Balanced Mix Design and Other Hot Topics

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PA Asphalt Pavement Association

July 26, 2023

PAPA-PennDOT Bus Tour

District 9

Altoona, PA

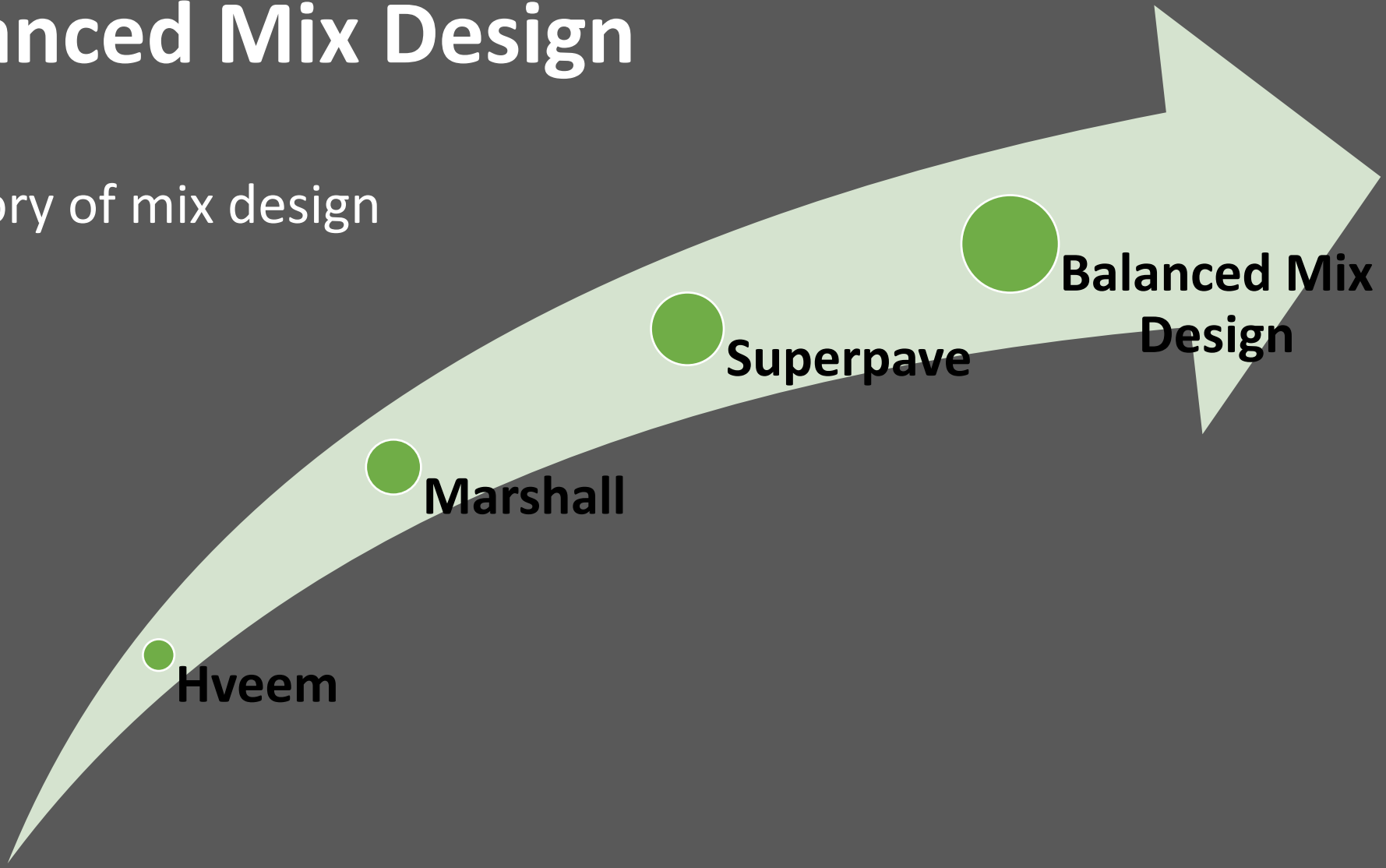
Balanced Mix Design

"asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress, taking into consideration mix aging, traffic, climate and location with then the pavement structure."

~ AASHTO PP 105-20 & FHWA ETG, Balanced Mix Design Task Force (2015)

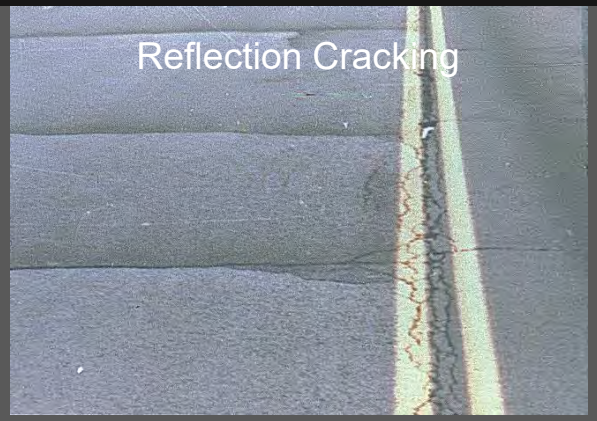
Balanced Mix Design

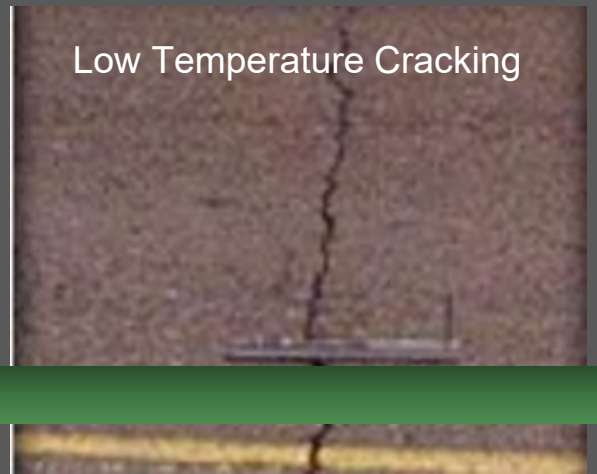
- History of mix design

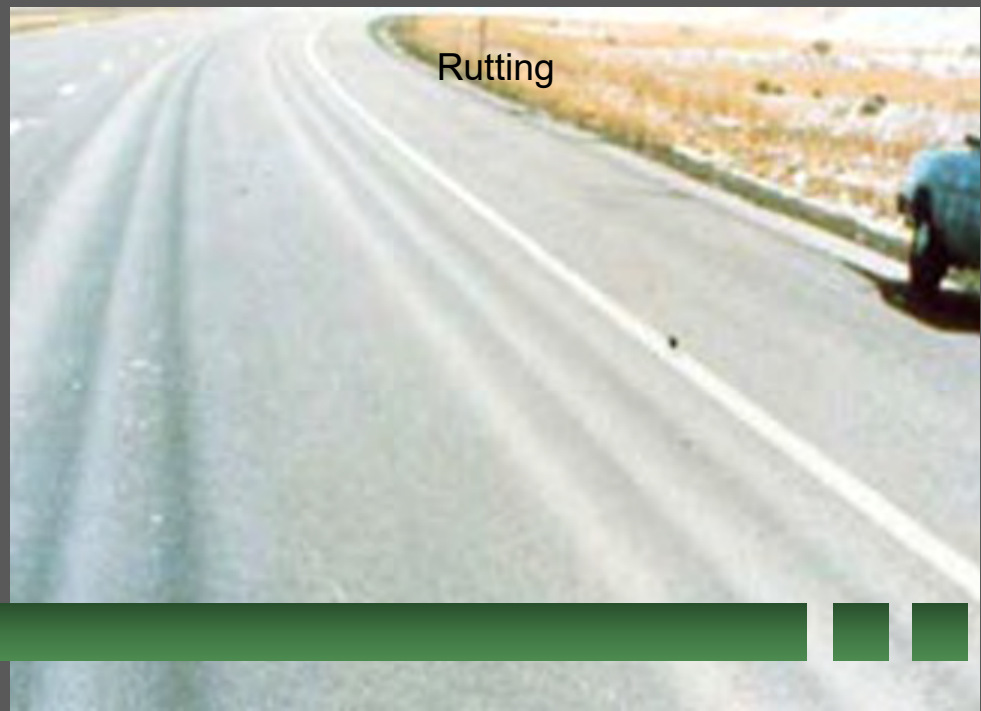


Balanced Mix Design

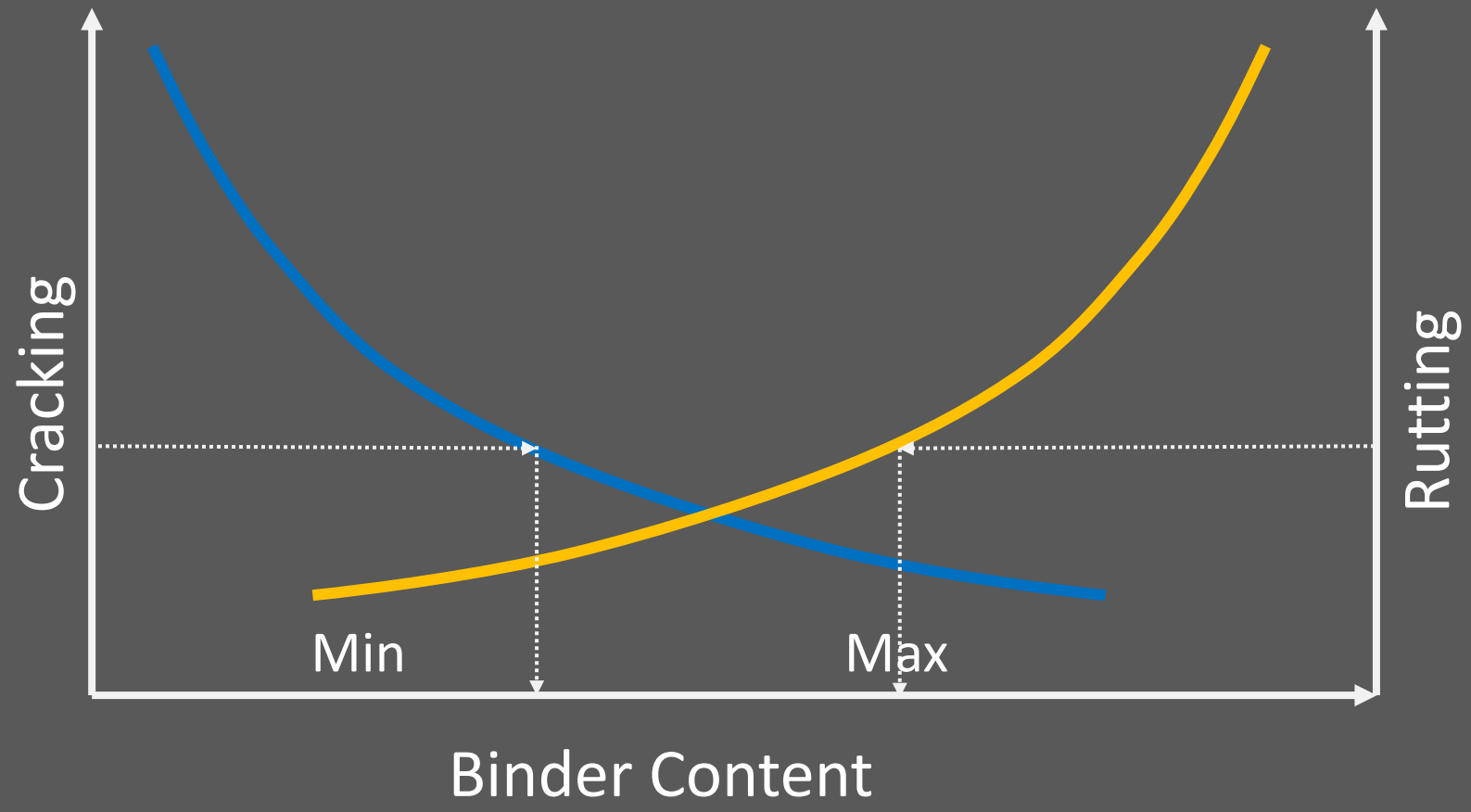
Asphalt Pavement Distresses







Balanced Mix Design

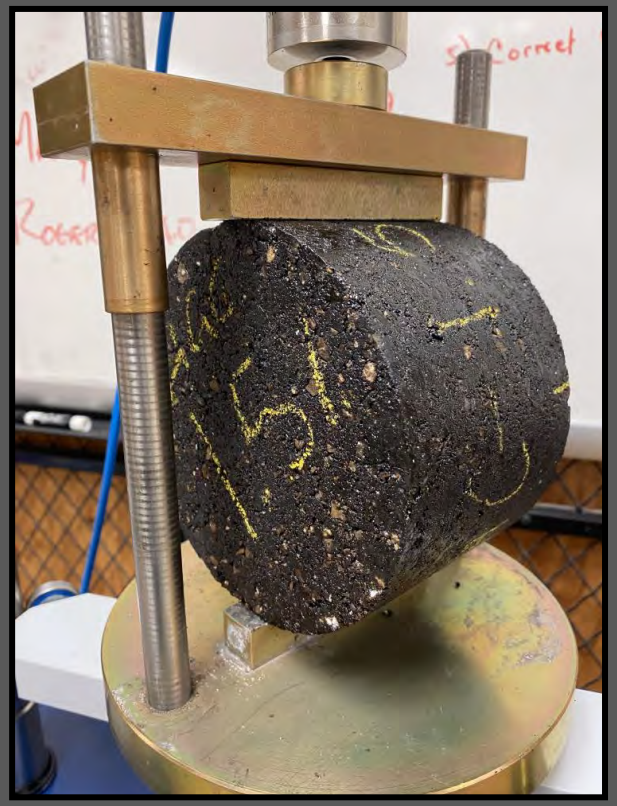


Balanced Mix Design

- 4 Approaches:
  A. Volumetric design + performance verification
  B. Volumetric design + performance optimization
  C. Performance-modified volumetric design
  D. Performance design

Balanced Mix Design

- Performance Tests:
  - Rutting
    - Hamburg Wheel Track Test (HWTT)
  - Cracking
    - IDEAL CT
  - Moisture Damage
    - Tensile Strength Ratio (TSR) and/or
    - HWTT Stripping Inflection Point (SIP)

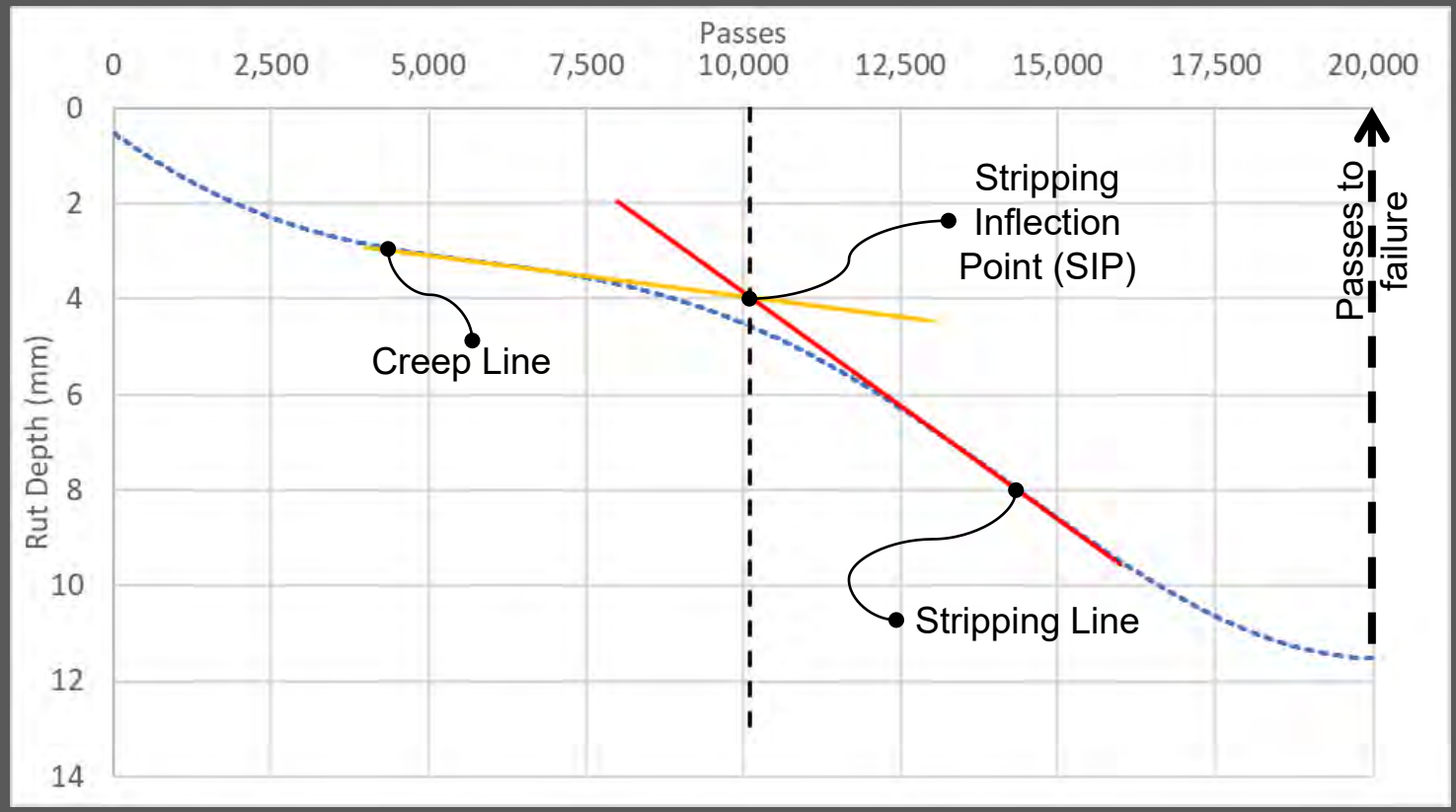


Balanced Mix Design

- Rutting: HWTT (AASHTO T 324)
  - Samples submerged
    - 50C water bath
  - 20,000 passes of steel wheel
  - Measures deformation vs. pass
    - Max deformation
    - No. of passes to 12.5 mm

Balanced Mix Design

- Rutting/Moisture Susceptibility: HWTT



Balanced Mix Design

- Cracking: IDEAL CT (ASTM D8225)
  - Test Temperature = 25C
  - Gyratory compacted specimens
    - 62 mm
    - 7% air voids
  - Measures Deformation vs. Load
    - Cracking Tolerance (CT) Index

Balanced Mix Design

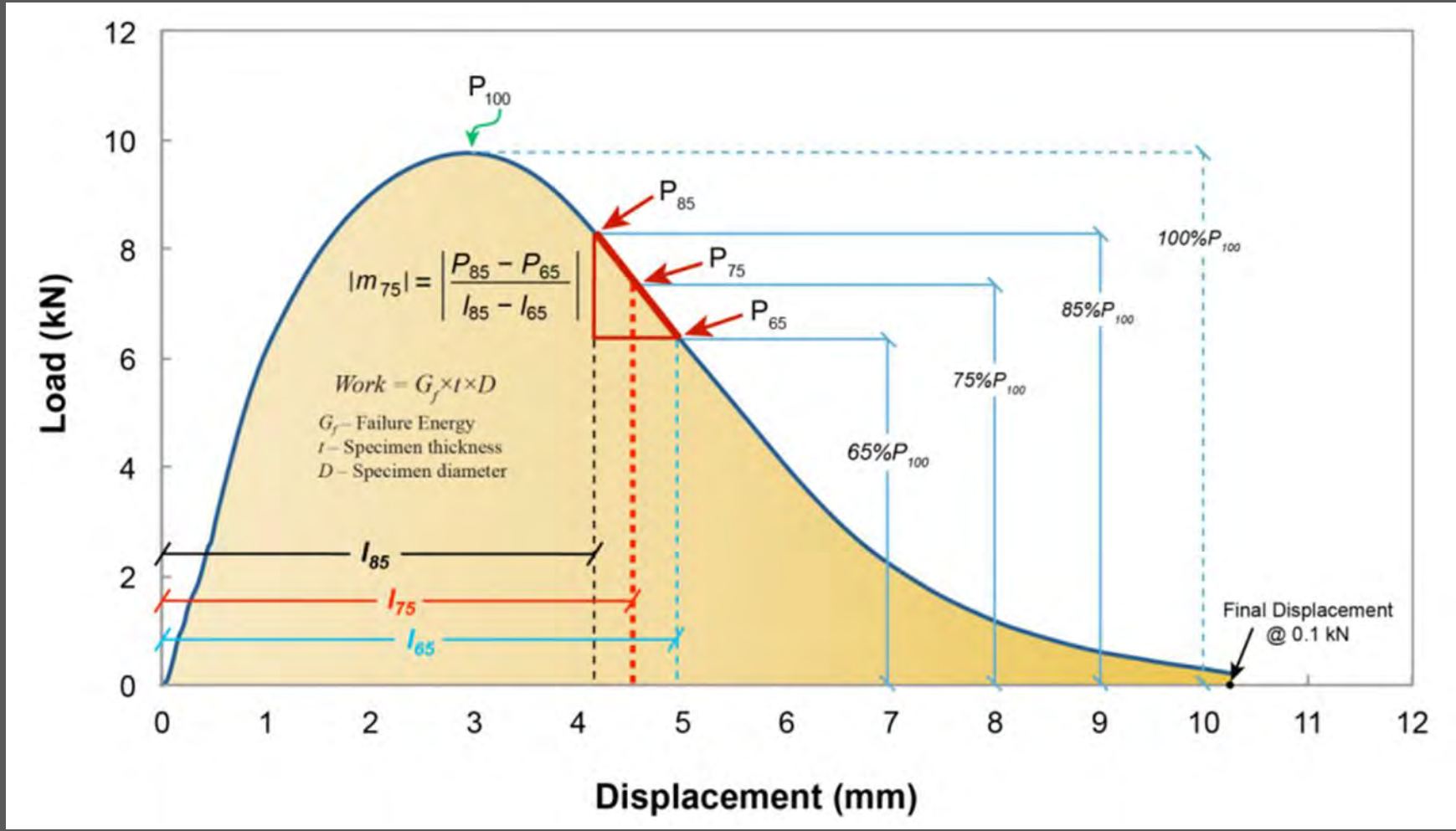
- IDEAL CT

$$CT_{Index} = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right)$$

where,

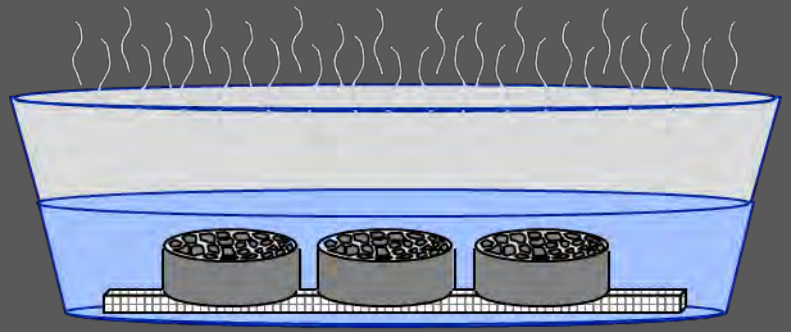
t	Specimen thickness (mm)
G_f	Failure energy
m_{75}	Slope of curve at 75% of peak load (post peak)
l_{75}	displacement at 75% of peak load
D	Specimen diameter

Source: Zhou, F. (2019). NCHRP IDEA Project 195.



Balanced Mix Design

- Moisture Susceptibility: TSR (AASHTO T 283)



3 Conditioned Specimens

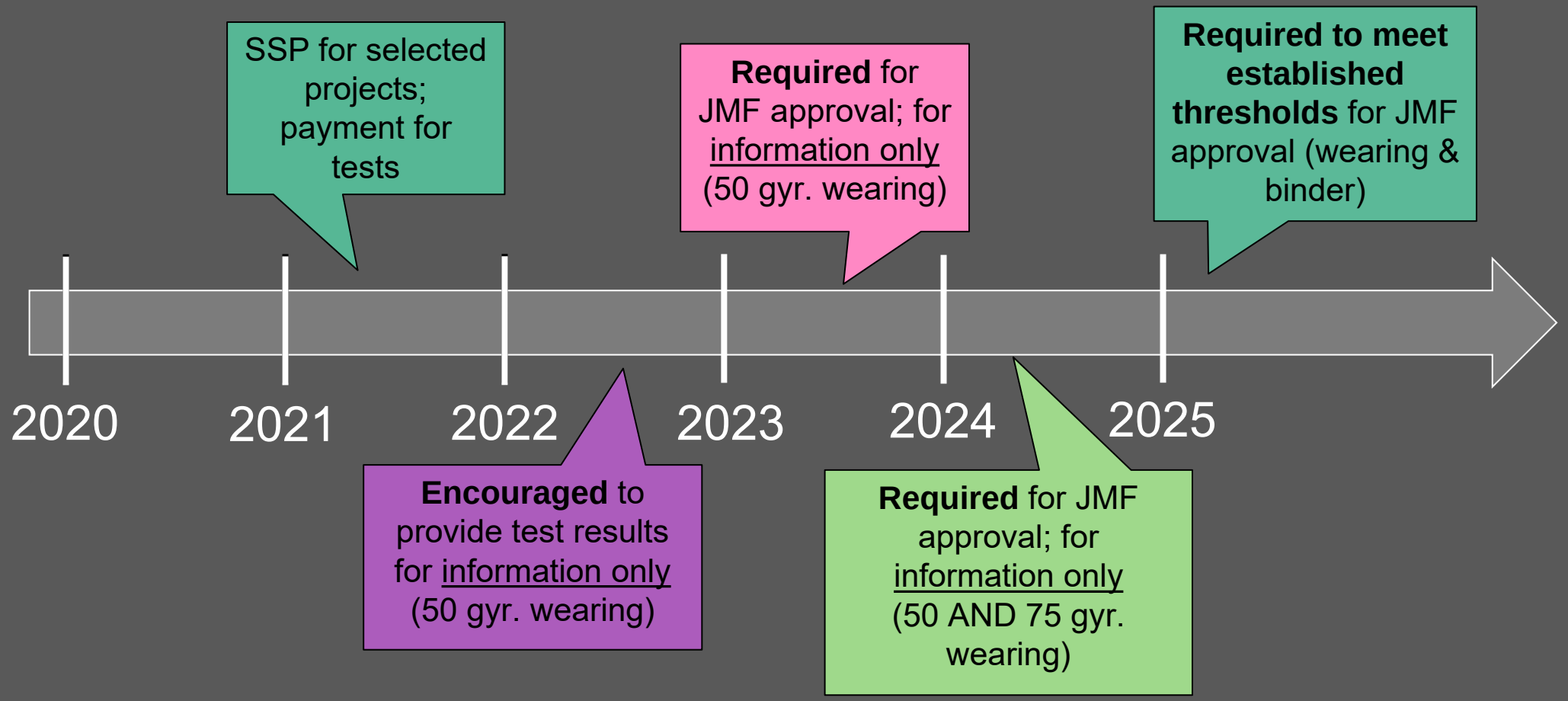
3 Dry Specimens
(2 hours @ 25 °C)

Tensile Strength Ratio (TSR) > 80%

Benefits of BMD

- Innovation
- Performance tests provide
  - Confidence
  - Risk assessment

Balanced Mix Design



Sustainable Asphalt Pavements

Federal Buy Clean Initiative

Buy Clean is a procurement policy to promote the purchase of ***construction materials*** and products with ***lower embodied greenhouse gas (GHG) emissions***, taking into account the life-cycle emissions associated with the production of those materials.

Construction Materials:

- **Concrete**
- **Steel**
- **Flat Glass**
- **Asphalt**

~50% of all manufacturing GHG emissions

98% of government's purchased construction materials

Federal Buy Clean Initiative | Office of the Federal Chief Sustainability Officer

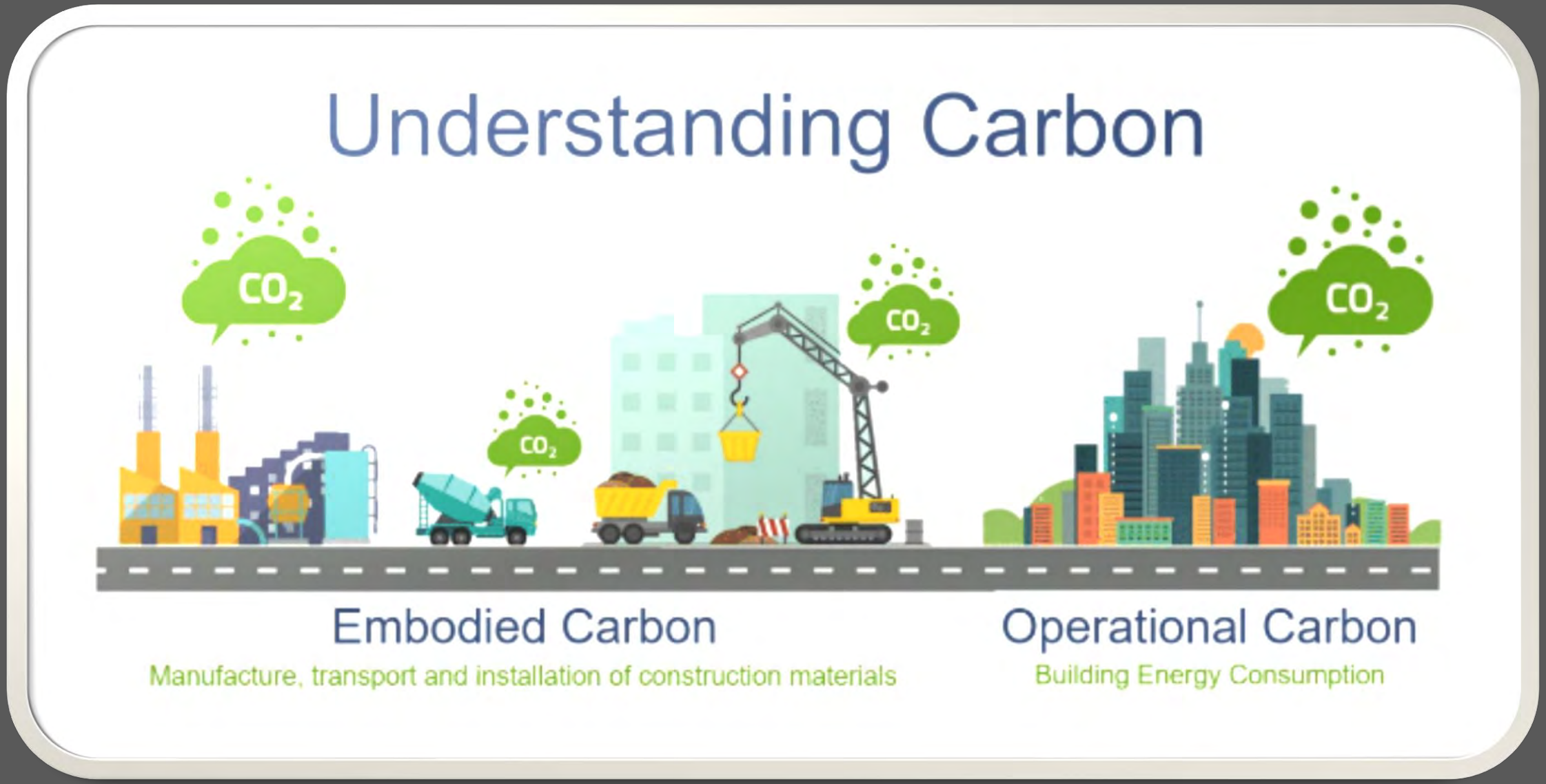


Image Credit: Building Transparency and Skanska USA

Environmentally Preferable Asphalt (P100 Facilities Standard)

- Federal office buildings, courthouses, and land ports of entry
- Requirements:
  - Submit an Environmental Product Declaration (**EPD**) for each asphalt mix
  - Use 2 environmentally preferable techniques:
    - **At least 20% RAP content**
    - **Warm mix technology (reduced onsite mix temperature)**
    - **Non-pavement recycled content (roof shingles, rubber, or plastic)**
    - **Improved energy/carbon efficiency of plants or equipment (e.g., natural gas)**
    - **Other environmentally preferable techniques (contractor can propose)**

https://www.gsa.gov/real-estate/design-construction/engineering-and-architecture/facilities-standards-p100-overview

Interim IRA Low Embodied Carbon Materials

- Defines low embodied carbon materials for 11 pilot projects.
  - Materials (concrete, cement, concrete masonry units, asphalt, steel, and glass).
  - Asphalt:

- **GSA IRA LEC Material Requirements**

GSA IRA Limits for Low Embodied Carbon Asphalt - May 16, 2023 (EPD-Reported GWPs, in kilograms of carbon dioxide equivalent per metric ton - $kgCO_2e/t$)		
Top 20% Limit	**Top 40% Limit**	**Better Than Average Limit**
55.4	**64.8**	**72.6**

Environmental Product Declaration

Environmental Product Declaration

- Quantified environmental information on the life cycle of a product,
- Enables comparisons between like products fulfilling the same function*

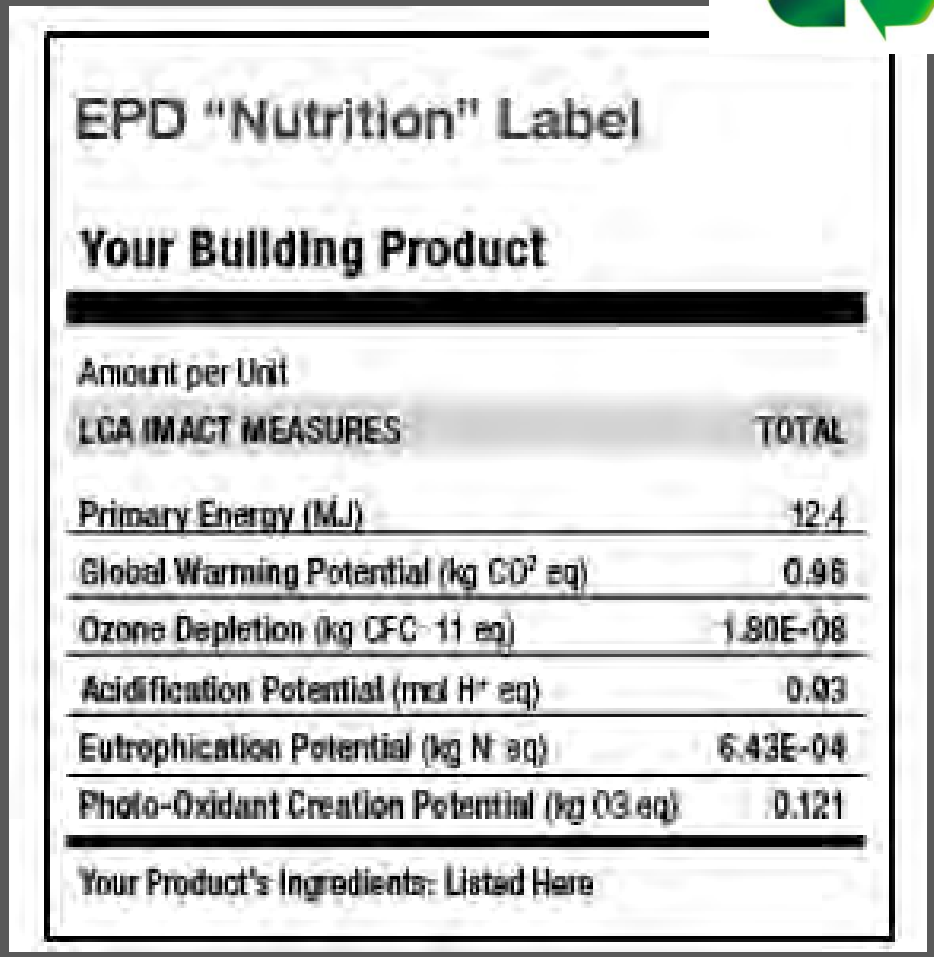
"Nutrition label" for environmental impacts

- ISO Type III Environmental Label

Independently verified

- NAPA Emerald EcoLabel: John Beath Environmental
- National Science Foundation
- Others…

*Source: ISO 14025:2006. **EPDs from different Product Categories should NOT be compared to each other.**



EPD "Nutrition" Label

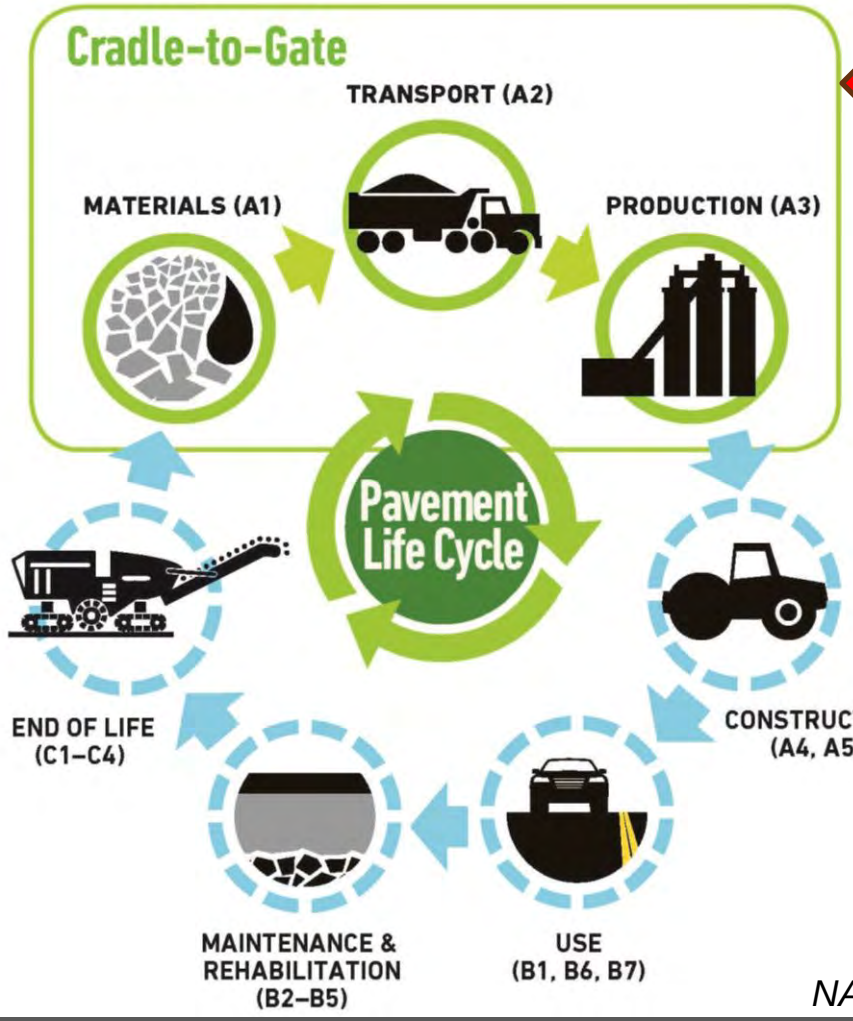
Your Building Product

Amount per Unit

LCA IMACT MEASURES	TOTAL
Primary Energy (MJ)	12.4
Global Warming Potential (kg CO^2 eq)	0.96
Ozone Depletion (kg CFC-11 eq)	1.80E-08
Acidification Potential (mol H^+ eq)	0.93
Eutrophication Potential (kg N eq)	6.43E-04
Photo-Oxidant Creation Potential (kg O3 eq)	0.121

Your Product's Ingredients: Listed Here

Environmental Product Declaration



NAPA

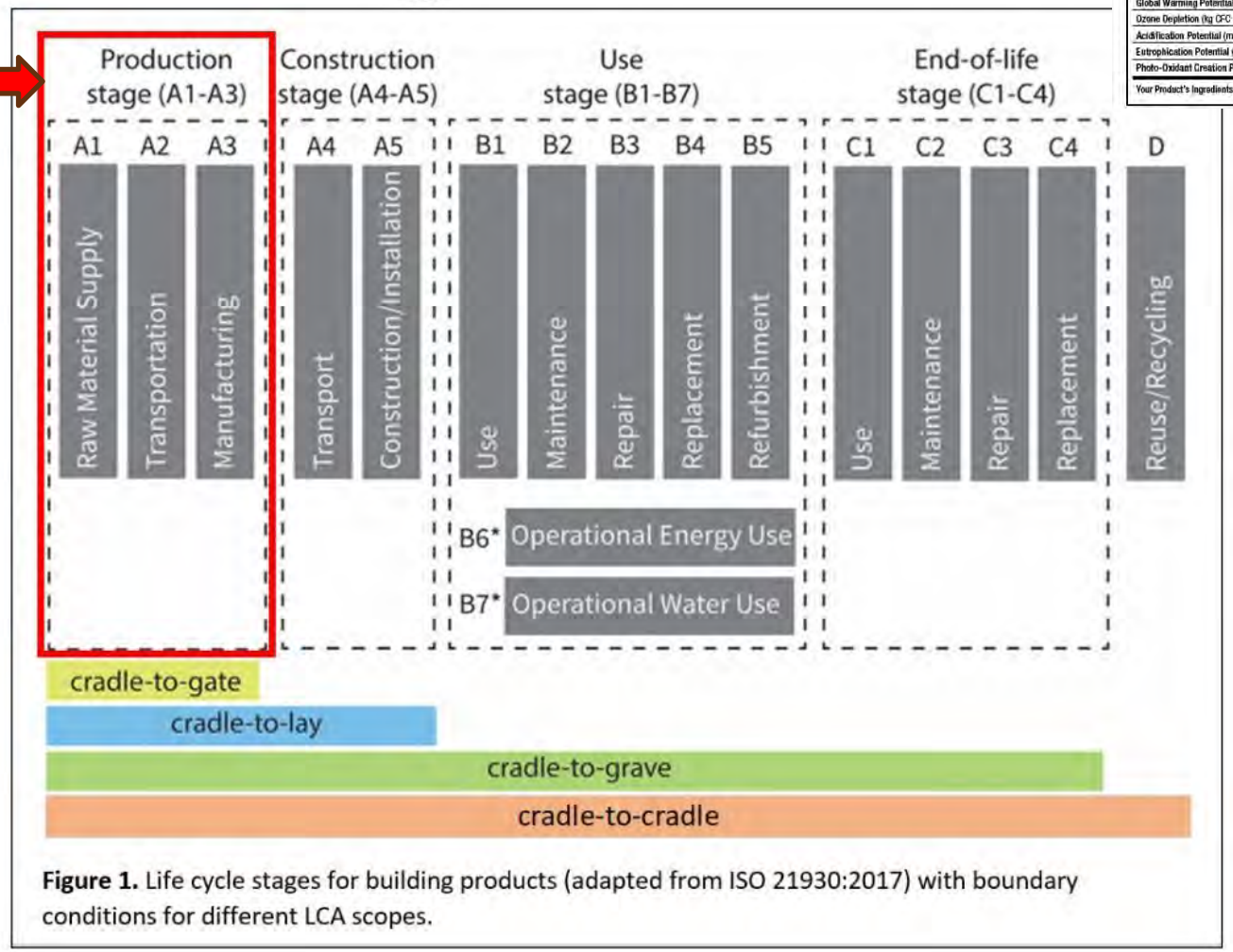


Figure 1. Life cycle stages for building products (adapted from ISO 21930:2017) with boundary conditions for different LCA scopes.

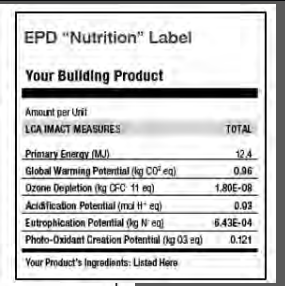


Image source: NAPA

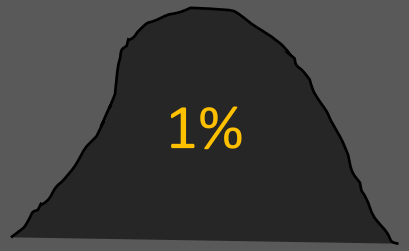
Sustainability

Two primary ways to reduce carbon emission in asphalt pavements:

1. Increase RAP
2. Reduce Temperatures

Importance of RAP

Increasing RAP

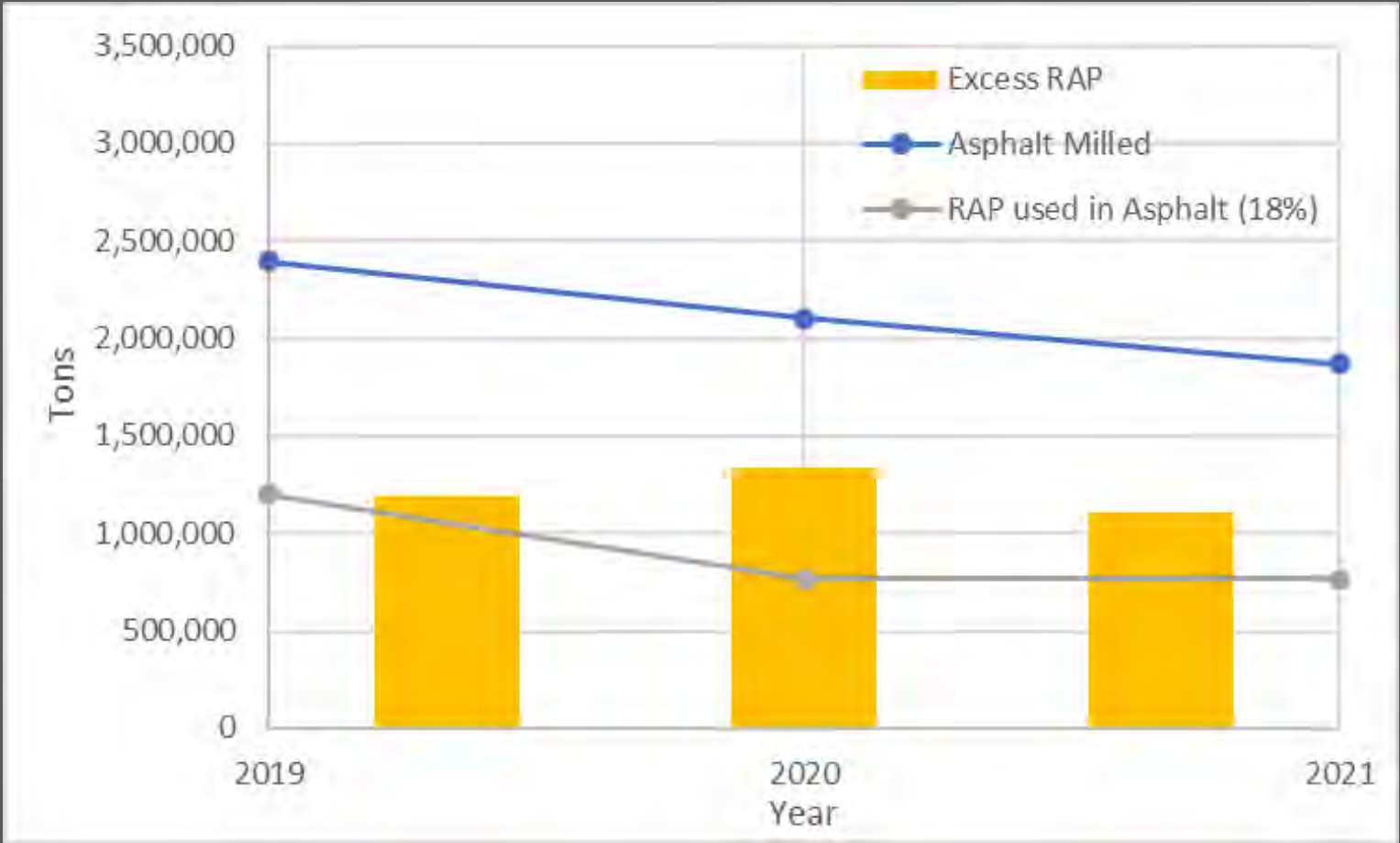


≈

= $CO_{2(e)}$ per 1000 cars

Increasing RAP in new asphalt mixtures by just 1% reduce nationwide = reduction emissions (CO_2e) of 30,000 passenger vehicles (U.S. EPA, 2018)

RAP in PA



Year	Asphalt Milled	Asphalt Placed	RAP in Asphalt	Difference
2019	2,394,076	6,667,762	1,200,197	1,193,879
2020	2,102,339	4,240,700	763,326	1,339,013
2021	1,869,704	4,252,700	765,486	1,104,218

Asphalt Mixes

Virgin asphalt pavement comprised of:

- Virgin Aggregate (coarse and fine)
- Asphalt Binder

Image sources:
NCAT
https://www.sbsg.com/products/sbsg-bulk-aggregates/
West, R. (NAPA QIP 129)

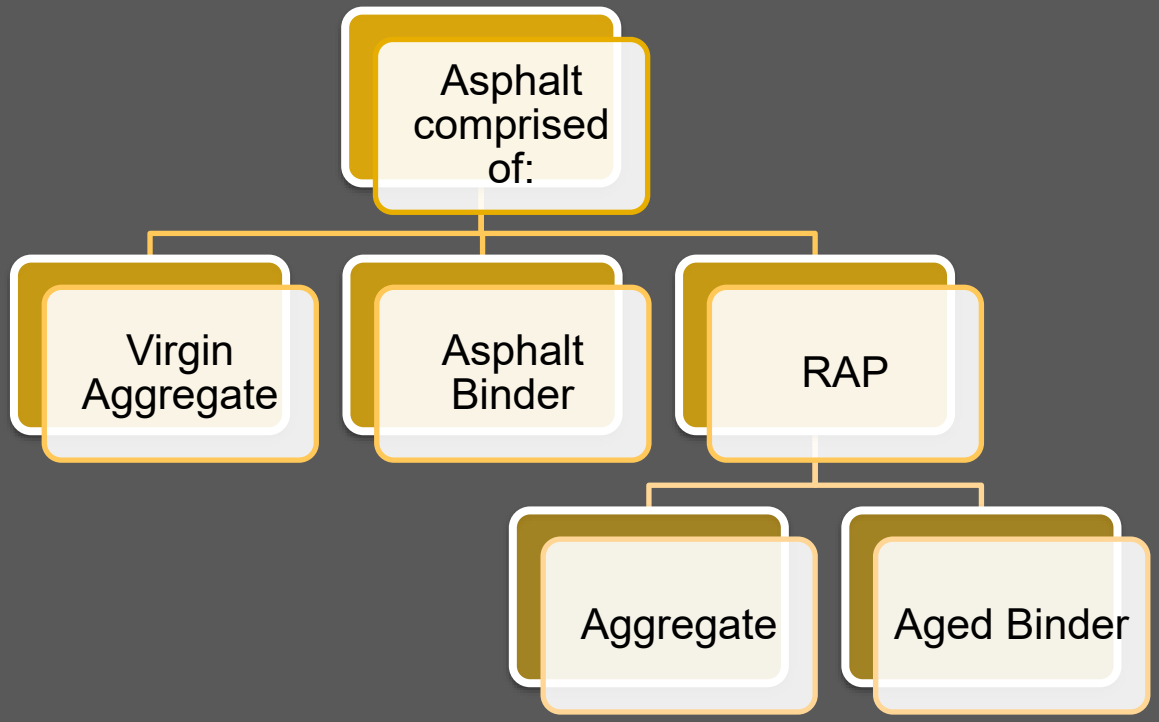
Reclaimed Asphalt Pavement

Aggregate

Aged Binder

Image sources:
West, R. (NAPA QIP 129)
Virginia Asphalt Association

RAP Mixes


Asphalt comprised of:
Virgin Aggregate
Asphalt Binder
RAP
Aggregate
Aged Binder

RAP Management

- RAP management and use is **highly regulated**
  - PA DEP permitting for **beneficial use** of RAP
  - Examples of requirements:
    - Clean stockpiles free of deleterious materials
    - Turn over the stockpile (cannot sit for prolonged period of time)
- Industry has invested in plant adaptions
  - Retrofitting of plants
  - Upgrade to drum plants (higher RAP capacity)
  - In-line screens, crushers

Performance of RAP Mixes: National Perspective

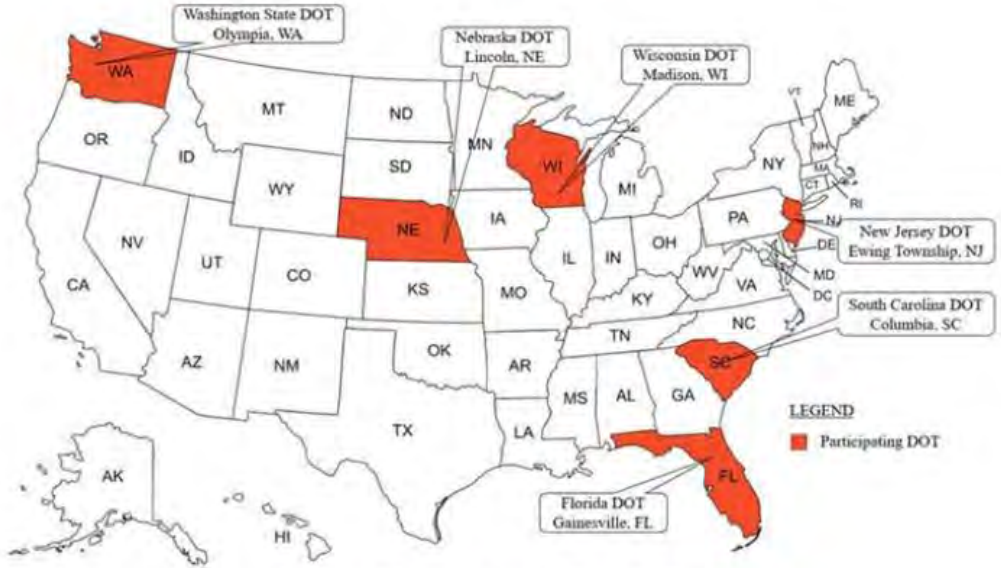


Image: University of Nevada Reno

Figure 1. Map of Participating State DOTs.

TechBrief

The Asphalt Pavement Technology Program is an integrated national effort to improve the long-term performance and cost-effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement suggestions, methods, procedures, and other tools for asphalt pavement materials selection, mixture design, testing, construction, and quality control.

Office of Preconstruction, Construction, and Pavements
FHWA-HIF-22-003
Date: July 2021

U.S. Department of Transportation
Federal Highway Administration

Resource Responsible Use of Reclaimed Asphalt Pavement in Asphalt Mixtures

This Technical Brief summarizes techniques employed by State DOTs in the use of high doses of reclaimed asphalt pavement (RAP) in asphalt mixtures and communicates the benefits observed.

The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the law or agency policies. However, compliance with applicable statutes or regulations cited in this document is required.

Introduction

Reclaimed asphalt pavement (RAP) has been used in asphalt pavement rehabilitation and reconstruction for decades. However, since the 2008 peak in asphalt binder price, the desire to increase the use of RAP has continued (1). It has been driven by the goal for cost-effective alternatives to virgin asphalt binder and the desire to make asphalt pavements more sustainable. However, this has created challenges for some State Departments of Transportation (DOTs) to specify, design, and control the quality of asphalt mixtures containing RAP. Other State DOTs have had success with varying RAP dosages. The primary concern is assuring that the high stiffness RAP binder in the mixture does not lead to long-term pavement durability issues such as raveling and cracking.

According to the National Asphalt Pavement Association (NAPA), the amount of RAP accepted/delivered to asphalt mixture producer facilities in 2019 was 97.01 million tons, and the RAP used in asphalt mixtures was 89.2 million tons (2). More than 97 percent of asphalt mixture reclaimed from old asphalt pavements was used in new pavement. Since 2009, the average percentage of RAP used in asphalt mixtures by weight has increased from 15.6 percent to 21.1 percent. All State DOTs allow the use of RAP at some dosages and conditions.

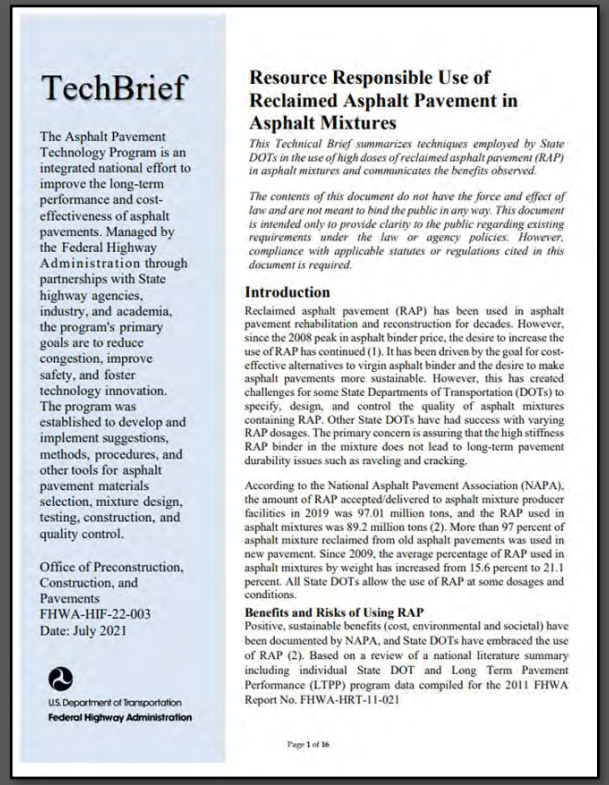
Benefits and Risks of Using RAP

Positive, sustainable benefits (cost, environmental and societal) have been documented by NAPA, and State DOTs have embraced the use of RAP (2). Based on a review of a national literature summary including individual State DOT and Long Term Pavement Performance (LTPP) program data compiled for the 2011 FHWA Report No. FHWA-HRT-11-021

Page 1 of 16

Performance of High RAP Mixes: National Perspective

- Performance of RAP mixes:
  - FL DOT: when accounting for traffic volume, and for RAP mixes with 30 – 50% RAP, performance was better than mixes without RAP
  - NE DOT: “the overall condition of the highway system has improved since the implementation of high RAP asphalt mixtures”
  - WS DOT: “No statistical evidence to suggest a difference in performance between high-RAP (> 20%) and up to 20% RAP mixtures”



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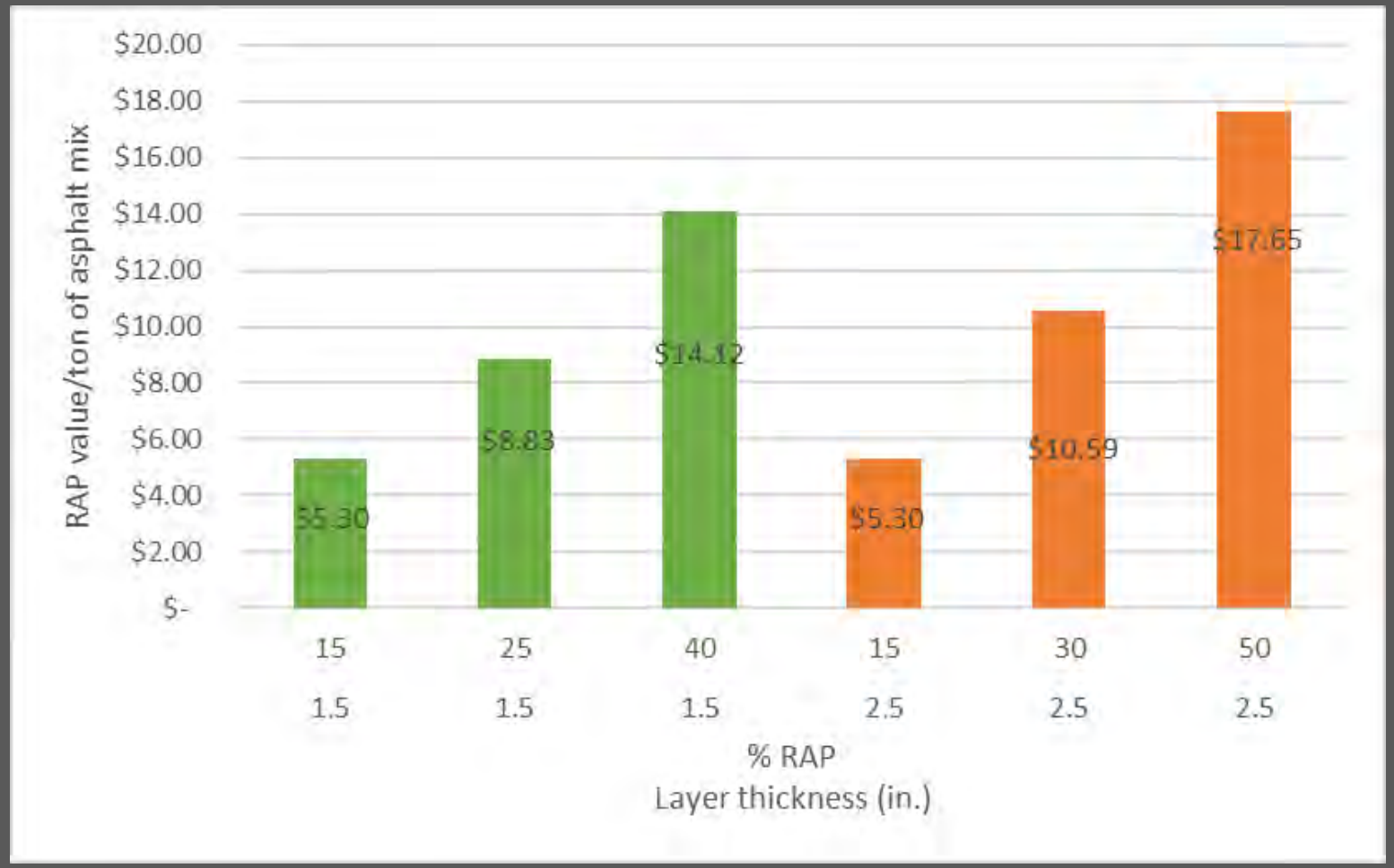
Page 1 of 16

Value of RAP

- Cost of Virgin Materials:
  - Aggregate:
    - $20/ton
    - 95% of mix
  - Asphalt binder:
    - $600/ton
    - 5% of mix

Avg. Value of RAP ≈ $10/ ton of mix



Cost Savings of RAP Mixes

- Ohio DOT High RAP project (2021)
  - Side-by-side comparison
    - Mill/fill:
      - Marshall Intermediate Course
      - Marshal Surface Course
  - Surface mixes:
    - High RAP: 55% RAP (53% RBR + 0.1% Recycling Agent)
    - Control: (20% RAP/ 16.3% RBR)

Cost Savings of RAP Mixes

- Ohio DOT High RAP project (2021)
  - Eric Biehl, P.E., State Asphalt Materials Engineer reported at OTEC, 2022. Related to cost savings associated with the high RAP section (assuming service life is equal):

For every 0.1% reduction in virgin asphalt binder, roughly $1/CY reduction in material cost

- Assumes $500/ton for asphalt binder

Actual costs (Asphalt Price Index at time of placement = $465.83/ton)

- Control Section (5.3% virgin asphalt binder)
- High RAP section (2.9% virgin asphalt binder) -> **$22.36/CY of mix Cheaper**

When asphalt binder costs increase significantly, overall material costs fluctuate less

- Increase in Asphalt Price Index to $736.67 (+270.84) translates to:
  - Control section increased by $28.71/CY
  - High RAP section increased by %15.71/CY

Cost Savings of RAP Mixes

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Cost savings associated with virgin aggregate:

- $50/CY ($25/ton) of aggregate for high RAP (45% virgin aggregate)

Total savings f0r 55% RAP vs. 20% RAP mix, if haul distance is the same:

- $40/CY of mix

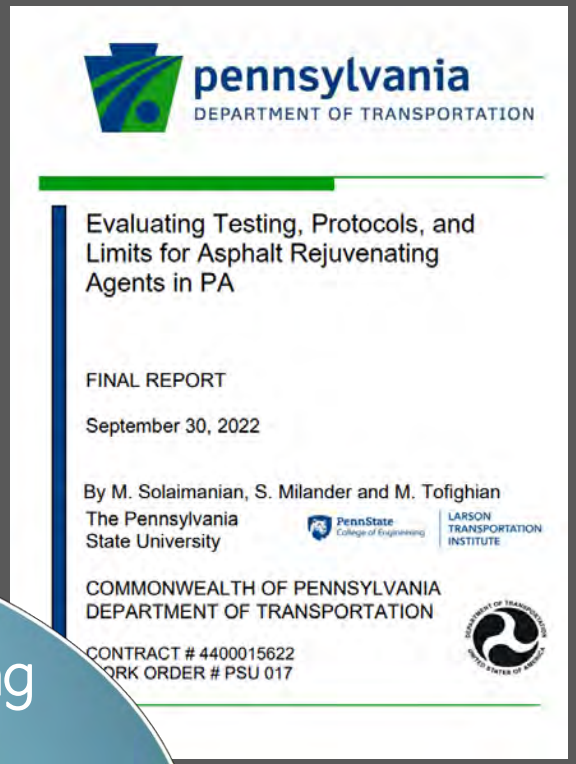
Haul distance not equivalent ($26.50/CY of mix), total savings

In 2019, 900k of Marshall surface mix placed, using 55% RAP would translate to:

- $12 million in cost savings

Responsible use of Resources

- Tools to successfully increase RAP %
  - Balanced Mix Design
  - Recycling agents
  - RAP binder correction factor
    - LVR High RAP mixes
    - SC DOT
    - GA DOT


pennsylvania
DEPARTMENT OF TRANSPORTATION

Evaluating Testing, Protocols, and Limits for Asphalt Rejuvenating Agents in PA

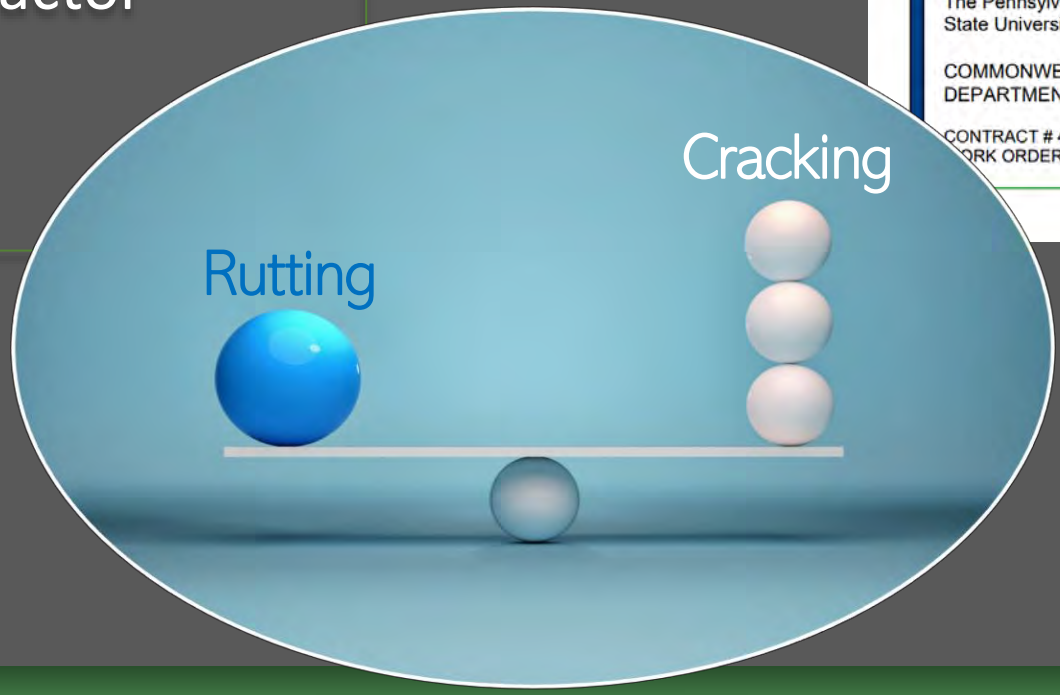
FINAL REPORT

September 30, 2022

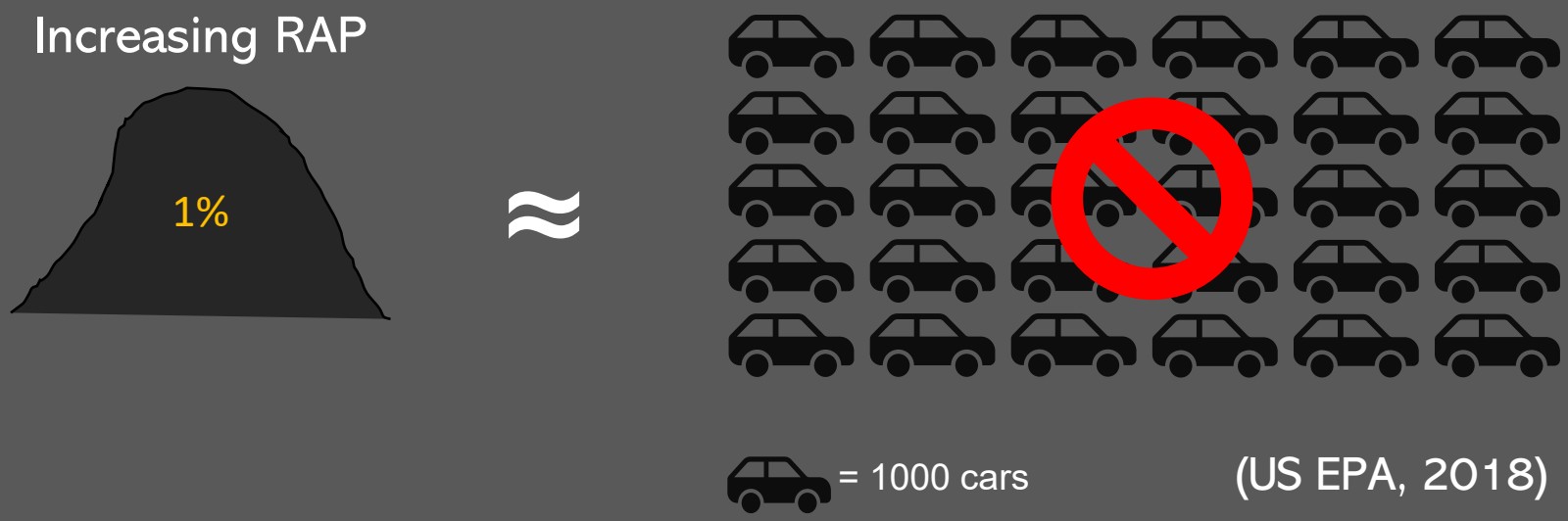
By M. Solaimanian, S. Milander and M. Tofighian
The Pennsylvania State University

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

CONTRACT # 4400015622
ORK ORDER # PSU 017



Importance of RAP



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Thank you

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Upcoming PAPA Events

TO REGISTER: PAPA Events (pa-asphalt.org)

PAPA ANNUAL CONFERENCE

Hershey, PA
January 15, 16 & 17, 2024

PAPA REGIONAL TECHNICAL MEETINGS

Pittsburgh | State College | Allentown
March 19, 20, & 21, 2024

PAPA ENVIRONMENTAL SEMINAR

Harrisburg, PA
April 10, 2024