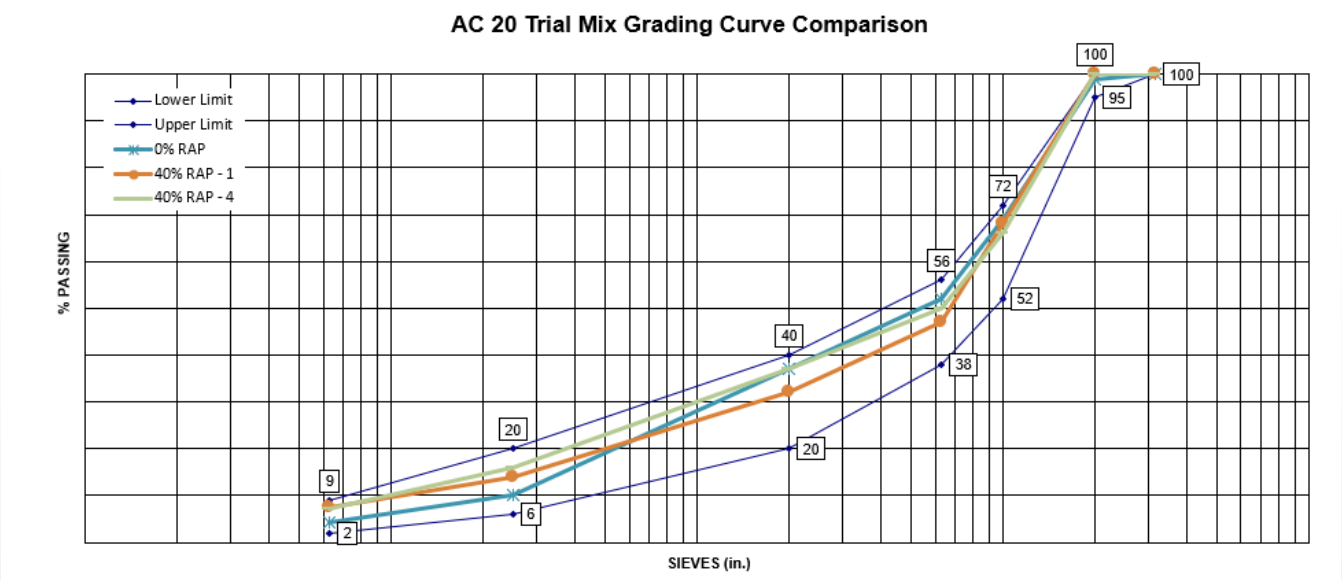
AC 20 – 0 % RAP

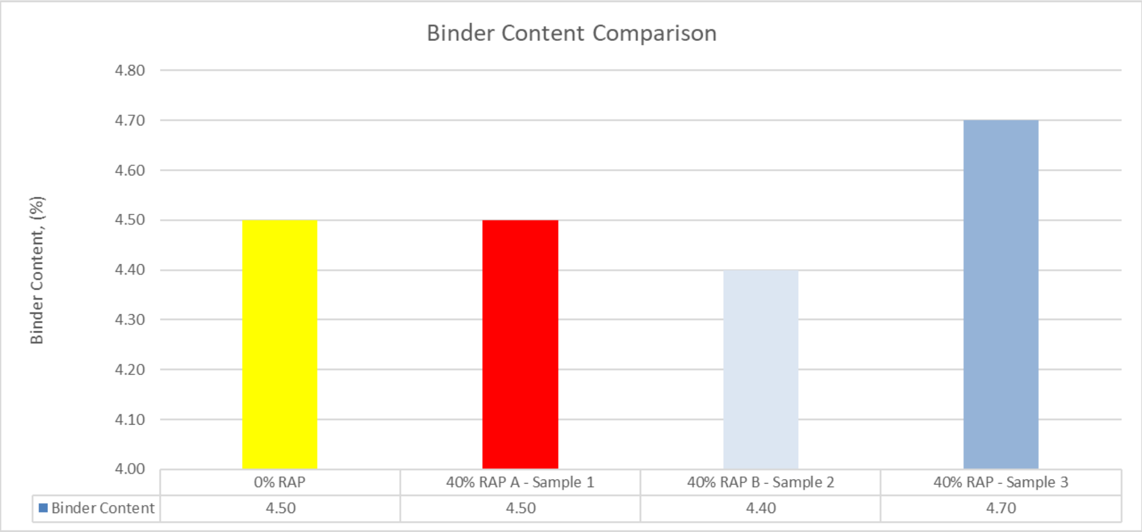
Performance Testing

AC 32 – Coarse RAP 40%

AC 32 – 0 % RAP

Materials Performance





Materials Performance

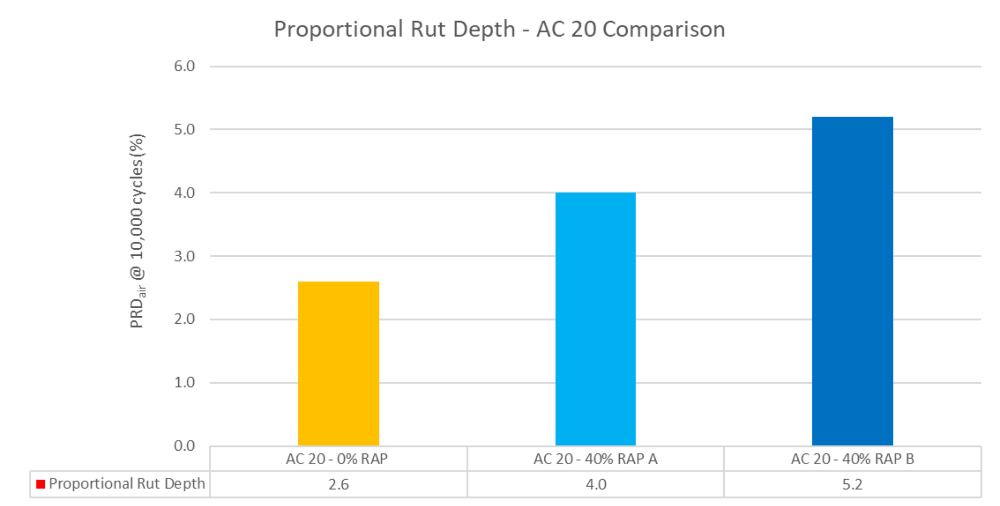
AC 20 – Control Mix

Core Reference	A
Height	60
Test Temperature (°C)	45
Wheel Tracking Slope (WTS_{air})	
WTS_{air} (mm/10^3 load cycles)	0.06
Proportional Rut Depth (PRD_{air})	
PRD_{air} @10,000 cycles (%)	2.6

Properties	
Void content – Minimum[5]	$V_{min\ 4,0}$
Void content – Maximum[5]	$V_{max\ 7,0}$
Resistance to permanent deformation[5]	$WTS_{AIR\ 1,0}$ $PRD_{AIR\ 9,0}$
Water sensitivity[5]	$ITSR_{70}$
Stiffness[4]	To be recorded

AC 20 – 40% RAP

Core Reference	A	B
Height	60	60
Test Temperature (°C)	45	
Wheel Tracking Slope (WTS_{air})		
WTS_{air} (mm/10^3 load cycles)	0.09	0.12
Proportional Rut Depth (PRD_{air})		
PRD_{air} @10,000 cycles (%)	4.0	5.2



Materials Performance

AC 20 – Control Mix

Water Sensitivity Test Results	
Method used	Method A
Number of specimens	6
Test temperature (ºC)	15
Average ITS Dry[1] (kPa)	9.112
Average ITS Wet (kPa)	7.906
ITSR[2] (%)	**86.8**
Failure type	Combination

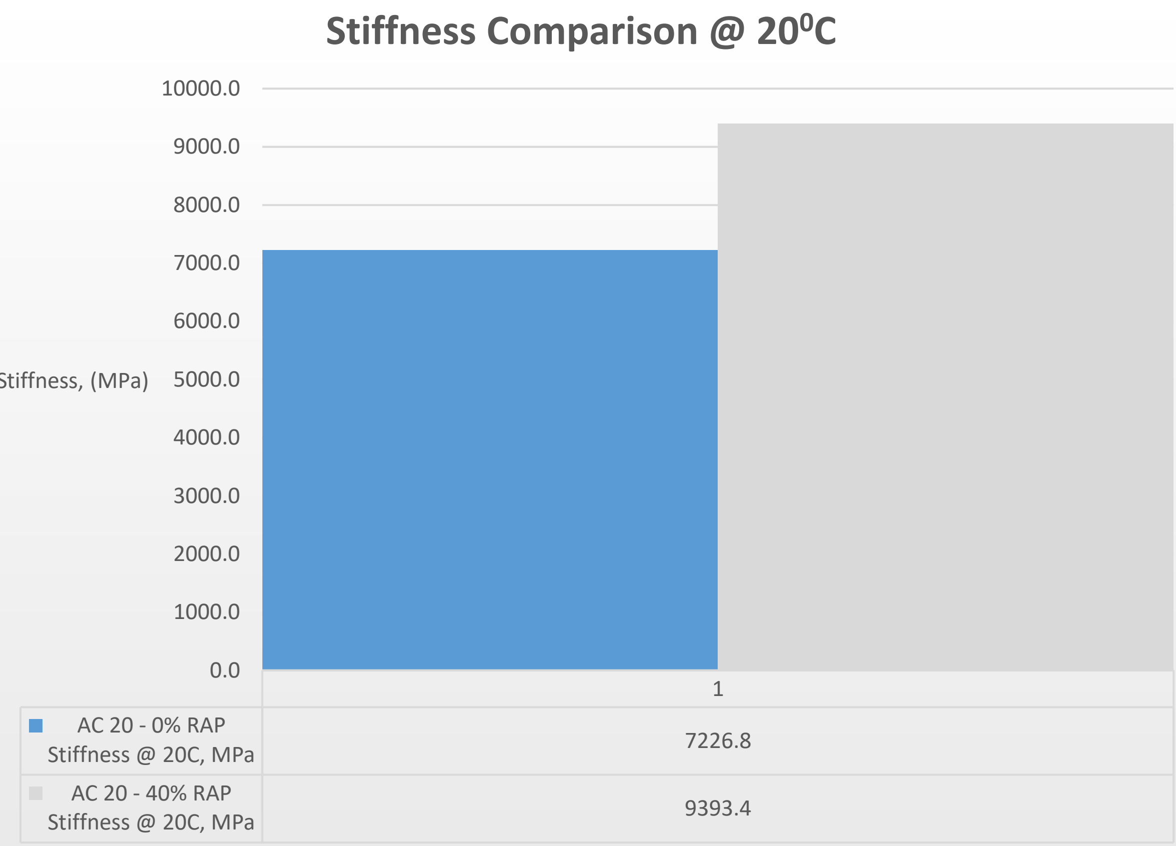
AC 20 – 40% RAP

Water Sensitivity Test Results		Tii Specification
Method used	Method A	Method A
Number of specimens	6	N/A
Test temperature (ºC)	10	N/A
Average ITS Dry[3] (kPa)	7.784	N/A
Average ITS Wet (kPa)	6.698	N/A
ITSR[4] (%)	**86.0**	**$ITSR_{70}$**
Failure type (delete as appropriate)	Combination	

Properties	
Void content – Minimum[5]	$V_{min\ 4,0}$
Void content – Maximum[5]	$V_{max\ 7,0}$
Resistance to permanent deformation[5]	$WTS_{AIR\ 1,0}$ $PRD_{AIR\ 9,0}$
Water sensitivity[5]	$ITSR_{70}$
Stiffness[4]	To be recorded

Materials Performance

AC 20 RAP 0% vs AC 20 RAP 40%

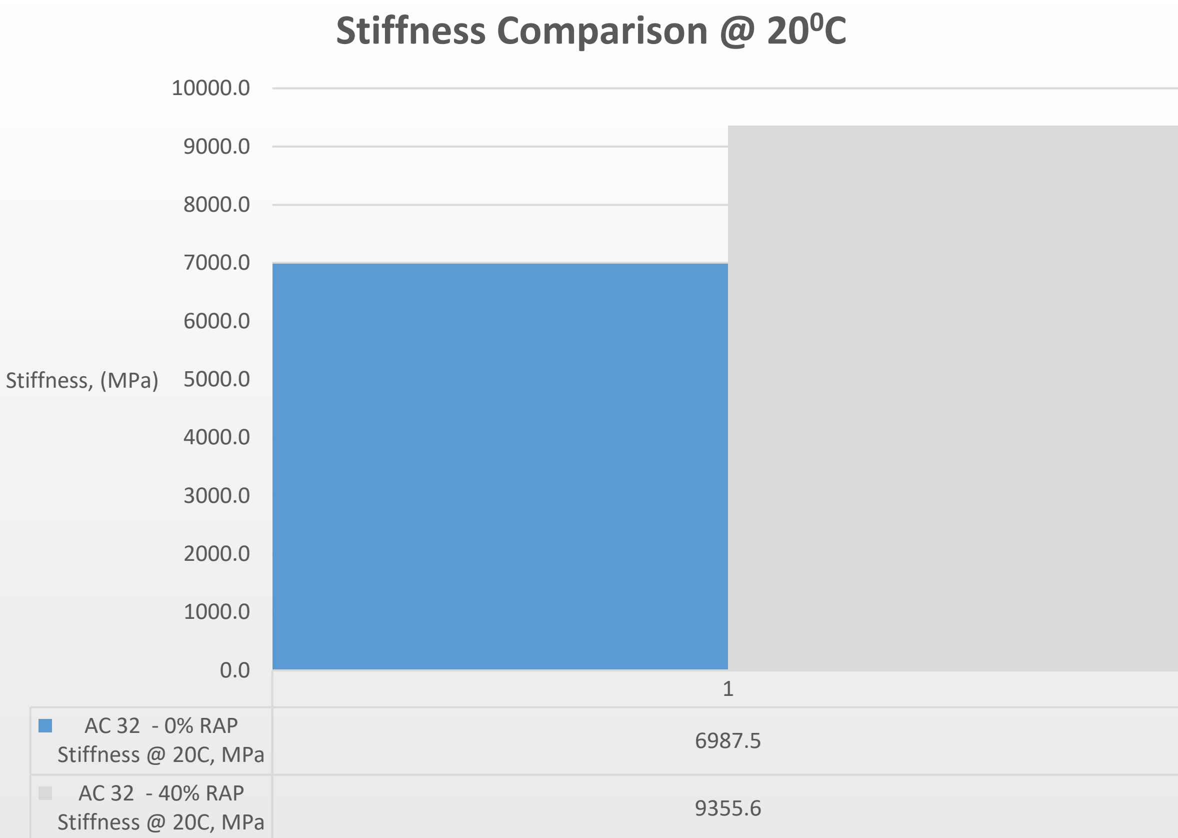


AC 20 - 0% RAP Stiffness @ 20C, MPa	
Average of 12 Samples	7226.8
Standard Deviation	411.28
Coefficient of variation	5.69%

AC 20 - 40% RAP Stiffness @ 20C, MPa	
Average of 12 Samples	9393.4
Standard Deviation	943.97
Coefficient of variation	10.05%

Materials Performance

AC 32 RAP 0% vs AC 32 RAP 40%



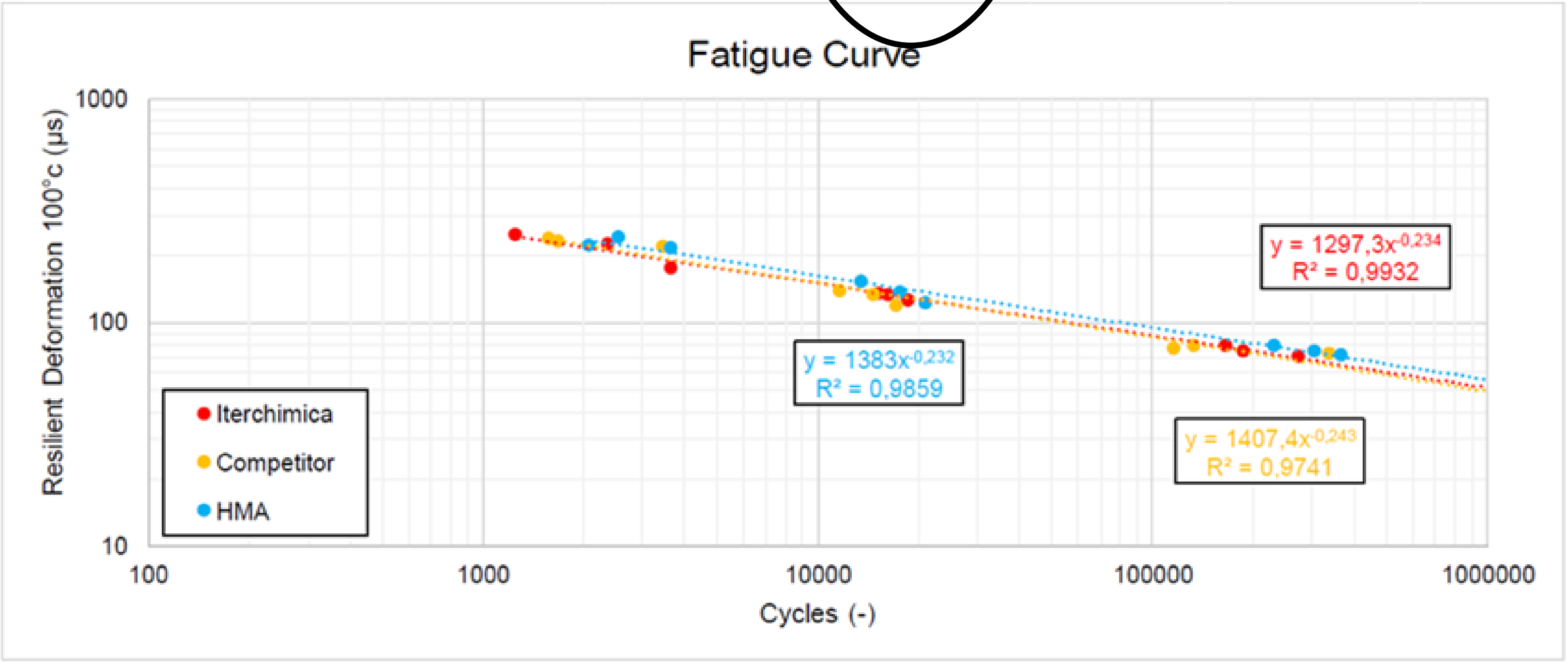
AC 32 - 0% RAP Stiffness @ 20C, MPa	
Average of 12 Samples	6987.5
Standard Deviation	513.91
Coefficient of variation	7.35%

AC 32 - 40% RAP Stiffness @ 20C, MPa	
Average	9355.6
Standard Deviation	1016.96
Coefficient of variation	10.87 %

Materials Performance

AC 20 – RAP 0%

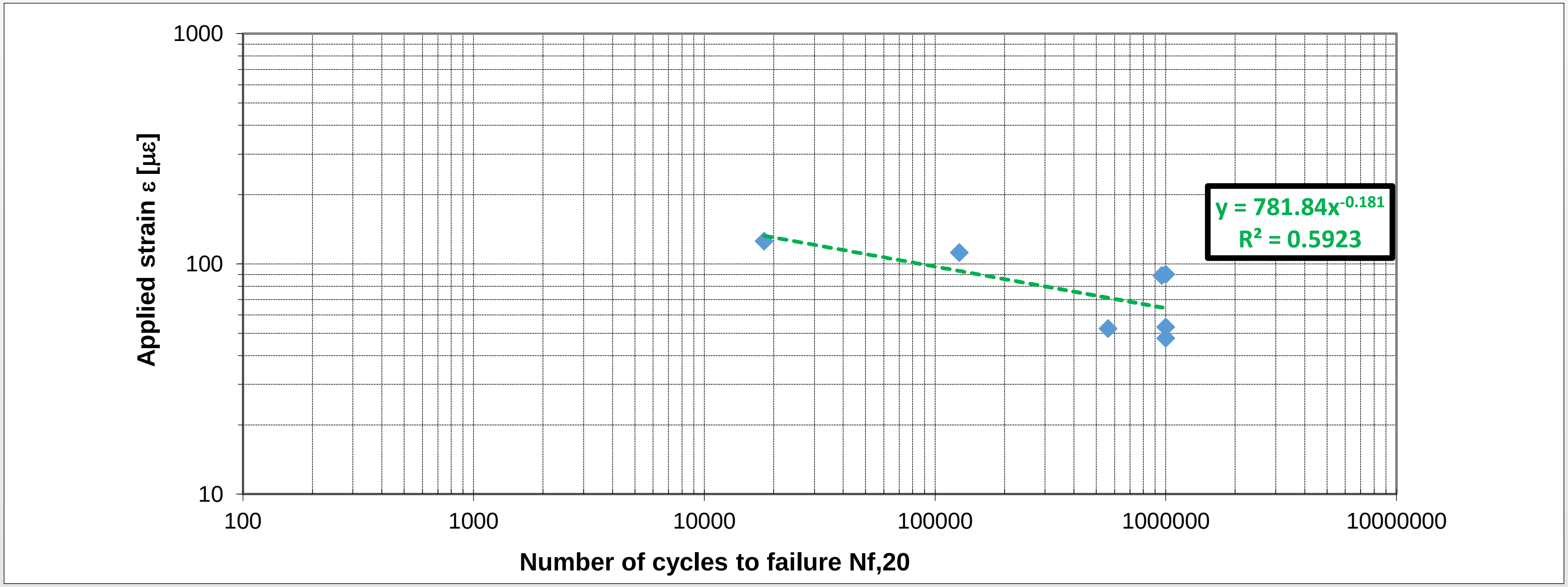
Parameters	Standard	AC 20 0% RAP	Iterchimica	Competitor	Units
Fatigue Test			N = 100		
Production Temperature	-	160 - 170	130 - 140	130 - 140	^0C
Compaction Temperature	-	150 - 155	120 - 125	120 - 125	^0C
Voids	EN 12697-8	3.5	1.4	1.5	%
ε_6	EN 12697-24 Appendix E	**56**	51	49	µs



Materials Performance

AC 20 – RAP 40%

Parameters	Standard	AC 20 40% RAP	Units
Fatigue Test	N = 100		
Production Temperature	-	160 - 170	^{0}C
Compaction Temperature	-	150 - 155	^{0}C
Voids	EN 12697-8	5.1	%
ε_6	EN 12697-24 Appendix E	64	µs



Pavement Design

Mechanistic Empirical Pavement Design Method

- Procedures for new pavement design and rehabilitation of existing pavements have been generally based on empirical approaches.
- Although empirical procedures have performed reasonably, they are limited in their ability to benefit from the vast number of emerging new products, construction practices, and design innovations that optimize performance of the pavement system and minimize traffic interruptions and costly maintenance and rehabilitation activities.

Pavement Design

MECHANISTIC EMPIRICAL PAVEMENT DESIGN METHOD

- Sustainable pavement design is a sequence of procedures, which if strictly followed, can potentially lead to a successful outcome.
- The selection of the appropriate cross section design, suitable for adapting to the objectives of pavement sustainability, is a primary concern.

Pavement Design

Mechanistic Empirical Pavement Design Method

- Asphalt mixtures containing up to 40-50% RAP are sufficient to be utilized as a binder course.
- Asphalt overlays containing 30% RAP have sufficient long-term performance, outperforming conventional mixtures concerning smoothness, as well as rutting and cracking resistance.

Pavement Design

Mechanistic Empirical Pavement Design Method

❖ There is great potential for modifying the cross-section design, for the purpose of optimizing the use of sustainable materials, regarding all types of pavements.

Sustainable pavement design is mainly based on:

- High quality
- Extended service life
- Adequate surface performance
- Cost-efficiency

Pavement Design

- **Pavement design 0% RAP**

Analysis Output

Layer No	Layer Type	Material	Thickness (mm)	Design Stiffness (MPa)	Poisson's Ratio	Critical Response Type	Critical Response Value	Structural Capacity (msa)	N/Nf	
1	Surface	HRA	45	2000	0.35	No tension	0	0.0	0.00	Success
2	Binder	AC20 70/100	65	3100	0.35	epsilon r (Microns)	-9	> 100	0.00	Success
3	Base 1	AC32 70/100	130	3100	0.35	epsilon r (Microns)	-15	> 100	0.00	Success
4	Base 2	AC32 40/60	160	4700	0.35	epsilon r (Microns)	-57	88.7	0.97	Success
5	Subbase	6F2 (CC-SPW-00600)	120	100	0.35	N/a	-	-	-	No Model
6	Capping	Not Considered	0	0	0	None	0	0.0	0.00	No Layer
7	Subgrade	Subgrade	Semi-infinite	49	0.45	epsilon z (Microns)	5776	3023.3	1.91	SUCCESS / FAIL / FAIL

FC = I

Surface Modulus = 62

- **Pavement design 40% RAP**

Analysis Output

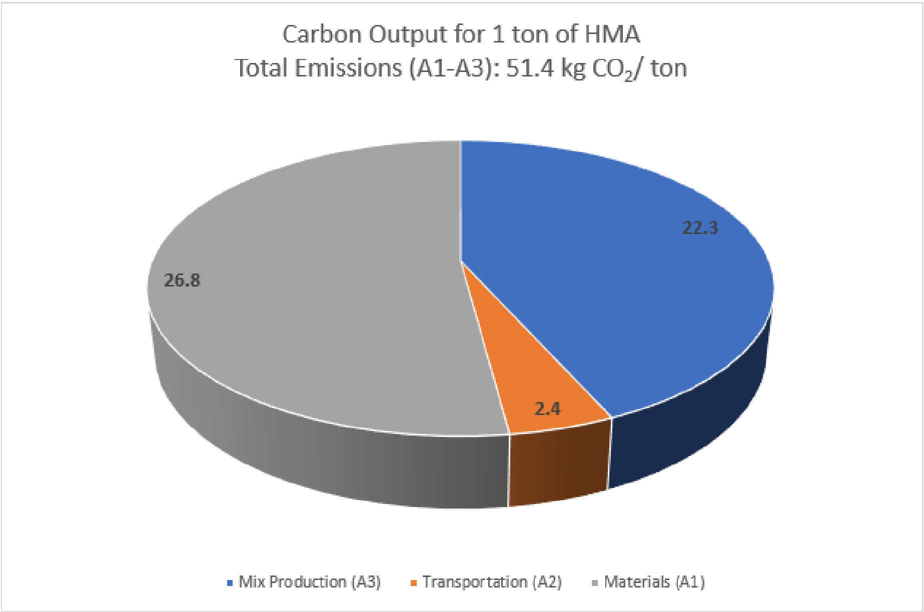
Layer No	Layer Type	Material	Thickness (mm)	Design Stiffness (MPa)	Poisson's Ratio	Critical Response Type	Critical Response Value	Structural Capacity (msa)	N/Nf	
1	Surface	HRA	45	2000	0.35	No tension	0	0.0	0.00	Success
2	Binder	AC 20 40% [S4] [D1] [F1]	65	7000	0.35	No tension	0	0.0	0.00	Success
3	Base 1	AC 32 40% RAP [S4] [D1] [F1]	100	7000	0.35	epsilon r (Microns)	-16	> 100	0.01	Success
4	Base 2	AC 32 40% RAP [S4] [D1] [F1]	130	7000	0.35	epsilon r (Microns)	-52	95.8	0.90	Success
5	Subbase	6F2 (CC-SPW-00600)	120	100	0.35	N/a	-	-	-	No Model
6	Capping	Not Considered	0	0	0	None	0	0.0	0.00	No Layer
7	Subgrade	Subgrade	Semi-infinite	49	0.45	epsilon z (Microns)	5776	3023.3	1.91	SUCCESS / FAIL / SUCCESS

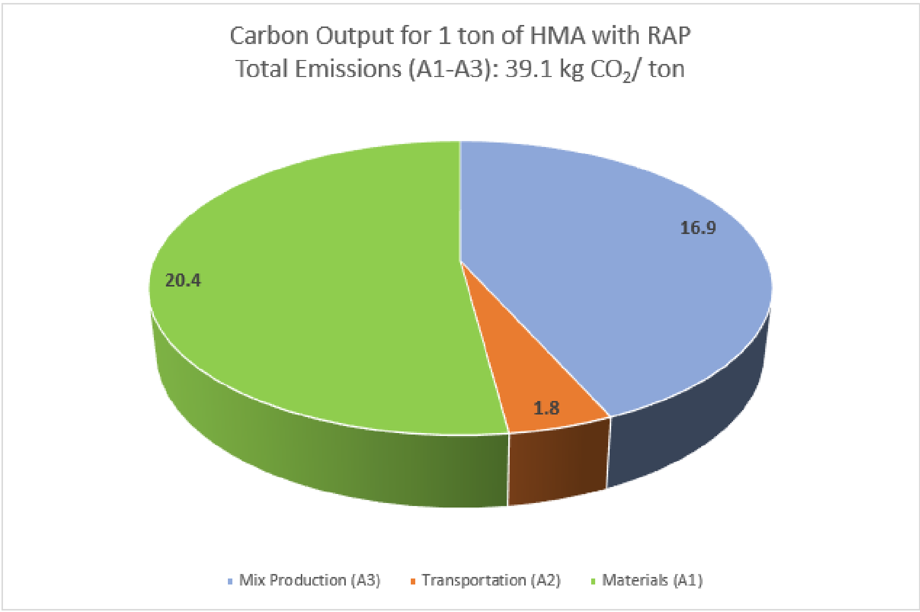
FC = I

Surface Modulus = 62

Pavement Design

Development of a Sustainable Pavement Design

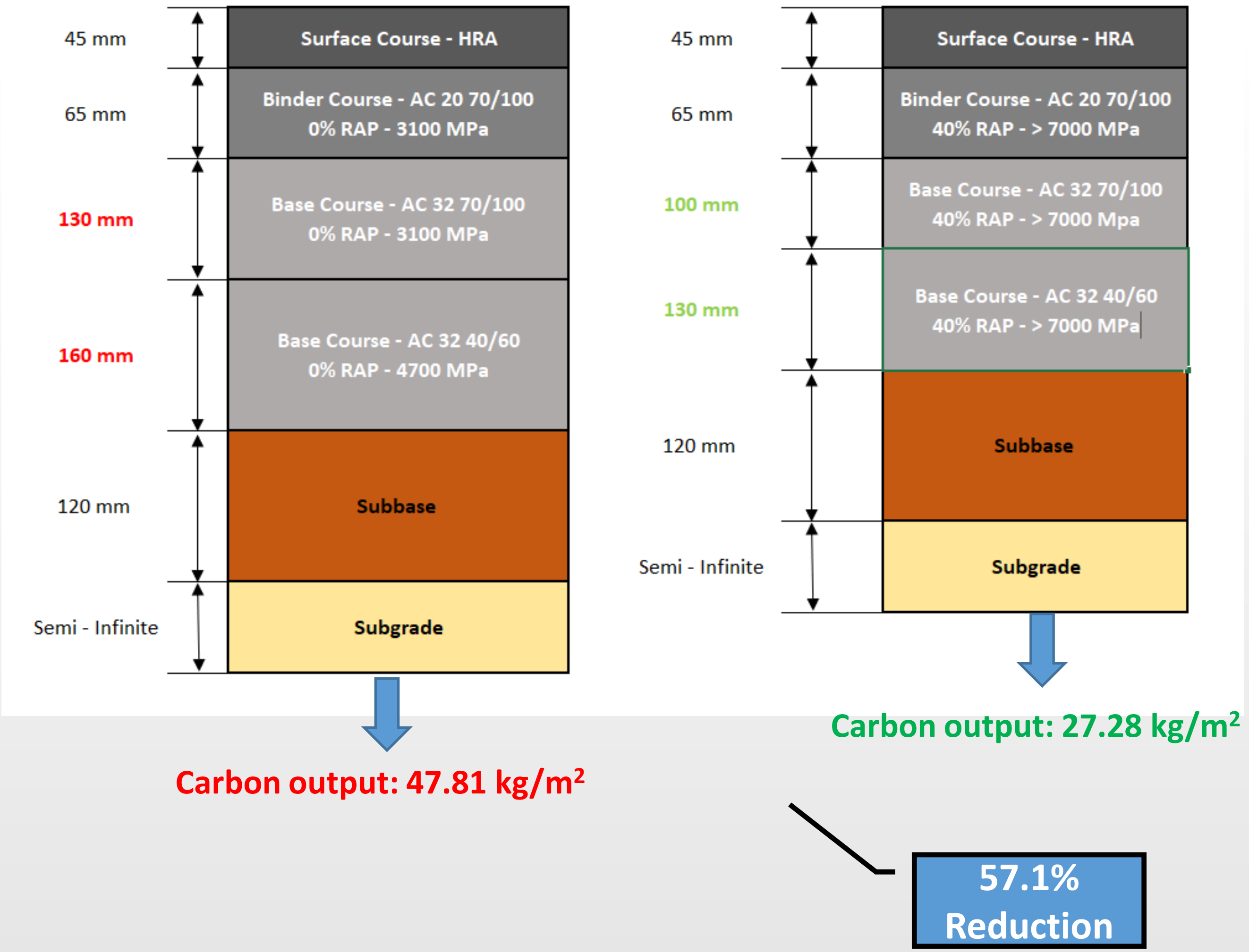




Source: National Asphalt Pavement Association, June 2022

Pavement Design

Development of a Sustainable Pavement Design



Conclusion

❖ Three groups of techniques may be implemented:

1. Reducing the demand for virgin materials, e.g., by recycling materials into new asphalt mixtures;
2. Reducing the energy consumption, e.g., by decreasing the production temperature of asphalt mixtures; and
3. Lengthening the service life of the pavements by optimizing the mechanical properties of asphalt mixtures.

❖ It is clear that there are numerous available options, concerning pavement materials, design as well as preservation in order to deliver a truly sustainable pavement.

Thank you

Designing low energy sustainable asphalt mixtures based on their mechanical properties and performance characteristics.