

Pavement Materials & Design

Asphalt Materials

4.3_Behavior and Properties of Asphalt cement

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Pavement Materials & Design

Asphalt Materials

Asphalt behavior

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Mechanical behavior of materials

- ❑ The mechanical behavior of materials is
 - the *response of the material to external loads*.
- ❑ All materials deform in response to loads; however, the specific response of a material depends on
 - The magnitude and type of load
 - The geometry of the element.
 - Its properties

Image source: <https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-5.2.1>

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Mechanical behavior of materials

Viscoelastic Behavior

- ❑ Viscoelasticity is the property of materials that exhibit both **viscous and elastic** characteristics when **undergoing deformation**

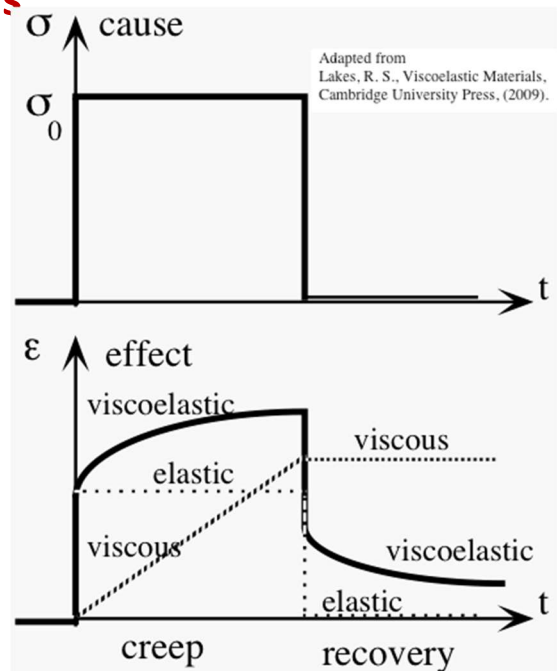


Image source: <https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-5.3>

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Mechanical behavior of materials

Viscoelastic Behavior

☐ **Asphalt is a viscoelastic material**

☐ Therefore, it

- **Have both elastic and viscous response**
- **Have delayed response**
- **Deformation depends on**
 - ❖ Applied load
 - ❖ Duration of Load
 - ❖ Rate of Loading
 - ❖ Temperature

Image source: <https://www.open.edu/openlearn/science-maths-technology/science/chemistry/introduction-polymers/content-section-5.3>

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Mechanical behavior of materials

Time of loading dependency



Video source: <https://www.youtube.com/watch?v=52H9p0A0c&t=16.4s>

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Mechanical behavior of materials

Time of loading dependency

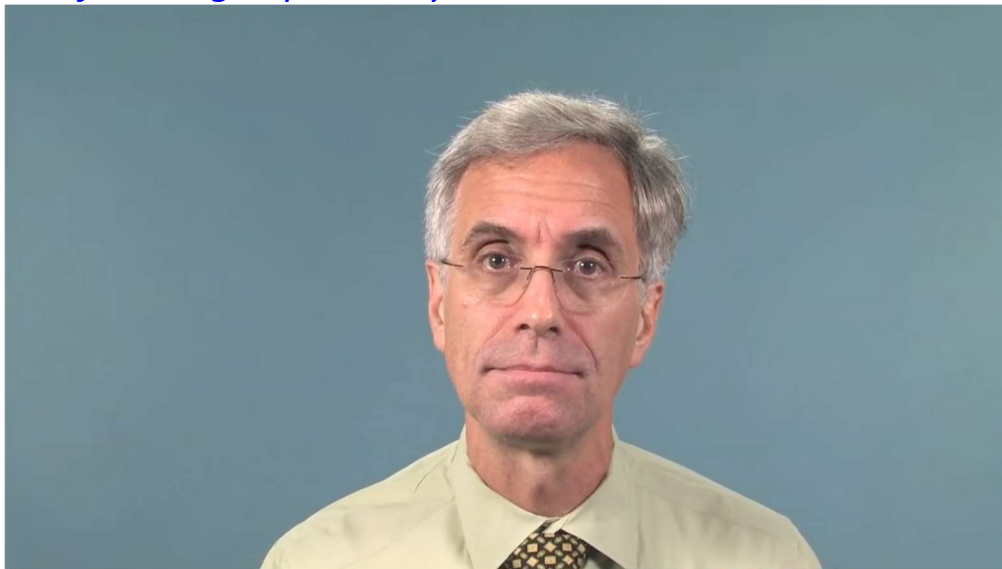


Video source: <https://www.youtube.com/watch?v=52H9p6tA0k4>

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Mechanical behavior of materials

Rate of loading dependency



Video source: <https://www.youtube.com/watch?v=Q1V0MeM744k>

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Mechanical behavior of materials

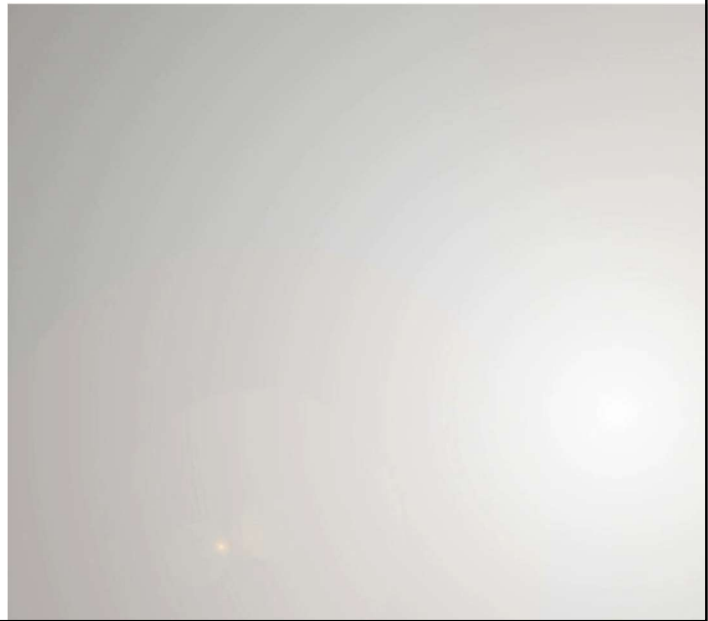
Temperature Dependency

From

room temperature (25 C)

to

High- Temperature (60 C)



https://www.youtube.com/watch?v=8W2_Qoc2Phk&list=PL2x3KfweyEamyo58tuUG6zDeGVP6R

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Mechanical behavior of materials

Temperature Dependency

From

room temperature (25 C)

to

Low Temperature (-30 C)

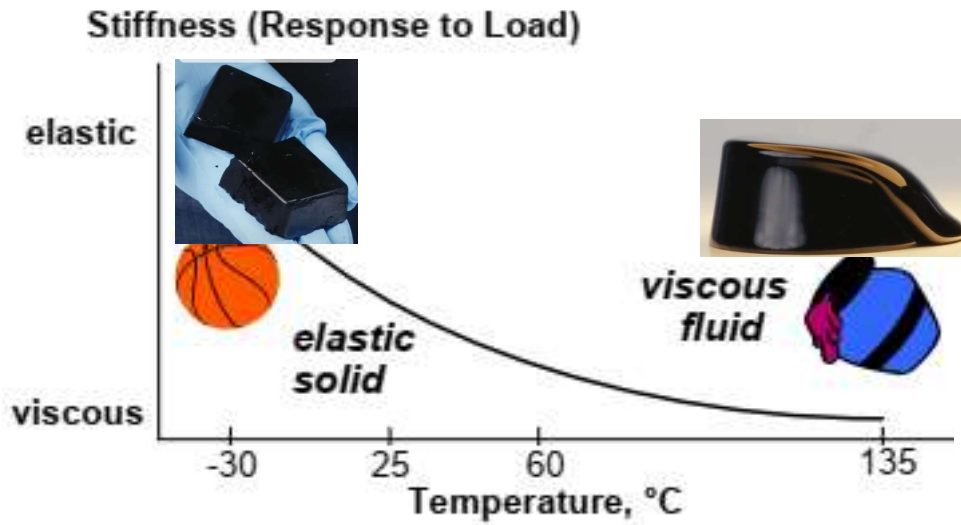


https://www.youtube.com/watch?v=8W2_Qoc2Phk&list=PL2x3KfweyEamyo58tuUG6zDeGVP6R

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Mechanical behavior of materials

Temperature Dependency

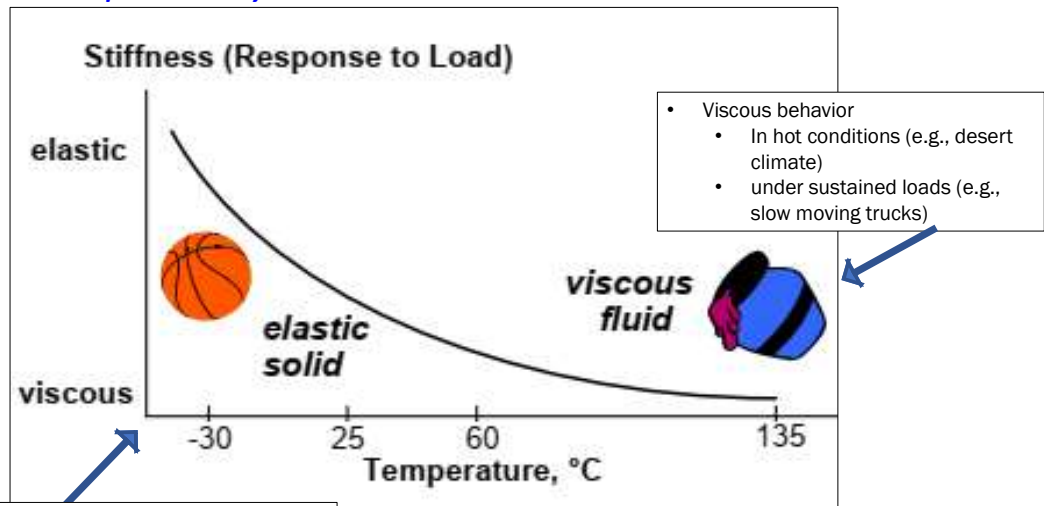


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Mechanical behavior of materials

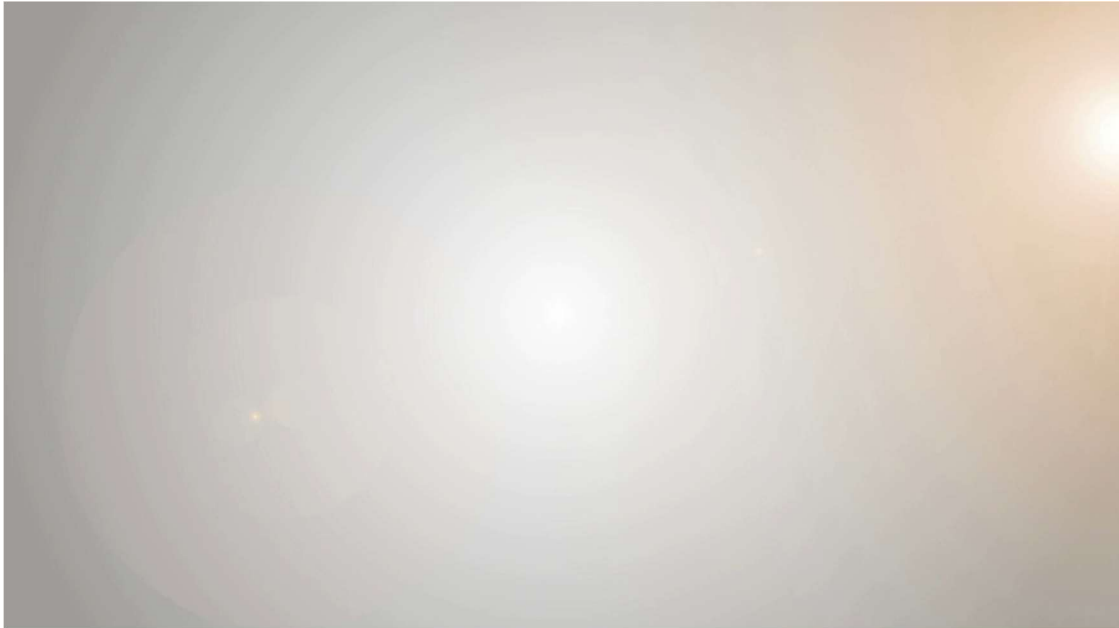
Temperature Dependency



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Standard bitumen verses Polymer Modified bitumen



https://www.youtube.com/watch?v=8tW2_QocZPc&list=PL2xs3Kfme-xEomyO5btUGSzDzGIVPbBr

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WHAT DO YOU
THINK ?



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What do You think ?



Image source : <https://in.pinterest.com/pin/433541901607583832/>



Image source : <https://www.whichcar.com.au/car-style/12-cartoon-cars>

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What do You think ?



Image source : <https://giphy.com/explore/towing>

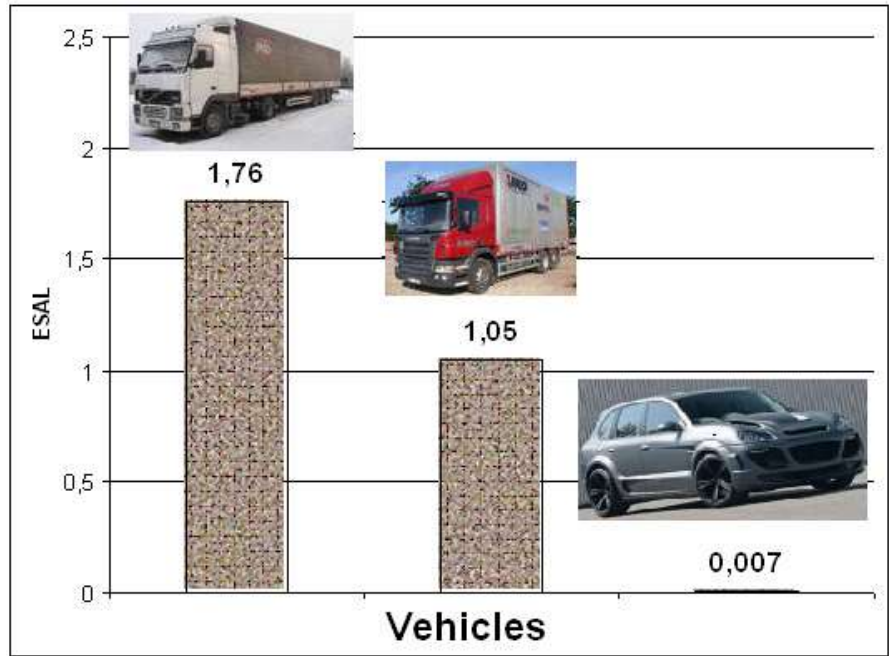


Image source <https://www.behance.net/gallery/67086875/Iconic-Cars-Animated-GIF>

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Some Typical Load Equivalency Factors for Vehicles on the Heavily Loaded Latvian Roads



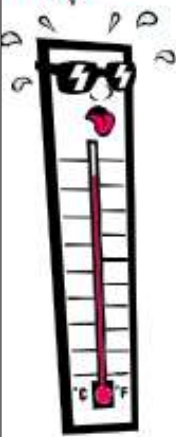
Hartono, Viktors & Srimovs, Juris & Naudums, Juris. (2010). Prediction of Rutting Formation in Asphalt Concrete Pavement. Baltic Journal of Road and Bridge Engineering. BALT J ROAD BRIDGE ENG. 5, 38-42. 10.3846/rjrb.2010.05.

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What do You think ?

High Temp



Traffic Load and Speed



Low Temp



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What do You think ?



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What do You think ?



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What do You think ?



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Pavement Materials & Design

Asphalt Materials

1.9 Asphalt Main Distress

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Distresses for pavements with asphalt concrete surfaces

A. Cracking / 3

1. Fatigue Cracking
2. Block Cracking
3. Edge Cracking
4. Longitudinal Cracking
5. Reflection Cracking at Joints
6. Transverse Cracking

B. Patching and Potholes / 15

7. Patch Deterioration
8. Potholes

C. Surface Deformation / 21

9. Rutting
10. Shoving

D. Surface Defects / 25

11. Bleeding
12. Polished Aggregate
13. Raveling

E. Miscellaneous Distresses / 29

14. Lane-to-Shoulder Dropoff
15. Water Bleeding and Pumping

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High temperature behavior

Rutting

☐ Asphalts cements behave like **viscous liquids and flow**.

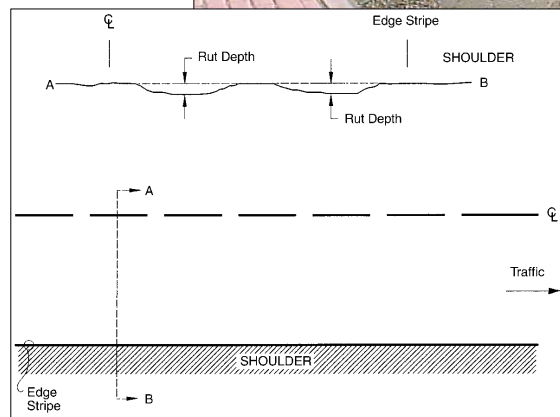
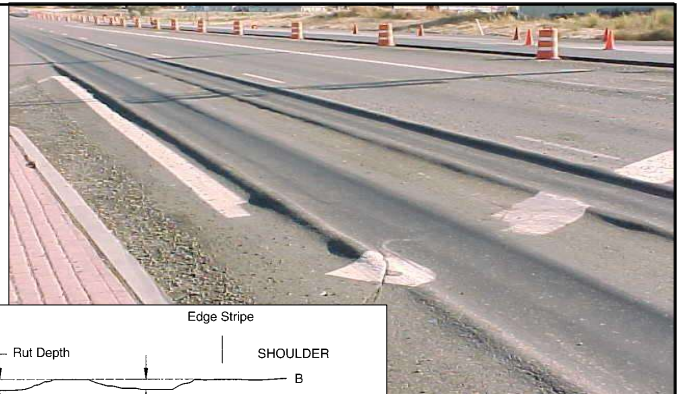
☐ *In hot conditions*

- ❖ Desert climate

☐ *Under sustained loads*

- ❖ Slow moving trucks

High severity rutting



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Rutting



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Rutting



Image source: <https://www.roadex.org/e-learning/lessons/permanent-deformation/permanent-deformation-rutting-classification/>

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Rutting

Qualitative representation of different types of rutting

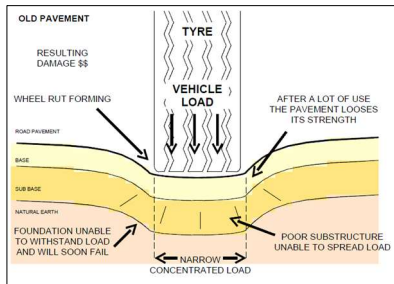
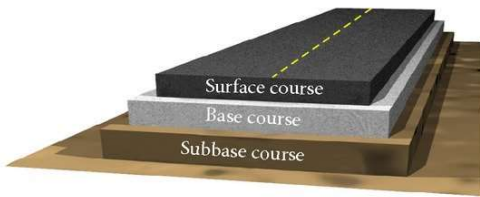


Image source: <http://www.road.com>
 Image source: Inzerillo, Laura & Mino, Gaetano & Bressi, Sara & Di Paola, Francesco & Noto, Silvia, (2016), Image Based Modeling Technique for Pavement Distress surveys: a Specific Application to Rutting, International Journal of Engineering and Technology, 16.



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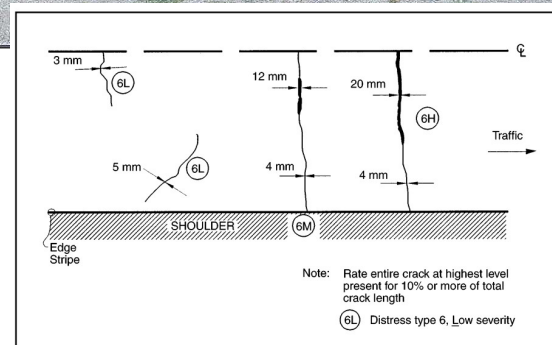
Low Temperature Behavior

Transverse cracking

- ❑ Asphalt cement behaves like an *elastic solid*
- ❑ In cold climates
 - ❖ Winter days
- ❑ Under rapid loading
 - ❖ Fast moving trucks



High severity transverse cracking



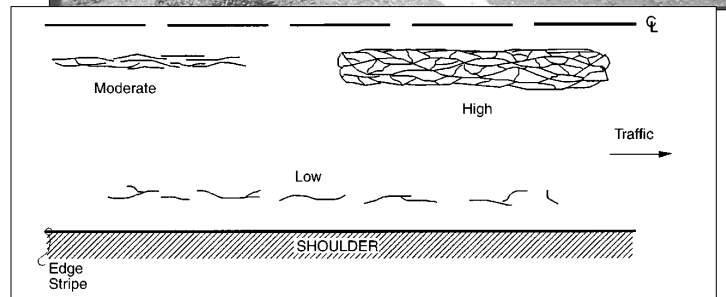
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Intermediate Temperature Behavior

Fatigue cracking

- ❑ Asphalt binders exhibit the characteristics of **both viscous liquids and elastic solids**
- ❑ *Most environmental conditions lie between the extreme hot and cold situations*

High severity
Alligator or fatigue
cracking



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Pavement Condition Survey

Google Maps

- ❑ https://www.google.com/maps/@31.970205,35.9091189,3a,75y,200.65h,66.25t/data=!3m6!1e1!3m4!1s_Ov7niijsbKh2xemnbuik9w!2e0!7i13312!8i6656
- ❑ <https://www.google.com/maps/@31.8365139,35.8932518,3a,90y,177.67h,65.37t/data=!3m6!1e1!3m4!1sHo9CHMuX6lURdiBoNAd17w!2e0!7i13312!8i6656>
- ❑ https://www.google.com/maps/@31.6479985,35.9805666,3a,75y,173.66h,84.12t/data=!3m6!1e1!3m4!1scD oLPUZkCxQ9PC_JJkZ9iw!2e0!7i13312!8i6656
- ❑ https://www.google.com/maps/@30.104076,35.4341196,3a,31.5y,162.96h,79.5t/data=!3m6!1e1!3m4!1sTKMH34_I4mhQ5PXd3GscQw!2e0!7i13312!8i6656

Image Source: <https://prezi.com/p/5zjdekpzrzlp/windshield-survey-barrio-logan/>

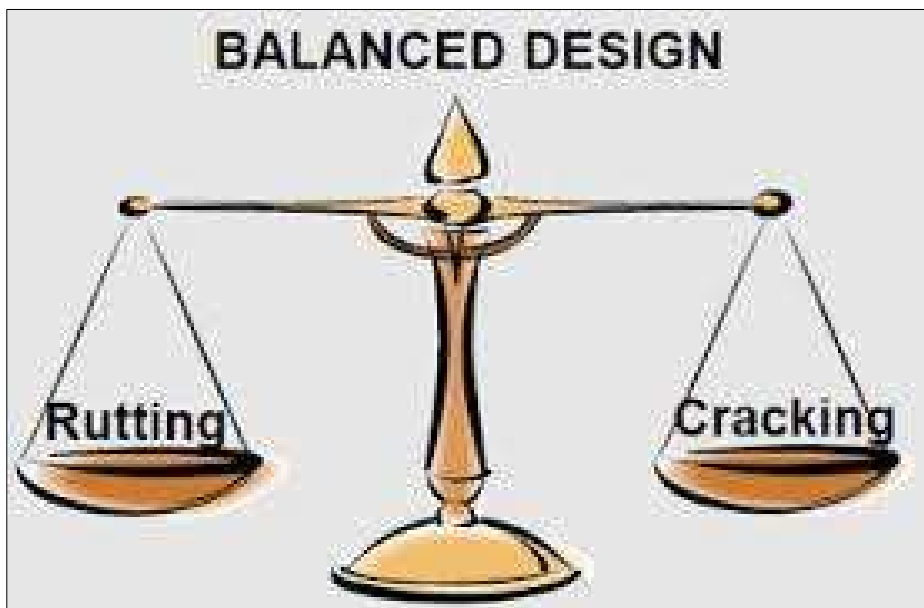
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Be Careful

Parameter	Rutting resistance	Workability	Moisture resistance ²	Thermal cracking resistance	Stiffness	Load-related cracking resistance	
	(Section 2)	(Section 3)	(Section 4)	(Section 5)	(Section 6)	(Section 7)	
Binder (Subsection 1)	Higher binder content	↓ ¹	↗	↔	↗↘ ⁴	↑	
	Harder binder	↑	↓	↗	↑	↘↑ ^{5,6}	
	SBS modified binder	↑	↓	↗	↗	↑	
	Binder aging	↑	↓	↘	↓	↑	
Aggregates (Subsection 2)	Higher filler content	↘	↓	↘	↗	↘	
	Higher coarse aggregate angularity	↑	↓	↔	↑	↑	
	Higher fine aggregate angularity	↑	↓	↔ ^x	↑	↔	
	Higher surface texture	↑	↓	↗	↑	↑	
	Stronger aggregates	↗	↘	↗	↗ ^x	↔ ^x	↗
	More cubical shape	↗	↑	↗ ^x	↔ ^x	↑	↗
	Coarser gradation	↘	↘	↘	↔	↘	↘
	Larger nominal maximum aggregate size (NMAS)	↑	↓	↘	↔	↑	↓
voids/advanced technologies (Subsection 3)	Higher air voids	↓	↑ ^x	↓	↘	↓	
	Higher RAP content (no treatment)	↑	↓	↔	↘	↗	
	Poor blending between RAP and virgin binder (and rejuvenator)	↓	↗ ^x	↘	↗ ^x	↗	↗
	WMA technology at HMA temperature	↔	↑	↘	↔ ³	↔ ^x	↔ ³
	WMA technology (with temperature reduction)	↘	↔	↘	↘ ³	↓	↔ ³

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Pavement Materials & Design

Asphalt Materials

Properties of Asphalt cement

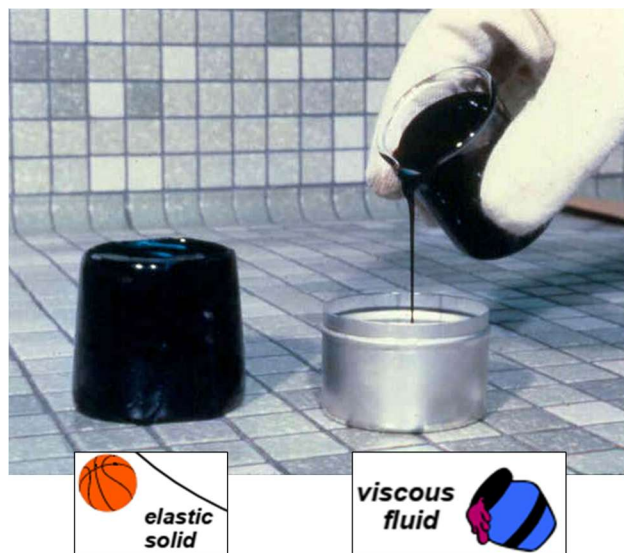
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Consistency

Definition

- ❑ Consistency is
 - the degree of *fluidity or plasticity* of binder at any particular temperature
- ❑ The consistency of binders varies with temperature
- ❑ Binders are graded based on ranges of consistency at a standard temperature



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Effect of binder additives

Standard bitumen versus Polymer Modified bitumen



https://www.youtube.com/watch?v=8tW2_QocZPc&list=PL2xs3Kfme-xEomyO5btUGSzDzGIVPbBr

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Properties of Asphalt cement

Temperature Susceptibility

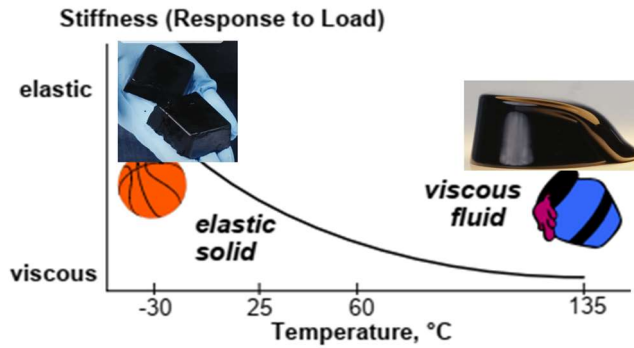
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Temperature Susceptibility

Definitions

- ❑ Binders are thermoplastic
 - Temperature *decreases*.....becomes *harder* (*more viscous*)
 - Temperature *increases*.....becomes *softer* (*less viscous*)



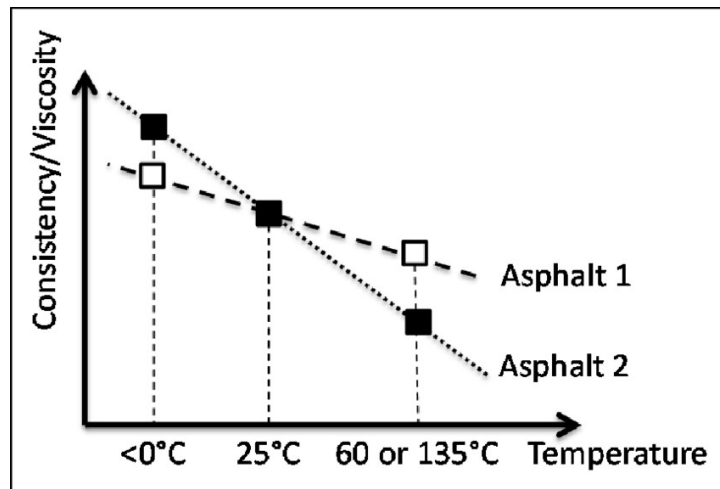
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Temperature susceptibility

Definitions

- ❑ Temperature susceptibility reflects
 - *how rapidly the properties of asphalt binders change with temperature*
 - *It represented in terms of indices such as*
 - ❖ Penetration index
 - ❖ Viscosity-temperature susceptibility



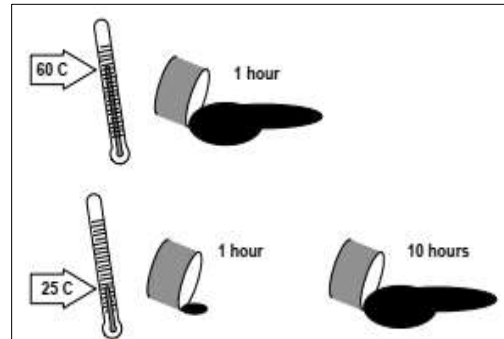
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Mechanical behavior of materials

Time-Temperature shift (or superposition)

- ❑ The flow behavior of an asphalt could be the same for
 - One hour at 60 °C
 - 10 hours at 25 °C
- ❑ The behavior at high temperatures over short time periods is **equivalent** to what occurs at lower temperatures and longer times.
 - This is often referred to as the *time-temperature shift* or *superposition* concept of asphalt cement



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Properties of Asphalt cement

Adhesion and Cohesion

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Adhesion and Cohesion

Adhesion is defined as

- The attraction process between **unlike** molecules that are brought into contact in such way that the adhesive binds to the applied surface or substrate.



Cohesion is defined as

- The attraction process between **similar** molecules
- Mainly as the result of chemical bonds that are formed between the individual components of the substance.

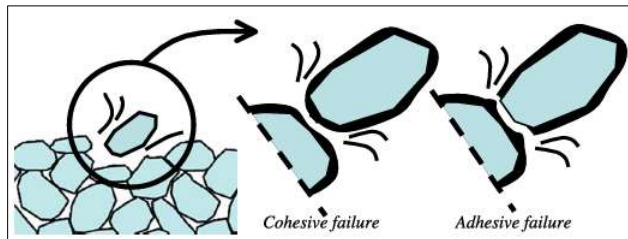


Adhesion and Cohesion

Thus, in bituminous mixtures

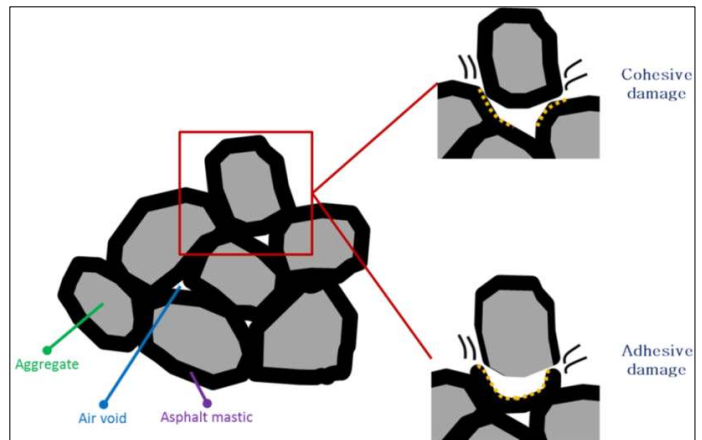
Adhesion

- is the binder's ability to **stick** to the aggregate in the paving mixture



Cohesion

- is the binder's ability to **hold** the aggregate particles in place in the finished pavement



<https://repository.bdeftt.nl/bitstream/handle/object/100233/3/19c25d0e-2a10-4430-b9aa-d95a313cafd>

<https://www.nottingham.ac.uk/research/groups/ceec/documents/projects/19c25d0e-2a10-4430-b9aa-d95a313cafd.pdf>

Deteriorated pavements due to water induced damage

- ❑ (a) ravelling caused by segregation
- ❑ (b) and (c) pothole formation



<https://repository.tudelft.nl/islandora/object/uuid%3A8b25d0e-2d0-4430-b9aa-d954315caaf4>

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Adhesion and Cohesion



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Adhesion and Cohesion

Anti-stripping modifier example

- ❑ Figure shows two aggregate samples from the same source after they have been coated with asphalt binder.
- ❑ The asphalt binder used with the sample on the left
 - contain no anti-stripping modifier,
 - which resulted in almost no aggregate-asphalt binder adhesion.
- ❑ The asphalt binder used with the sample on the right
 - contains 0.5% (by weight of asphalt binder) of an anti-stripping modifier
 - which results in good aggregate-asphalt binder adhesion.



Anti-stripping modifier example.

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Properties of Asphalt cement

Durability

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Durability (Age hardening)

Definitions

- ❑ Asphalt, like any **organic matter** is affected by factors like
 - *Presence of oxygen*
 - *Ultraviolet rays*
 - *Changes in temperature.*
- ❑ These factors are **responsible** for **hardening** of bitumen.
 - *This hardening process, referred to as **asphalt aging***
- ❑ **Aging is generally** defined as
 - *change in the rheological properties of asphalt binders/mixtures due to changes in chemical composition during **construction** and its service life period.*
- ❑ Aging of asphalt binders occurs during
 - *The production of asphalt mixtures*
 - *while in service when exposed to the surrounding environment*

<https://civilblog.org/2015/04/17/6-factors-influencing-aging-of-bitumen-binders/>

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Durability (Age hardening)

Definitions

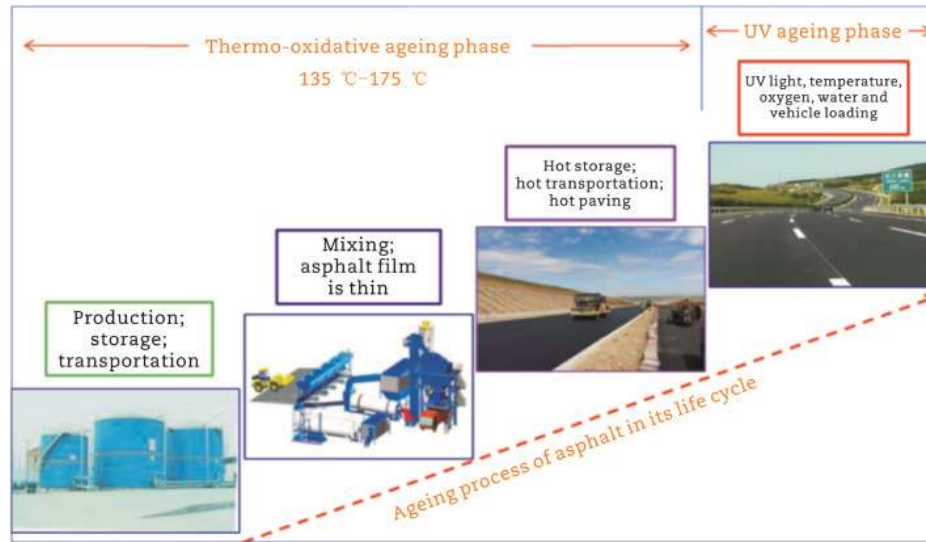
- ❑ **Hardening results in**
 - *Decrease in penetration value*
 - *Increase in softening point temperature*
 - *Increase in penetration index (PI).*
 - *Increase in viscosity increases*
 - *becomes stiffer and brittle.*
- ❑ There are two types of aging:
 - *Short-term aging*
 - *Long-term aging*

<https://civilblog.org/2015/04/17/6-factors-influencing-aging-of-bitumen-binders/>

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Durability (Age hardening)



<https://www.sciencedirect.com/science/article/pii/S2097049822000178>

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Durability (Age hardening)

Short-term aging

- Happens during asphalt mix production and construction
- Happens at fast rate

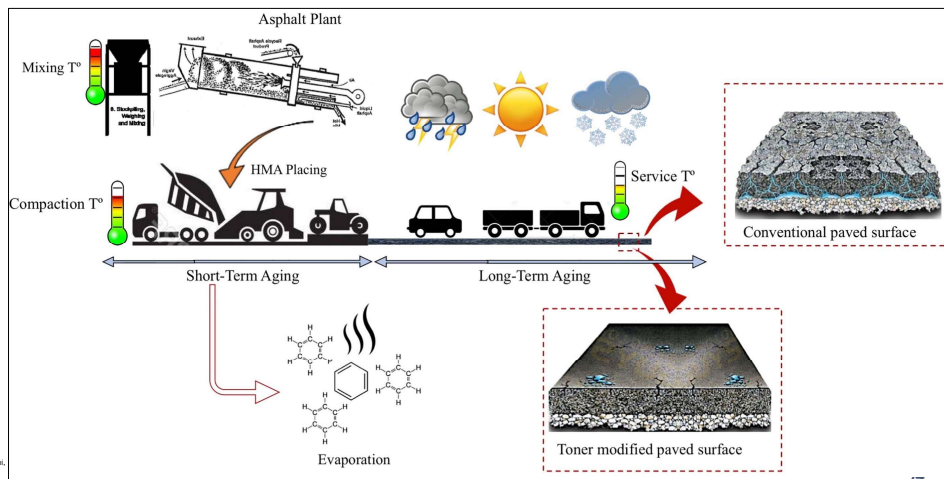


Image source: Performance Evaluation of Using Waste Toner in Bituminous Material by Focusing on Aging and Moisture Susceptibility. Mohammed Ali Nazari, Purnia Inqalabani, Ph.D.; Fereshtoon Moghadas Nejad, Ph.D.; and Ali Khodaili, Ph.D.

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Age hardening

Long term- aging

- ❑ Happens during the life of the pavement, due to exposure to air and water
- ❑ Happens at a relatively slow rate in a pavement

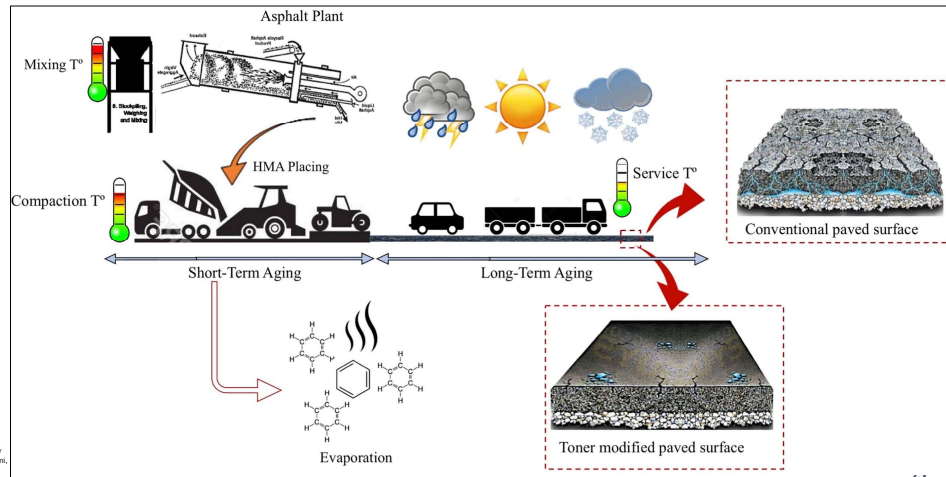


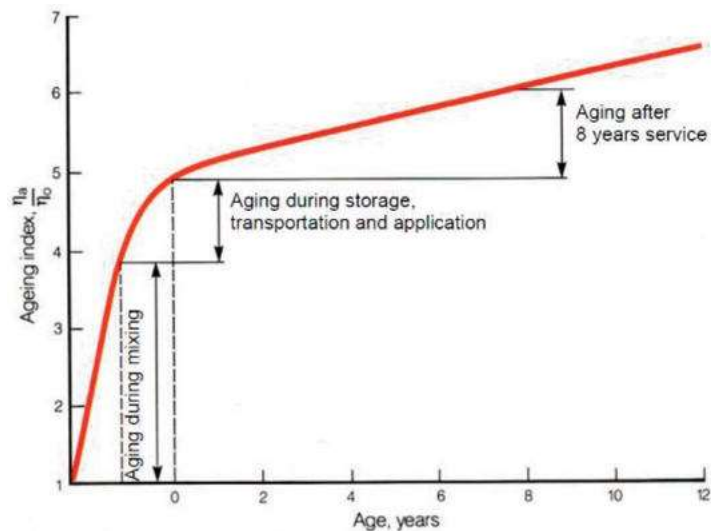
Image source: Performance Evaluation of Using Waste Toner in Bituminous Material by Focusing on Aging and Moisture Susceptibility. Mohammad Ali Notani; Pournia Hajikarimi, Ph.D.; Ferestoon Moghaderi Nejad, Ph.D.; and Ali Khodoli, Ph.D.

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Durability (Age hardening)

Long-term aging

- ❑ Consequently, great attention should be given to the recommended temperatures during mixing and compaction stages Why?



<https://www.intechopen.com/chapters/60251>

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Mechanical behavior of materials

Aging effect

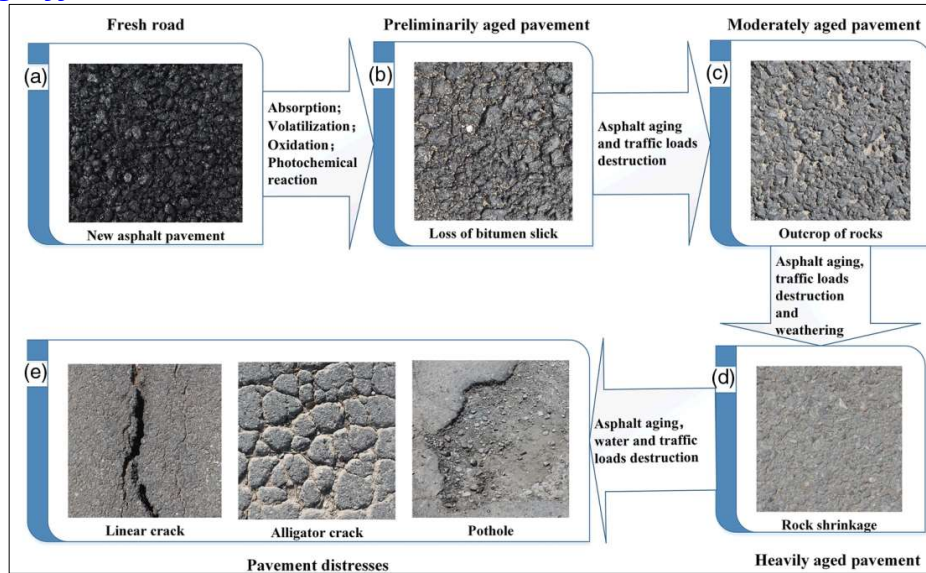


Image source: Yifan Pan, Xianfeng Zhang, Jie Tian, Xu Jin, Lun Luo, Ke Yang, "Mapping asphalt pavement aging and condition using multiple endmember spectral mixture analysis in Beijing, China." J. Appl. Rem. Sens. 11(1) 016003 (6 January 2017). <https://doi.org/10.1117/1.JRS.11.016003>

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Mechanical behavior of

Aging effect

- The spectra and corresponding digital photos and color values of the asphalt pavement in
 - Preliminarily aging stage
 - ❖ P1, P2, and P3
 - Moderately aging stage
 - M1, M2, and M3
 - Heavily aging stage
 - ❖ H1, H2, and H3

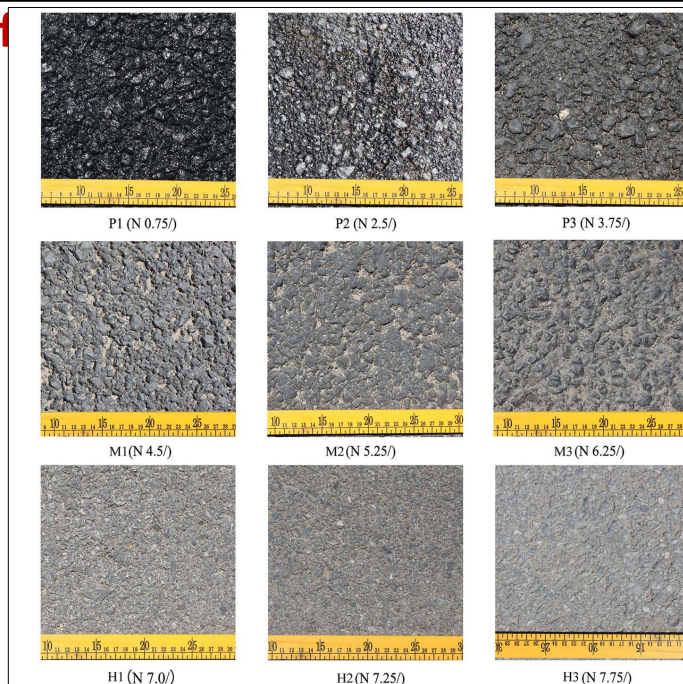


Image source: Yifan Pan, Xianfeng Zhang, Jie Tian, Xu Jin, Lun Luo, Ke Yang, "Mapping asphalt pavement aging and condition using multiple endmember spectral mixture analysis in Beijing, China." J. Appl. Rem. Sens. 11(1) 016003 (6 January 2017). <https://doi.org/10.1117/1.JRS.11.016003>

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