

# Best Practices for the Use of Recycled Materials in Asphalt Pavements



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**Public Works Officers Institute**  
**March 19, 2025**



# Outline

- Introduction to CCPIC
- Overview of pavement performance
  - Recommendations for best practices
- RAP and local government asphalt mixes
  - Recommendations for what to do now
- AB 2953
  - New state law
- Questions and discussion

# CCPIC Mission and Vision

- **Website**
  - [www.ucprc.ucdavis.edu/ccpic](http://www.ucprc.ucdavis.edu/ccpic)
- **Mission**
  - CCPIC works with local governments to increase pavement technical capability through timely, relevant, and practical support, training, outreach and research
- **Vision**
  - Making local government-managed pavement last longer, cost less, and be more sustainable



# City and County Pavement Improvement Center



- Sponsored by the League of California Cities, County Engineers Association of California, and the California State Association of Counties
- Chartered September 28, 2018

# CCPIC Organization

- **Governance**
  - Governance Board consisting of 6 city and 6 county transportation professionals
- **Current Funding**
  - Seed funding from SB1 through:
    - Institute of Transportation Studies at UC Davis, UC Berkeley, UC Los Angeles, UC Irvine
    - Mineta Transportation Institute at San Jose State University

# CCPIC Scope

- **Technology Transfer:**
  - Training courses
  - Pavement engineering and management certificate program for working professionals through UC Berkeley ITS Tech Transfer
  - Outreach
- **Technical Resources:**
  - Technical briefs, guidance, sample specifications, tools, and other resources
- **Resource Center:**
  - Outreach, questions, pilot study documentation, and forensic investigations
- **Research and Development:**
  - For local government needs that are not covered by State and Federal efforts
  - Adapting work done for state government

# Pavement Engineering & Management (PEM) Certificate Program

- **PEM Certificate Program Overview**
  - For engineers, asset managers, upper-level managers, technicians and construction inspectors
  - 88.5 hours of training
    - 56.5 hours in core classes, 32 hours in electives
    - Majority of classes to be offered online
  - In four categories:
    - Fundamentals
    - Management
    - Materials and Construction
    - Design

# Pavement Engineering & Management Certificate: Curriculum

|                                              | Fundamentals                                               | Hrs | Management                                                        | Hrs | Materials and Construction                                                          | Hrs  | Design                                                                       | Hrs |
|----------------------------------------------|------------------------------------------------------------|-----|-------------------------------------------------------------------|-----|-------------------------------------------------------------------------------------|------|------------------------------------------------------------------------------|-----|
| <b>CORE</b><br>56.5 required                 | CCA-01 Introduction to Pavement Engineering and Management | 10  | CCB-01 Life Cycle Cost Analysis                                   | 4   | CCC-01 Asphalt Concrete Materials and Mix Design                                    | 8    |                                                                              |     |
|                                              | CCA-02 Pavement Sustainability                             | 4   | CCB-02 Pavement Management Systems and Preservation Strategies    | 10  | CCC-02 Pavement Preservation Treatments, Materials, Construction, Quality Assurance | 8    |                                                                              |     |
|                                              |                                                            |     |                                                                   |     | CCC-03 Pavement Construction Specifications and Quality Assurance                   | 12.5 |                                                                              |     |
| 56.5                                         | <b>Fundamentals, CORE</b>                                  | 14  | <b>Management, CORE</b>                                           | 14  | <b>Materials and Construction, CORE</b>                                             | 28.5 | <b>Design, CORE</b>                                                          | 0   |
| <b>ELECTIVE</b><br>32 required<br>84 offered |                                                            |     | CCB-21 Financing and Cash Flow for Pavement Networks              | 4   | CCC-21 Concrete Materials & Mix Design                                              | 8    | CCD-21 Asphalt Pavement Structural Section Design                            | 8   |
|                                              |                                                            |     | CCB-22 Integrated Asset Management for Multi-Functional Pavements | 8   | CCC-22 In-Place Recycling                                                           | 8    | CCD-22 Design, Construction, and Maintenance of Interlocking Concrete Pavers | 6   |
|                                              |                                                            |     |                                                                   |     | CCC-23 Gravel Roads Engineering, Construction, and Management                       | 8    | CCD-23 Concrete Pavement Design                                              | 8   |
|                                              |                                                            |     |                                                                   |     | CCC-24 Roadway Construction Phasing, Scheduling, and Traffic Control                | 4    |                                                                              |     |
|                                              |                                                            |     |                                                                   |     | MISC Classes from Pavement Construction Inspection Certificate curriculum           |      |                                                                              |     |
|                                              |                                                            |     |                                                                   |     | CCC-26 Pavement Construction Management                                             | 8    |                                                                              |     |
|                                              |                                                            |     |                                                                   |     | CCC-27 Asphalt Pavement Maintenance Construction                                    | 6    |                                                                              |     |
|                                              |                                                            |     |                                                                   |     | TS-10 Work Zone Safety                                                              | 8    |                                                                              |     |
| 84                                           | <b>Fundamentals, ELECTIVE</b>                              | 0   | <b>Management, ELECTIVE</b>                                       | 12  | <b>Materials and Construction, ELECTIVE</b>                                         | 50   | <b>Design, ELECTIVE</b>                                                      | 22  |
| <b>Total for Certificate</b><br>88.5 hours   | <b>Fundamentals</b>                                        | 14  | <b>Management</b>                                                 | 26  | <b>Materials and Construction</b>                                                   | 78.5 | <b>Design</b>                                                                | 22  |

# Pavement Construction Inspection (PCI) Certificate Program

- **PCI Certificate Program Overview**
  - For engineers, material testing technicians and construction inspectors
  - 80.5 hours of training
    - 68.5 hours in core classes, 12 hours in electives
    - Majority of classes to be offered online

# Pavement Construction Inspection Certificate: Curriculum

|                                       | Core                                        | Hrs                                                                            |
|---------------------------------------|---------------------------------------------|--------------------------------------------------------------------------------|
| CORE<br>68.5<br>required              | <a href="#">PD-01</a>                       | Construction Inspection 16                                                     |
|                                       | CCI-01                                      | Asphalt Pavement Construction Inspection 4                                     |
|                                       | CCI-02                                      | Concrete Pavement Construction Inspection 4                                    |
|                                       | CCI-03                                      | Concrete Street Improvements Construction Inspection 4                         |
|                                       | CCI-04                                      | Pavement Preservation Construction Inspection 4                                |
|                                       | <a href="#">CCC-02</a>                      | Pavement Preservation Treatments, Materials, Construction, Quality Assurance 8 |
|                                       | <a href="#">CCC-03</a>                      | Pavement Construction Specifications and Quality Assurance 12.5                |
|                                       | CCC-26                                      | Pavement Construction Management 8                                             |
|                                       | <a href="#">TS-10</a>                       | Work Zone Safety 8                                                             |
| 68.5                                  | Core                                        | 68.5                                                                           |
|                                       | Electives (choose 12 hours from list below) | Hrs                                                                            |
| ELECTIVE<br>12 required<br>26 offered | CCC-22                                      | In-Place Recycling 8                                                           |
|                                       | CCC-24                                      | Roadway Construction Phasing, Scheduling, and Traffic Control 4                |
|                                       | CCI-06                                      | Construction Inspection of Asphalt-Rubber Pavement Materials 2                 |
|                                       | <a href="#">PD-02</a>                       | Construction Inspection of Traffic Signals 8                                   |
|                                       | <a href="#">TS-18</a>                       | Excavation and Trenching Safety 4                                              |
| 12                                    | Electives                                   | 26                                                                             |
| 80.5                                  | Total required for certificate              |                                                                                |

# CCPIC Self-Paced Classes Currently Open for Enrollment

([www.techtransfer.Berkeley.edu](http://www.techtransfer.Berkeley.edu))

| Code   | Title                                                        | Date                 | Location |
|--------|--------------------------------------------------------------|----------------------|----------|
| CCB-21 | Financing and Cash Flow for Pavement Networks                | Any time, self paced | Online   |
| CCC-21 | Concrete Materials and Mix Design                            | Any time, self paced | Online   |
| CCI-02 | Concrete Pavement Construction Inspection                    | Any time, self paced | Online   |
| CCI-03 | Construction Inspection of Concrete Street Improvements      | Any time, self paced | Online   |
| CCI-04 | Pavement Preservation Construction Inspection                | Any time, self paced | Online   |
| CCI-06 | Construction Inspection of Asphalt-Rubber Pavement Materials | Any time, self paced | Online   |

# CCPIC Online Classes Currently Open for Enrollment

([www.techtransfer.Berkeley.edu](http://www.techtransfer.Berkeley.edu))

| Code   | Title                                     | Date                | Location |
|--------|-------------------------------------------|---------------------|----------|
| CCC-01 | Asphalt Concrete Materials and Mix Design | April 14 – 17, 2025 | Online   |
| CCA-02 | Pavement Sustainability                   | May 20 - 22, 2025   | Online   |

# Prepaid Training Packages

- TechTransfer now offers a streamlined way for agencies to purchase CCPIC certificate training packages for employees. ***Agencies can purchase a prepaid training package for employees to complete an entire certificate program for \$2,110 per person.*** This price covers all core classes and electives to complete either the Pavement Engineering and Management Certificate or the Pavement Construction Inspection program. Funds never expire, are fully transferable within the agency, and can be applied to any class offered by TechTransfer, so even though they are non-refundable, there's no risk that training funds will be lost if an employee is reassigned or leaves the agency or if training needs change. Training packages are not eligible for group discounts. For more information, email [registrar@techtransfer.Berkeley.edu](mailto:registrar@techtransfer.Berkeley.edu).

## Our Mission

CCPIC works with local governments to increase pavement technical capability through timely, relevant, and practical support, training, outreach and research

## Our Vision

Making Local Government-Managed Pavement Last Longer, Cost Less, and Be More Sustainable

## Governance

[CCPIC Documents](#)

## Useful Links

- [CSAC](#)
- [League of CA Cities](#)
- [UCPRC](#)
- [ITS Davis](#)
- [ITS Berkeley](#)
- [MTI](#)
- [CSU Chico](#)
- [CSU Long Beach](#)
- [CalPoly SLO](#)

## Best Practices, Technical Briefs

### Answers to common problems

- [Writing and Enforcing Specs for Asphalt Compaction](#)
- [Writing Concrete Specs for Durability and Sustainability](#)
- [Unpaving to Create Affordable, Safe, Smooth Gravel Roads](#)
- [Pavement Condition Index \(PCI\)](#)

## Sample Specifications

### Model Specs

- [HMA-LG model specification \(Greenbook format\)](#)
- [Interlocking Concrete Pavement \(Paver\) model specification](#)
- [Superpave HMA for Local Government Model Specification Language](#)
- [Asphalt Compaction Model Specification Language](#)
- [Concrete Pavement Model Specification Language](#)

## Pavement Contact List

### Be a Part of the Pavement Contacts

- [Click](#) to join the CCPIC's contact list to stay in touch with the latest pavement trends

## Training Classes

### Pavement Training

- [About CCPIC subsidized training](#)
- [Currently offered training classes](#)
- [Subscribe to monthly training update emails](#)
- [Survey on your Agency's pavement training needs. Thanks.](#)

## Guidance

- [Guidance for interlocking concrete pavement \(pavers\)](#)
- [Chemical Dust Control and Stabilization Treatments on Unpaved Roads](#)
- [Stabilization of Subgrade Soils](#)
- [Guide for Partial-and Full-Depth Pavement Recycling in California](#)
- [Use of RAP in Gap-Graded Asphalt Rubber Mixes](#)

## Tools

### Pavement Software Tools

- Life Cycle Cost Analysis Comparison Spreadsheet & ChangeLog ([Download](#))
- Unpaved Road Chemical Treatment Selection [Website](#)
- Asphalt Paving Compaction Temperature ([Download & Install](#))

## Technical Topics and Updates

### Technical Topics

1. [Tech Topic 1988: Compaction](#)
2. [Tech Topic 1999: Pothole Primer](#)
3. [Tech Topic 2001: Rut Resistance](#)
4. [Tech Topic 2002: Moisture Sensitivity](#)
5. [Tech Topic 2004: Foamed Asphalt](#)
6. [Tech Topic 2005: Performance Graded \(PG\) Asphalts](#)
7. [Tech Topic 2006: Performance Graded-Polymer Modified \(PG-PM\) Asphalts](#)

## Outreach - Presentations

- [Asphalt pavement distresses and PCI/pavement management \(PDF\), July 20, 2022](#)
- [Asphalt compaction and tack coats \(PDF\), July 20, 2022.](#)

## Workshops

## News And Events

### Survey on Pavement Training Needs

[Please take 5 minutes to fill out a short survey on your agency's pavement training needs. Thanks.](#)

May 1, 2023

In-person presentations for northern counties and cities in Redding. Hosted by Panos Kokkas, Trinity County and Shasta College.

- [Asphalt compaction \(Slides, PDF\), by John Harvey](#)
- [Engineering gravel roads, by Dave Jones.](#)

July 1, 2022

[New document posted on Asphalt Compaction Model Specification](#)

April 4, 2022

[New document posted on Superpave HMA for local governments](#)

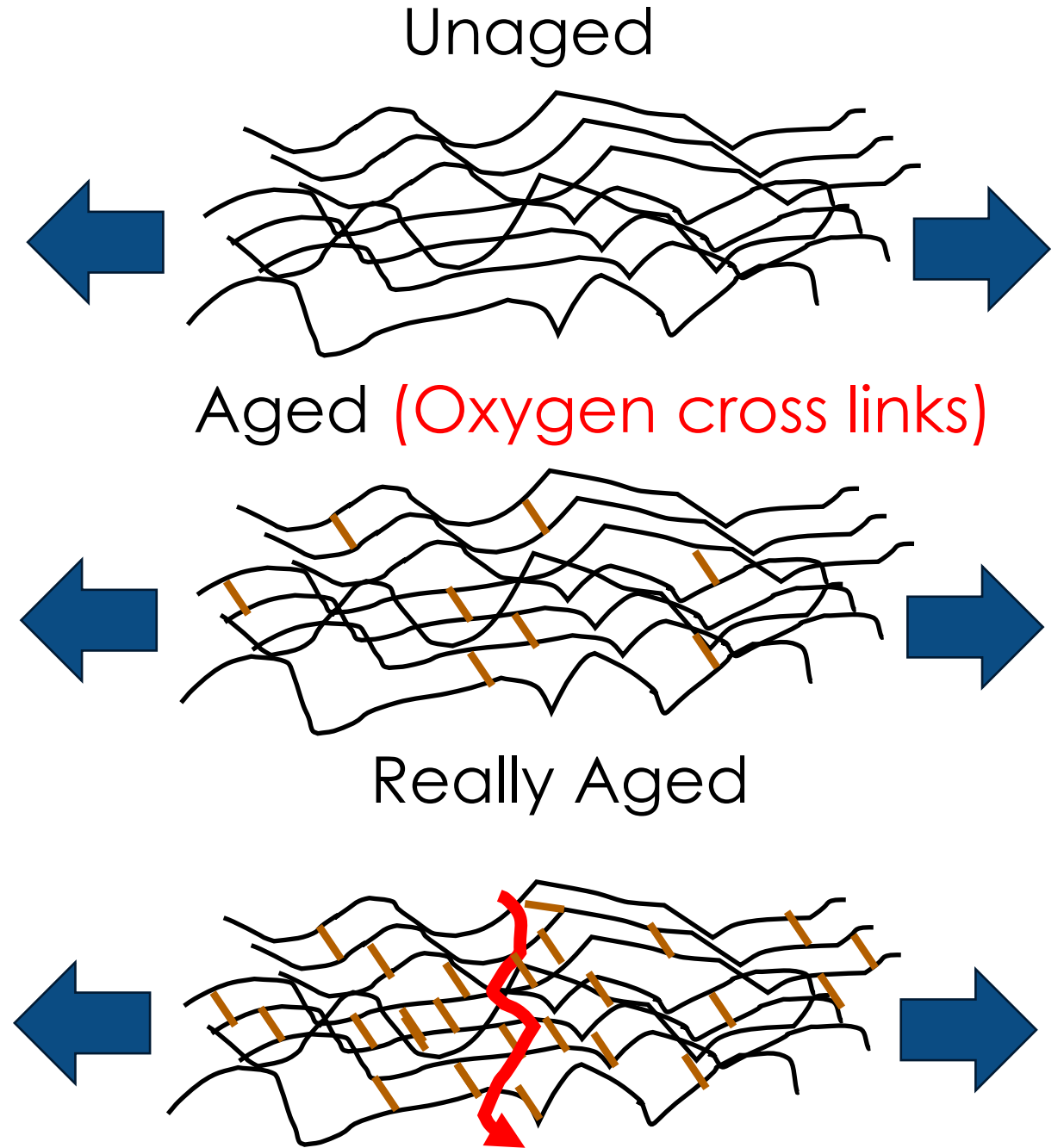
[Previous News Items](#)



# Asphalt Pavement Performance

# Aging

- Aging primarily due to oxidation of hydrocarbon chains in binder
  - Some loss of lighter components to air also, volatilization
- Oxidation is cross linking which makes chains less able to flow under stress, they can't relax the thermal contraction stresses
- Aging reaches a point where asphalt has to crack to relieve tensile stress

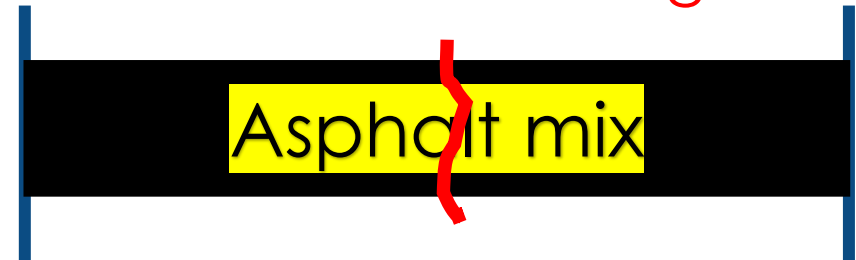


# Aging Leads to Age Related Cracking

- Increased stiffness and less relaxation results in higher tensile stress under thermal contraction strains

- Day/night
- Winter/summer

Restrained thermal contraction  
leads to cracking

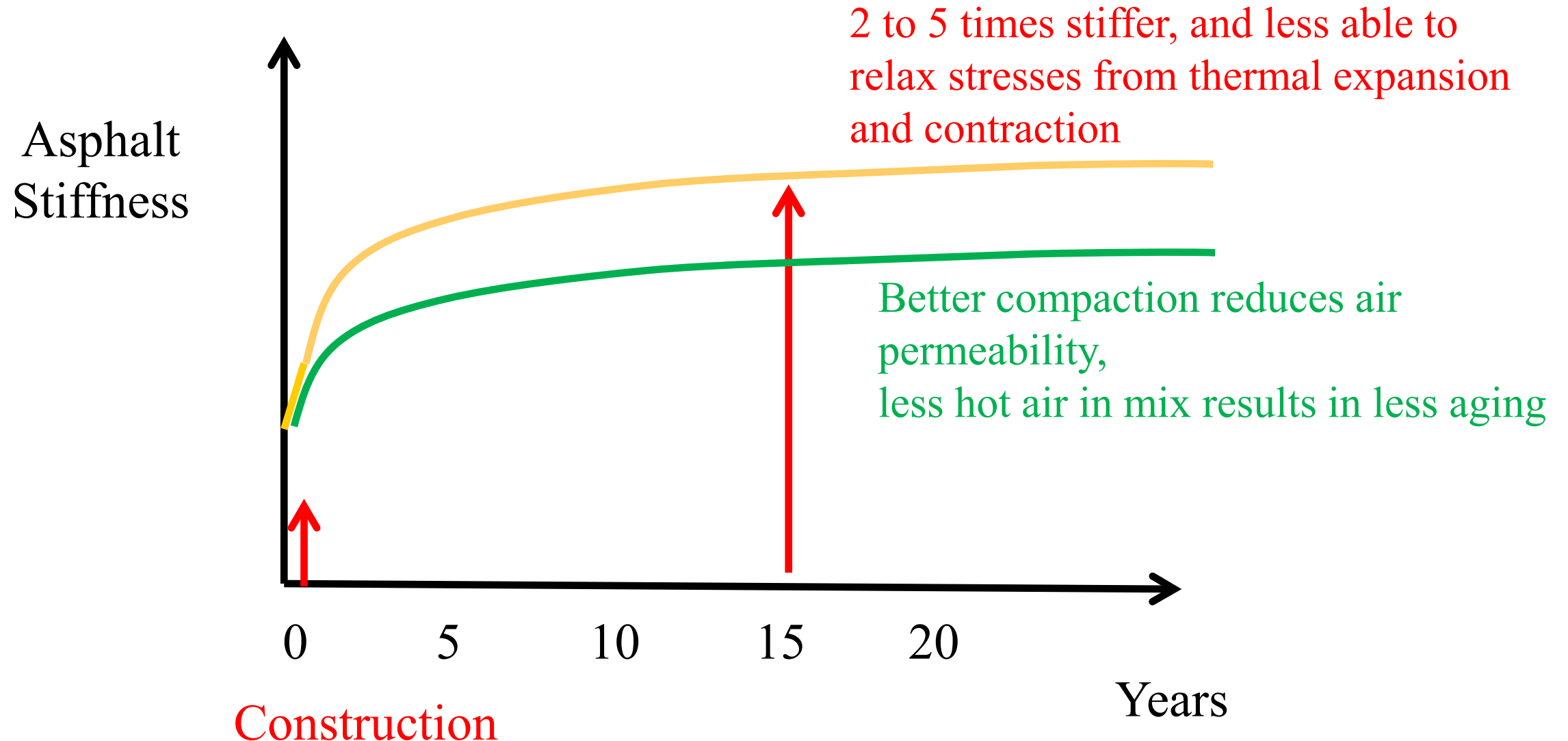


Tensile strain comes from asphalt contracting when gets cold  
 $\text{Stress} = \text{Stiffness} \times \text{strain}$ , higher stiffness = higher tensile stress

When aging asphalt gets stiff enough, the tensile stress

# Aging

Amount of aging depends on  
climate region, asphalt chemistry,  
construction compaction, modifiers



# Age Related Cracking Leading to Block Cracking

- **Top down**

- Most aged at top
- Most difference in temperature at top

- **May also be reflective cracking from shrinkage cracks in cement treated base**



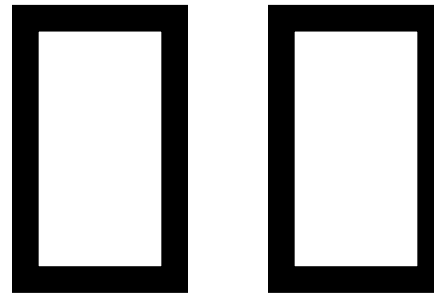
# Age-Related Cracking: Strategies

- Use mixes that are softer at low and intermediate temperatures for the surface
  - Top 2 to 4 inches
  - 64-16 or 64-22 instead of 64-10 or for example
- Keep the surface protected from aging
  - Can potentially perpetually use fog seals, or slurry seal or micro surfacings
  - Slurry seal typically not used on RHMA/ARHM
- What frequency?
  - After aging has progressed
    - About 7 to 12 years
  - Before cracking starts
    - Do not let cracking get extensive
  - Doing more frequently is not cost-effective



# Bottom Up Fatigue Cracking

At *moderate*  
temperatures, tensile  
strains under loading



**Asphalt**  
**Concrete**

← **Tensile Strain  $\epsilon_t$**  →

Base

Sub-Base

Subgrade

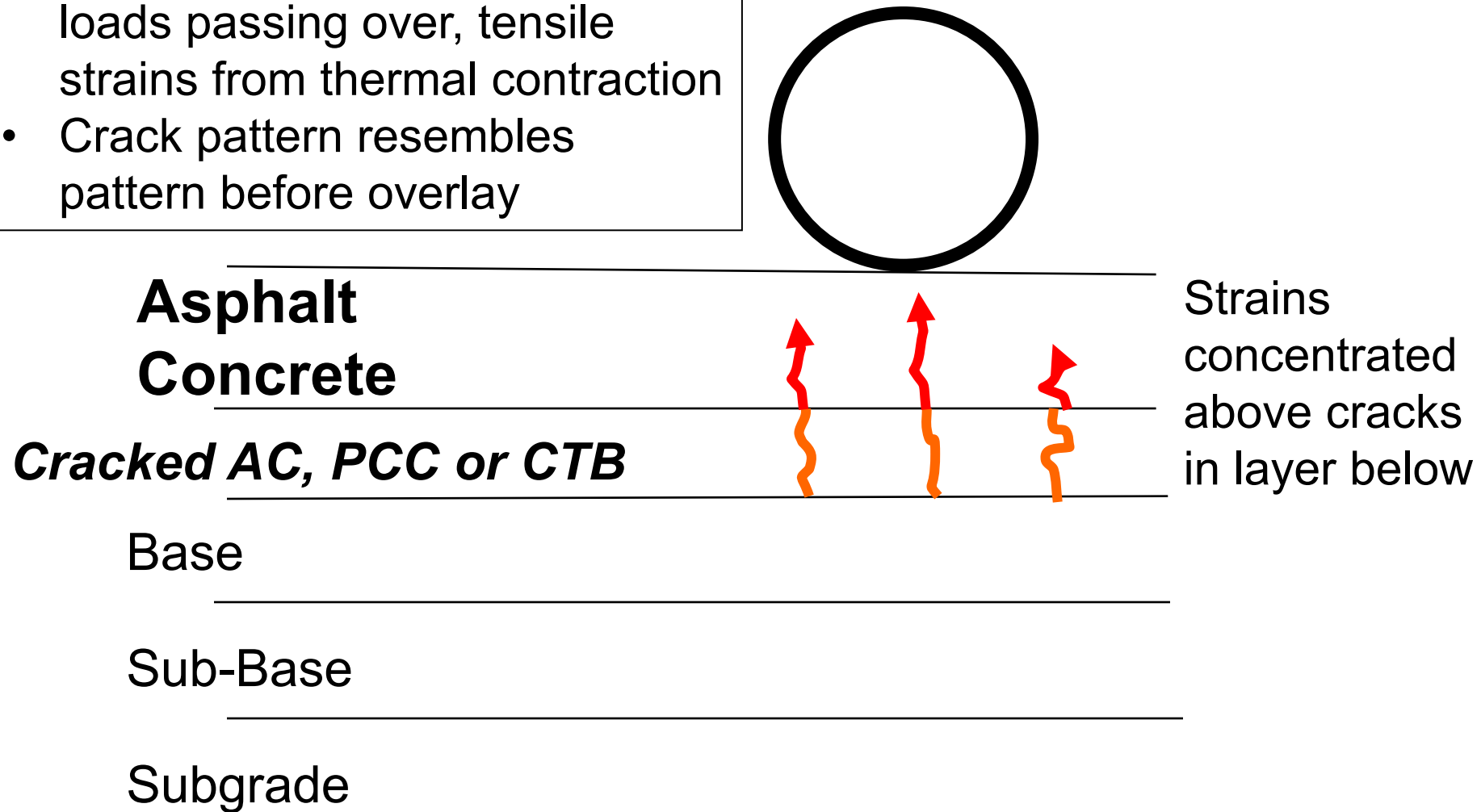
# Fatigue Cracking in Wheel Paths

- Fatigue cracking will occur wherever heavy vehicles pass
- Preservation does not stop fatigue cracking



# Reflective Fatigue Cracking

- Shear and tensile strains from loads passing over, tensile strains from thermal contraction
- Crack pattern resembles pattern before overlay



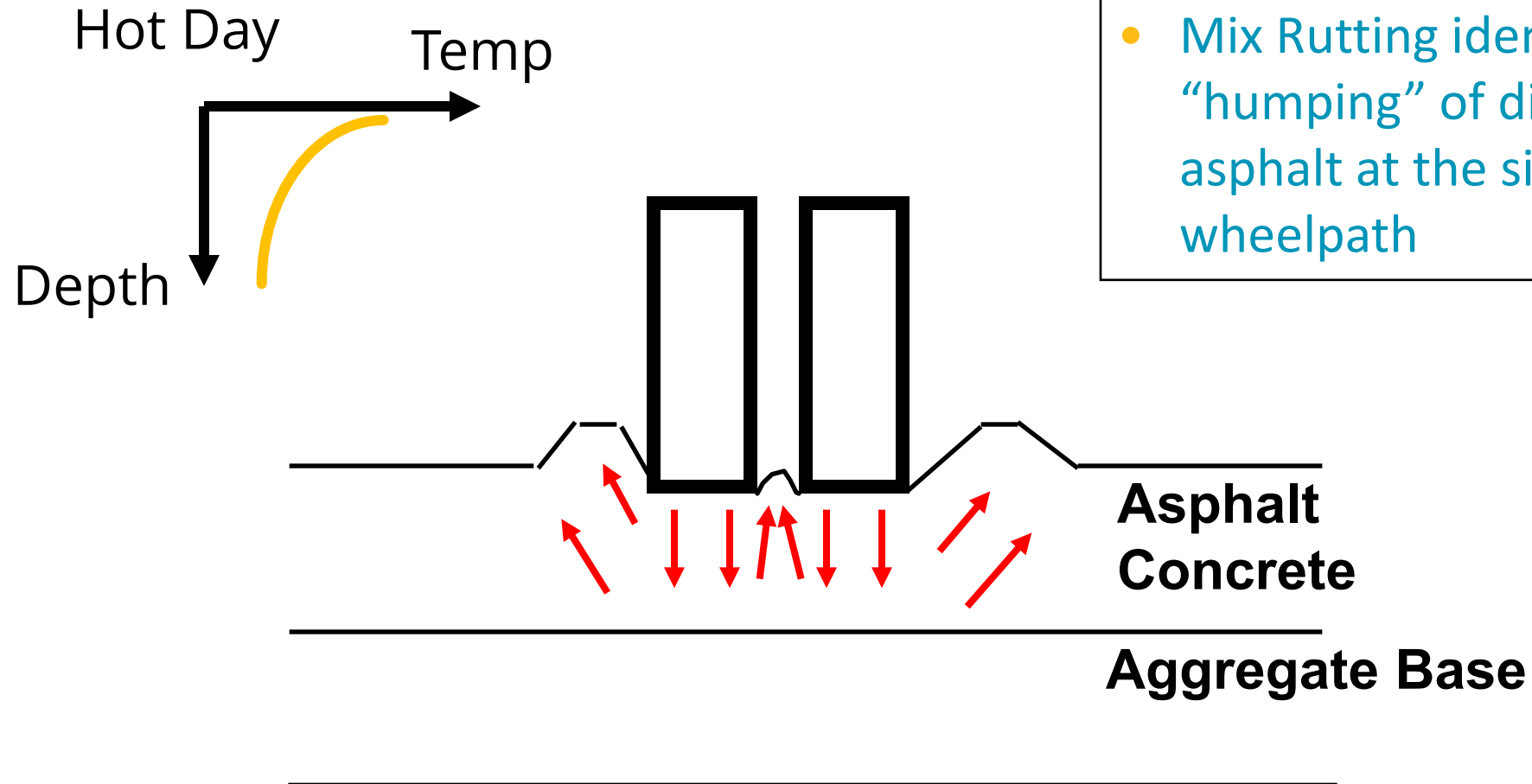
# Load-Related Fatigue Cracking: Strategies

- Fatigue cracking becomes alligator cracking, and eventually forms potholes
- Surface treatments will slow a little, but mostly helps with block cracking, not fatigue
- Will need to do periodic mill and fill with digouts of localized deep cracking
- Mill and fill may not be cost-effective once alligator cracking is extensive
  - Consider partial-depth (cold in-place recycling ) or full-depth reclamation (FDR) depending on crack and rutting depth
- Do not let wheel path cracking become extensive or must reconstruct



# AC/HMA Mix Rutting

- High shear stresses at edges of tires
- Asphalt softer under slow moving traffic
- Mix Rutting identified by “humping” of displaced asphalt at the sides of wheelpath



# AC/HMA Mix Rutting

- Poor compaction makes rutting happen faster
- Much more shearing
- Some due to more compaction from traffic
  - But only in wheel paths
  - Doesn't help with aging and block cracking
- Want stiffer binder, and/or with polymer or rubber



# Summary of Desired Mix Stiffnesses

- **Age related cracking leading to block cracking;** all asphalt pavements everywhere
  - Softer at intermediate and low temperatures in top 4 inches, particularly top 2 inches
  - Polymer and rubber modification help
- **Fatigue cracking;** only asphalt pavement with heavy vehicle loading
  - Softer if  $\leq 3$  inches
  - Stiffer in bottom 1.5 inches if  $> 3$  inches, keep top 1.5 to 2 inches soft
  - Even stiffer in bottom 4 inches if  $> 6$  inches, keep top soft
- **Rutting;** only asphalt pavement with heavy vehicle loading
  - Not too soft in the top 2 to 4 inches at high



Goldilocks, PE  
Checking asphalt stiffnesses



# **RAP and Local Government Asphalt Mixes**

# What is RAP?

- **Reclaimed Asphalt Pavement**

- Millings from existing pavement
  - Streets and highways
  - Parking lots
- Plant wasted material
- Can include many mix designs, patches, or be primarily from one existing road
- Conventional, rubberized and polymer binders

- **Aged**

- Amount of oxidation depends on age, climate, depth below surface, air void content (air permeability)



# Why Use RAP in HMA and RHMA?

- **Cost Effectiveness: can reduce cost for material producer and buyer**
  - Virgin binder costs a lot more than binder in RAP
- **Environmental Benefits: can reduce global warming potential and other environmental impacts**
  - Depending on transport, processing and use of recycling agents
- **Finite Resource Conservation: reduces use of finite aggregate sources**



# Cost effectiveness

- Asphalt binder:  
about  
\$600/ton
- Virgin  
aggregate:  
about \$40/ton
- RAP:  
about \$40/ton

| Material                   | %             | cost/ton | mat cost    |
|----------------------------|---------------|----------|-------------|
| virgin asphalt binder      | 5.0%          | \$600    | \$30        |
| virgin agg                 | 95.0%         | \$40     | \$38        |
| RAP (95% agg 5% binder)    | 0.0%          | \$40     | \$0         |
| <b>Total material cost</b> | <b>100.0%</b> |          | <b>\$68</b> |

| Material                   | %             | cost/ton | mat cost    |
|----------------------------|---------------|----------|-------------|
| virgin asphalt binder      | 4.3%          | \$600    | \$26        |
| virgin agg                 | 80.8%         | \$40     | \$32        |
| RAP (95% agg 5% binder)    | 15.0%         | \$40     | \$6         |
| <b>Total material cost</b> | <b>100.0%</b> |          | <b>\$64</b> |

| Material                   | %             | cost/ton | mat cost    |
|----------------------------|---------------|----------|-------------|
| virgin asphalt binder      | 3.8%          | \$600    | \$23        |
| virgin agg                 | 71.3%         | \$40     | \$29        |
| RAP (95% agg 5% binder)    | 25.0%         | \$40     | \$10        |
| <b>Total material cost</b> | <b>100.0%</b> |          | <b>\$61</b> |

| Material                   | %             | cost/ton | mat cost    |
|----------------------------|---------------|----------|-------------|
| virgin asphalt binder      | 3.0%          | \$600    | \$18        |
| virgin agg                 | 57.0%         | \$40     | \$23        |
| RAP (95% agg 5% binder)    | 40.0%         | \$40     | \$16        |
| <b>Total material cost</b> | <b>100.0%</b> |          | <b>\$57</b> |

# Environmental benefits

- [Using National Asphalt Pavement Association Calculator](#)
  - A1 is the materials contribution to Global Warming Potential in kg/short ton

| Mix                         | Agg   | Neat Binder | Rejuvenator | RAP | Mass Balance | A1 GWP/sh ton |
|-----------------------------|-------|-------------|-------------|-----|--------------|---------------|
| 0% RAP Unmodified           | 95    | 5           | 0           | 0   | 100          | 30.3          |
| 20% RAP Unmodified          | 76    | 4           | 0           | 20  | 100          | 24.4          |
| 40% RAP Unmodified w/ Rejuv | 56.96 | 3           | 0.042       | 40  | 100          | 20.0          |

# Finite resource conservation

- **Aggregate supplies are limited in many parts of the state**
- **Existing permitted quarries have limited supplies left**
  - Only Placer, Nevada, Sutter/Yuba, Fresno and Bakersfield areas have 50 year demand currently permitted
  - Some areas will run out by 2035 or sooner (San Diego County, San Fernando/Saugus/Newhall, San Bernardino, Palmdale, Ventura County)
- **Starting new quarries is difficult**
  - Typical time for permit process is about 10 years
  - About 50% probability that will be successful after 10 years
- **Importing aggregate**
  - Increases costs
  - Increases environmental impacts

## AGGREGATE SUSTAINABILITY IN CALIFORNIA

Fifty-Year Aggregate Demand Compared to Permitted Aggregate Reserves

By

John P. Clinkenbeard (PG #4731)  
and Fred W. Gius (PG #7788)

2018

Contributions By:  
Matt O'Neal, Joshua Goodwin  
and Lawrence L. Busch

GIS Design and Map Layout By:  
Milton Fonseca



### LEGEND

- 50-year demand that will not be met by existing permitted reserves.
- Permitted aggregate reserves.
- 50-year demand is < 200 million tons.
- 50-year demand is > 200 to 500 million tons.
- 50-year demand is > 500 to 800 million tons.
- 50-year demand is more than 800 million tons.

### Examples

- 50-year demand for aggregate is 100 million tons; permitted reserves total 25 million tons of the 50-year demand.  
25/100 Million Tons (permitted reserves/ 50-year demand)  
11 to 20 Years (years of permitted reserves remaining)
- 50-year demand for aggregate is 510 million tons; permitted reserves are greater than or equal to the 50-year demand.  
550/510 Million Tons (permitted reserves/ 50-year demand)  
More Than 50 Years (years of permitted reserves remaining)

Areas With Short Term Aggregate Supply

- < 10 years of permitted reserves remaining in the study area.

Aggregate Production Areas  
(Symbols represent one or more aggregate mines, tonnage represents 2016 annual production)

- < 0.5 Million Tons per Year
- > 0.5 - 1.5 Million Tons per Year
- > 1.5 - 3 Million Tons per Year
- > 3 - 5 Million Tons per Year
- > 5 Million Tons per Year

### Population

1 Dot = 100 Persons  
(based on 2010 Census Data)

- City
- Interstate Route
- U.S. Route
- State Route
- Primary Highway
- Secondary Highway
- County Boundary



0 10 20 40 60  
Miles

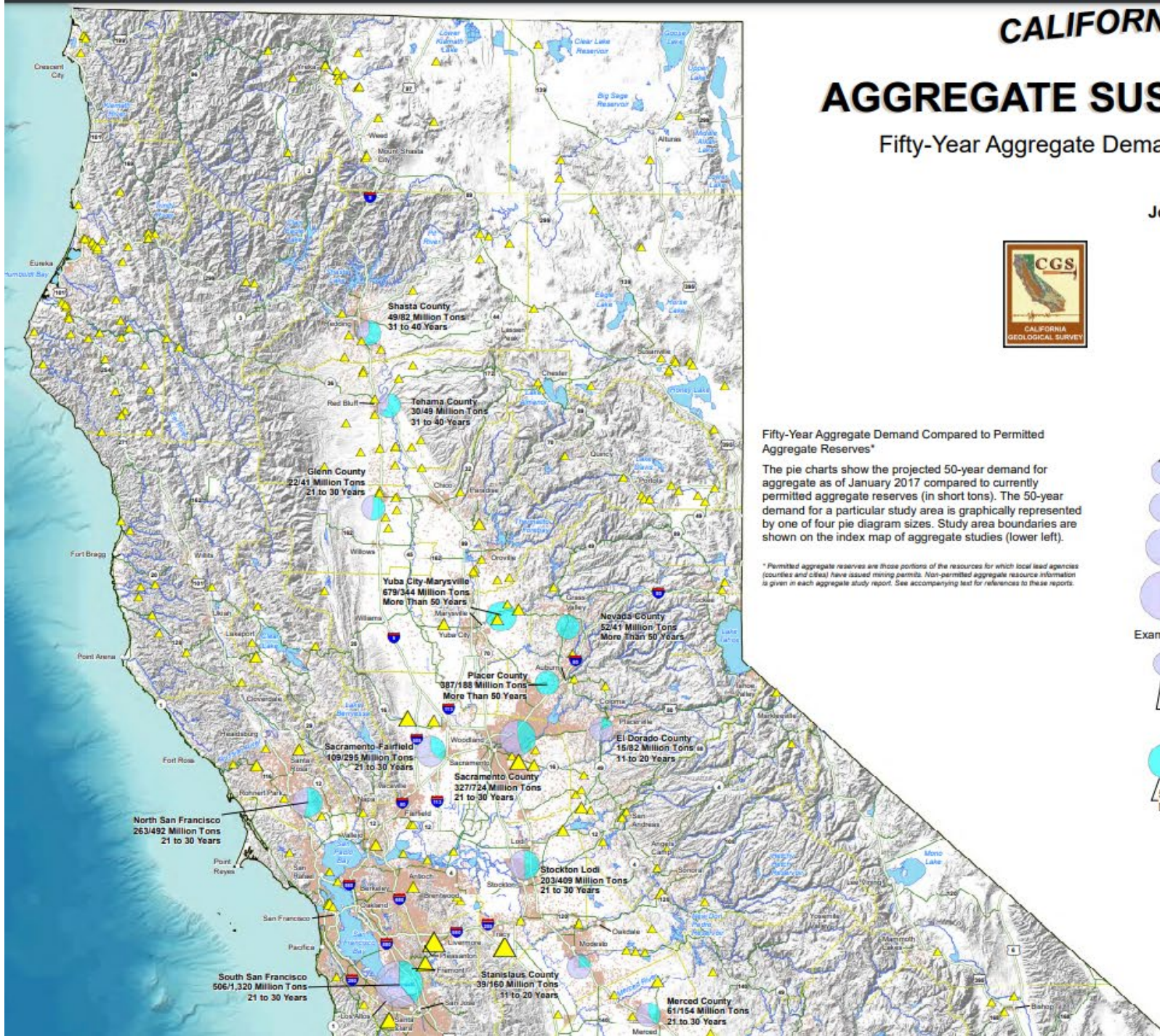
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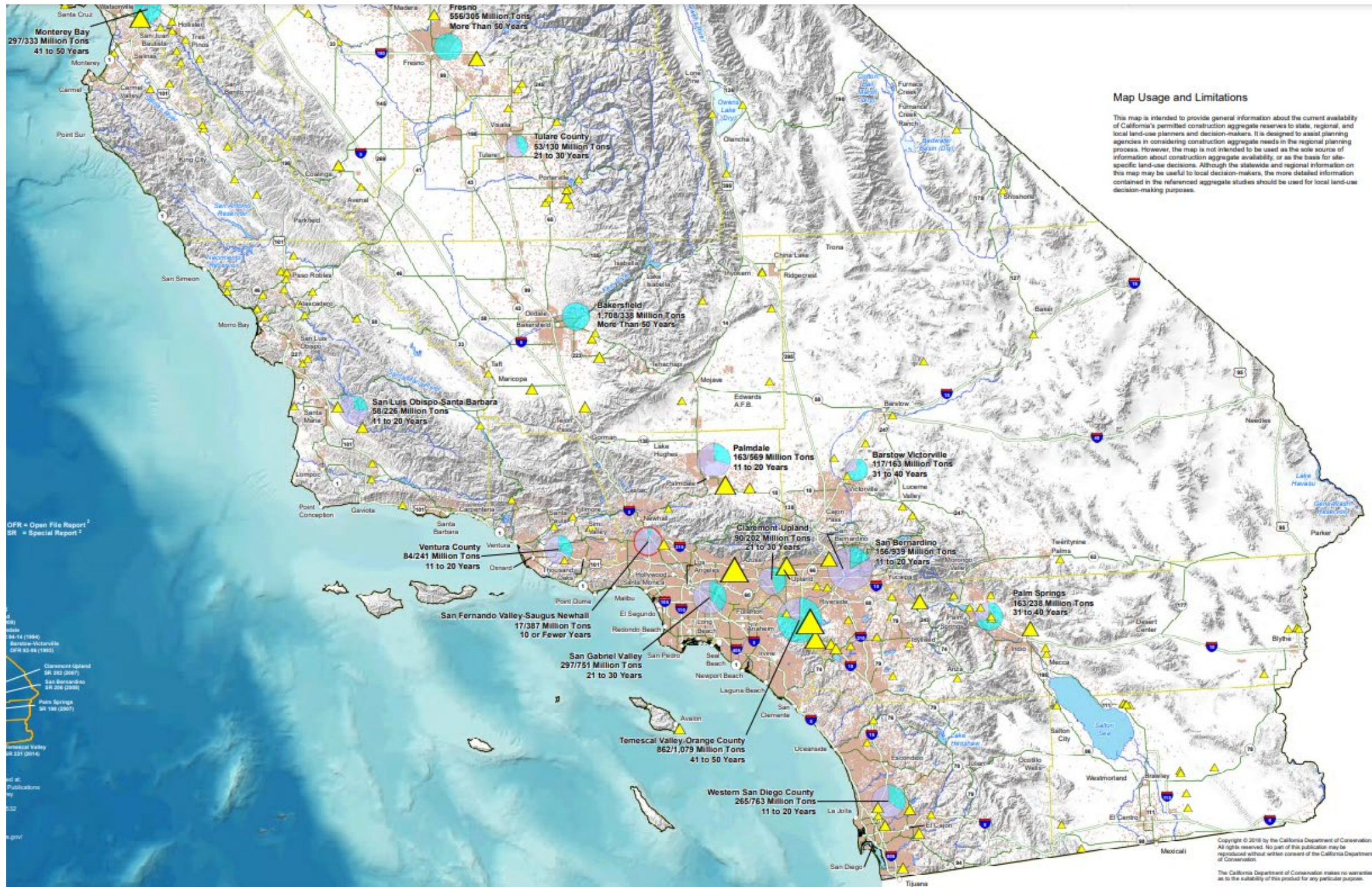
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### Fifty-Year Aggregate Demand Compared to Permitted Aggregate Reserves\*

The pie charts show the projected 50-year demand for aggregate as of January 2017 compared to currently permitted aggregate reserves (in short tons). The 50-year demand for a particular study area is graphically represented by one of four pie diagram sizes. Study area boundaries are shown on the index map of aggregate studies (lower left).

\* Permitted aggregate reserves are those portions of the resources for which local lead agencies (counties and cities) have issued mining permits. Non-permitted aggregate resource information is given in each aggregate study report. See accompanying text for references to these reports.





# RAP Availability

- **Proportional to population centers**
  - More milling in urban centers than rural
- **RAP availability varies across the state, reports are that it is:**
  - Somewhat limited in Sacramento area
  - Plentiful in Inland Empire
- **What are you seeing in your region?**



# What does RAP do in mixes?

- **Binder**

- With time at mixing temperatures RAP binder and virgin binder “blend”
- Blended binder is stiffer than virgin binder in proportion to amount and stiffness of RAP
- Does all the RAP binder blend?
  - Experiments indicate that a large proportion blends (80 to 100%)
  - Amount of blending increases with amount of time at high temperatures
  - Amount of blending appears to increase with use of rejuvenating agent (RA)

- **Aggregate**

- RAP aggregate replaces virgin aggregate in gradation

- **Rejuvenating agent can be used: increases amount of blending and softens blended binder**

- RA is added to the binder before mixing
- Used when going to a softer virgin binder still results in too stiff a mix

# Is it beneficial to include RAP in new mixes?

- **Age related cracking leading to block cracking;** all asphalt pavements everywhere
- Softer at intermediate and low temperatures in top 4 inches, particularly top 2 inches
- **Do not let RAP increase the mix stiffness at low, intermediate temperatures**
- **Fatigue cracking;** only asphalt pavement with heavy vehicle loading
- Softer if  $\leq 3$  inches
- Stiffer in bottom 1.5 inches if  $> 3$  inches, keep top 1.5 to 2 inches soft
- Even stiffer in bottom 4 inches if  $> 6$  inches, keep top soft
- **RAP can help increase the mix stiffness for bottom of thicker asphalt layers**
- **Rutting;** only asphalt pavement with heavy vehicle loading
- Not too soft in the top 2 to 4 inches at high temperatures
- **RAP can help increase mix stiffness at high temperatures**



# Engineering the performance of new mixes using RAP

- RAP is one of the tools that can be used to engineer the Goldilocks stiffness of the mix
- Main tools:
  - Blended binder PG grading
  - Hamburg Wheeltrack test for rutting
  - Likely in the future: IDEAL-CT mix test
    - Mix stiffness using indirect tensile strength (IDEAL-CT protocol)
    - Mix age related cracking using IDEAL-CT cracking index



# Blended Binder Performance (PG) Grading

- “True PG grade” = the PG grade of the blended RAP and virgin binder
- Find the ranges of RAP that result in meeting the PG temperature requirements:
  - Minimum high temperature stiffness
  - Maximum intermediate temperature stiffness (after aging)
  - Maximum low temperature and creep modulus (after aging)
- Can increase the RAP content by using a softer virgin binder
  - Current Caltrans and Greenbook specifications require one “step down” lower virgin PG binder for 15 to 25% RAP without doing the testing
  - Example: use PG 58-22 instead of PG 64-16

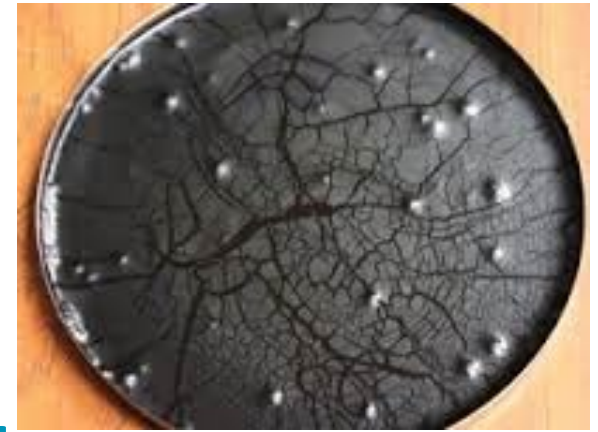
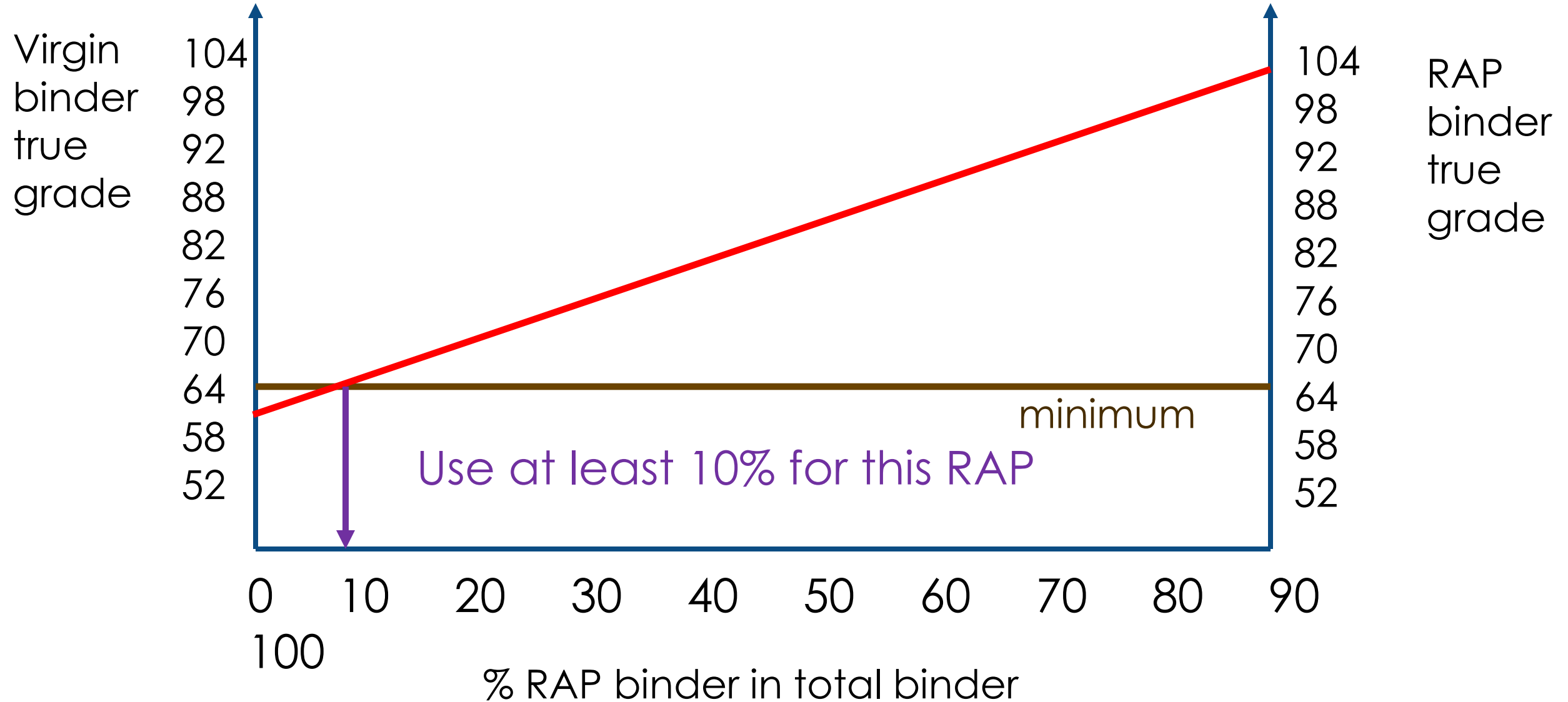


Image: Rutgers University

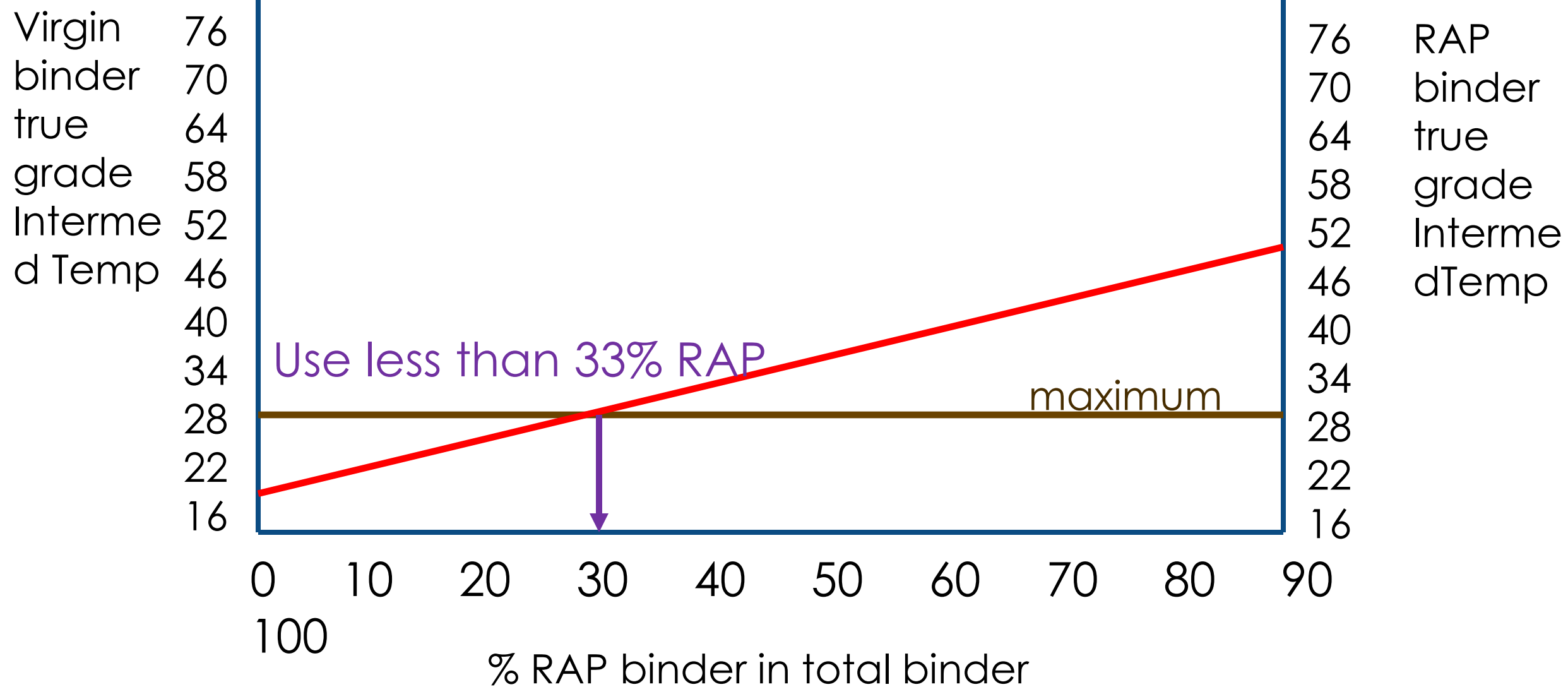
# Blended binder PG grading: high temperature

PG 64-16 requires minimum 64°C, how much RAP if use PG58-22



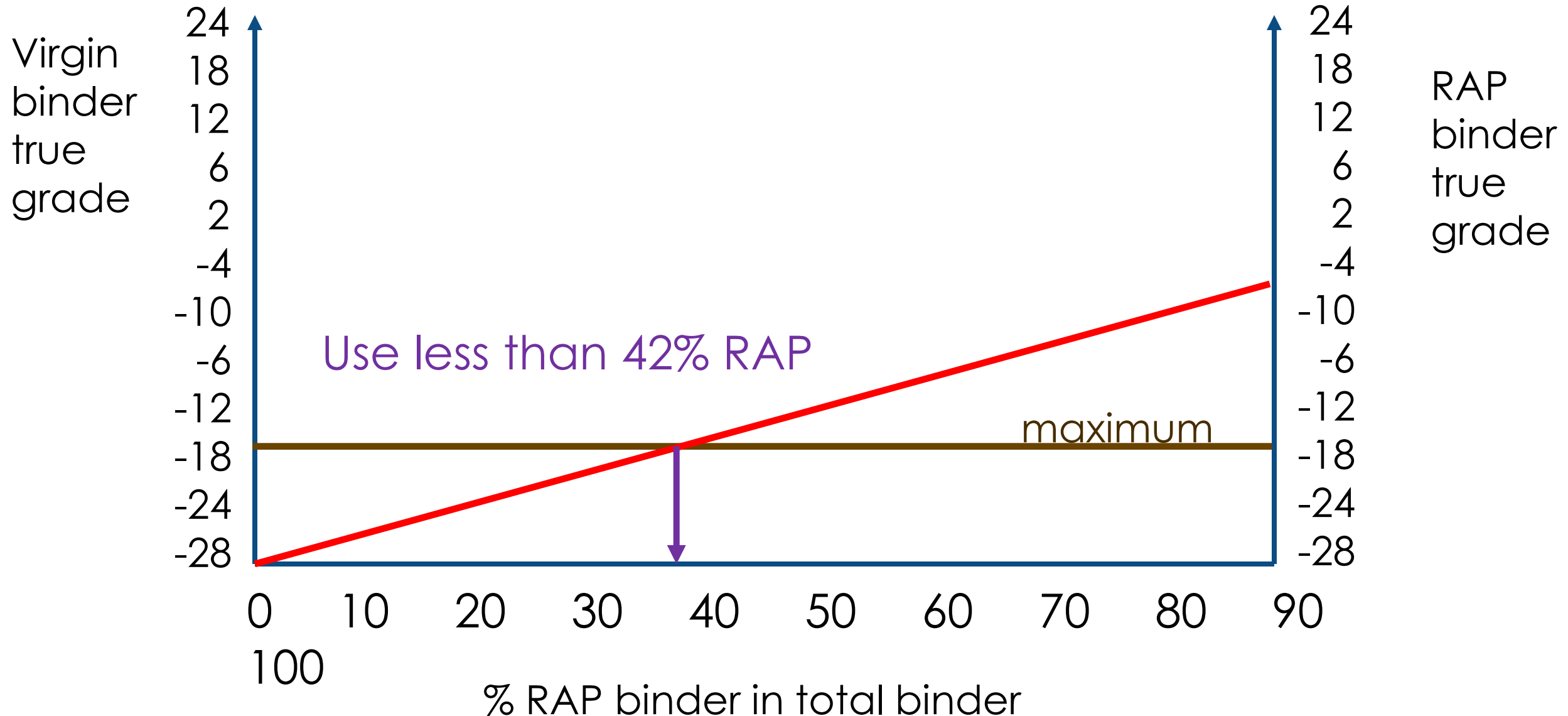
# Blended binder PG grading: intermediate temperature

PG 64-16 requires maximum 28°C; , how much RAP if use PG58-22



# Blended binder PG grading: low temperature

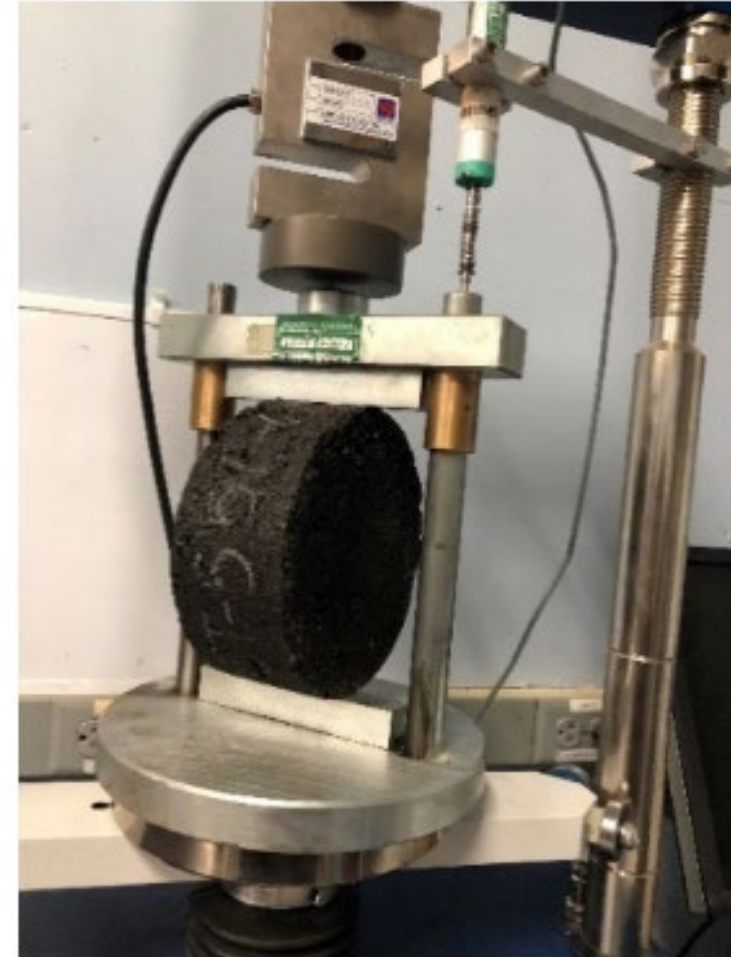
PG 64-16 requires maximum -16°C for critical property (m, S); how much RAP if use PG58-22



# Potential Future Test in Specs: IDEAL-CT test

ImageUCPRC,  
<https://escholars.hip.org/uc/item/52d1d1q5>

- Uses simple load frame
- Superpave compacted test specimen
- Run at 25C (77F)
  - No temperature cabinet needed for testing
- Run in two aging conditions:
  - Plant sampled
  - Plant sampled + 20 hours at 100C (212F) in the oven (medium term oven aging [MTOA])
- Gives two results from one test:
  - Strength correlated to stiffness
  - IDEAL-CT index related to age related cracking



# Rejuvenating/Recycling Agents

- Chemicals that help with blending of virgin and RAP binders
- Several types: tall oil, vegetable oil, petroleum distillate
- Included in binder blend when doing blending charts
- Contractors will consider use when >25% RAP or really aged RAP to help meet required binder properties if step down binder not enough
  - These are costly, so contractors try to limit their use
- **IDEAL-CT testing helps check if they are working**
  - IDEAL-CT strength will be too soft if RAP binder hasn't blended



Image: TAMU  
<https://tti.tamu.edu/researcher/paving-the-way-tti-pavement-research-provides-economic-environmental-benefits/>

# Summary of Effects of RAP on Local Government Mixes

- RAP can help reduce cost and environmental impact
- AB 2953 requires following Caltrans specifications for RAP content or have a public hearing why not following
  - There is a new bill that does not allow opt out
  - Caltrans does not use HMA on the surface, local govt does
  - Use of RAP in aggregate base is successful if meet CT specs
- RAP improves rutting resistance but can hurt age related cracking; Caltrans specs address through binder replacement limits and use of step down virgin binder (PG64-16 to PG58-22)
  - The limiting of the high temperature grade is being questioned
- Working knowledge of basic concepts helps to understand the mixes being delivered, look at the JMF
- Consider use of CCPIC mix specification
  - Results in higher binder contents for pavement with few or no heavy vehicles, helps with aging
  - Can include Caltrans RAP specification

Caltrans, industry and UCPRC working on further development of higher RAP mixes

## Goals:

- Same or better performance
- Lower life cycle cost
- Lower environmental impact
- Constructable

# What to Do Now

- Ask for Job Mix Formula sheet from mix supplier
- Check to see:
  - Is RAP in the mix?
  - How much?
  - What is the virgin binder grade?
  - Is there recycling/rejuvenating agent in the mix?
- For surface mixes, try to limit the amount of RAP below 10%
- If there is more than 15% and less than 25% the binder grade should be reduced 6C
  - PG58-22 instead of PG64-16
- Always get good compaction, it slows aging
- Use the CCPIC HMA spec for residential and arterial streets

# Comments on Some Recycled Materials in Pavement

- Recycled tire rubber
  - Some misconceptions about gap vs dense vs open gradations
- Reclaimed Asphalt Pavement (RAP)
- Recycled plastic in asphalt
- Recycled Concrete Aggregate (RCA)

# AB 2953 Excerpts

*SECTION 1. Section 42704.6 is added to the Public Resources line 2 Code, to read:*

*42704.6 (a) To the extent feasible and cost effective, the department and a local agency that has jurisdiction over a street or highway shall use advanced technologies and material recycling techniques that reduce the cost of maintaining and rehabilitating streets and highways and that exhibit reduced levels of greenhouse gas emissions through material choice and construction method.*

*(b) Beginning January 1, 2024, a local agency that has over a street or highway shall, to the extent feasible and cost effective, apply standard specifications that allow for the use of recycled materials in streets and highways.*

*(c) Beginning January 1, 2024, and until January 1, 2027, the standard specifications described in subdivision (b) shall allow recycled materials at or above the level allowed in the department's [Caltrans] standard specifications that went into effect on October 22, 2018, line 12 for all of the following:*

*(1) Recycled base and subbase materials as set forth in Sections 25-1.02 and 26-1.02 of the department's standard specifications.*

*(2) Reclaimed asphalt pavement and other materials in asphalt as set forth in Section 39-2.02B of the department's standard specifications.*

*(3) Reclaimed aggregate, fly ash, returned plastic concrete, and other materials in concrete as set forth in Sections 90-1.02, 90-2.02, and 90-9 of the department's standard specifications.*

# Recycled Base and Subbase Materials:

## 2023 Caltrans vs. 2021 Greenbook

- *25-1.02B Class I, II, and III Aggregate Subbase* is comparable to *200-2.6, Select Subbase*
  - SS has a slightly higher Sand Equivalent requirement (20 vs. 18).
  - SS does not list reclaimed processed LCB or CTB as a component material.
- *26-1.02B Class 2 Aggregate Base* is comparable to *200-2.4, Crushed Miscellaneous Base*
  - CMB has the same R-Value requirement, 78, but a much higher minimum SE, 35 vs. 22.
  - CMB allows up to 3% brick.
  - CMB limits gravel particles retained on the No. 4 sieve to 15% or less
  - CMB does not list reclaimed processed LCB or CTB as a component material.

# Recycled Base and Subbase Materials:

## 2023 Caltrans vs. 2021 Greenbook

- *26-1.03B Class 3 Aggregate Base* is comparable to *200-2.5, Processed Miscellaneous Base*
  - PMB has a much higher R-Value requirement (60 vs. 50)
  - PMB has a slightly higher SE requirement (20 vs. 18)
  - PMB allows crushed porcelain and up to 3% brick
  - PMB limits gravel particles retained on the No. 4 sieve to 75% or less
  - PMB does not list reclaimed processed LCB or CTB as a component material.
- ***Recommendations:***
  - Specify CMB or PMB
  - Include a Special Provision adding reclaimed processed LCB or CTB as allowable component materials

# Reclaimed Aggregate ... and Other Materials in Concrete

## 2023 Caltrans vs. 2021 Greenbook

- *Section 90* vs. *Subsection 201-1*
- *201-1 in the 2024 Edition* has been completely re-written and is consistent with *Caltrans Section 90*. *No Special Provisions needed*.
- *2021 and earlier Editions* contain some, but not all, of the provisions needed to satisfy AB 2953. *Special Provisions needed*.
  - Special Provisions will be difficult and time consuming to prepare.
  - *A general statement of intent to comply with AB 2953 may be simpler.*
  - Alternate Class (Table 201-1) mixes may be more commonly submitted.
  - For assistance, contact Nathan Forrest, P.E., Technical Director, California Nevada Cement Association, [Nathan.Forrest@cncement.org](mailto:Nathan.Forrest@cncement.org), (520) 235-0480

# References

- **AB 2953 (Public Resources Code 42704.5 and 42704.6):**  
[https://leginfo.legislature.ca.gov/faces/codes\\_displayText.xhtml?lawCode=PRC&division=30.&title=&part=3.&chapter=14.&article=1.](https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=PRC&division=30.&title=&part=3.&chapter=14.&article=1.)
- **National Asphalt Pavement Association, “Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage 2022”:**  
[https://go.asphaltpavement.org/is138?utm\\_content=292852875&utm\\_medium=social&utm\\_source=linkedin&hss\\_channel=lcp-2615788](https://go.asphaltpavement.org/is138?utm_content=292852875&utm_medium=social&utm_source=linkedin&hss_channel=lcp-2615788)
- **San Diego County Building Better Roads Guidance Document R-1, Reclaimed Asphalt Pavement (RAP) Use Up to 25%”:**  
[https://www.sandiegocounty.gov/content/dam/sdc/dpw/COUNTY\\_ROADS/bbr-documents/R-1\\_25Percent\\_RAP%20v5%2002202023.pdf](https://www.sandiegocounty.gov/content/dam/sdc/dpw/COUNTY_ROADS/bbr-documents/R-1_25Percent_RAP%20v5%2002202023.pdf)

# Questions?

- **John Harvey:** [jtharvey@ucdavis.edu](mailto:jtharvey@ucdavis.edu)
- **Erik Updyke:** [eupdyke@ucdavis.edu](mailto:eupdyke@ucdavis.edu)
- We are available for follow up meetings (free) in person or by web meeting