National Seminar PSMTS: Challenges and Innovations in Nusantara Capital City (IKN) Infrastructure Development in Clay Shale Land Using BIM Technology as Support, Universitas Lambung Mangkurat, 28 October 2023

Green transportation infrastructure materials for Infrastructure Development

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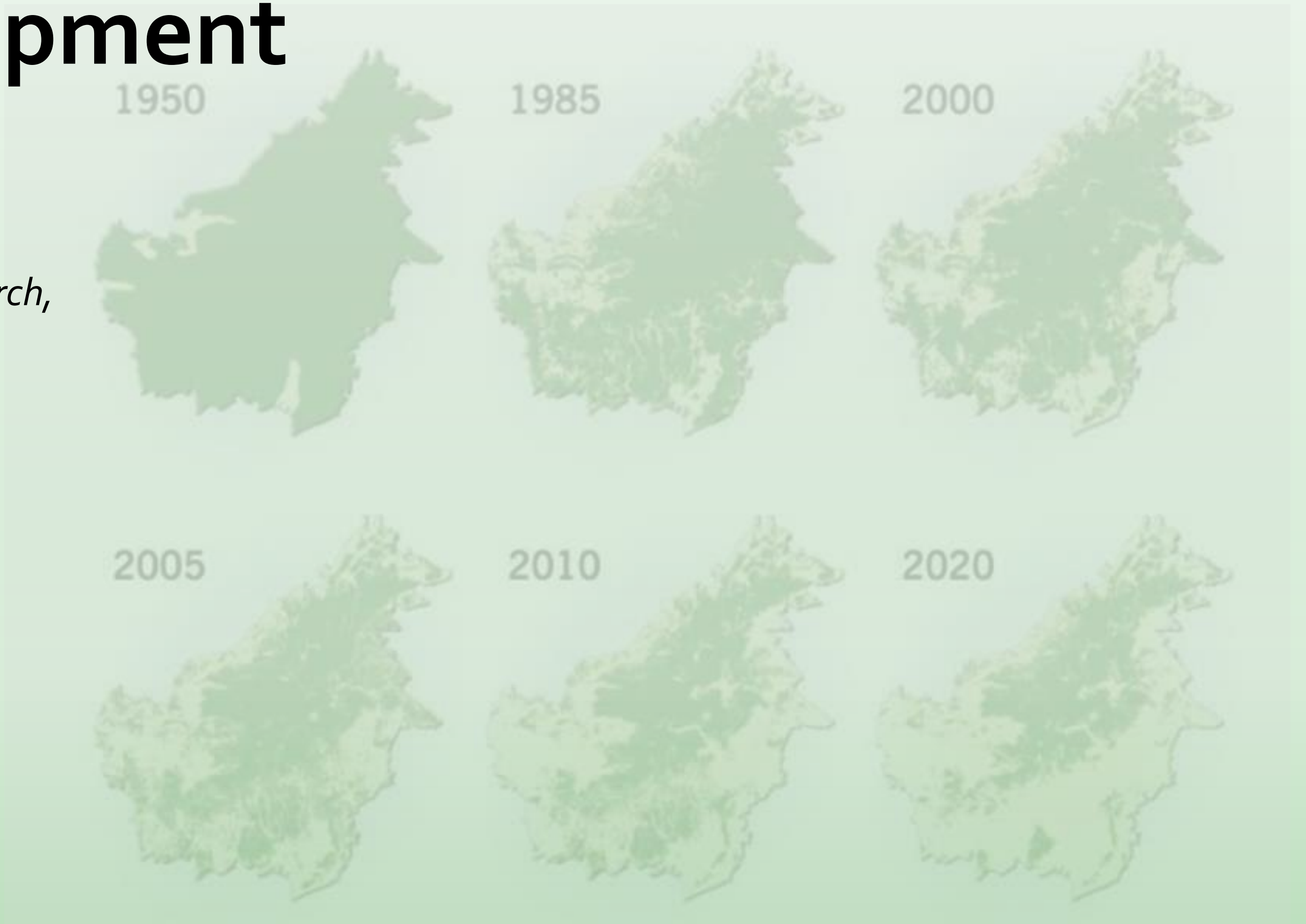


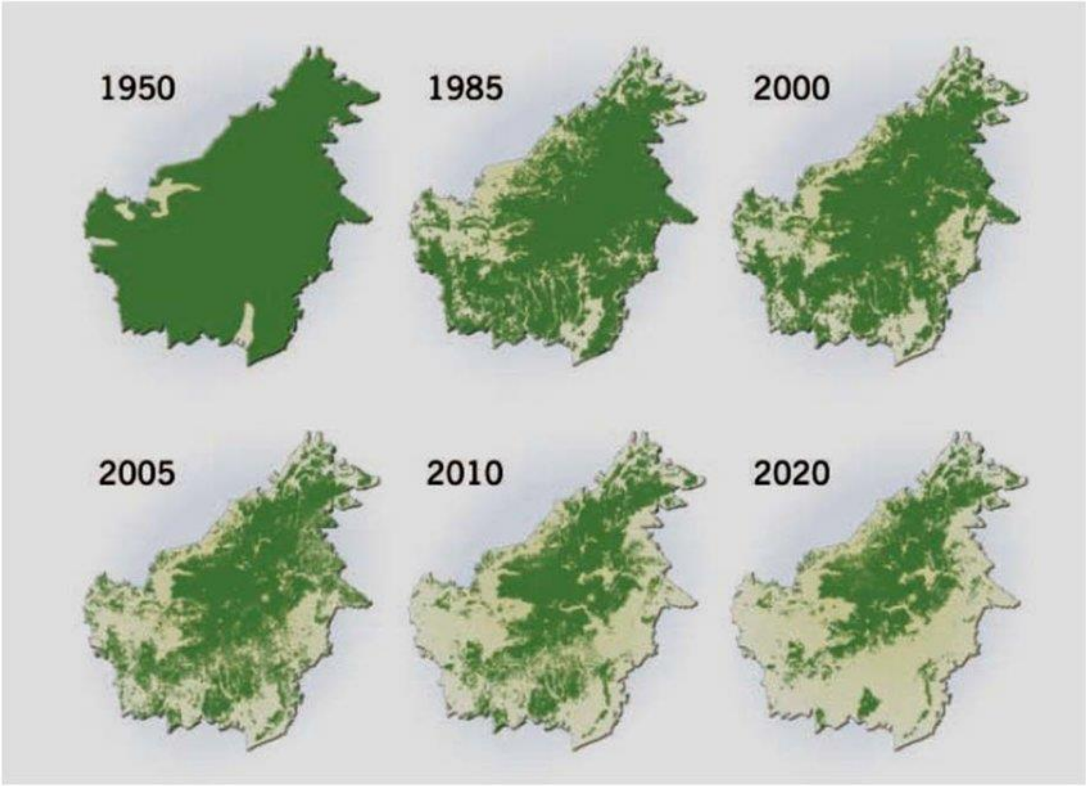
Outline

Definition of green transportation infrastructure

Asphalt materials produced by green technology

Research on waste and secondary materials

Urban drainage systems



Green Transportation Infrastructure

- Roadway design that integrates transportation functionality and ecological sustainability
- An environmental approach is used throughout the planning, design, and the construction
- The result is a highway that will benefit transportation, the ecosystem, urban growth, public health and surrounding communities

What is green technology

- Green technology describes the use of technology and science to create products that are more environmentally friendly.
- The goal is to protect the environment and in some cases, to even repair past damage done to the environment

Nusantara: Sustainable Forest City

Tropical forest are preserved as a carbon sink
and built area are controlled to minimalize emission and footprint

Goal: To become carbon -neutral city by 2045

Prof. Mohammed Ali Berawi
M.Eng.Sc, Ph.D
Deputy of Green and Digital Transformation
Authority of IKN

Building Smart and Green Nusantara
Capital City
Bali, 10 November 2022

Nusantara: Smart City

Dynamic, inclusive, and ready for the future: A city supported by technology
as the accelerator to increase productivity and life quality

Our talk today

Green infrastructure materials

- ✓ Climate resilient materials
- ✓ Sustainable urban drainage

The challenges


Kecamatan Sepaku, Kalimantan Timur, Indonesia
Jl. Negara No.1, Sepaku, Kec. Sepaku, Kabupaten Penajam Paser Utara,
Kalimantan Timur 76147, Indonesia
Lat -0.906859°
Jl. Negara

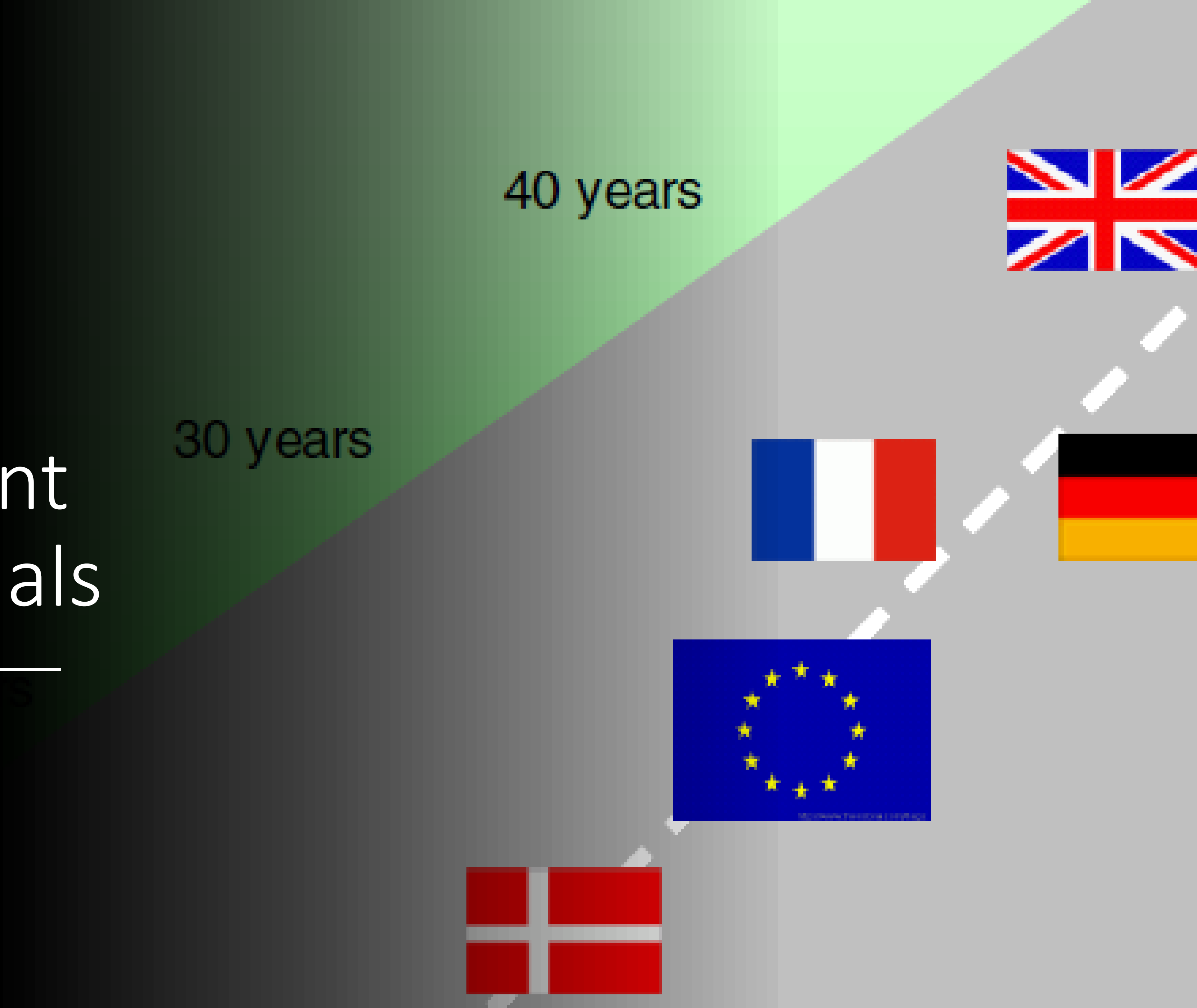
Expansive Soil

- Clay: a fine-grained soil
- Prone to large volume changes
  →Changes in water content
- Smectite clay minerals have the most dramatic shrink-swell capacity
- Magnitude of expansive, soil-related movements varies based on geologic and climatic conditions
  - Varies with depth of seasonal moisture change
  - Deeper cracks in drier seasons
  - Site drainage
  - Moisture control during and after construction

Expansive Clay Movement Mitigation Methods

- Partial over-excavation and select fill replacement
- Chemical injection
- Moisture conditioning/water injection
- Lime-slurry injection
- Cement/lime/fly ash stabilization
- Surcharging
- Moisture barriers (horizontal and/or vertical)
- Hybrid systems

Climate resilient asphalt materials



Long-life (durable) asphalt materials

- Asphalt materials are “live” products, subject to changes

- Resistance against degradation in service, due to changes in chemical-mechanical properties

- What causes these changes:
  - Thermal? Hot, cold, frost
  - Loss of volatile components?
  - Moisture?
  - Winter maintenance?

- What is the biggest challenge in the mixture design?

Threats from climate change

AECOM

Senin, 03 Mei 2021 11:15

Angkutan Berat Hancurkan Jalan Kuala Kurun-Palangka Raya

Truk Terperosok, Antrean Mengular

Share 0 Tweet

TERPEROSOK: Truk dengan bermuatan berat terperosok di tengah jalan raya, sehingga mengakibatkan antrean panjang di Desa Tanjung Karitak, Kecamatan Sepang, ruas Palangka Raya - Kuala Kurun.(WARGA FOR RADAR SAMPIT)

Selasa, 26 April 2022 21:51

Jalan Kurun-Palangka Raya Kembali Rusak

Editor - DPRD Gunung Mas, Gunung Mas, Kalimantan Tengah - 1,047 Views

Kendaraan truk angkutan terjadi macet di jalan trans Kalimantan di Desa Teluk Nyatu, Kecamatan Kurun Kabupaten Gumas, Senin (25/4/2022). (foto: Heriyadi)

Dimana akar permasalahan nya?

Musuh utama perkerasan jalan

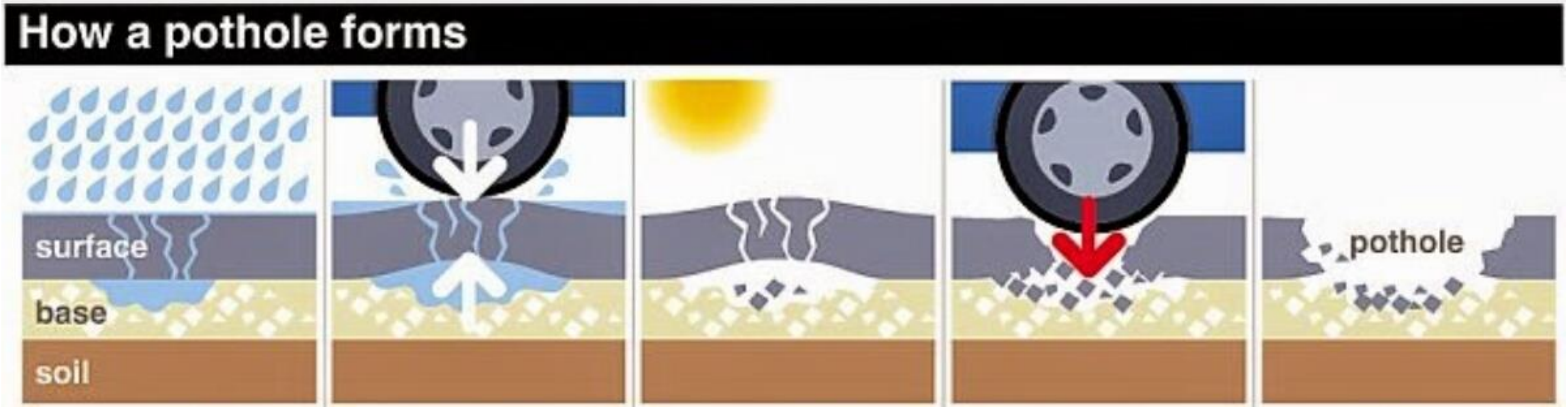
- Air
- …..Air
- ……….Air

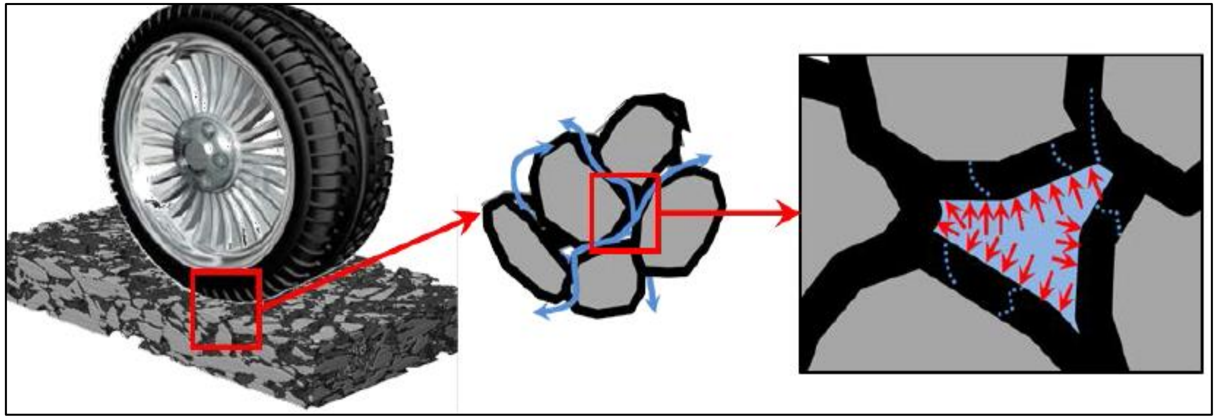
Lapisan aspal mengelupas

Drainase tidak memadai?

Masalah desain? Pembebanan berlebih? Drainase?

Moisture and Traffic





- ✓ Moisture diffusion
- ✓ Advective transport
- ✓ Wheel loading
- ✓ Pumping action

***Degradation** of the **cohesive strength** of the asphalt binder*

***Loss** of the **adhesion bond** between aggregate & asphalt binder*

Solaimanian, M., Harvey, J., Tahmoressi, M., Tandon, V. "Test methods to predict moisture sensitivity of hot-mix asphalt pavements." Transportation Research Board National Seminar. San Diego, California. 2003

Asphalt materials produced by green technology

Different approaches to green*er* asphalt technology

❑Use of longer-life materials

- ✓Current technology: polymer modified asphalts
- Future development: self-healing materials

❑Low energy construction

- Current technology: low temperature asphalts (WMA, HWMA, CMA)
- Future development: bio-based (plant-based) binders

❑Use of waste and secondary materials

❑Reclaim, reuse and recycling

Increase demand

Energy use

Finite resource

Polymer Modified Asphalt (PMA) to improve service life

Type of modifier	Example
Thermoplastic elastomers	Styrene–butadiene–styrene (SBS) Styrene–butadiene–rubber (SBR) Styrene–isoprene–styrene (SIS) Styrene–ethylene–butadiene–styrene (SEBS) Ethylene–propylene–diene terpolymer (EPDM) Isobutene–isoprene copolymer (IIR) Natural rubber Crumb tyre rubber Polybutadiene (PBD) Polyisoprene
Thermoplastic polymers	Ethylene vinyl acetate (EVA) Ethylene methyl acrylate (EMA) Ethylene butyl acrylate (EBA) Atactic polypropylene (APP) Polyethylene (PE) Polypropylene (PP) Polyvinyl chloride (PVC) Polystyrene (PS)
Thermosetting polymers	Epoxy resin Polyurethane resin Acrylic resin Phenolic resin
Chemical modifiers	Organo-metallic compounds Sulphur Lignin
Fibres	Cellulose Alumino-magnesium silicate Glass fibre Asbestos Polyester Polypropylene
Adhesion improvers	Organic amines Amides
Antioxidants	Amines Phenols Organo-zinc/organo-lead compounds
Natural asphalts	Trinidad Lake Asphalt (TLA) Gilsonite Rock asphalt
Fillers	Carbon black Hydrated lime Lime Fly ash

Source: Shell Bitumen Handbook

Site Feature	Condition Description		Potential Increase In-Service Life attributed to the use of a PMB in Years[1]
Water Table Depth/Drainage	Shallow; adequate drainage		5-8
	Shallow; inadequate drainage		0-2
Traffic	Low	Stop and Go/Intersections	5-10
		Thoroughfares	3-6
		Heavy loads/Special containers	5-10
	Moderate Volumes		5-10
	High Volumes		5-10
Climate	Hot		5-10
	Mild		2-5
	Cold		3-6
Existing Pavement Condition	HMA	Good condition	5-10
		Poor condition; extensive cracking[2]	1-3
		Good condition[2]	3-6

Notes:

1. The range of the increase in service life is based on the mechanistic-empirical damage-based analyses, comments from the experts and engineering judgment.
2. Without the use of any reflection cracking mitigation techniques.

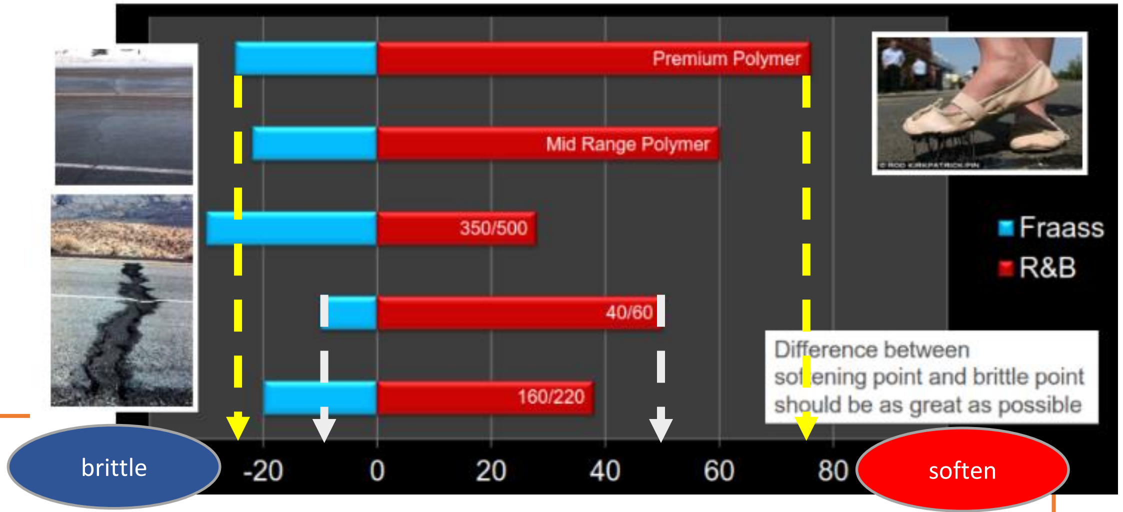
Source: Asphalt Institute, IS-215

Polymer modified bitumen

+

=

Penetration Min / Max	Softening point	Brittle point
70 / 130	70°C	-10°C



Lancaster, I. " Bitumen & Bituminous Materials", IAT Training Day, 2013

EN 14023:2010 (E)

Table 1 — Framework specifications for polymer modified bitumens – Properties applying to all polymer modified bitumens

PROPERTY		TEST METHOD	UNIT	Classes for all polymer modified bitumens									
				2	3	4	5	6	7	8	9	10	11
Penetration at 25 °C		EN 1426	0,1 mm	10-40	25-55	45-80	40-100	65-105	75-130	90-150	120-200	200-300	
Softening Point		EN 1427	°C	≥ 80	≥ 75	≥ 70	≥ 65	≥ 60	≥ 55	≥ 50	≥ 45	≥ 40	
Cohesion [a]	Force ductility [a] (50 mm/min traction) or	EN 13589 followed by EN 13703	J/cm^2	≥ 3 at 5 °C	≥ 2 at 5 °C	≥ 1 at 5 °C	≥ 2 at 0 °C	≥ 2 at 10 °C	≥ 3 at 10 °C	≥ 0,5 at 15 °C	≥ 2 at 15 °C	≥ 0,5 at 20 °C	≥ 0,5 at 25 °C
	Tensile test [a] (100 mm/min traction) or	EN 13587 followed by EN 13703	J/cm^2	≥ 3 at 5°C	≥ 2 at 5 °C	≥ 1 at 5 °C	≥ 3 at 0 °C	≥ 3 at 10 °C					
	Vialit pendulum [a] (Impact test)	EN 13588	J/cm^2	≥ 0,7									
Resistance to hardening [b]	Retained Penetration	EN 12607-1	%	≥ 35	≥ 40	≥ 45	≥ 50	≥ 55	≥ 60				
	Increase in Softening point		°C	≤ 8	≤ 10	≤ 12							
	Change of mass [c]		%	≤ 0,3	≤ 0,5	≤ 0,8	≤ 1,0						
Flash Point		EN ISO 2592	°C	≥ 250	≥ 235	≥ 220							

[a] One cohesion method shall be chosen based on end application. Vialit cohesion (EN 13588) shall only be used for surface dressing binders.

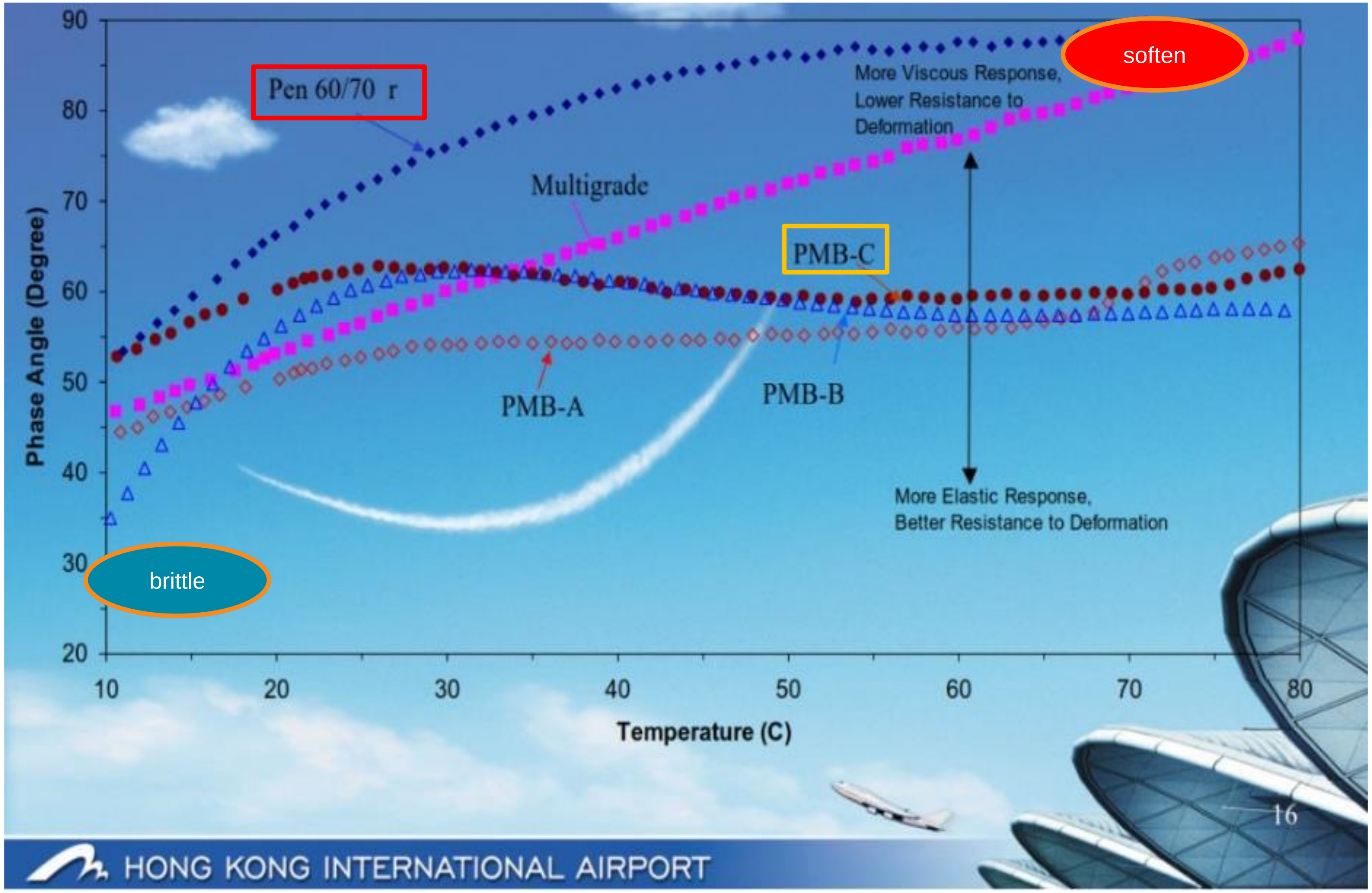
[b] The main test is the RTFOT at 163 °C. For some highly viscous polymer modified bitumens where the viscosity is too high to provide a moving film it is not possible to carry out the RTFOT at the reference temperature of 163 °C. In such cases the procedure shall be carried out at 180 °C in accordance with EN 12607-1.

[c] Change of mass can be positive or negative.

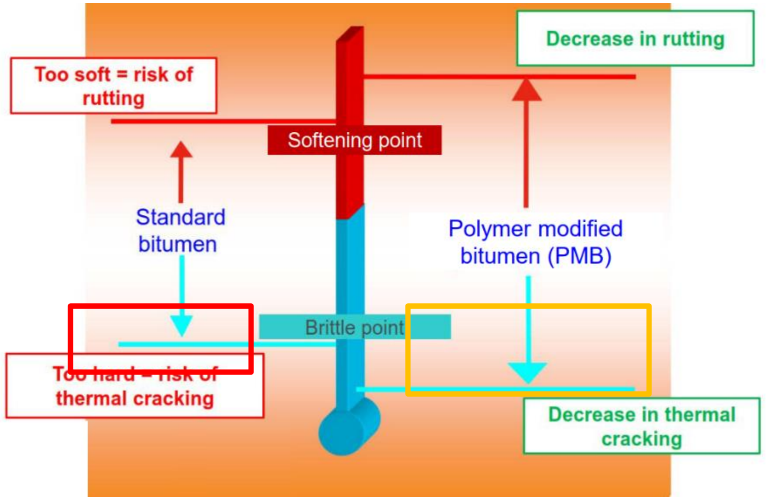
No.	Jenis Pengujian	Standar	Tipe II Aspal yang Dimodifikasi C Elastomer Sintetis - wax
1.	Penetrasi pada 25 °C 100 gram, 5 detik (0,1 mm)	SNI 2456:2011	Min. 45
2.	Kekentalan pada temperatur 135°C (cSt)	ASTM D2170-10	Maks. 3000
3.	Titik Lembek (°C)	SNI 2434:2011	Min. 60
4.	Daktilitas pada 25°C (cm)	SNI 2432:2011	Min. 100
5.	Titik Nyala (°C)	SNI 2433:2011	Min. 232
6.	Kelarutan dalam Trichloroethylene (%)	ASTM D2042-01	Min. 99
7.	Berat Jenis aspal	SNI 2441:2011	Min. 1,0
8.	Stabilitas Penyimpanan: Perbedaan titik lembek (°C)	ASTM D5976 part 6.1 dan SNI 2434:2011	Maks. 2,2
9.	Kadar parafin lilin (%)	SNI 03-3639-2002	Maks. 2
10.	Keelastisan setelah pemulihan (%)	AASHTO T301-99	Min. 60
Pengujian Residu Aspal hasil TFOT (SNI 06-2440-1991) atau RTFOT (SNI 03-6835-2002):			
11.	Berat yang Hilang (%)	SNI 06-2440-1991	Maks. 0,8
12.	Penetrasi pada 25°C (% asli)	SNI 2456:2011	Min. 65
13.	Daktilitas pada 25°C (cm)	SNI 2432:2011	Min 75

Dirjen Bina Marga. Spek Interim No: KB 01.13-Db/289 (21 Juni 2016)

Successful application of PMA (thermoplastic elastomer) for runway surfacing, for durability and climate resilience



Li, D.C.H, Fung, W.F., Widyatmoko, I., Elliott, R.C., Larsen, B., "Planning, Design and Implementation of Major Runway Resurfacing at Hong Kong International Airport", Sixth International Conference on Road & Airfield Pavement Technology (6th ICPT), 20-23 July 2008, Sapporo, Japan



More than 15 years in service and still performing well

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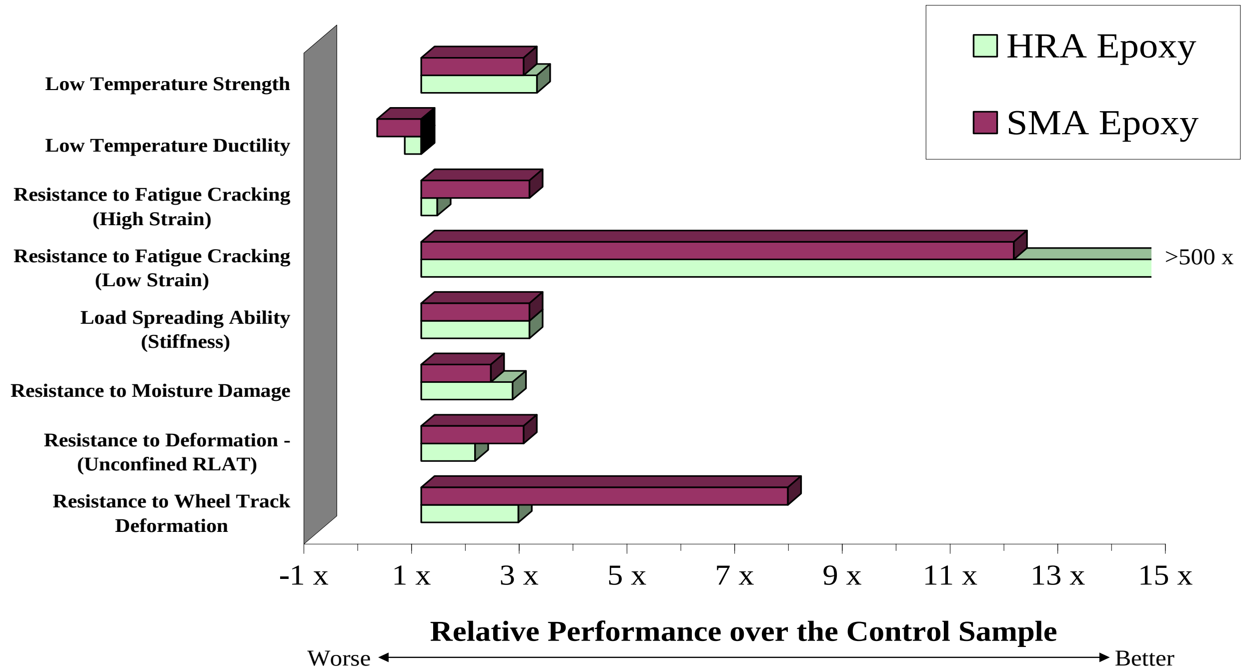
PMA (thermosetting polymer) for long life asphalt surfacing



Use of epoxy asphalt in England

1983 M4 L1 Trial, near Hammersmith flyover	0/20 PA	Del (115-135)°C	Wimpey Asphalt & Shell Epoxy	8 years no issue	9th year removed for strengthening program
1983 M6 L1-3 Trial, near Keele service area	30/14 HRA @42mm thickness	Del >120°C	Tarmac Roadstone & Shell Epoxy	@22 years, better than HRA PMB	2005 overlaid by TSCS
1984 A38 Burton on Trent to Lichfield (SB) Trials	0/20 PA @50mm thickness	Del >115°C Compaction (80-100)°C	ARC & Shell Epoxy	14 years, no fretting	
1987 A38 Burton on Trent to Lichfield(SB) Trials	0/20 PA@50mm thickness	Del >109°C Compaction >70°C	Tarmac & Shell Epoxy	19 years, no issue	
2012 A390 Truro, Cornwall	0/14 SMA @40mm thickness	Del >100°C Compaction >70°C	Cormac & Colas Epoxy	2 years, no issue	Removed due to road re-alignment scheme

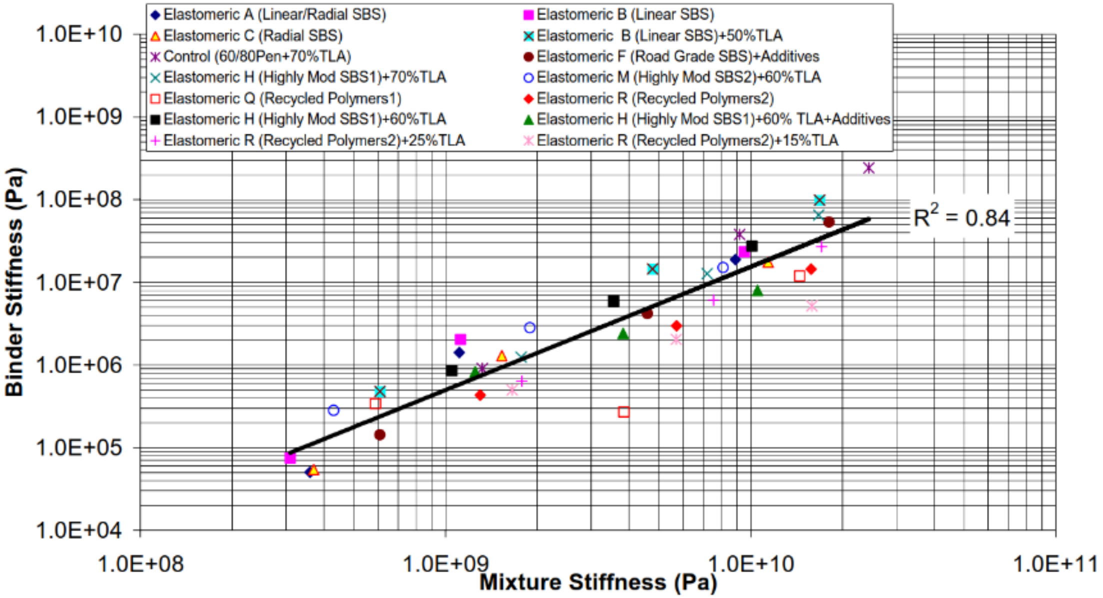
Dinnen, J. Farrington, J and Widyatmoko, I, “Experience with the use of epoxy-modified bituminous binders in surface courses in England”, Asphalt Professional No 82, February 2020

1) Widyatmoko, I, Zao, B., Elliott, R.C., and Lloyd, W.G., “Curing Characteristics and the Performance of Epoxy Asphalts”, 10th International Conference on Asphalt Pavements, Quebec, Canada, 12-17 August 2006
2) Widyatmoko, I., Elliott, R.C., Lloyd, W., G., “Development of Long Life Deformation Resistant Hot Rolled Asphalt Surfacing”, Journal of the Institute of Asphalt Technology, Asphalt Professional No:18, January 2006
3) Elliott, R.C., Widyatmoko, I., Chandler, J., Badr. A., and Lloyd, W.G., “Laboratory and Pilot Scale Assessment of Long Life Surfacing for High-Traffic Roads”, 4th Eurasphalt & Eurobitume Congress, Denmark, 2008
4) Widyatmoko, I and Elliott, R. “Strength characteristics and durability of epoxy asphalts”, Construction Materials, 2014. http://dx.doi.org/10.1680/coma.13.00029

Natural asphalt + polymers for heavy duty mastic asphalt surfacing

Orthotropic bridge deck → subject to large movements

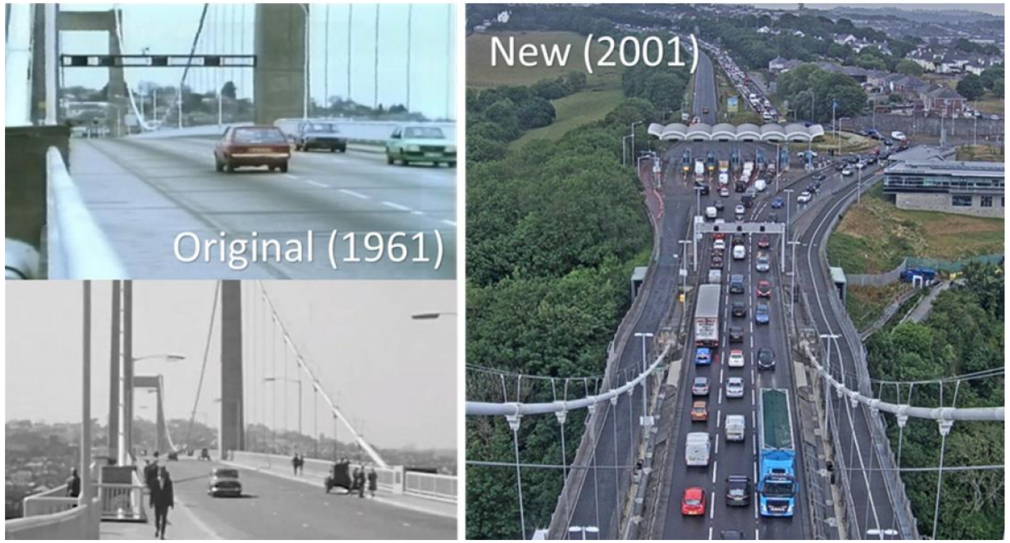
- Mastic asphalt: PMB v. non-PMB
- Non PMB mastic asphalt failed prematurely at 70ºC wheeltrack testing



Sample ID	Mastic Binder	Mean Rut Rate* (mm/h)	Mean Rut Depth* (mm)
Mix E	60/80pen +70%TLA	**	>25
Mix R	Recycled polymers	6.9	7.7
Mix T	Highly modified SBS1 +60%TLA +additives	6.5	6.2
Mix U	Recycled polymers +25%TLA	9.6	10.2

1) Widyatmoko, I., Elliott, R.C., and Read, J.M., "Development of Heavy-Duty Mastic Asphalt Bridge Surfacing incorporating Trinidad Lake Asphalt and Polymer Modified Binders", International Journal of Road Materials and Pavement Design, Vol. 6/4, 2005, pp. 469-483. ISSN 1468-0629
2) Widyatmoko, I. and Elliott, R.C., "Characteristics of Elastomeric and Plastomeric Binders in Contact with Natural Asphalts", Construction and Building Materials, Volume 22, No.3, March 2008, pp. 239-249, Elsevier, ISSN 0950-0618. doi:10.1016/j.conbuildmat.2005.12.025

Successful application of polymer modified asphalts for bridge deck

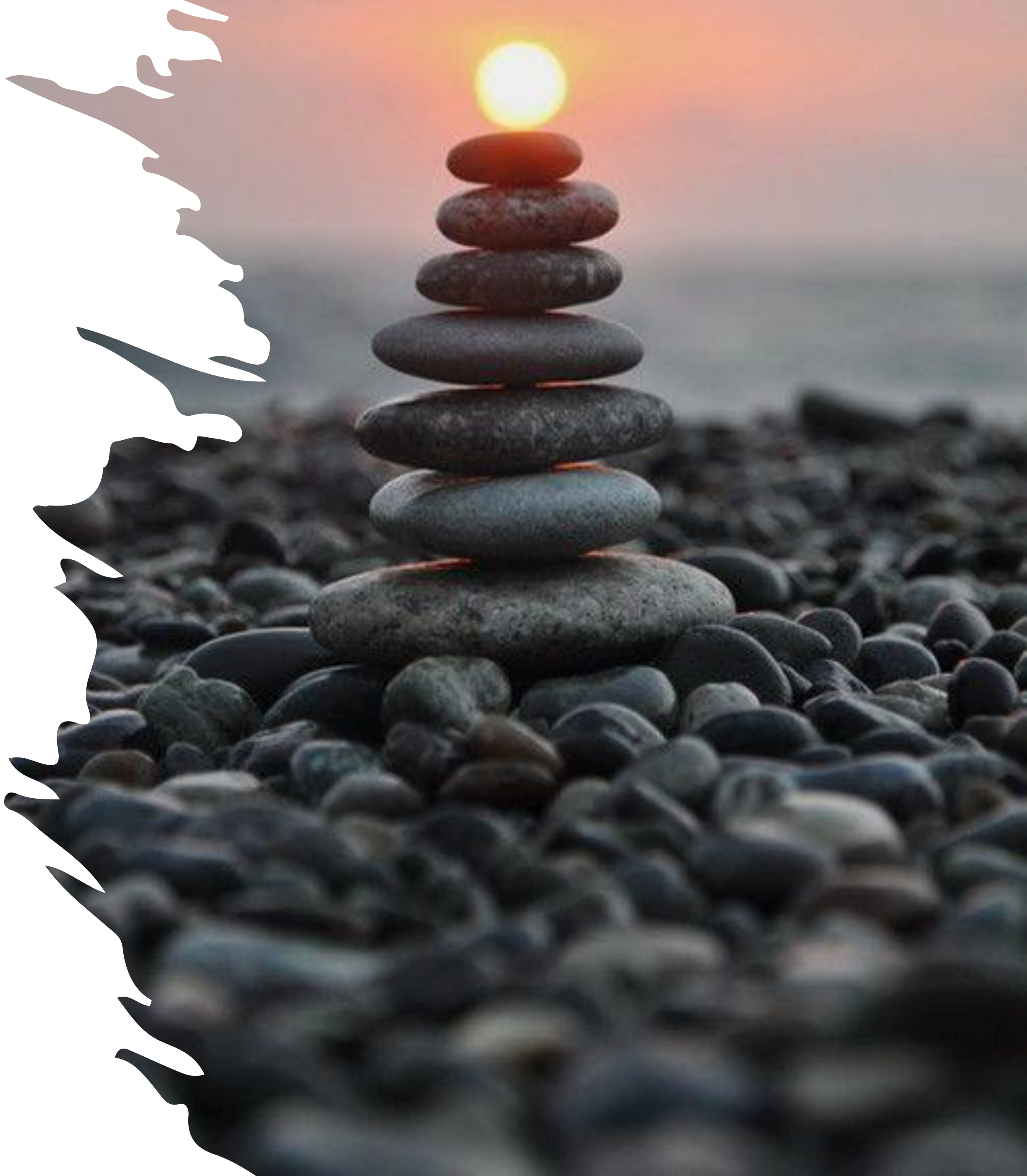


Surfacing System	Traffic Speed (kph)	Horizontal Tensile Microstrain			Predicted Life (years)	
		Permissible limits	FEM Deck	FEM Cantilever	Deck	Cantilever
Existing MA	Standstill (0)	278	571	680	0.1	0.0
Existing MA	There are obstacles (0 – 20)	278	365	440	3.1	0.9
Existing MA	Free-flowing (50)	278	220	260	>20	>20
GA/PMMA	Standstill (0)	322	440	470	2.4	1.5
GA/PMMA	There are obstacles (0 – 20)	322	320	330	>20	17
GA/PMMA	Free-flowing (50)	322	175	195	>20	>20
EA	Standstill (0)	341	395	410	5.0	3.8
EA	There are obstacles (0 – 20)	341	175	235	>20	>20
EA	Free-flowing (50)	341	<100	170	>20	>20

Forensic investigation	Selection of surfacing system options	Design of new surfacing system	Installation of new surfacing system
Carry out site inspection Recover material samples from site Perform laboratory testing Establish the condition of the existing surfacing system	Review the track record of surfacing and waterproofing material options Collect the mechanical properties of the nominated options Compare advantages and disadvantages for each option	Review mechanical properties of surfacing systems Analyse past and future (design) traffic Carry out finite element analysis Recommend the best performing surfacing system	Record and monitor the installation of the new surfacing system as repair material Monitor the performance of the new system post installation for future review prior to major rehabilitation work

1) Widyatmoko, I. “Damages of Orthotropic Bridge Deck Surfacing: Forensic Investigation, Remedial Work and Performance Monitoring”. Jurnal Kejuruteraan 33(2) 2021: 281-291. https://doi.org/10.17576/jkukm-2021-33(2)-14
2) Widyatmoko, I and Elliott, R.C., “Tamar Bridge - Investigation of surfacing defects, design and specification”, Proceedings of the 5th International Conference on Forensic Engineering: Informing the Future with Lessons from the Past, The Institution of Civil Engineers (ICE), London, 2013

Research on waste and secondary materials



Waste derived materials

Binder modifier

- Crumb Tyre Rubber
- Waste plastic
- Waste cooking oil
- Waste engine oil
- Recycled shingles

Mixture additive

- Power station wastes
  - Pulverised fly ash (PFA)
  - Furnace bottom ash (FBA)
- Domestic wastes (IBA)
- Waste paper

Aggregate replacement

- Reclaimed aggregate
- Reclaimed asphalt
- Reclaimed concrete
- Rubber & plastic waste
- Concrete & demolition waste

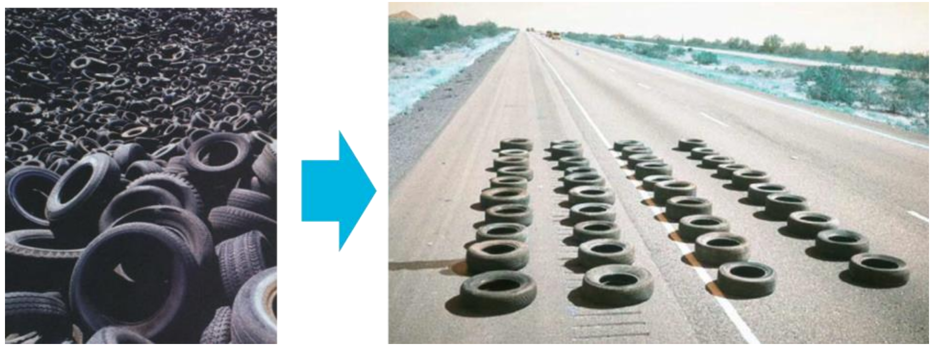
Artificial (processed) aggregate

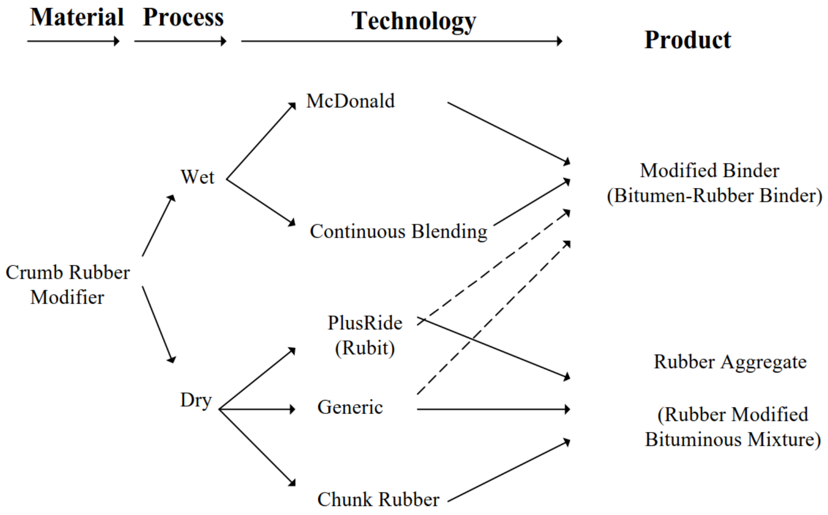
- Steel slags:
  - BOS – basic oxygen slags
  - EAF – electric arc furnace
- Blast furnace slags, including GBBS (granulated)
- Non-ferrous slags
  - Phosphorous slags
  - ISF – aluminium/zinc slags
- Geopolymer aggregate

Papers dan reports are available from:
https://www.researchgate.net/profile/Daru-Widyatmoko

Use of reclaimed crumb rubber in asphalt mixtures

- Wet process: dispersing the rubber particles in the bitumen to produce rubberised bitumen, which is then mixed with aggregate to form a mixture
  - Road pavement
  - Surface dressing, slurry seal
  - Joint sealant, waterproofing layer
- Dry process: rubber particles act as a partial replacement to some of the aggregate sizes
  - Sport surfaces
  - Playground surfaces





Asphalt rubber: benefits

- improved durability and resistance to age-hardening;
- improved resistance to surface initiated and fatigue/reflection cracking;
- reduced temperature susceptibility;
- improved resistance to rutting;
- lower pavement maintenance costs due to improved pavement durability and performance;
- reduced construction times due to thinner lifts (layer);
- better chip retention due to thicker binder films;
- reduced spray and noise (open graded surface course)

[source: www.Phoenix-Environmental.com]

References

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- Widyatmoko, I., Elliott, R.C., Grenfell, J., Airey, G.D., Collop, A.C., and Waite, S., "Characteristics of Rubberised Bitumen Blends", Asphalt Rubber 2009 (AR 2009), Nanjing, China, November 2-4, 2009.
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Use of plastic and non-ferrous metal wastes

Non-ferrous metal wastes as aggregates in highway construction

IP 8/06

dti
Department of Trade and Industry

A M Dunster, F Moulinier, R M Harrex

BRE Construction Division

I Widyatmoko

Scott Wilson

bre

information paper

This information paper summarises the output from a series of research projects carried out by BRE in conjunction with Scott Wilson between 2000 and 2004. Detailed reports on several parts of the programme are available from the Waste and Resources Action Programme (WRAP).

This information paper describes general considerations associated with the use of industrial by-products in construction. It also describes the use of by-products from non-ferrous metals production as bound aggregate. Slag derived from the production of zinc was used to construct demonstration roadways made from concrete and asphalt. Concretes containing crushed waste refractory bricks from aluminium smelters were also produced and assessed. In situ performance of the roads and leaching capacity of the materials were also evaluated.

It will be of interest to highway engineers, local authorities, specifiers and other potential users of by-product materials in construction.

Phase 1 – Basic Waste Characterisation.	Assessment of crushing/grinding of wastes and leaching behaviour (spent pot linings only)
Phase 2 – Basic Mix Characterisation.	Development of mix-designs and assessment of basic mechanical properties (workability, setting, strength development, density etc). Leach testing of bound materials
Phase 3 – Development of Mixes for Construction Purposes.	Development of final mix designs for demonstration phase of project
Phase 4 – Demonstration of Technology.	Construction of trial sections of roadway (and control areas) on a site and assessment of performance and leaching behaviour in service over a 1 year period (ferro-silicate slag only)

Table 1 Waste streams of non-ferrous metals industry

Non-ferrous metals producer	Waste stream		
Primary aluminium	Spent pot linings	Refractory bricks	Coal fired power station ashes
Secondary aluminium	White dross	Salt slag	Refractory bricks
Primary and secondary lead	Ferro-silicate slag	Refractory bricks	–
Primary and secondary zinc	Ferro-silicate slag	Refractory bricks	–

Table 3: Comparison of Materials Properties, Mean Values

Property	**DBM50**		**DBM50P**	**DBM50S**		
RSA Content & Type	*Control*		*20% Manufactured plastic aggregate*	*33% ISF Slag*		
Binder Content (by weight of mixture)	*4.0%*		*4.6%*	*4.0%*		
Source*	*Site-0 months*	*Site-18 months*	*Lab*	*Lab*	*Site-0 months*	*Site-18 months*
Density (Mg/m^3)	2.341	2.379	2.027	2.698	2.652	2.661
Air Voids (%)	9.5	8.6	7.5	2.4	2.9	3.1
Stiffness, MPa at: 10°C	10020	-	6420	10470	13130	-
20°C	3590	4760	3760	3950	4130	4530
30°C	1060	-	2020	1180	980	-
Deformation Resistance: Permanent Strain (%)^	2.2	2.2	1.5	1.8	3.1	2.4
Strain Rate (με/cycle)^^	1.5	1.2	0.5	0.8	2.3	2.3
Resistance to Moisture Damage (3rd Cycle Stiffness Ratio)	1.13	0.99	0.87	0.91	1.20	1.36

Note: *Denote laboratory (*Lab*) or site (*Site*) manufactured/compacted samples; Site-0 and Site-18 denote core removed immediately after construction and after 18 months respectively. ^After 3600 cycles. ^^Between 2600 and 3600 cycles.

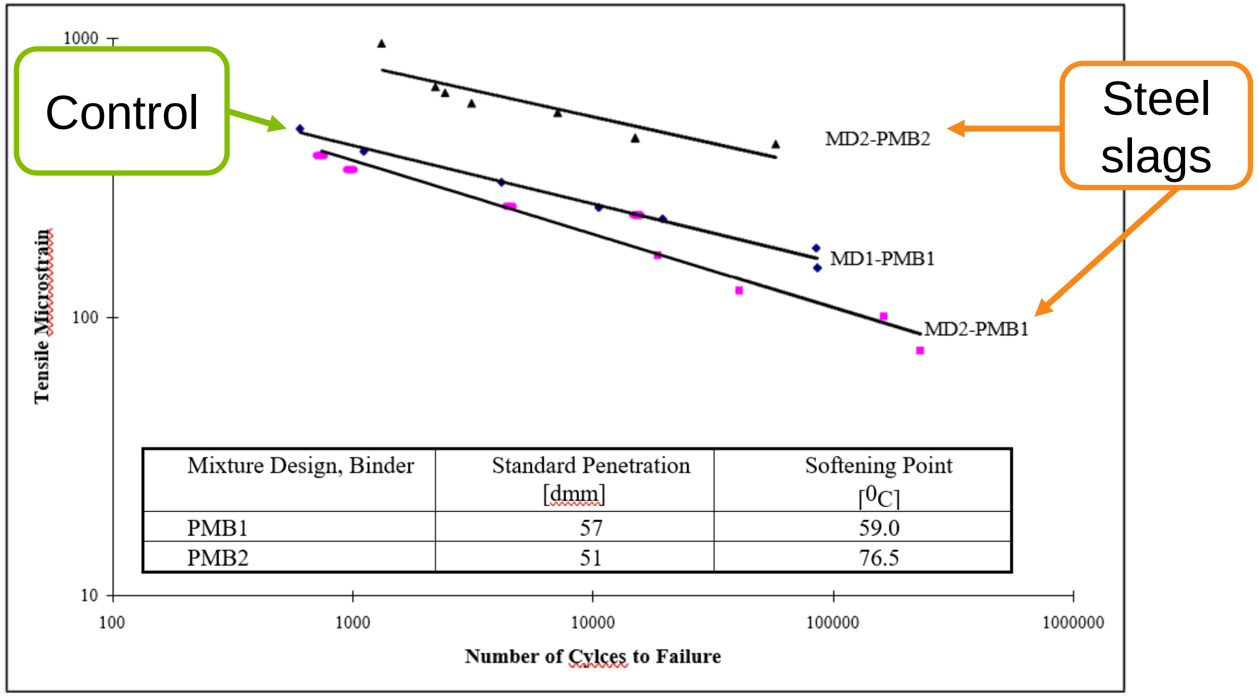
Table 2 Properties of concrete placed on site

	Bay	Control bays (without ISF)			Test bays (with ISF)		
	ISF slag (% replacement of sand, by volume)	0	0	0	50	50	50
	Slump (mm)	70	80	95	110	125	65
	Measured air content (%)	–	–	–	7.6	7.5	6.8
Compressive strength (water stored) cubes (N/mm^2)	At 3 days	35.0	30.0	31.5	27.0	25.0	35.0
	At 7 days	40.5	35.0	35.5	33.0	28.5	39.0
	At 28 days	47.5	43.5	42.5	38.0	35.0	44.0
	At 91 days	53.5	46.0	45.0	42.5	41.5	49.0

1) Widyatmoko, I., Dunster, A, and Moulinier, F., "Performance and benefits from using waste plastic-based aggregate in asphalts", International Conference on Sustainable Construction Materials and Technologies, Coventry, 2007.
2) Widyatmoko, I.; Moulinier, F.; and Dunster, A. "Added value potential of processed plastic aggregate and ISF slag in asphalt". 10th International Conference on Asphalt Pavements. Quebec, Canada, 2006.
3) Dunster, A.M., Moulinier, F, Abbott, B, Conroy, A., Adams, K., Widyatmoko, D., "Added Value of Using New Industrial Waste Streams in both Concrete and Asphalt. Feasibility of Using Waste Material in Asphalt Applications." The Waste & Resources Action Programme, R&D Report: Aggregates, 2005, ISBN 1-84405-186-2

Use of steel slags in roads

- ✓ By-products of steel manufacturing processes
  - Electric arc furnace (EAC) process
- ✓ MD1 (primary), MD2 (steel slags)
- ✓ Steel slags as coarse and fine aggregates and filler
- ✓ Polymer modifier binders:
  - PMB1 for MD1 and MD2
  - PMB2 for MD2 only



Mixture Design, Binder	Standard Penetration [dmm]	Softening Point [^{0}C]
PMB1	57	59.0
PMB2	51	76.5

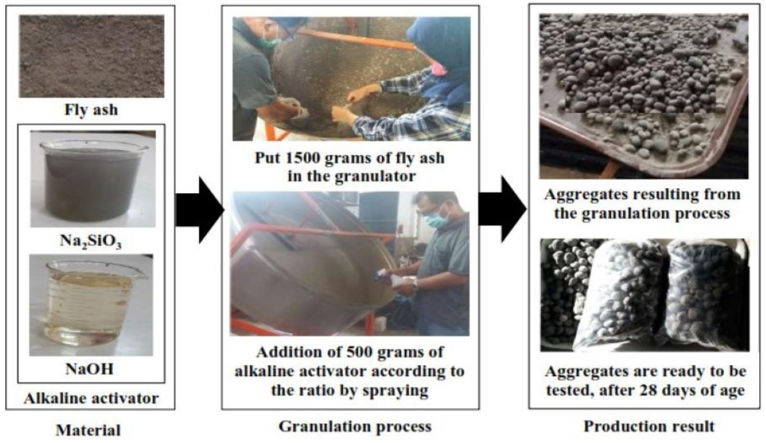
Material	Mixture Design 1 (MD1), [%]	Mixture Design 2 (MD2), [%]
Coarse Aggregate	62.2	58.5
Fine Aggregate	21.4	24.5
Filler	10.5	11.3
Fiber	0.0	0.05
Binder	5.9	5.65

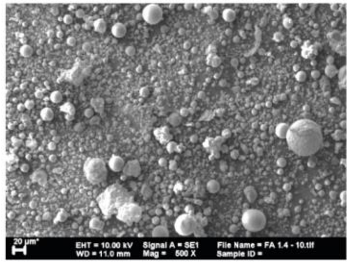
Mixture Clause 943	Air voids maximum = 5.5%	Rut rate at 45^{0}C [mm/h] maximum = 2	Rut rate at 60^{0}C [mm/h] maximum = 4	Rut Depth at 45^{0}C [mm] maximum = 5	Rut Depth at 60^{0}C [mm] maximum = 7
MD1-PMB1	3.85%	0.89	1.66	2.75	4.15
MD2-PMB1	3.92%	0.86	1.36	3.03	4.87
MD2-PMB2	4.19%	0.52	0.51	1.87	2.19

Ellis, C.; and Widyatmoko, I. (1999). Performance and durability aspects of asphalts incorporating electric arc furnace steel slag aggregates designed for use in thin pavement surfacings. Proceedings of the 3rd European Symposium on Performance and Durability of Bituminous Materials and Hydraulic Stabilised Composites. Leeds, United Kingdom

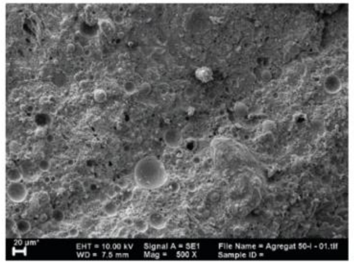
Geopolymer artificial aggregate in asphalt

Manufacturing | Aggregate properties | Asphalt mixture properties

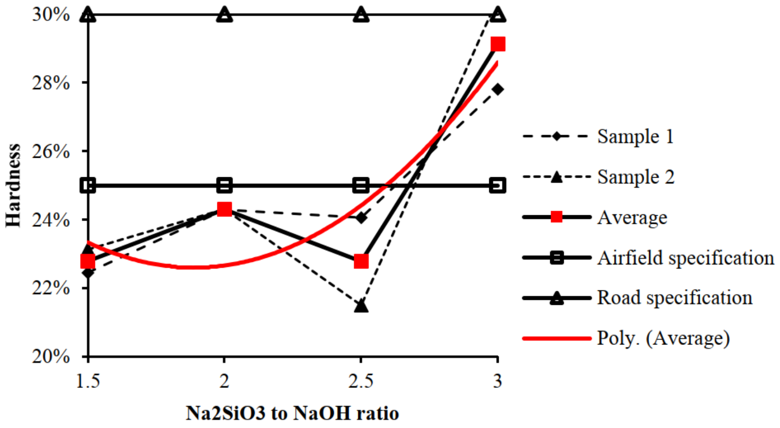


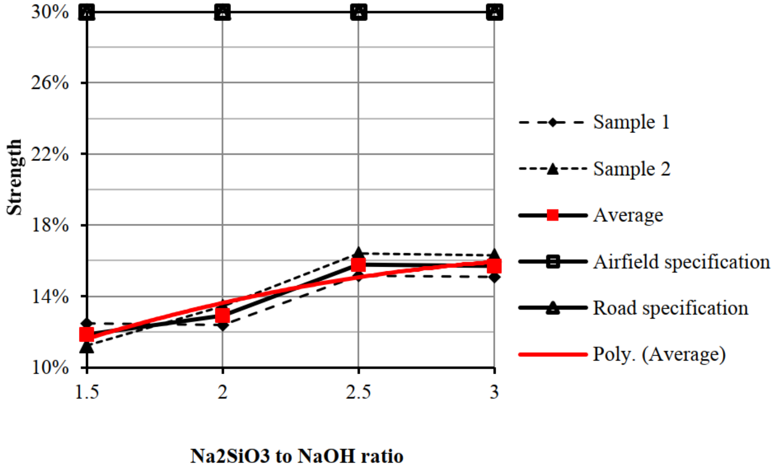


Fly ash (500X)



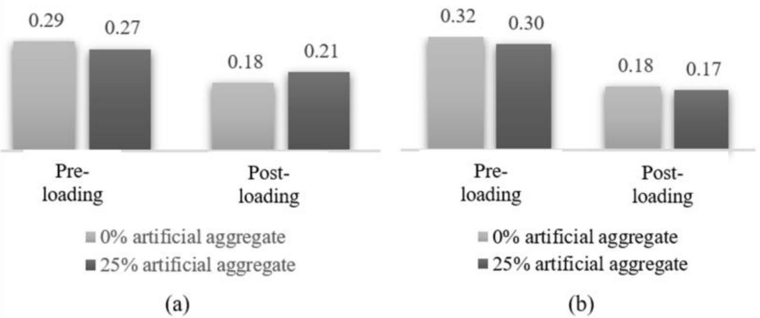
Artificial Aggregates (500X)





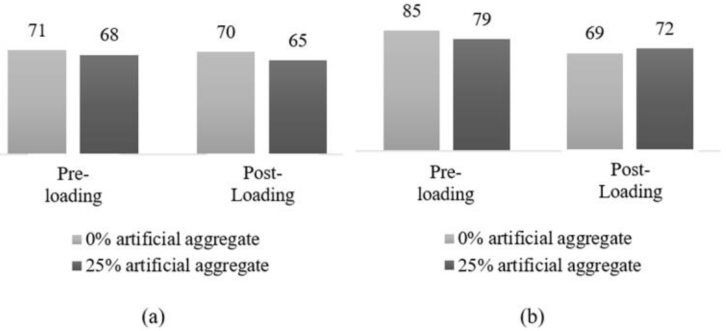
- **Macrotexture (texture depth)**

Comparison of the results of ACSC **texture depth** measurements without (0%) and with 25% artificial aggregate (a) dense graded, (b) open graded



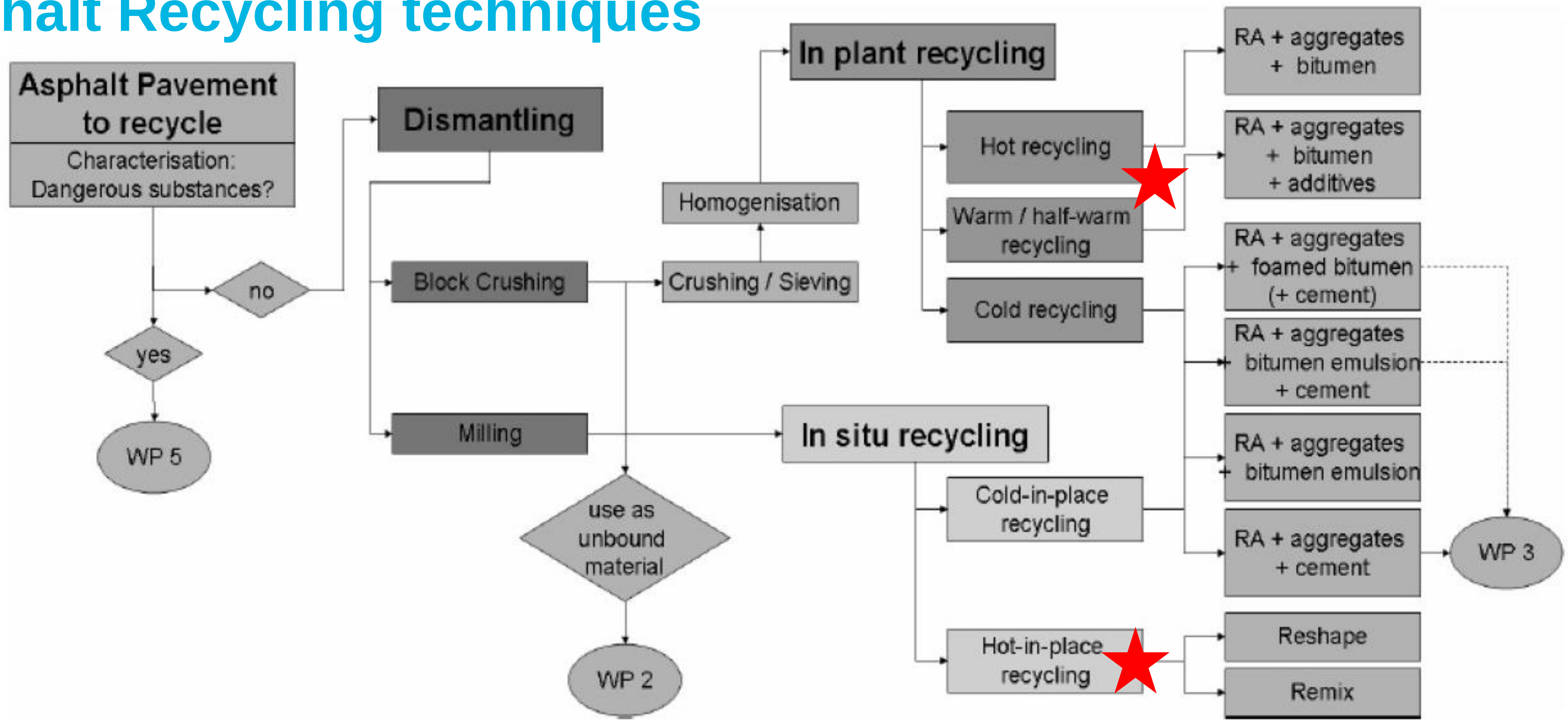
- **Skid Resistance**

Comparison of the results of ACSC **skid resistance** measurements without (0%) and with 25% artificial aggregate (a) dense graded, (b) open graded, pre- and post-wheel track loading.



1) Karyawan IDMA, Ekaputri JJ, Widyatmoko I and Ariatedja E, "The Effects of Na2SiO3/NaOH Ratios on the Volumetric Properties of Fly Ash Geopolymer Artificial Aggregates", Materials Science Forum 967 (2019). DOI: 10.4028/www.scientific.net/MSF.967.228
2) Karyawan IDMA, Ekaputri JJ, Widyatmoko I and Ariatedja E, "The Effect of various Na2SiO3/NaOH Ratios on the Physical Properties and Microstructure of Artificial Aggregates", Journal of Engineering Science and Technology, Vol. 15, No. 2 (2020) 1139 – 1154
3) Karyawan IDMA, Widyatmoko I, Ekaputri JJ, and Ariatedja E. "Texture and Skid Resistance of Asphalt Concrete Surface Course incorporating Geopolymer Artificial Aggregates". 12th International Conference on Road and Airfield Pavement Technology, 2021

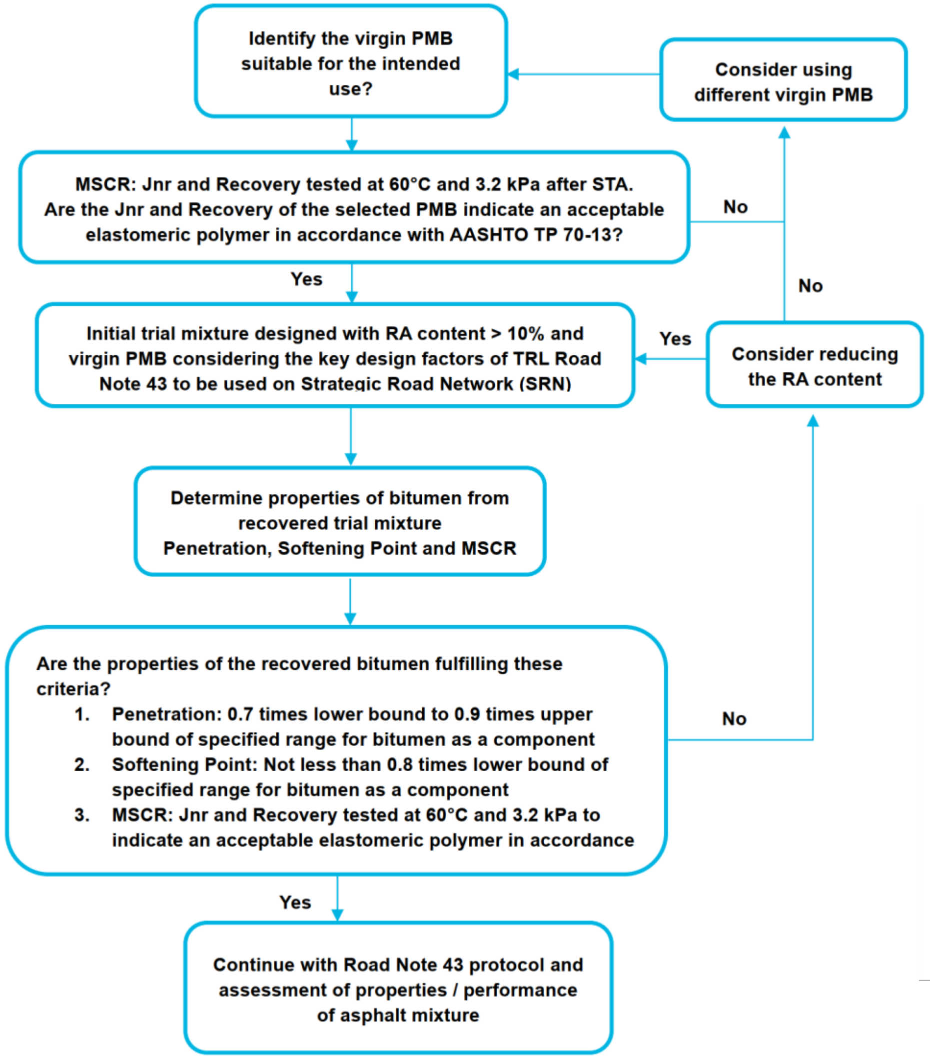
Asphalt Recycling techniques

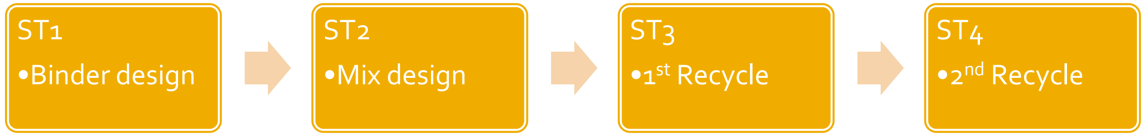


1) De Bock, L., Arm, M., de Lurdes Antunes, M., Descantes, Y., Gaspar, L., Mollenhauer, K., and Thogersen. F. “Developing best practices on recycling or safe disposal of road materials in Europe – the DIRECT-MAT project”, XXIV PIARC World Road Congress, Mexico City, 2011
2) Troeger, J and Widyatmoko, I. “Development in Road Recycling”, 11th Annual International Conference on Pavement Engineering and Infrastructure, Liverpool, 2012
3) Widyatmoko, I. “Mechanistic-Empirical Mixture Design for Hot Mix Asphalt Pavement Recycling”, Construction and Building Materials 22(2):2008. doi:10.1016/j.conbuildmat.2006.05.041
4) Nichols, J.C., Carswell, I., Widyatmoko, I., Elliott, R.C., Harris, J.H., and Taylor, R., “Recycling Surfacings into Thin S urfacing Systems”, Construction Materials 161, Issue CM3, August 2008, pp. (“Howard Medal for Best Paper 2009” by ICE Journal 'Construction Materials', Thomas Telford, London)
5) Widyatmoko, I., and Sunarjono, S., “Some Considerations to Implement Foamed Bitumen Technology for Road Construction in Indonesia”, 1st European Asian Civil Engineering Forum (EACEF) International Conference, Jakarta, 2007

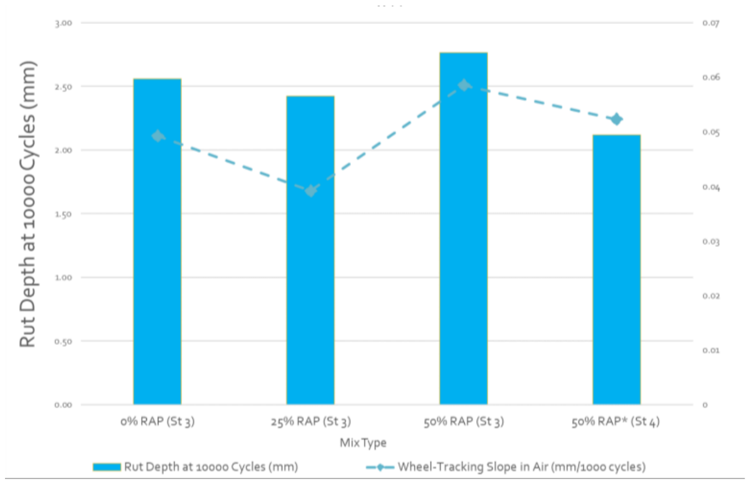
Multiple Recycling with RA containing PMB

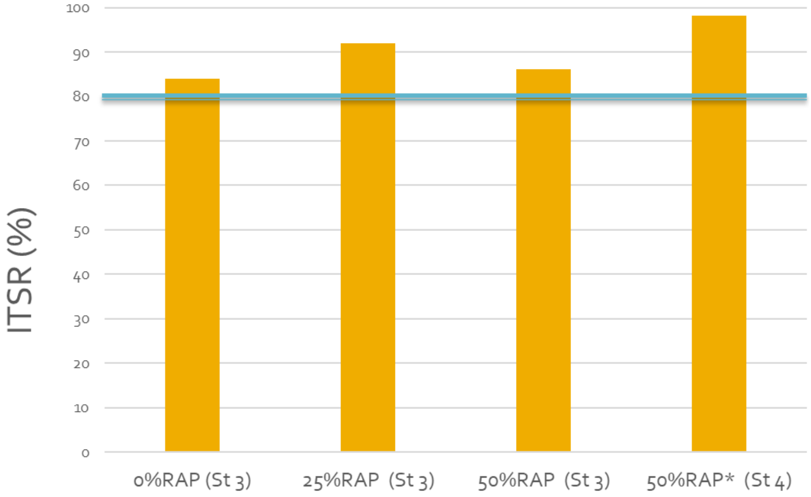
https://aecom.com/uk/wp-content/uploads/2021/06/report_highways-england_60618808_1-979_subtask-1.pdf





Test	Stage 1: PMB 'B' (75-130/75)			Stage 2 (MRTFOT blending) 25% RA 'M42'/ 75% PMB 'B'		Stage 2 (MRTFOT blending) 50% RA 'M42'/ 50% PMB 'B'		Stage 3: Asphalt Mixtures Recovered binders		Stage 4: Asphalt Mixtures Recovered binders		
	NA	STA	LTA	STA	LTA	STA	LTA	0% 'M42' / 100% 'B'	25% 'M42'/ 75% 'B'	50% 'M42'/ 50% 'B'	RAP*	50% 'RAP*'/ 50% 'B'
Penetration (dmm)	94	66	40	52	33	36				44	33	44
Softening Point (°C)	90.5	88	67.6	73.6	65.6	61.6	66	85.5	63.6	72.6	66.8	71





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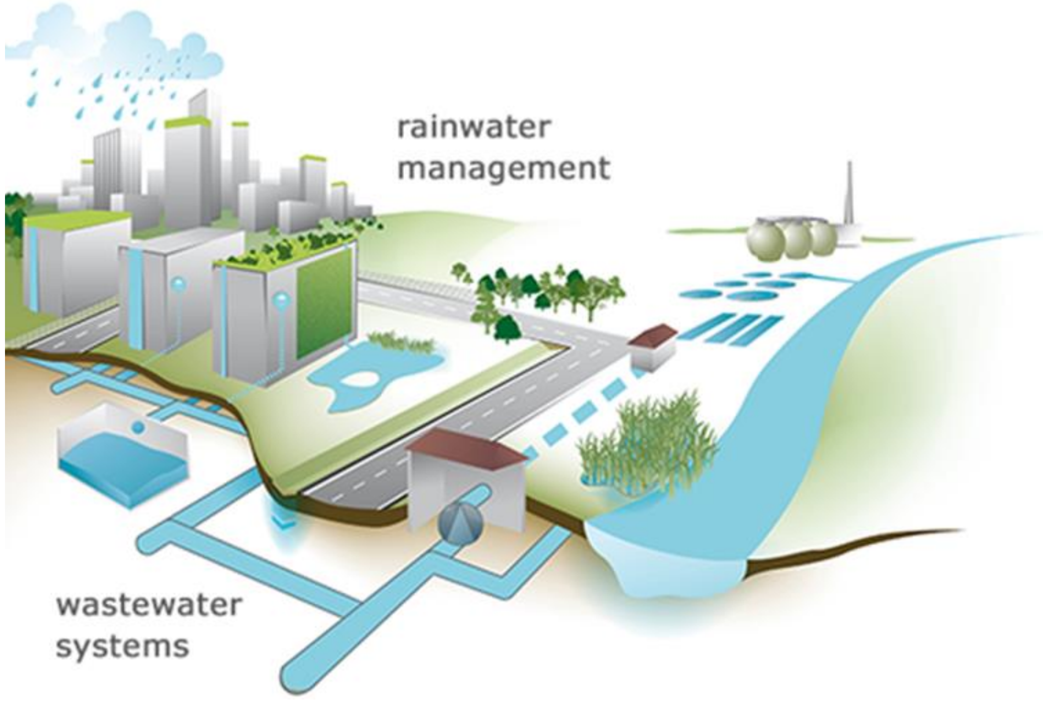
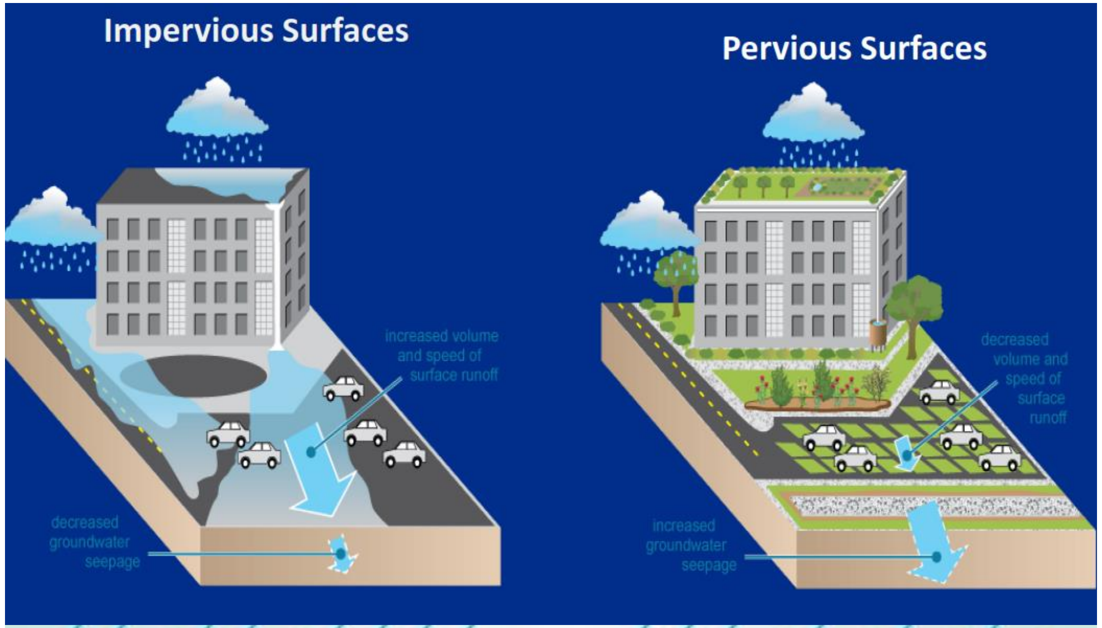
Urban Drainage Systems

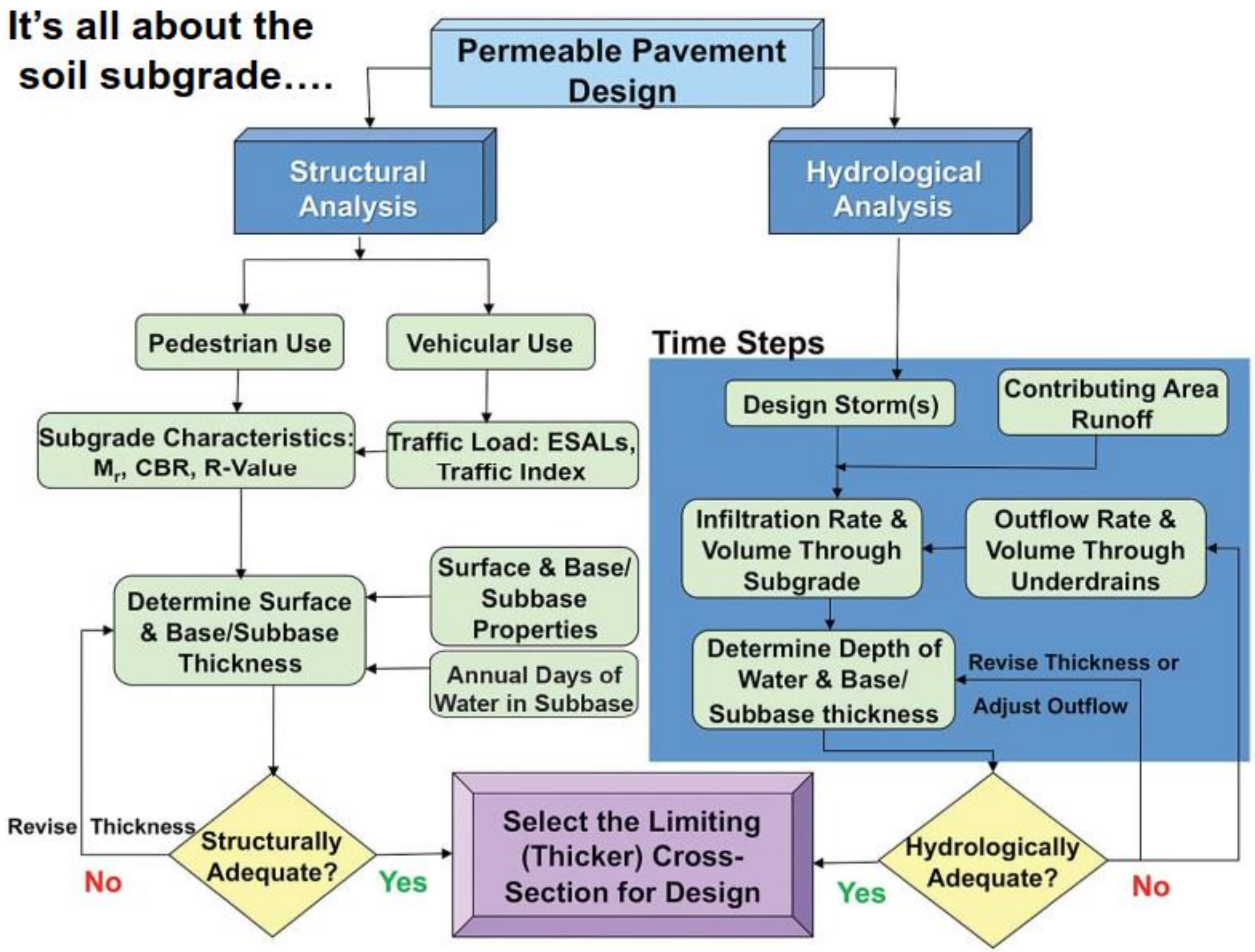


Permeable Pavements



1. It allows rainfall to be captured and to percolate into the ground.
2. It reduces stormwater runoff
3. It recharges groundwater
4. It supports sustainable construction

Hydrologic and structural design overview



Type & application

- Material/Pavement Type
  - Porous media?
  - Porous asphalts?
  - Porous concrete?
  - Block paving?
  - Permeable Interlocking Concrete Pavement?
- Application
  - Parking area
  - Roads – rural
  - Roads – urban
  - Roads – intercity
  - ...others.

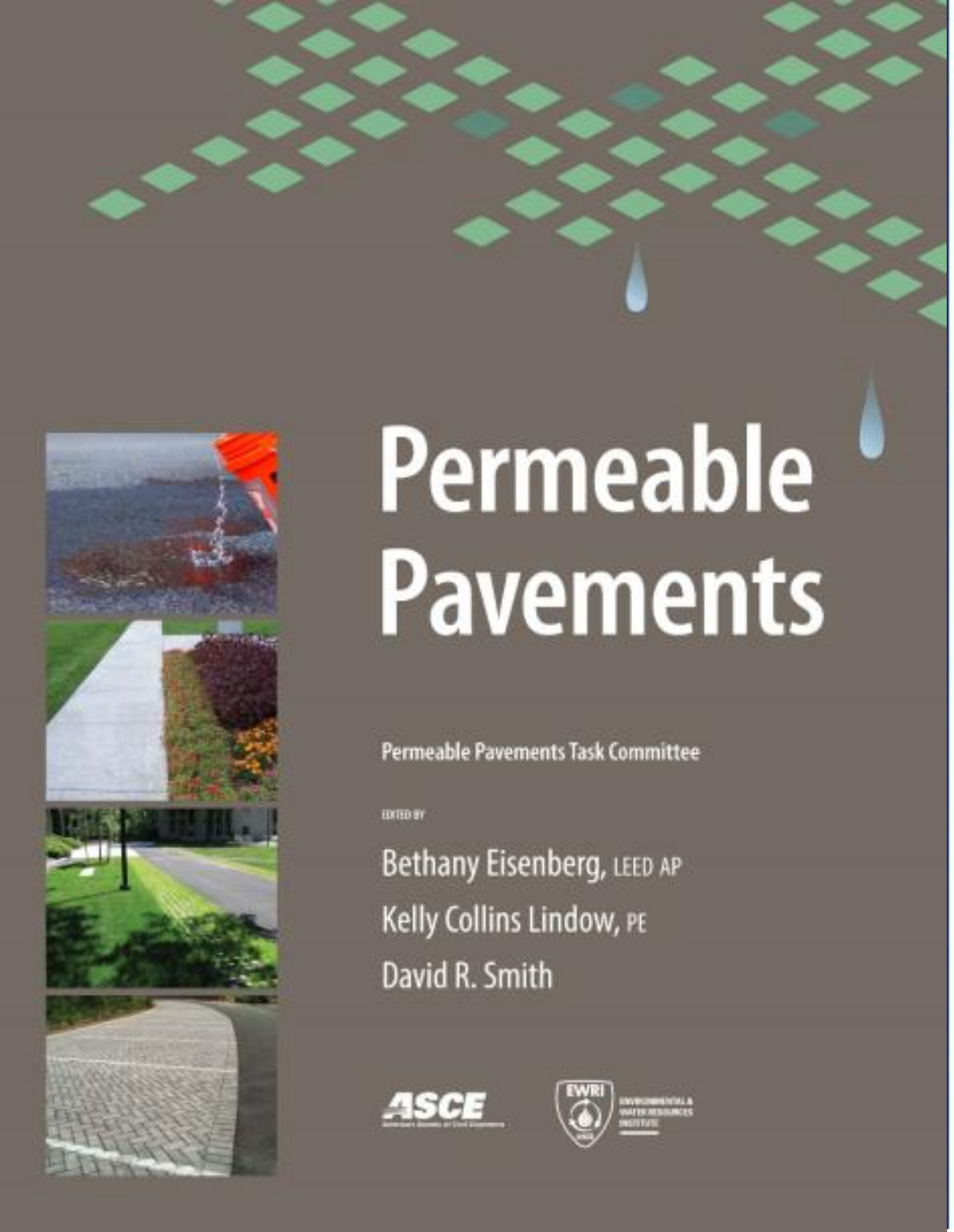
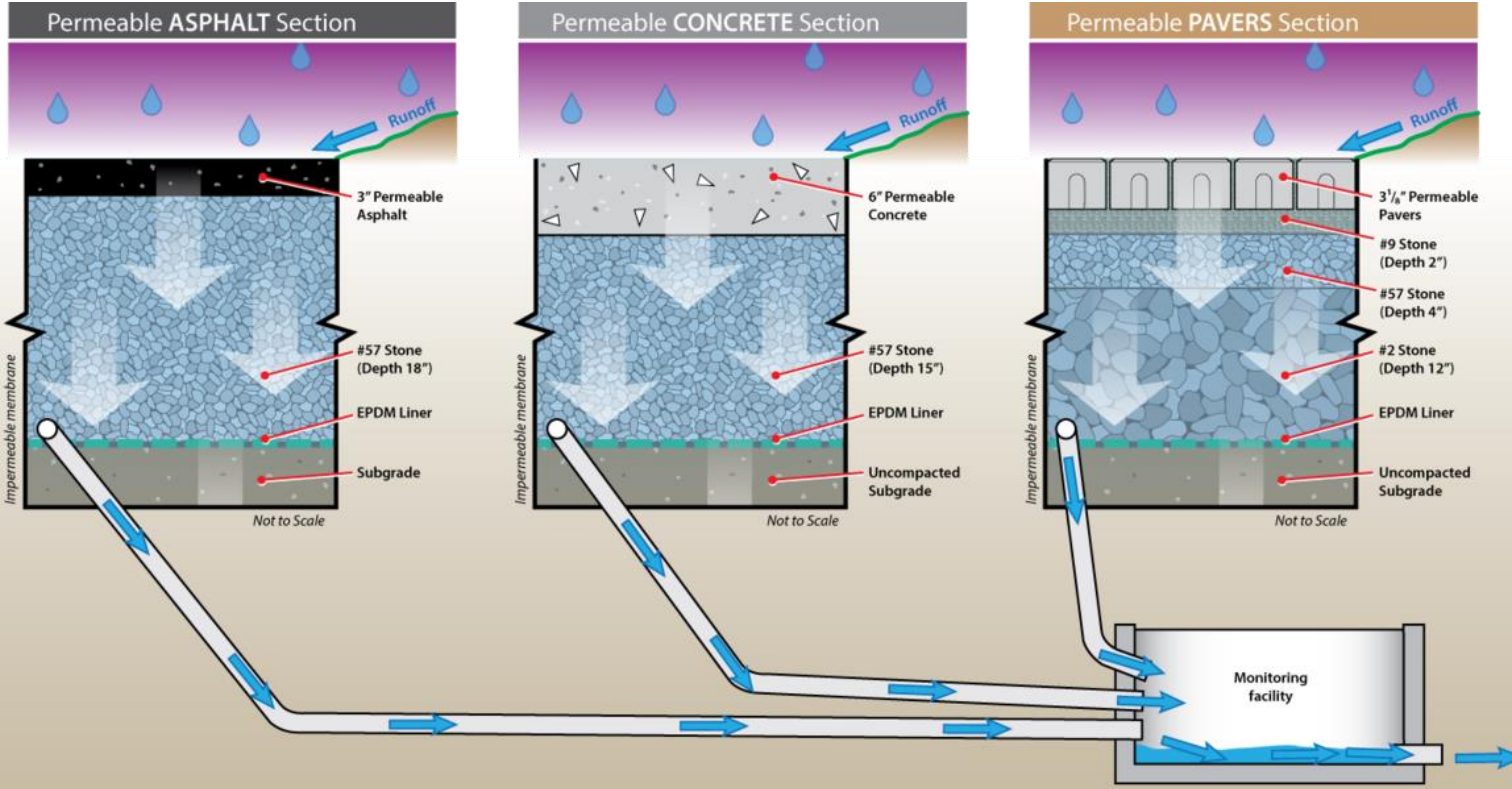


Table 1-1 Typical Permeable Pavement Types

MATERIAL AND DESCRIPTION	DETAIL
Porous asphalt (PA) Porous asphalt is similar to conventional asphalt, except the fines are removed to create greater void space. Additives and higher-grade binders are typically used to provide greater durability and prevent draindown of the asphalt binder.	
Pervious concrete (PC) Pervious concrete is produced by reducing the fines in the mix to maintain interconnected void space and has a coarser appearance than standard concrete. Additives may be added to increase strength.	
Permeable interlocking concrete pavement (PICP) PICP is made of interlocking concrete pavers that maintain drainage through stone-filled gaps between the pavers. The pavers are not permeable.	
Grid pavement systems (plastic or concrete) Grid pavement systems are modular grids filled with turf and/or gravel. Open-celled concrete or plastic structural units are typically filled with small uniformly graded gravel that allows infiltration through the surface.	



https://www.usgs.gov/media/images/permeable-pavement-test-plot-cross-sections


12
VIA GRAND AVE

Pervious Pavement in Parks:
Commodore Park, San Jose

Pervious pavers

Pervious concrete

Permeable rubber

Porous asphalt

Pervious Pavement Over Infiltration Trench

Santa Clara Valley
Urban Runoff
Pollution Prevention Program

EOA inc.

Pervious Concrete

Dr Art Miller (Penn State)

- “Thus the limiting infiltration rate for the porous pavement tested would depend on the soil infiltration rate of the soil that supports the pavement”
- To avoid restricting the flow through the concrete the stone base must be as porous as the concrete. ¾ to ¼ inch stone with no fines does not restrict the flow and can provide the necessary storage

Grid pavement system

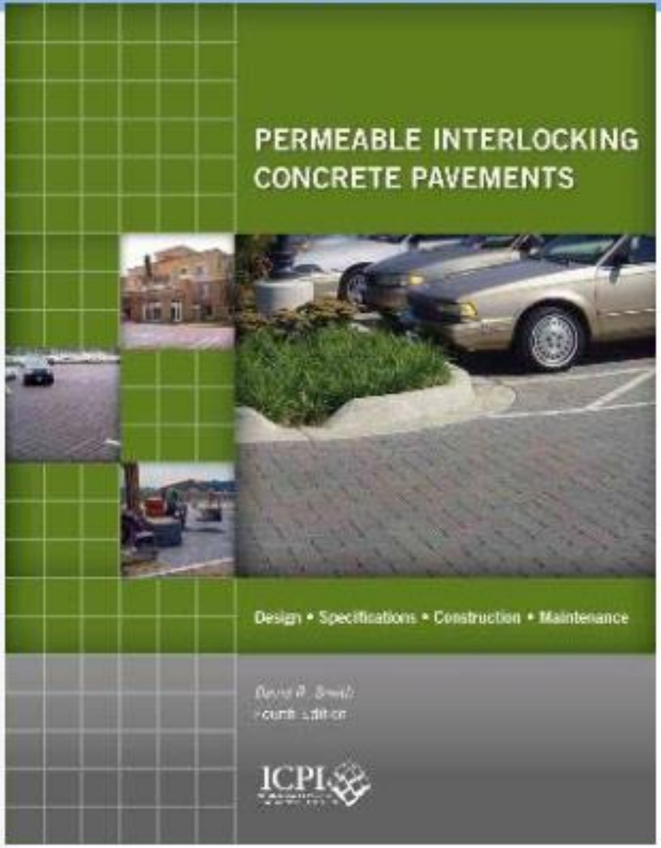
Porous Asphalt

- Void content ~20%
  → Noise reduction (PA16 4 dB < AC or SMA)
  → Improved water drainability
  → Improved water Retention

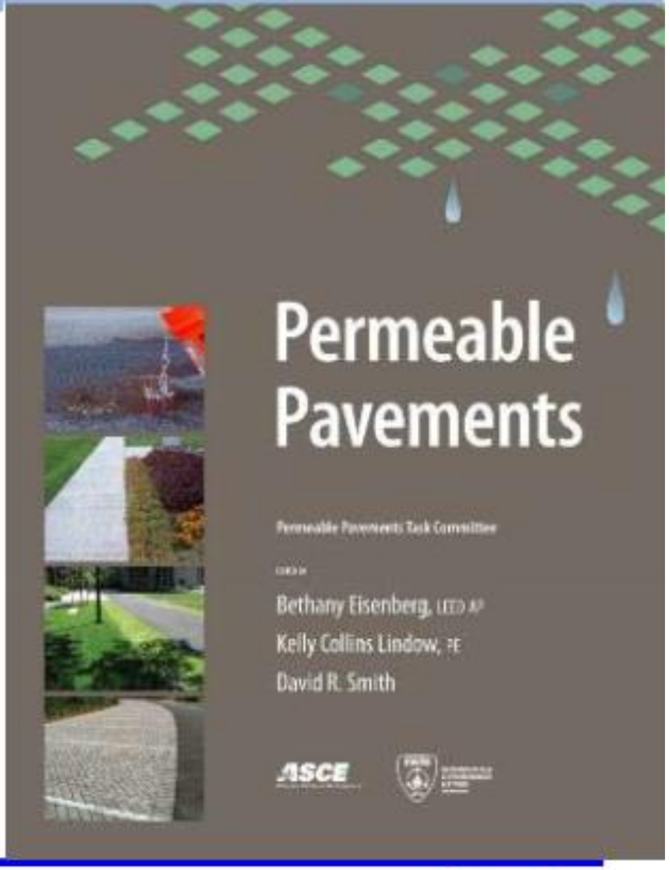
- Stone skeleton
  → Improved resistance against deformation
  → Lower resistance against shear stresses

ICPI & ASCE Resources

Permeable Interlocking Concrete Pavements
Design, Specifications, Construction & Maintenance
(100 pages)



Permeable Pavements
ASCE e-book
(250 pages)



Defects and failures

Settlement of Base/Subbase

Settlement and Ponding at Transition


What is Wrong Here?


Joint Much Too Wide


Too Complicated


Loss of Permeability or Heavy Flows


Deep Clogging


Joint Raveling


Large Scale Raveling


High Severity Raveling

Thank You

DEFINITION OF GREEN TRANSPORTATION INFRASTRUCTURE

ASPHALT MATERIALS PRODUCED BY GREEN TECHNOLOGY

RESEARCH ON WASTE AND SECONDARY MATERIALS

URBAN DRAINAGE SYSTEMS

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Nottingham, 28 October 2023