Modification of Bitumen with Waste Materials for Enhanced Aggregate Retention in Surface-Dressed Roads

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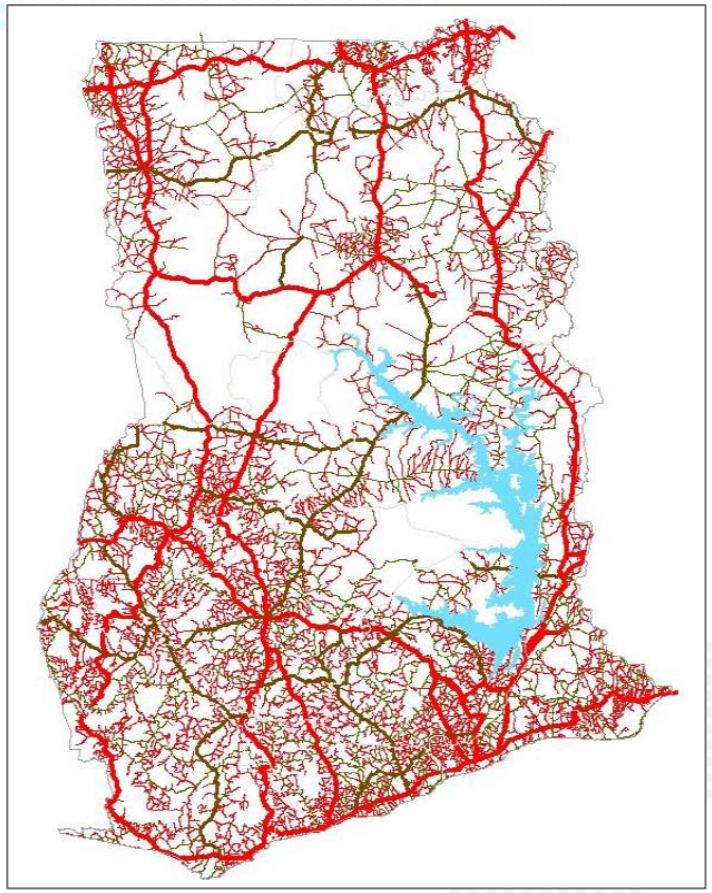
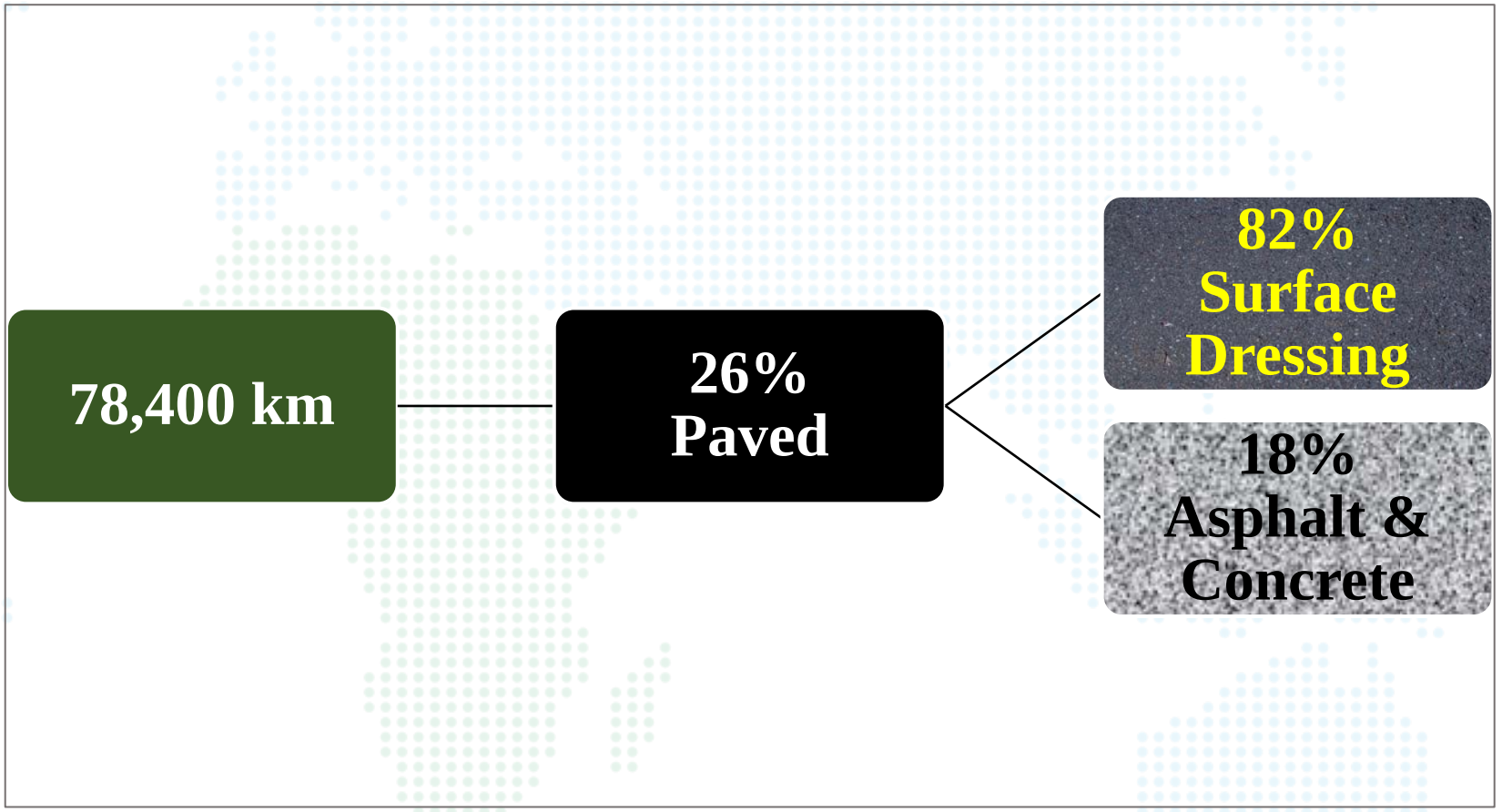
TRECK

75 YEARS IRF GLOBAL

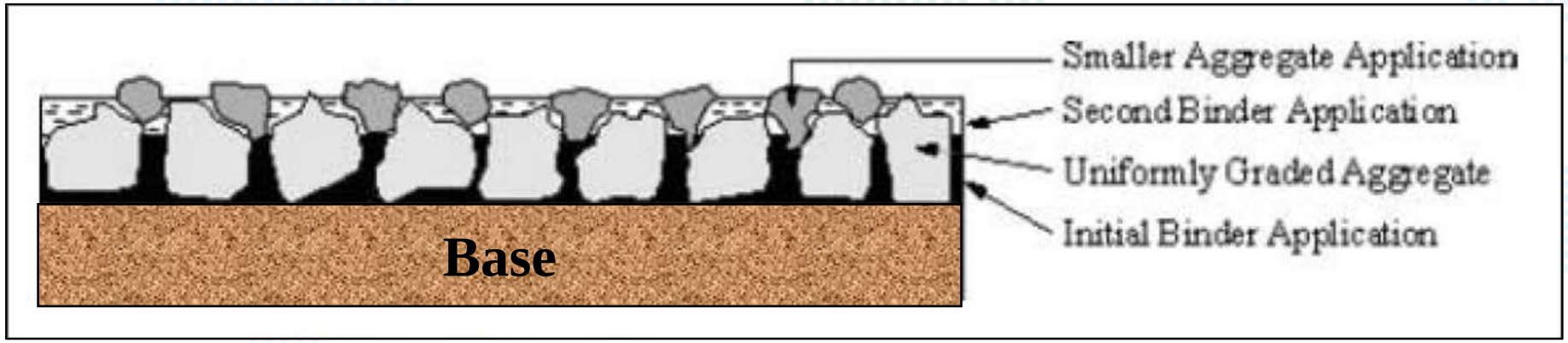
Ghana's Road Network Size in 2019





2019 Annual Progress Report, Ministry of Roads and Highways (https://ndpc.gov.gh/media/Ministry_of_Roads_and_Highways_APR_2019.pdf)

Surface Dressing



Adapted from Buss et al. (2016) https://www.oregon.gov/ODOT/Programs/ResearchDocuments/SPR777_ChipSeal.pdf

Aggregate Loss (Raveling)

- **Traffic:** abrasive forces dislodge aggregates
- **Moisture:** weakens the aggregate–bitumen bond
- **Aging:** bitumen becomes brittle and easily cracks

Plastic Wastes

https://africa.cgtn.com/2019/06/10/ghana-epa-total-ban-on-plastics-not-practical/

https://newsghana.com.gh/ghanaian-company-turns-plastic-wastes-into-valuable-products/

https://www.graphic.com.gh/features/features/plastic-waste-or-value.html/

HDPE = High-density polyethylene

LDPE = Low-density polyethylene

PET = Polyethylene terephthalate

EPS = Expanded polystyrene foam

GTR = Ground tyre rubber

Expanded Polystyrene Foam (Styrofoam)

https://www.bioenergyconsult.com/foam-packaging/

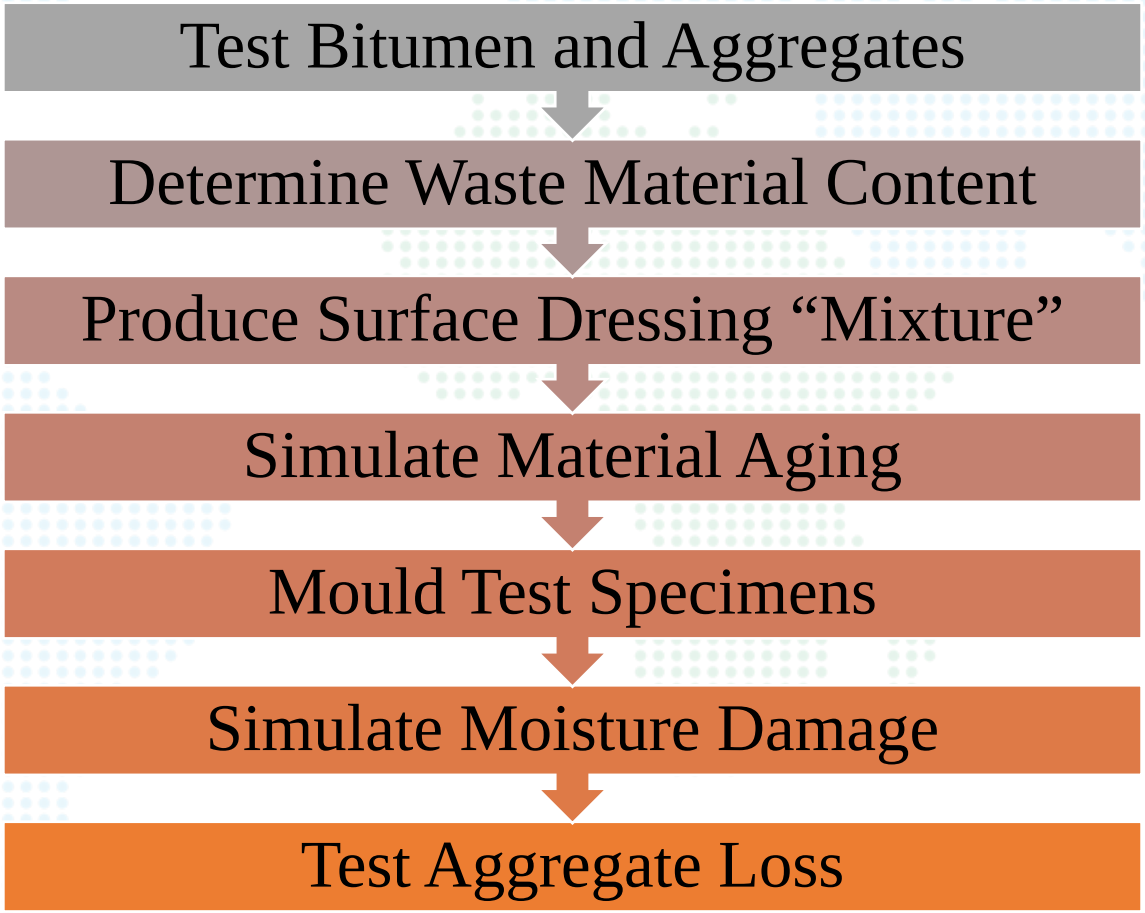
- Food packaging
- Industrial packaging
- Building & construction

Waste Tyres (GTR)

https://www.gepecotech.com/release/blog/22.html

Research Question & Methodology

Can waste **plastics**, **styrofoam**, and **tyres** modify bitumen to improve aggregate retention on surface-dressed roads?



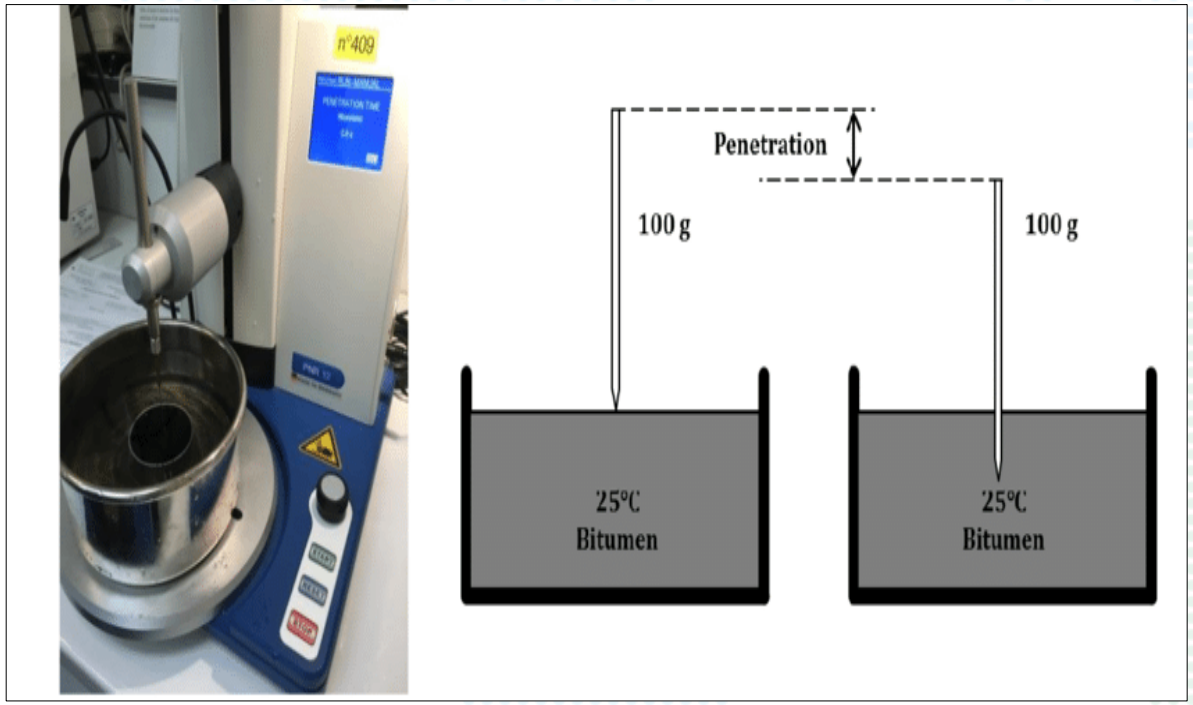
Granite Aggregate Test Results

Property	Value	Specification*
Flakiness Index	18%	30% (max)
Elongation Index	12%	35% (max)
Aggregate Crushing Value	20%	25% (max)
Los Angeles Abrasion	25%	30% (max)
10% Fines	280 kN	210 kN (min)
Water Absorption	0.2%	1% (max)

***Standard Specification for Road and Bridge Works, Ghana's Ministry of Roads and Highways, 2007**

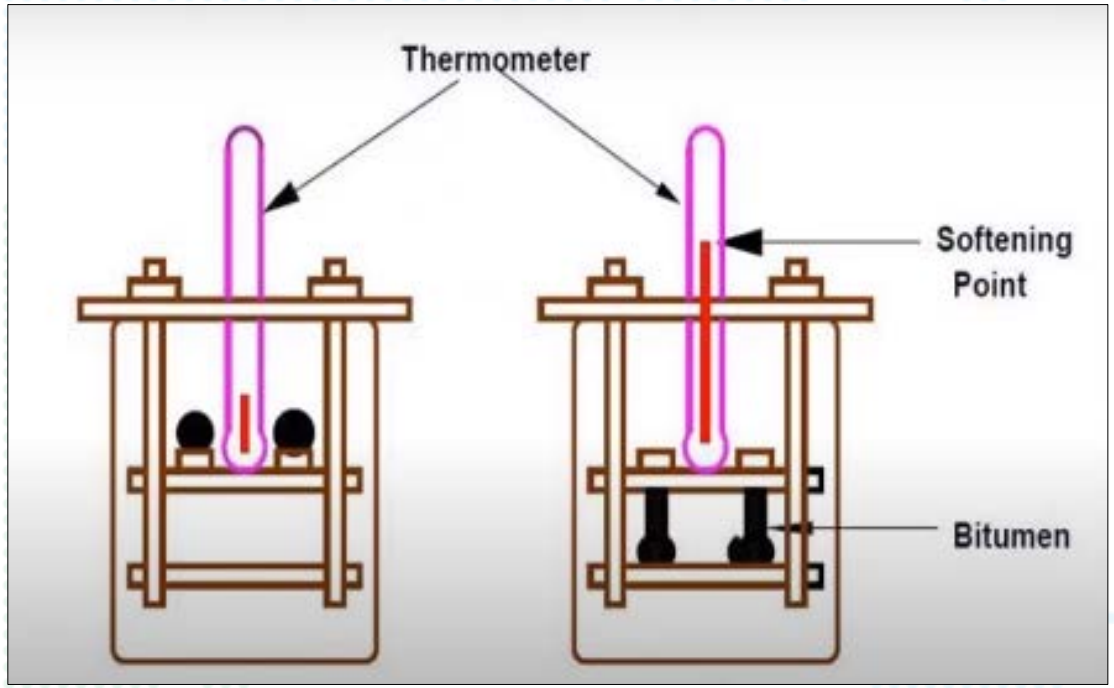
Waste Material Content Determination

Penetration Test (ASTM D5)



https://www.google.com/search?q=softening+point+test+bitumen&source=lmns&tbm=vid&bih=892&biw=1920&rlz=1C1SQJL_enUS930US930&hl=en&sa=X&ved=2ahUKEwivh9jn967-AhUatycCHet5ANYQ_AUoAnoECAEQAg#fpstate=ive&vld=cid:3efa0dc5,vid:Uh_t2C9SN3M

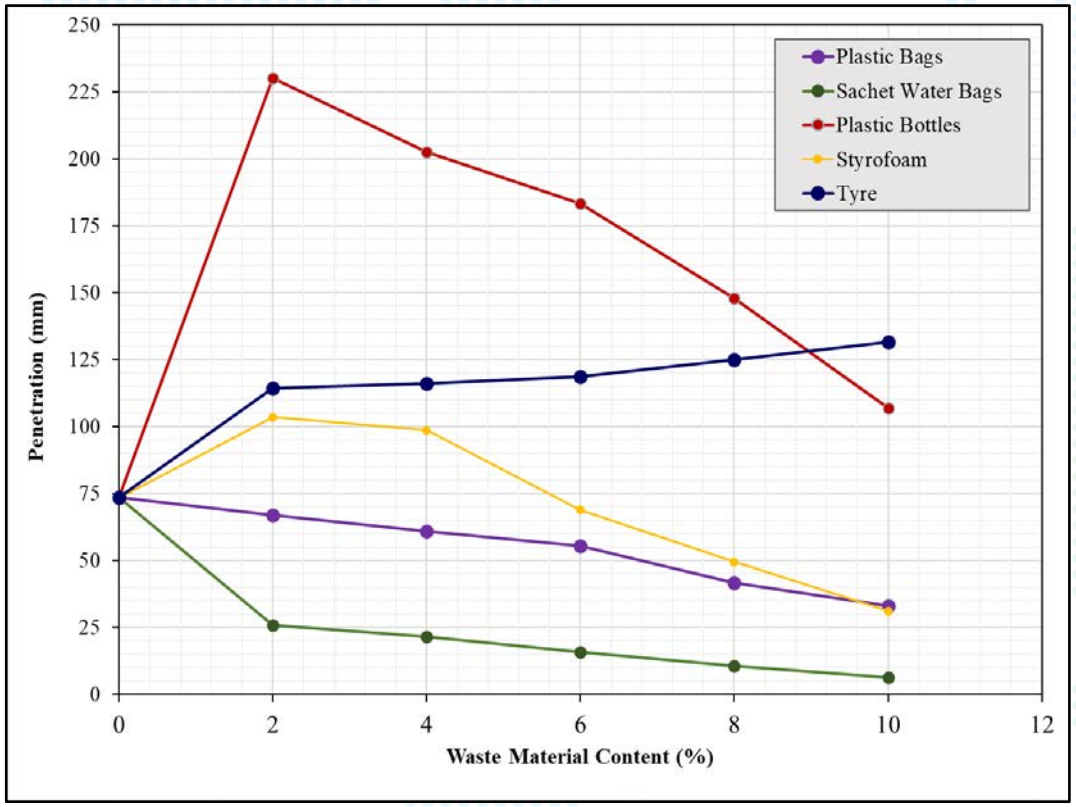
Softening Point Test (ASTM D36)



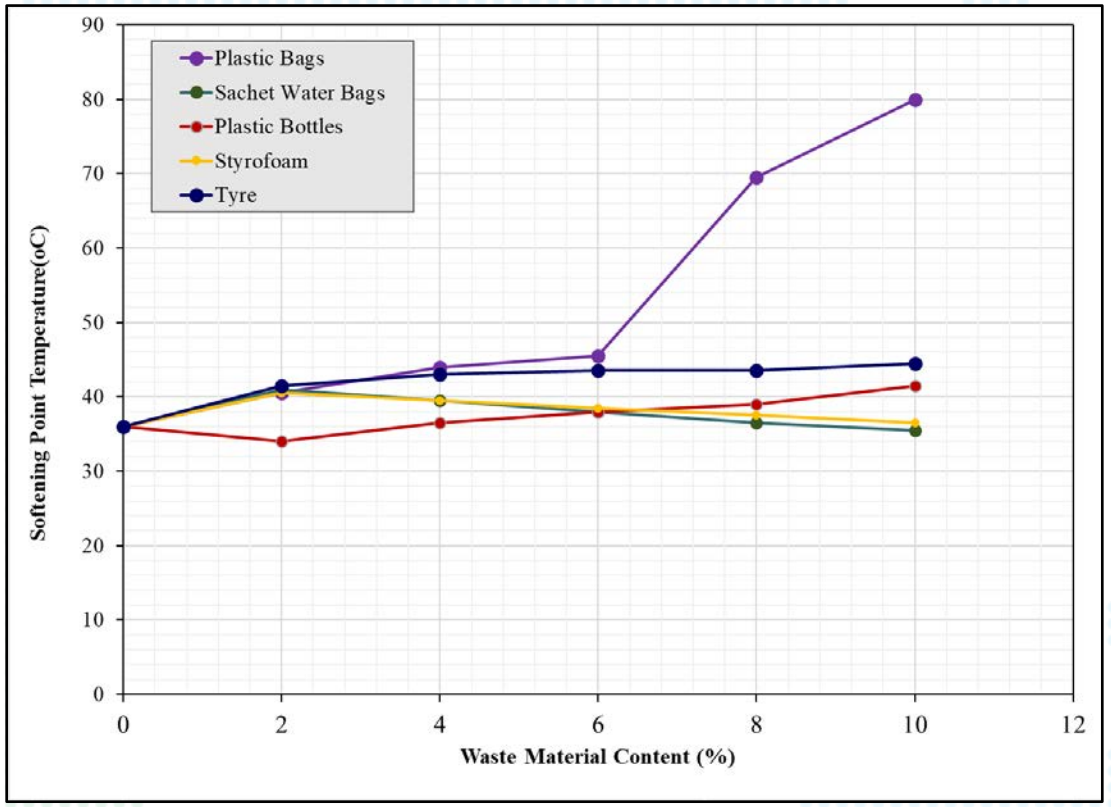
https://www.google.com/search?q=softening+point+test+bitumen&source=lmns&tbm=vid&bih=892&biw=1920&rlz=1C1SQJL_enUS930US930&hl=en&sa=X&ved=2ahUKEwivh9jn967-AhUatycCHet5ANYQ_AUoAnoECAEQAg#fpstate=ive&vld=cid:3efa0dc5,vid:Uh_t2C9SN3M

Waste Material Content Determination

Penetration



Softening Point Temperature



Specimen Preparation and Conditioning

Mixture Preparation

- 75% granite (10mm &14mm)
- 25% quarry dust (for stability)
- 6% bitumen content (by weight of aggregate)
- Aggregate & bitumen mixing @ 165 ^{o}C

Short-Term Aging

- Mixture in oven @ 130 ^{o}C for 3 hrs.
- 6 Marshall specimens (50 blows per face)
- 3 specimens in water @ 25 ^{o}C for 12 hrs
- 3 dry specimens at room temperature

Long-Term Aging

- Mixture in oven @ 95 ^{o}C for 5 days
- 6 Marshall specimens (50 blows per face)
- 3 specimens in water @ 25 ^{o}C for 12 hrs
- 3 dry specimens at room temperature

Cantabro Abrasion Loss Test (TXDOT: TEX-245-F)

https://pavementinteractive.org/reference-desk/testing/aggregate-tests/los-angeles-abrasion/

Before Testing

After Testing

$$\text{Abrasion Loss (\%)} = \left(\frac{\text{Mass Before Testing} - \text{Mass After Testing}}{\text{Mass Before Testing}}\right)$$

- High abrasion loss means poor aggregate retention (weak bonding)
- Low abrasion loss means better aggregate retention (strong bonding)

Cantabro Abrasion Loss (%)

Bitumen Modifier	Short-Term Aging		Long-Term Aging	
	Dry Specimen	Wet Specimen	Dry Specimen	Wet Specimen
Unmodified Bitumen (AC-10)	1.8	**6.6**	100.0	100.0
Styrofoam (EPS)	**1.5**	7.0	100.0	100.0
Sachet Water Bag (LDPE)	4.3	15.0	100.0	100.0
Plastic Bottle (PET)	6.0	16.6	100.0	100.0
Grocery Bag (HDPE)	4.0	10.9	87.8	89.3
Ground Tyre Rubber (GTR)	3.2	7.4	**34.5**	**44.2**

Conclusion & Recommendation

- Ground tyre rubber modification produced better aggregate retention under the combined effect of moisture and long-term aging
- Field studies are recommended to validate the laboratory results