The Role of Pavement in Reducing Greenhouse Gas Emissions

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Briefing for California State Government Agencies
from the
National Center for Sustainable Transportation
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National Center for Sustainable Transportation

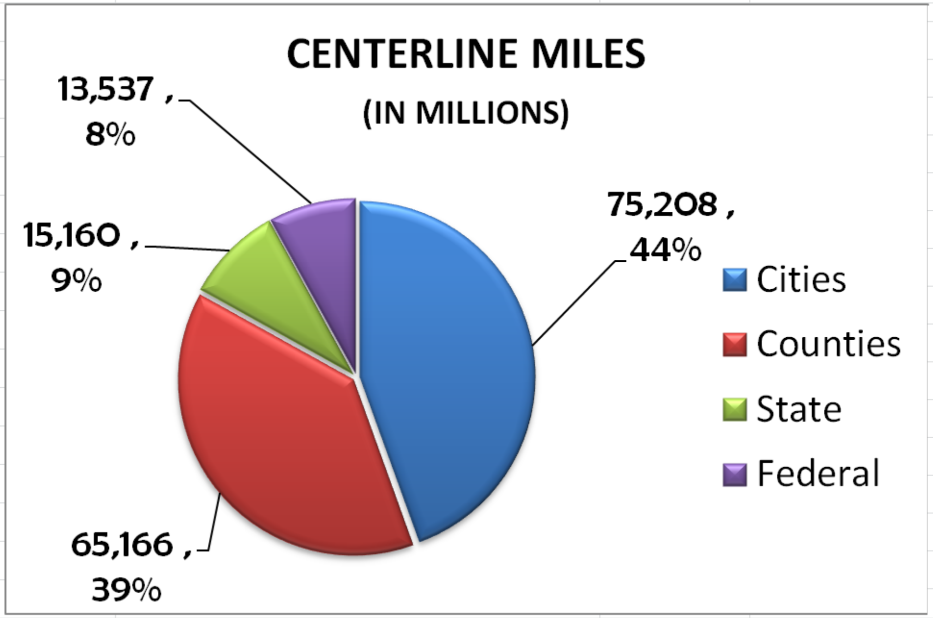
Why care about pavements?

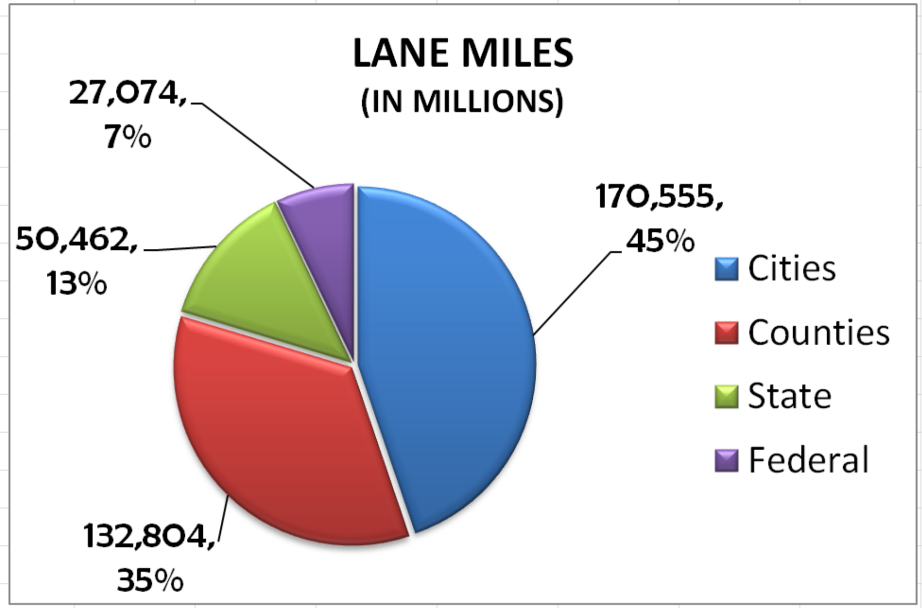
- We depend on pavement for most of our modern human activities
  - Societal benefits
  - Movement of freight and commodities
    - Economic competitiveness
  - Regardless of propulsion method (petroleum, electric, etc)
  - Active transportation
  - Rail

Why care about pavements?

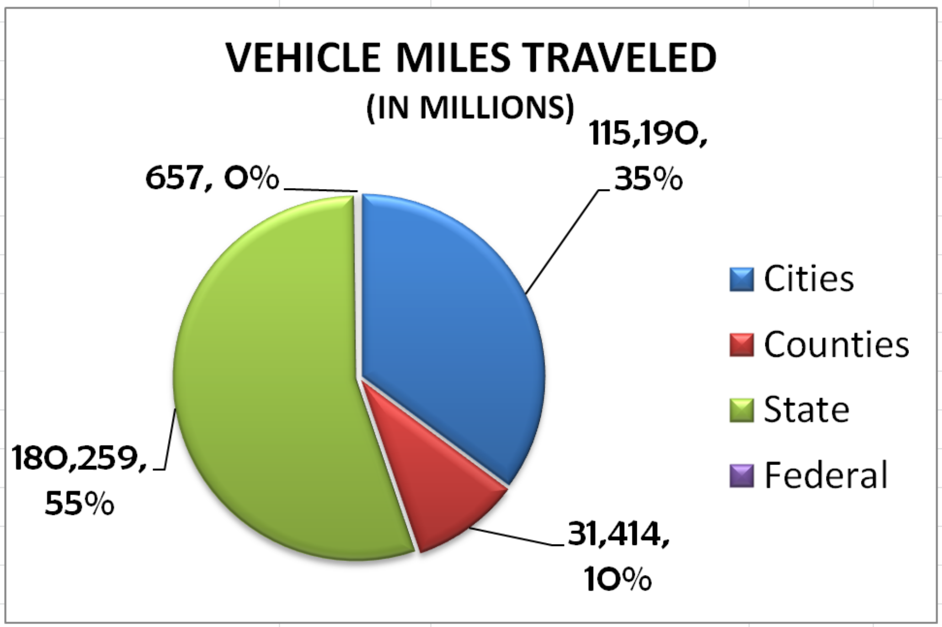
- They cost a lot of money
  - Based on 2008 data, the total expenditures for highways in the U.S. was $182.1 billion (FHWA Highway Statistics 2010)
  - Most expensive asset for most local governments
  - 95% of cost in California: maintenance, rehabilitation and reconstruction (M&R)
  - There is an optimal time and treatment for M&R for each segment of the network, which overall requires:
    - Funding to catch up on backlog
    - Steady funding to preserve network
    - Asset management (pavement management system) to predict what, when, where, how much

Who owns and operates California pavements?





http://www.dot.ca.gov/hq/tsip/hpms/hpmslibrary/hpmspdf/2010PRD.pdf

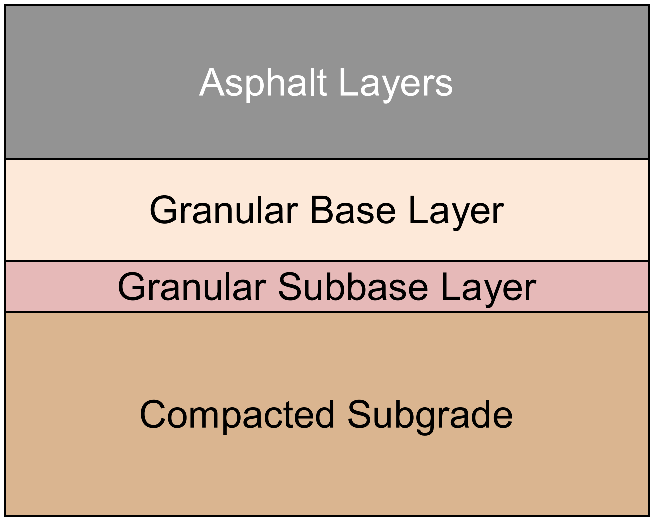


National $ Spent on Transportation in 2008 (US Census Bureau)

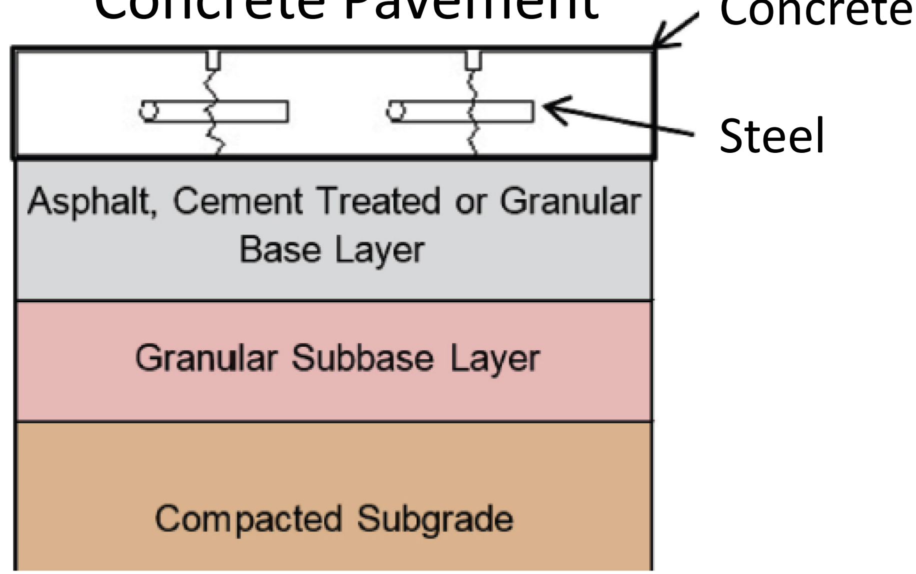
STATE GOVERNMENT	LOCAL GOVERNMENT
97,508,989	61,053,150

What are Pavements Made Of?

Asphalt Pavement



Concrete Pavement



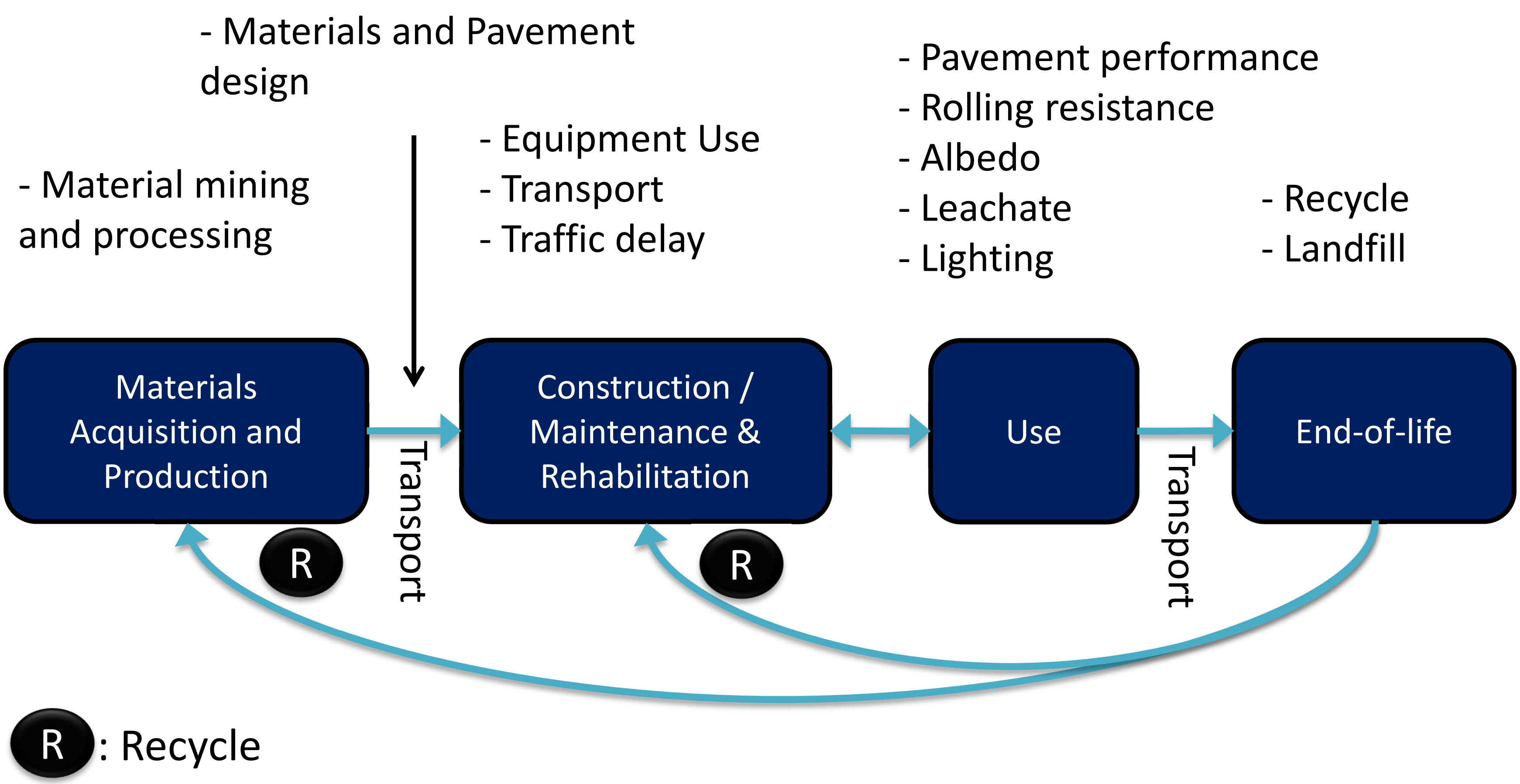
- Mostly sand, gravel, crushed stone
- Some asphalt and/or cement to hold rocks together
- Asphalt and cement are 5 to 30 percent by volume of top layers, but have most of cost and environmental impact

What Does M&R Involve?

- Treatments for functional problems and seal surface
  - Seals and thin overlays on asphalt pavements
  - Make the surface smoother and/or restore skid resistance
    - Overlays and seal coats on asphalt
    - Grinding and slab replacements on concrete
- Treatments for structural problems (cracks, broken pavement)
  - Overlays
  - In-place recycling of asphalt
  - Total or partial reconstruction where underlying pavement is badly damaged

Where can environmental impacts be reduced?

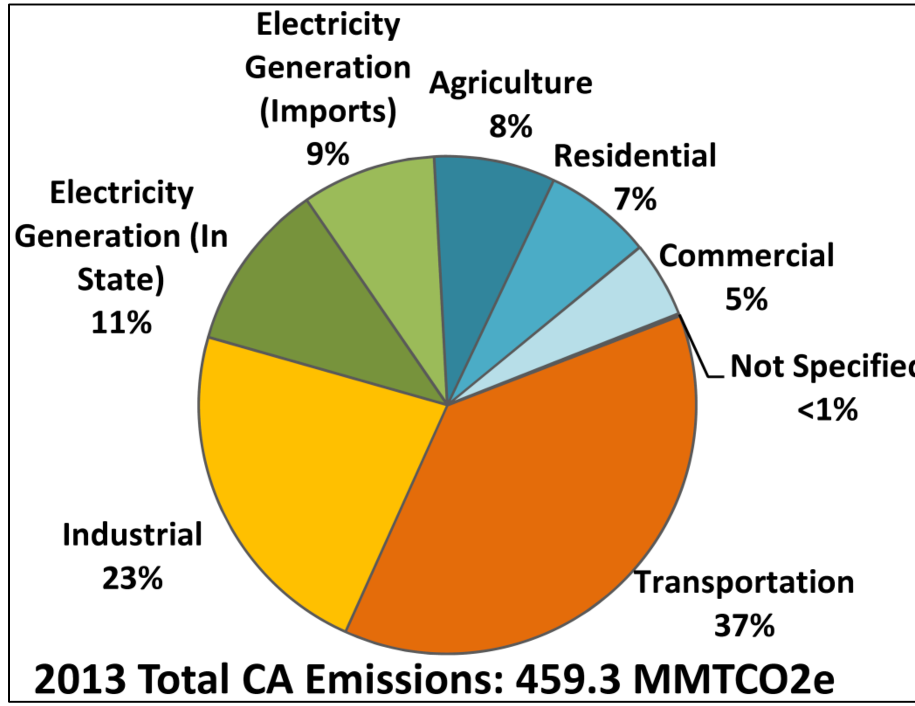
- Use Life Cycle Assessment (LCA) to find out
- Use Life Cycle Cost Analysis (LCCA) to prioritize based on improvement per $ spent



From: Kendall et al., *2010*

How do Pavements Contribute to GHG Emissions?

- Out of 459 MMT CO2e
  - On road vehicles 155 MMT
    - Pavement roughness and other effects can change vehicle fuel use by about 0 to 4 %
  - Refineries 29 MMT
    - Paving asphalt about 1 % of refinery production
  - Cement plants 7 MMT
    - Paving cement about 5 % of cement plant production
  - Commercial gas use 13 MMT
    - Very small amounts for asphalt mixing plants
  - Mining 0.2 MMT
    - Large portion for aggregate mining



http://www.arb.ca.gov/cc/inventory/data/data.htm

What is most important?

- For highest traffic segments:
  - On road vehicles and pavement/vehicle interaction most important
- On lower traffic segments:
  - Materials (mostly) and construction most important

Strategies to Improve Sustainability of Asphalt Pavement Materials & Construction

- <u>Improve durability with construction compaction specifications</u>
  - 1% change in air-voids = about 10% change in cracking life
  - Warm mix
  - Strict compaction requirements
  - Caltrans has reduced typical air-voids from about 11% to 7% since mid-90s
- Use reclaimed asphalt pavement (RAP), and tire rubber
  - Caltrans more than 30% of asphalt has recycled rubber
  - Caltrans allows up to 25% binder replacement with recycled asphalt
- Reduce asphalt needed over the life cycle
  - Improved pavement design methods
  - Better construction quality, more durable materials
- Alternative binders to asphalt?
  - Mostly bio-based, and used as asphalt extenders in blends with RAP
  - Environmental, economic, and societal impacts must be determined

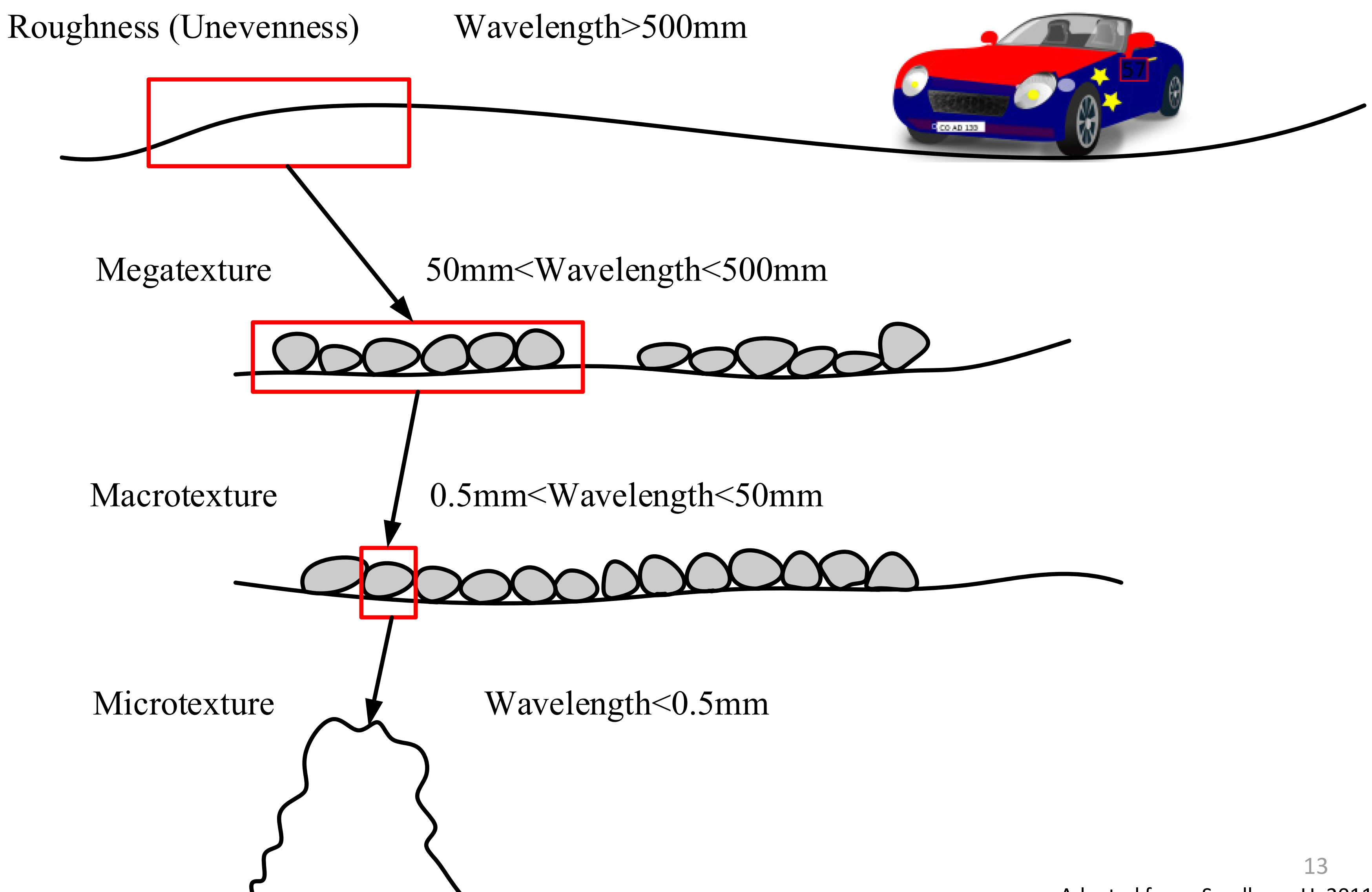
Strategies to Improve Sustainability of Concrete Pavement Materials & Construction

- Reduce cement and cementitious content in concrete
  - Context sensitive
  - Current Caltrans specifications
    - 70% portland cement
    - 25% allow various options for cement replacement
    - 5% inter-ground limestone
- Reduce concrete and maintenance needed over the life cycle
  - Improved pavement design methods
  - Better construction quality
  - More durable materials
- Reduce energy and GHGs during cement and concrete production
- Increase use of recycled and marginal materials as aggregate

Local Government Practices for Asphalt and Concrete Materials & Construction

- Many local agencies are lacking:
  - Asphalt compaction specifications
  - Use of
    - Rubberized asphalt
    - Recycled asphalt pavement in new hot mix
    - Warm mix additives
  - Use of lower cement contents in concrete
  - Use of cement blended with fly ash, slag and/or limestone to reduce GHG content
  - Thinner concrete pavement designs
- Lack of sufficient information and confidence to allay risk aversion

Use Stage: Pavement surface characteristics

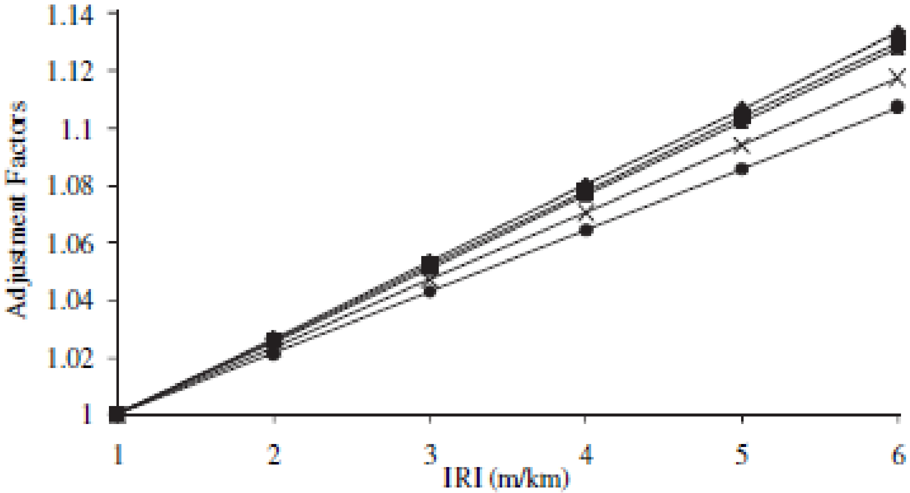


Adapted from: Sandberg, U. 2011.

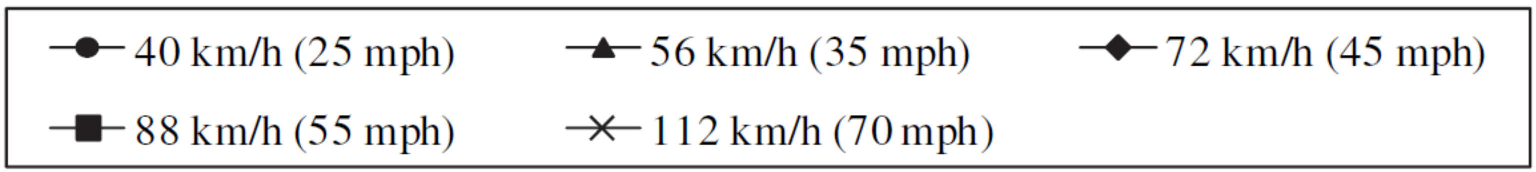
Pavement Rolling Resistance

- Roughness
  - Measured with International Roughness Index (IRI)
  - Dissipates energy through suspension and tire distortion
- Macrotexture
  - Measured with Mean Texture Depth or Profile Depth (MPD)
  - Dissipates energy through tire tread distortion
- Deflection
  - Dissipates energy through pavement structure distortion
  - Current UCPRC/MIT/Mich St U/Oregon St U study to be finished in 2017

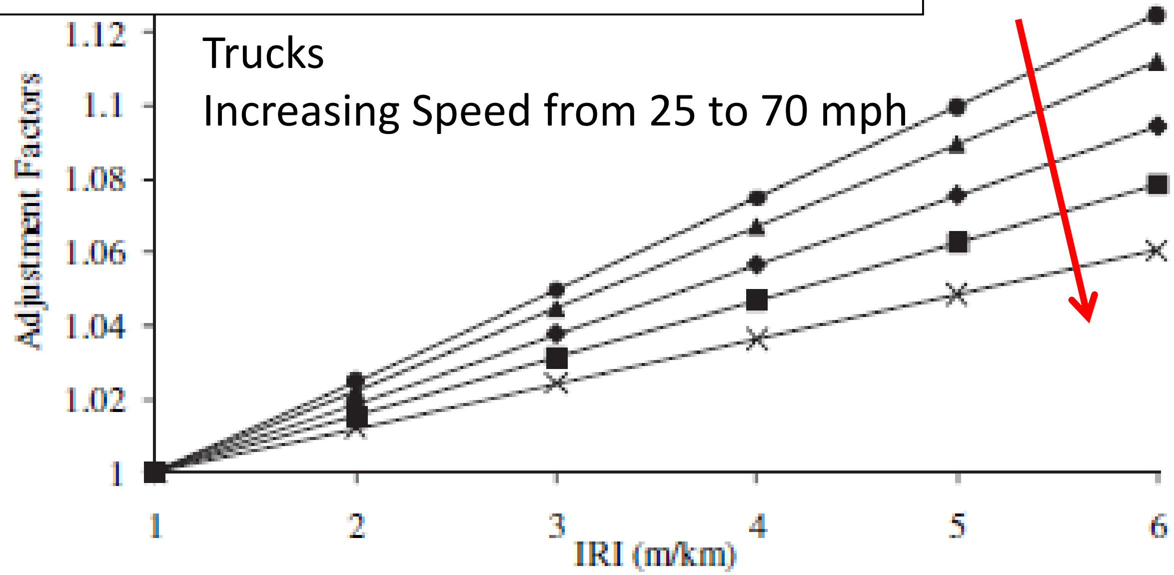
Use Stage: Interaction of fuel use, speed and IRI (NCHRP 720)



(a) Passenger car



- Cars more sensitive at faster speeds
- Trucks at slower speeds
- Some offset from faster driving on smoother pavement



(e) Articulated truck

Tradeoffs of Keeping Pavements Smooth

- Keeping pavements smooth requires maintenance
  - More than current
  - Increased environmental impact from maintenance
    - Still less than rehabilitation and reconstruction
- Big fuel savings only on highest traffic routes
  - Doesn’t mean let low volume roads go bad
  - Use LCA and LCCA to determine tradeoff of $/GHG improvement and cutoff where no benefit
- M&R doesn’t give full benefit if don’t get smoothness from construction
  - Smoothness specifications so not “born rough”

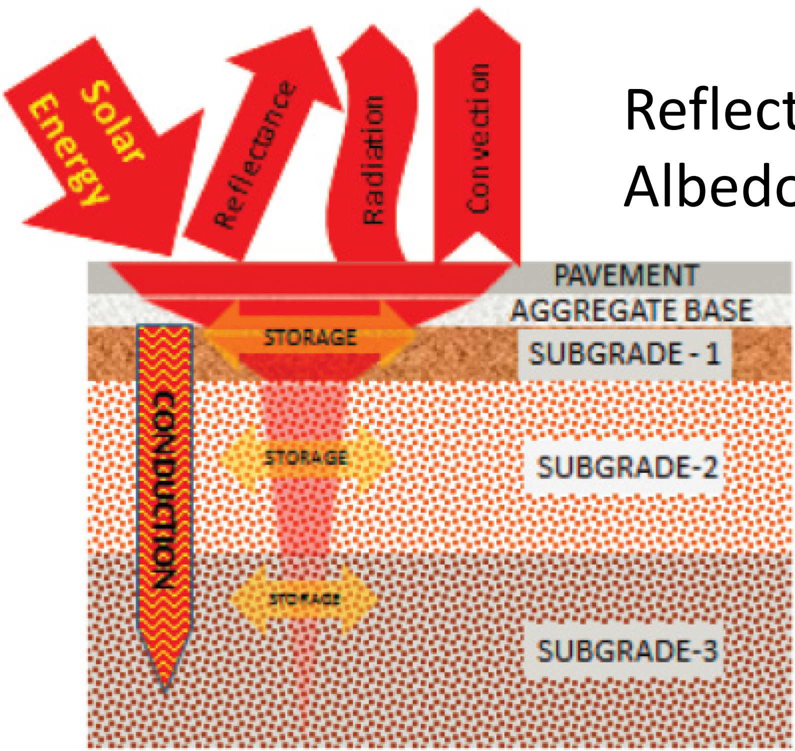
Preliminary optimal roughness trigger by traffic level on Caltrans network

Traffic group	Daily PCE of lane-segments range	Total lane-miles	Percentile of lane-mile	Optimal IRI triggering value (m/km, inch/mile in parentheses)	Annualized CO_2-e reductions (MMT)*	Modified total cost-effectiveness ($/t$CO_2$-e)
1	<2,517	12,068	<25	-----	0	N/A
2	2,517 to 11,704	12,068	25~50	2.8 (177)	0.14	1,169
3	11,704 to 19,108	4,827	50~60	2.0 (127)	0.10	857
4	19,108 to 33,908	4,827	60~70	2.0 (127)	0.13	503
5	33,908 to 64,656	4,827	70~80	1.6 (101)	0.26	516
6	64,656 to 95,184	4,827	80~90	1.6 (101)	0.30	259
7	>95,184	4,827	90~100	1.6 (101)	0.45	104
Total					**1.38**	**416**

Urban Heat Island: Thermal Model

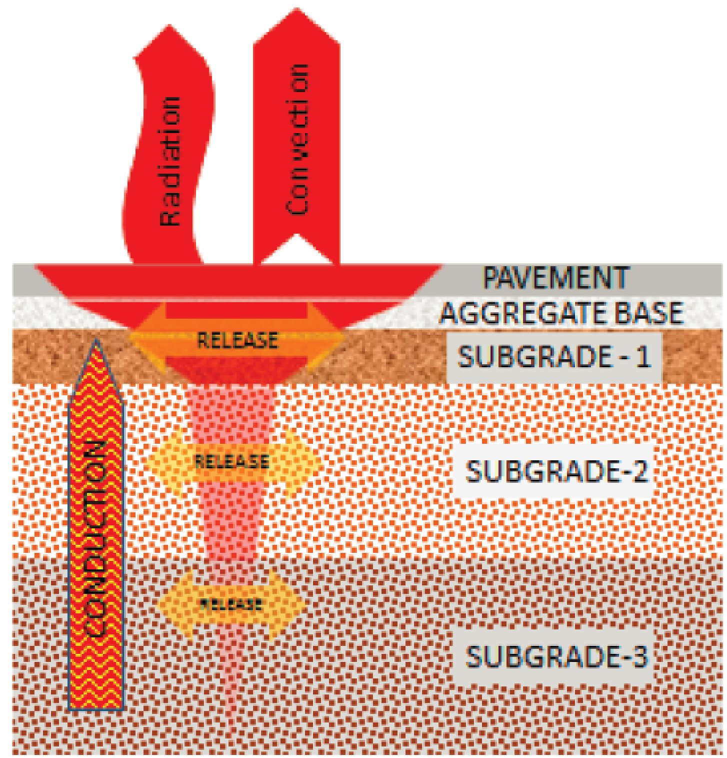
- Pavement is 25 to 40% of urban surfaces
- Tradeoffs: change to high reflection materials and construction vs. building heating/cooling

Basic Thermal Model - Day



Reflectance:
Albedo 0 to 1

Basic Thermal Model - Night



From NCPTC/NCAT 2013

LBNL/USC/UCPRC Study Currently Recently Completed: Life Cycle Assessment and Co-benefits of Cool Pavements

- Sponsored by CARB, Caltrans in response to AB 296
- Modeled 50 year GHG emissions
  - Change of urban pavements to higher reflectivity materials
  - Change of urban temperatures due to pavement albedo across the year
  - Change in building energy use due to temperature change
- Preliminary conclusions (currently being critically reviewed)
  - Much larger increase of GHG from changing materials than reduction from building energy savings
- Report to be published in Fall 2016

Pavement sustainability recommendations

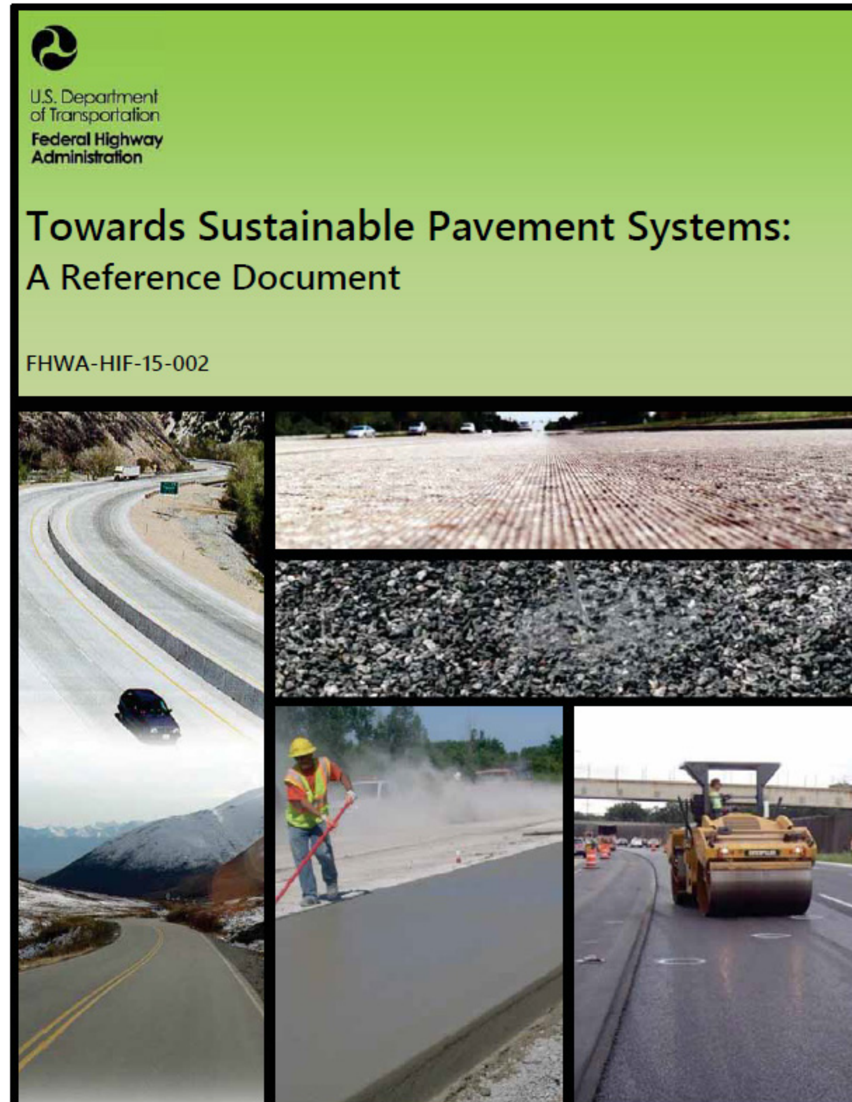
- Most effective strategies to reduce GHG from pavement depend on traffic levels
  - Low traffic: materials and construction
    - Improvement in design and construction
    - Recycled materials
    - Timely pavement preservation
    - Local government offers big opportunities for improvement
  - Highest traffic: pavement/vehicle interaction
    - Smoothness most important
  - Heat island: proceed cautiously until LCA results verified

Pavement sustainability recommendations

- Pavement management systems
  - Can be used to integrate cost (LCCA) and environmental benefit (LCA) calculations at network level
- Use LCA and LCCA to evaluate policies
  - Quantify benefits and identify unintended consequences before implementing legislation or regulations
- Need better environmental data
  - Consider mandating Environmental Product Declarations (EPD) for all pavement materials
  - FHWA/Caltrans/TRB workshops on EPDs in fall 2017

FHWA Towards Sustainable Pavements Reference Document

- State of the knowledge
- Search on "FHWA pavement sustainability"
- Organized around LCA
- Also at web site
  - Tech briefs
  - Literature database
- Coming soon: Pavement LCA Guidelines



Current and Future Work at UCPRC

- Caltrans projects:
  - LCA for pavements
  - Application of LCA to Caltrans materials, design, use stage questions
  - Recycled materials, thin concrete, rubberized asphalt, long life pavement
  - Smoothness research and measurement certification
  - Pavements for bicycling
  - Freight damage and freight route choice based on roughness
  - Support for pavement management system and life cycle cost analysis
- FHWA and FAA
  - LCA for pavement (both)
  - Pavement sustainability task group new 5 year contract (FHWA)
  - Recycled materials (FAA)
- NCST
  - White paper and policy brief on pavement LCA
  - Recycled asphalt pavement


Questions?
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