Understanding RAP and its Effect on Local Government Asphalt Mixes

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CEAC Policy Meeting

August 23, 2024

City and County Pavement Improvement Center

City and County Pavement Improvement Center

CCPIC Mission and Vision

- **Website**
  - 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

City and County Pavement Improvement Center

- **University of California Partners**
  - University of California Pavement Research Center (lead)
  - UC Berkeley ITS Tech Transfer
- **California State University Partners**
  - CSU-Chico, CSU-Long Beach, Cal Poly San Luis Obispo

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

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Pavement Engineering & Management Certificate: Curriculum

	Fundamentals	Hrs	Management	Hrs	Materials and Construction	Hrs	Design	Hrs
CORE 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	**Fundamentals, CORE**	14	**Management, CORE**	14	**Materials and Construction, CORE**	28.5	**Design, CORE**	0
ELECTIVE 32 required 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	**Fundamentals, ELECTIVE**	0	**Management, ELECTIVE**	12	**Materials and Construction, ELECTIVE**	50	**Design, ELECTIVE**	22
Total for Certificate 88.5 hours	**Fundamentals**	14	**Management**	26	**Materials and Construction**	78.5	**Design**	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 68.5 required	PD-01	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
	CCC-02	Pavement Preservation Treatments, Materials, Construction, Quality Assurance	8
	CCC-03	Pavement Construction Specifications and Quality Assurance	12.5
	CCC-26	Pavement Construction Management	8
	TS-10	Work Zone Safety	8
68.5	Core		68.5
	Electives (choose 12 hours from list below)		Hrs
ELECTIVE 12 required 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
	PD-02	Construction Inspection of Traffic Signals	8
	TS-18	Excavation and Trenching Safety	4
12	Electives		26
80.5	Total required for certificate		

CCPIC Classes Currently Open for Enrollment and Planned Through November 2024

Code	Title	Date	Location
CCB-21	Financing and Cash Flow for Pavement Networks	All the time	Online (Self-Paced)
CCI-02	Concrete Pavement Construction Inspection	All the time	Online (Self-Paced)
CCI-03	Construction Inspection of Concrete Street Improvements	All the time	Online (Self-Paced)
CCI-04	Pavement Preservation Construction Inspection	All the time	Online (Self-Paced)
CCI-06	Construction Inspection of Asphalt-Rubber Pavement Materials	All the time	Online (Self-Paced)
CCA-01	Introduction to Pavement Engineering and Management	October 9 - 16, 2024	Online
CCC-02	Asphalt Pavement Preservation Treatments, Materials, Construction and Quality Assurance	November 4 - 7, 2024	Online

Prepaid Training Packages

- **Agencies can buy a package of training hours and use it however they want to**

- 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.

Reclaimed Asphalt Pavement (RAP)

It’s not just black rock

City and County
Pavement Improvement Center

Outline

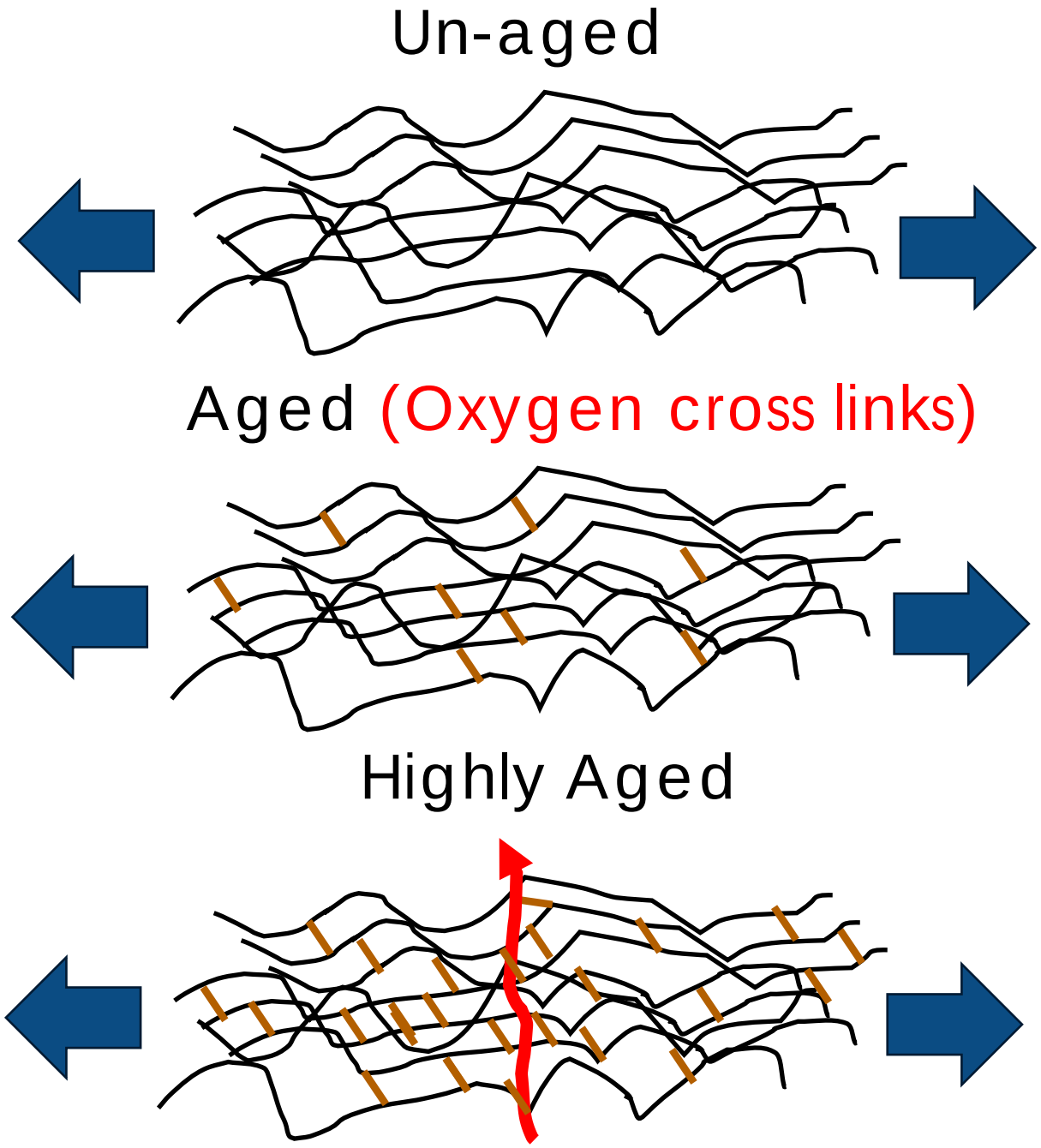
- Overview of Pavement Performance
- What is RAP?
- Why use RAP in new mixes?
- What does RAP do in new mixes?
- Is it beneficial to include RAP in new mixes?
  - RAP and pavement performance
- Engineering the performance of new mixes using RAP
- Proposed UCPRC recommendations for Caltrans
- Preliminary recommendations for Local Government

Review of Asphalt Pavement Distresses

- Aging and block cracking
- Fatigue cracking
- Rutting

Aging

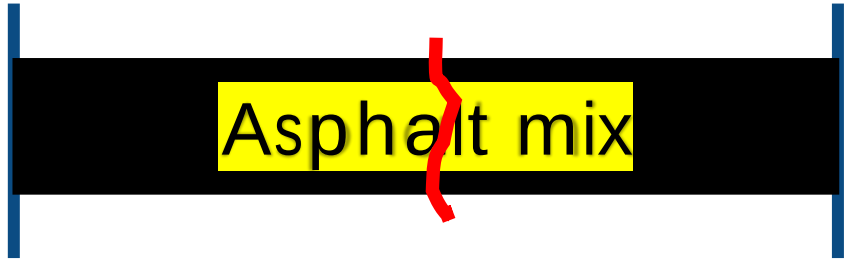
- **Aging primarily due to oxidation of hydrocarbon chains in binder**
  - Some loss of lighter components to air also, volatilization
- **Oxidation is cross-linking which makes chains less able to flow under stress, they can't relax the thermal contraction stresses**
- **Aging reaches a point where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

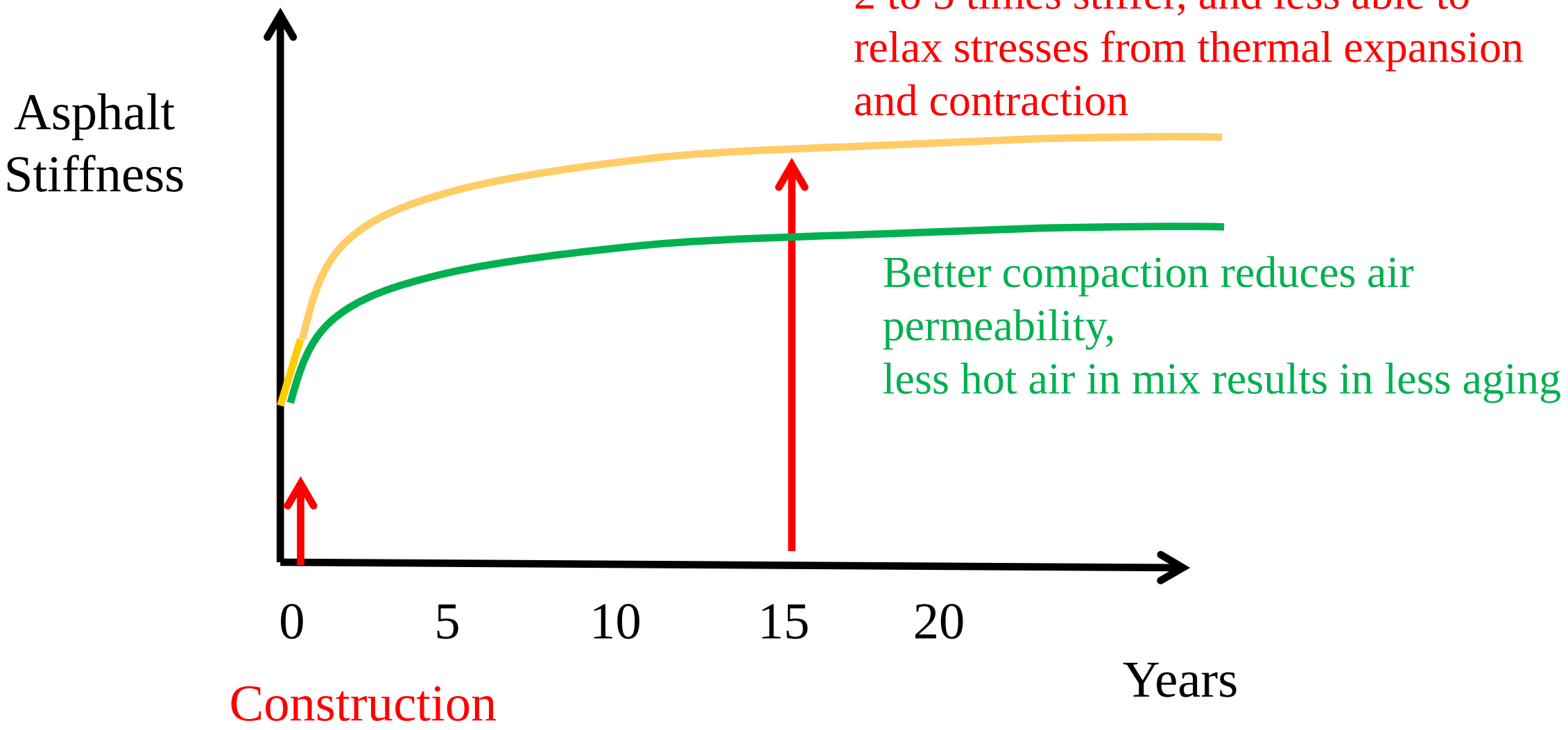
Restrained thermal contraction leads to cracking



Stiffness = stress/strain
Tensile strain comes from asphalt contracting when gets cold
Stress = Stiffness x strain, higher stiffness = higher tensile stress
When aging asphalt gets stiff enough, the tensile stress is higher than the tensile strength => transverse crack

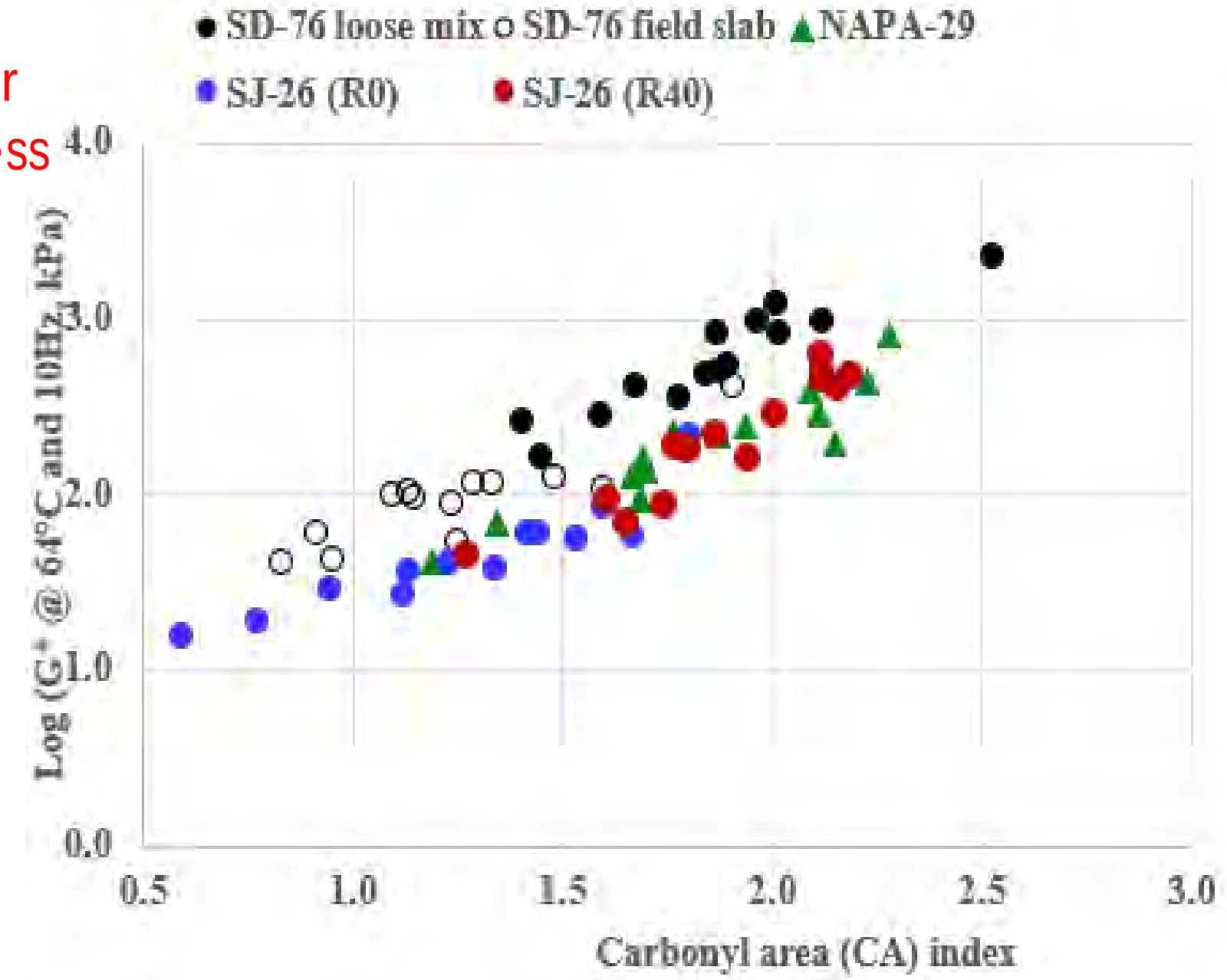
Aging

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



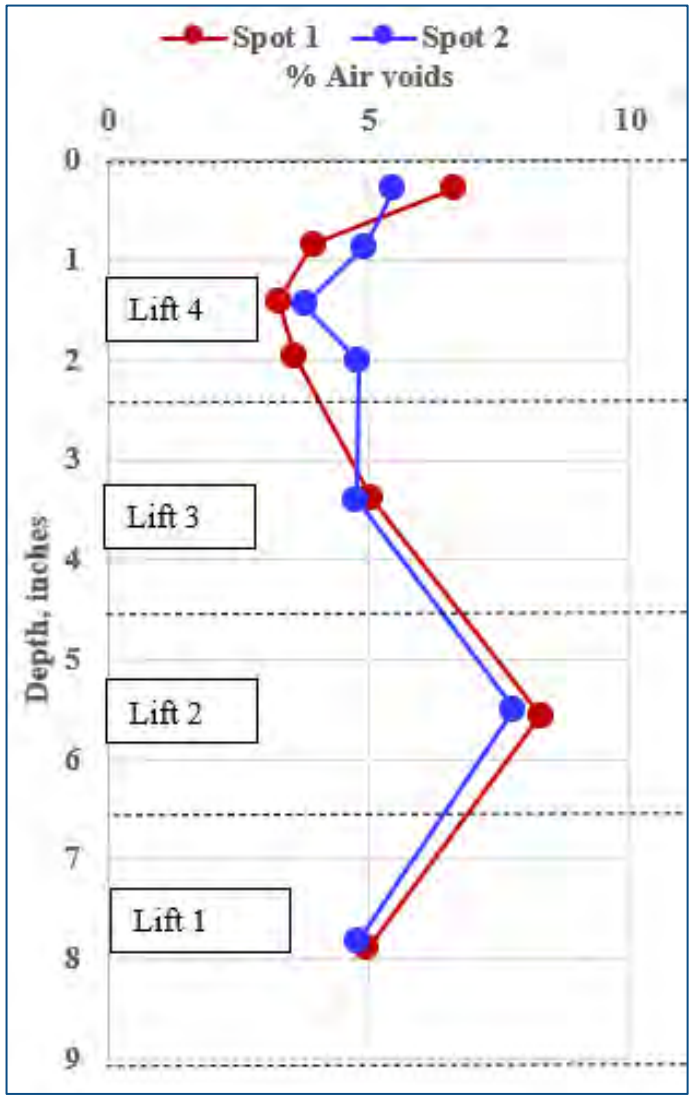
Aging

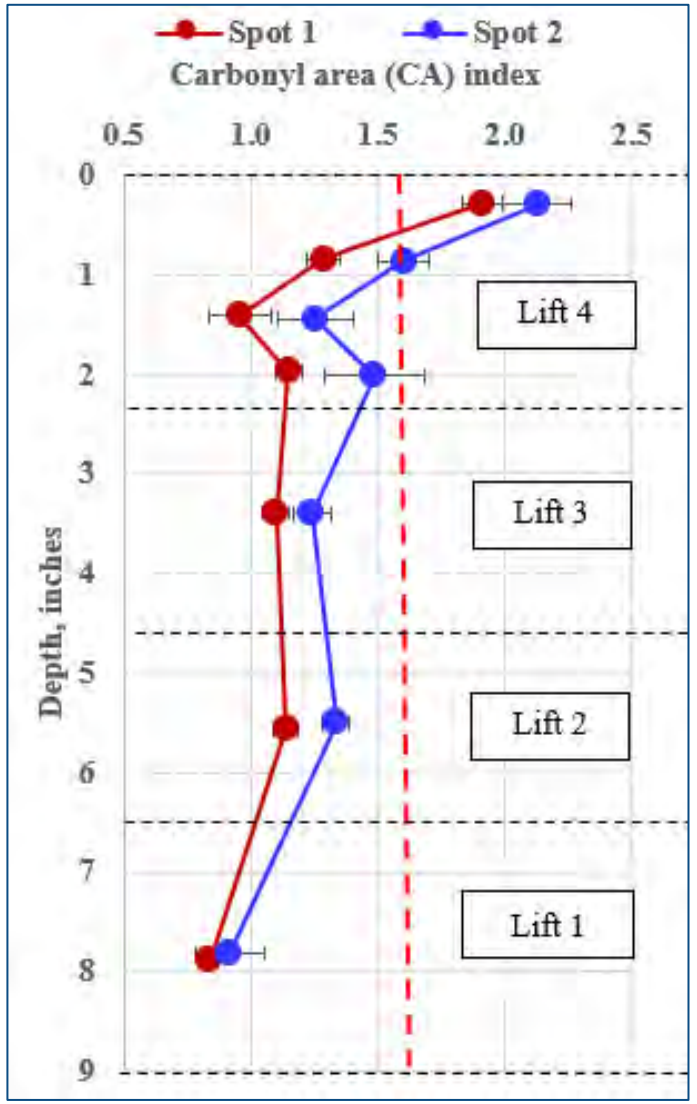
- Aging in the asphalt binder is measured by Carbonyl Index
- Carbonyl is the chemical result of oxidation
- Carbonyl content predicts stiffness increase with aging

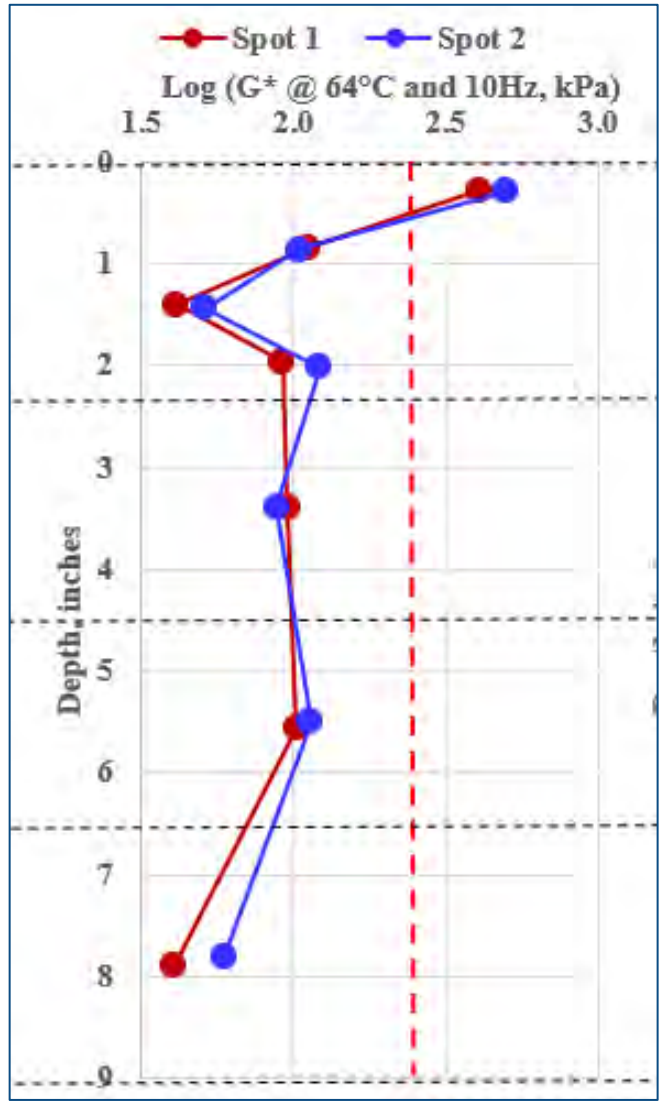


Aging

- On State highways nearly all aging in top 4 inches
- San Diego 76 after 6 years

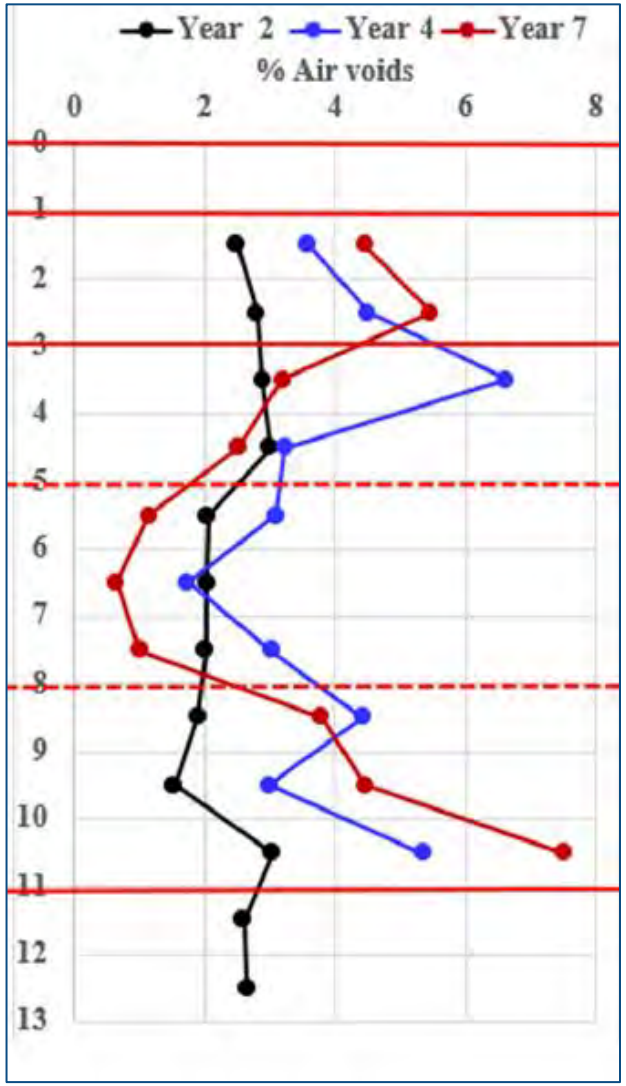


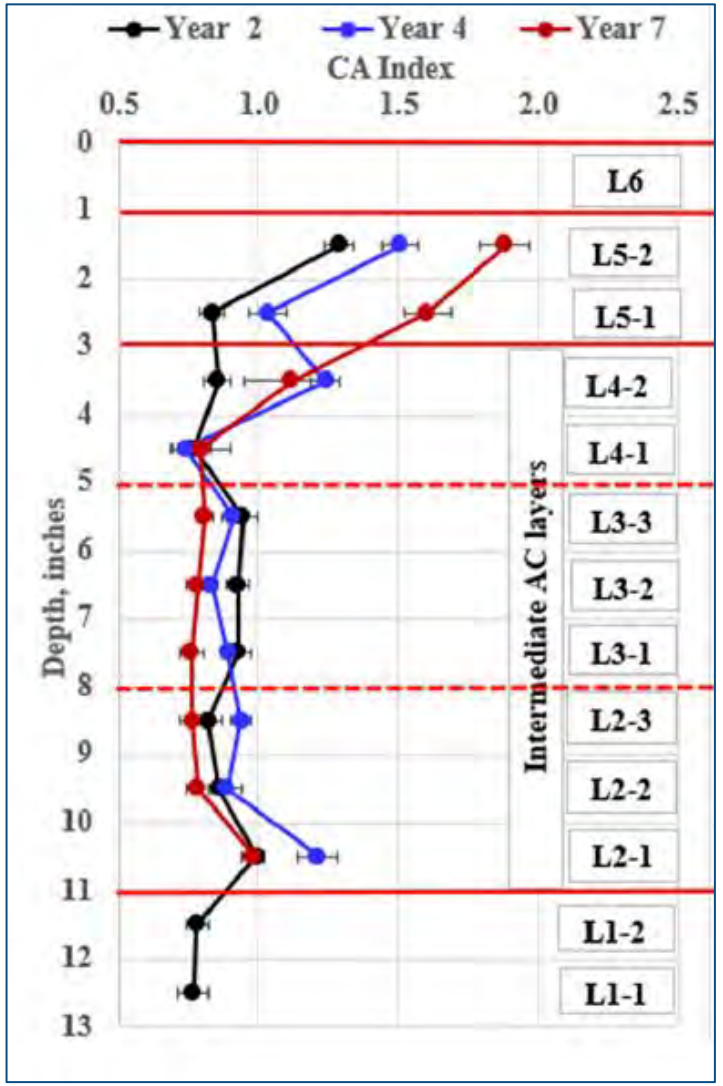


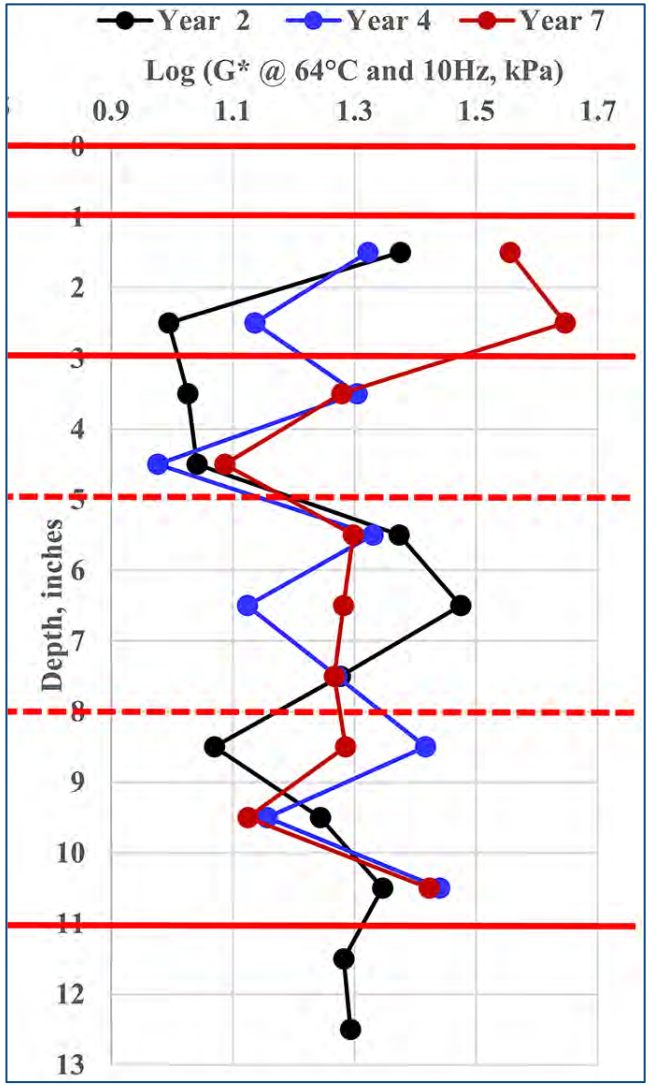


Aging

- On state highways nearly all aging in top 4 inches
- Tehama 5 after 2, 4 and 7 years



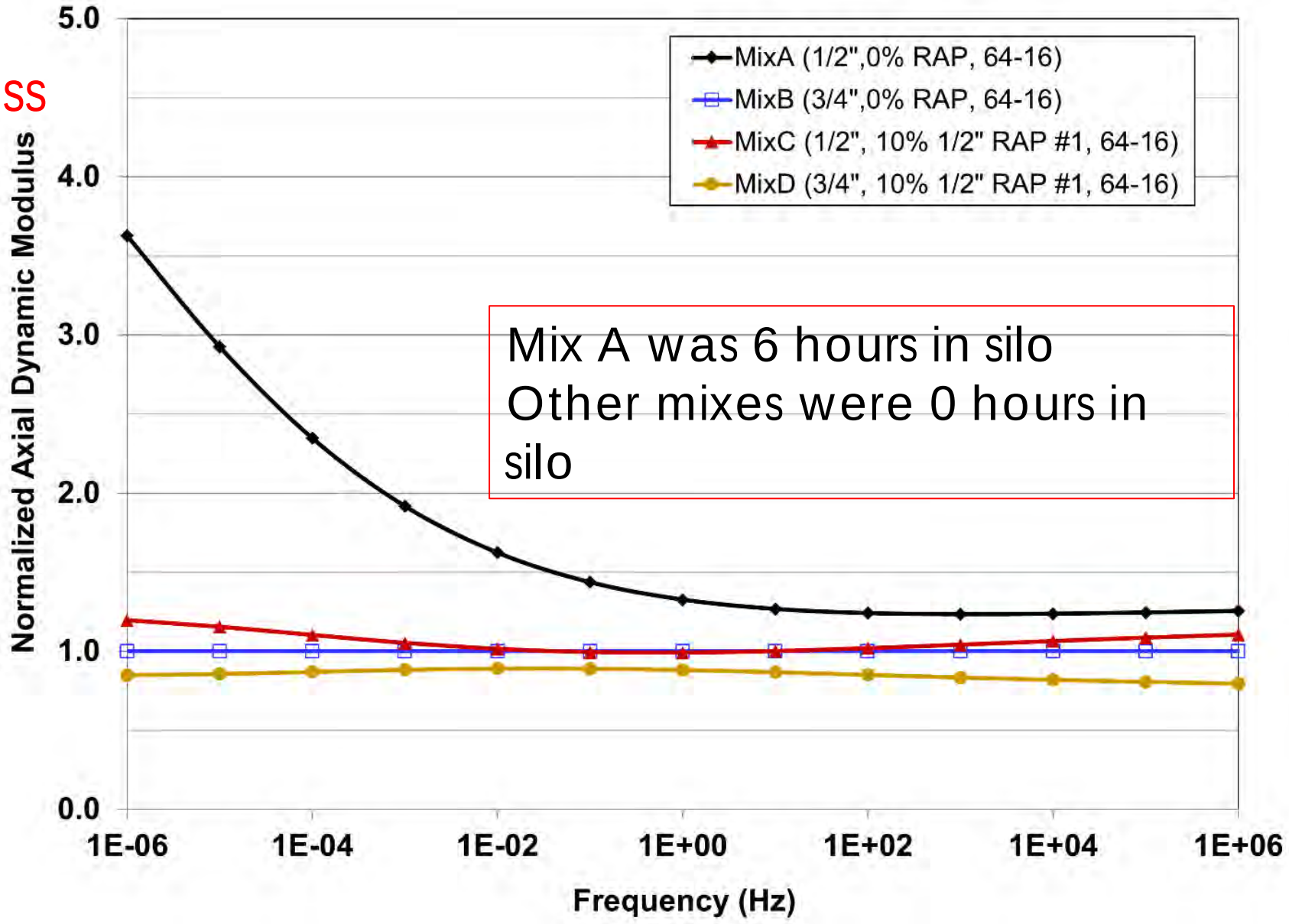




Aging

Mix Stiffness

- Oxidation also occurs at high temperatures in silos
- Mix is temporarily stored for 0 to 16 hours
- Siloing is typically needed to have smooth trucking and paving operation



Hot temps/slow loads Cold temps/fast loads

Image: world highways

Age-Related Cracking Leading to Block Cracking

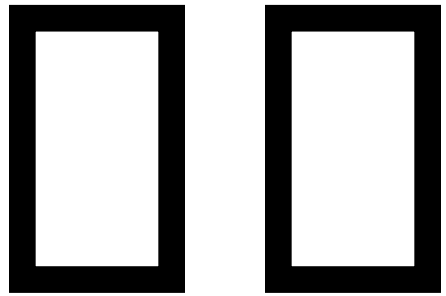
- **Top down**
  - Most aged at top
  - Most difference in temperature at top
- **May also be reflective cracking from underlying concrete pavement joints or shrinkage cracks in cement treated base**

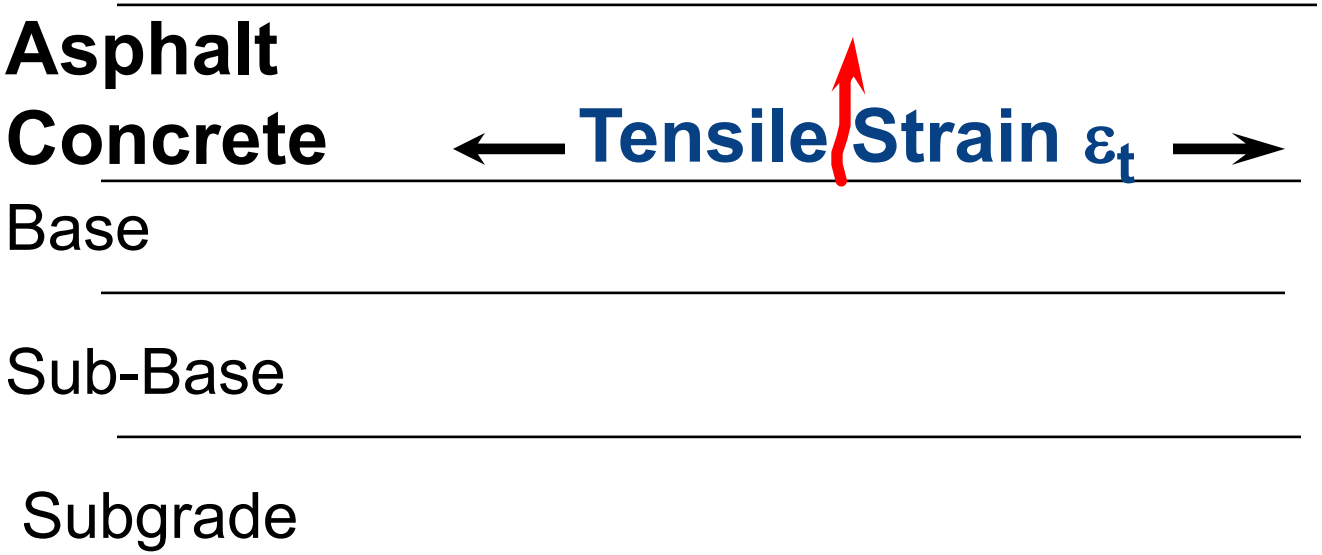
Age-Related Cracking: Strategies

- Use mixes that are softer at low and intermediatee 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 use perpetual 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





Load-Related: Bottom-Up Fatigue Cracking

- **Interaction** of asphalt concrete layer, support of underlying structure, materials selection, construction compaction
- **Traffic loading:**
  - Only the truck loads count, cars are too light
  - Slower speeds = longer durations = bigger strains
- **Environment:**
  - Temperature
  - Water sensitivity

Initial Wheel Path Cracking

- May be transverse or longitudinal
- Then the other direction cracks to create small blocks in a wheelpath
- **Fatigue only occurs in the wheelpaths of heavy vehicles (> F-450 or similar)**

Cracks Connect: Alligator Cracking

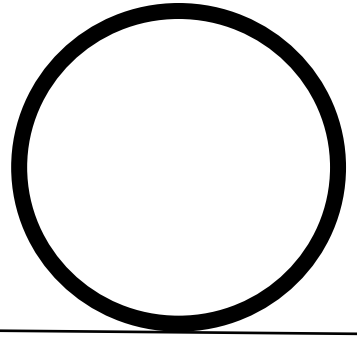
- Distress descriptions can be seen in the ***FHWA Distress Identification Manual***

Fatigue Cracking in Wheel Paths

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

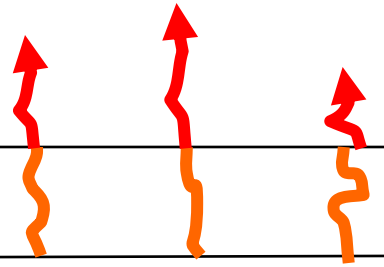
Reflective Fatigue Cracking

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



Asphalt Concrete

Cracked AC, PCC or CTB



Strains concentrated above cracks in layer below

Base

Sub-Base

Subgrade

Reflective Cracking of Underlying Block Cracking and Longitudinal Joint, 7 Years Old

Avoid putting longitudinal joints in the wheel paths!

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

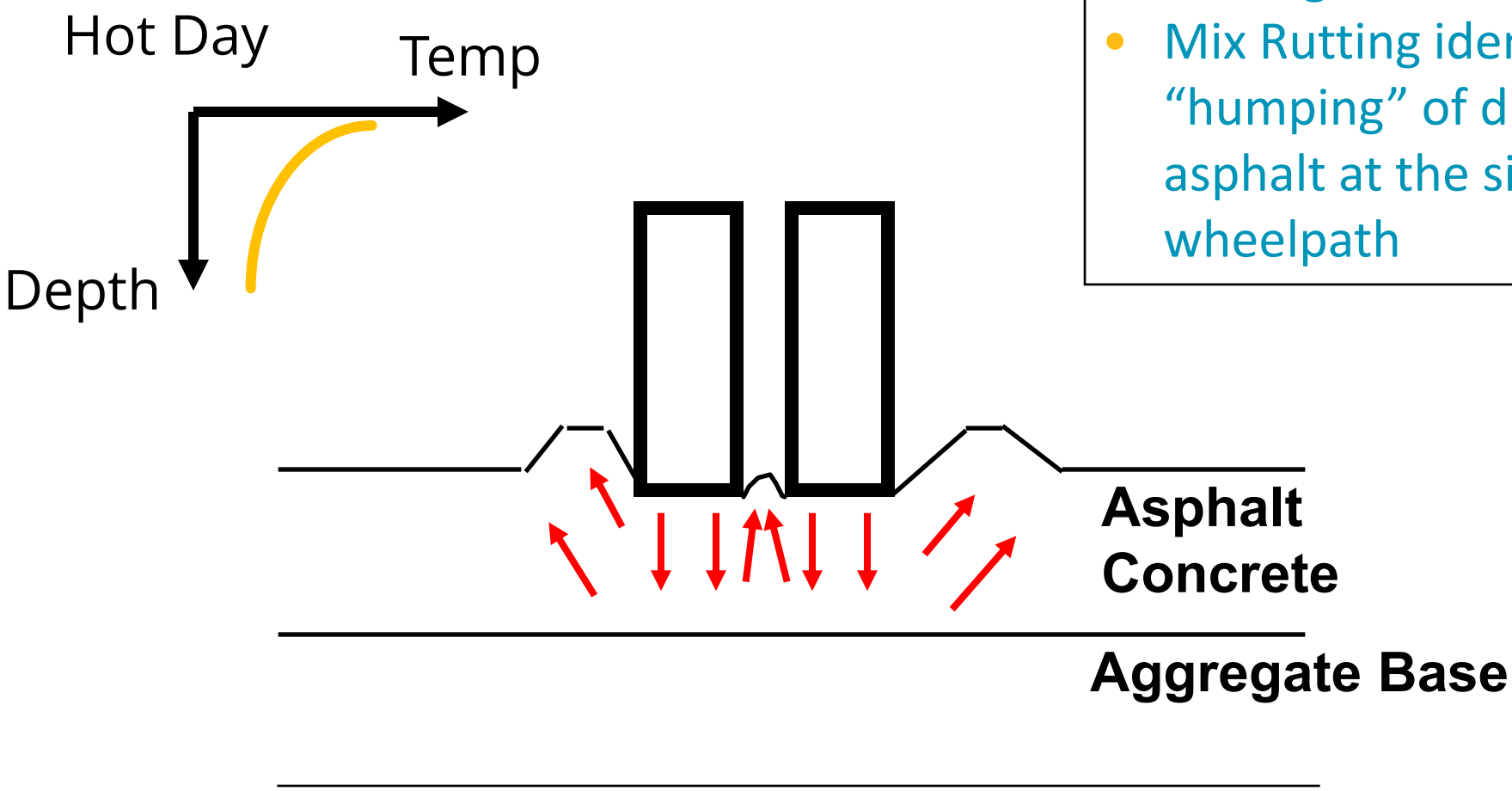
What Stiffness of Binder for Fatigue and Reflective Cracking?

- **It depends!**

- If the new asphalt thickness is ≤ 3 inches, will generally want softer binder
- If the new asphalt thickness is > 3 inches, will generally want stiffer binder
  - With increasing stiffness as thickness increases
- Why?
  - Thin asphalt layers do not influence the amount of bending, want to be able to bend with little resistance
  - Thicker asphalt layers influence the amount of bending, stiffer binder reduces bending
  - For intermediate thicknesses (3 to 6 inches) want not too stiff, not too soft
- PG binder specification is written for thin surface layers

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

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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 ≤ 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 temperatures

Goldilocks, PE Checking asphalt stiffnesses

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
Total material cost	**100.0%**		**$68**

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
Total material cost	**100.0%**		**$64**

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
Total material cost	100.0%		$61

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
Total material cost	100.0%		$57

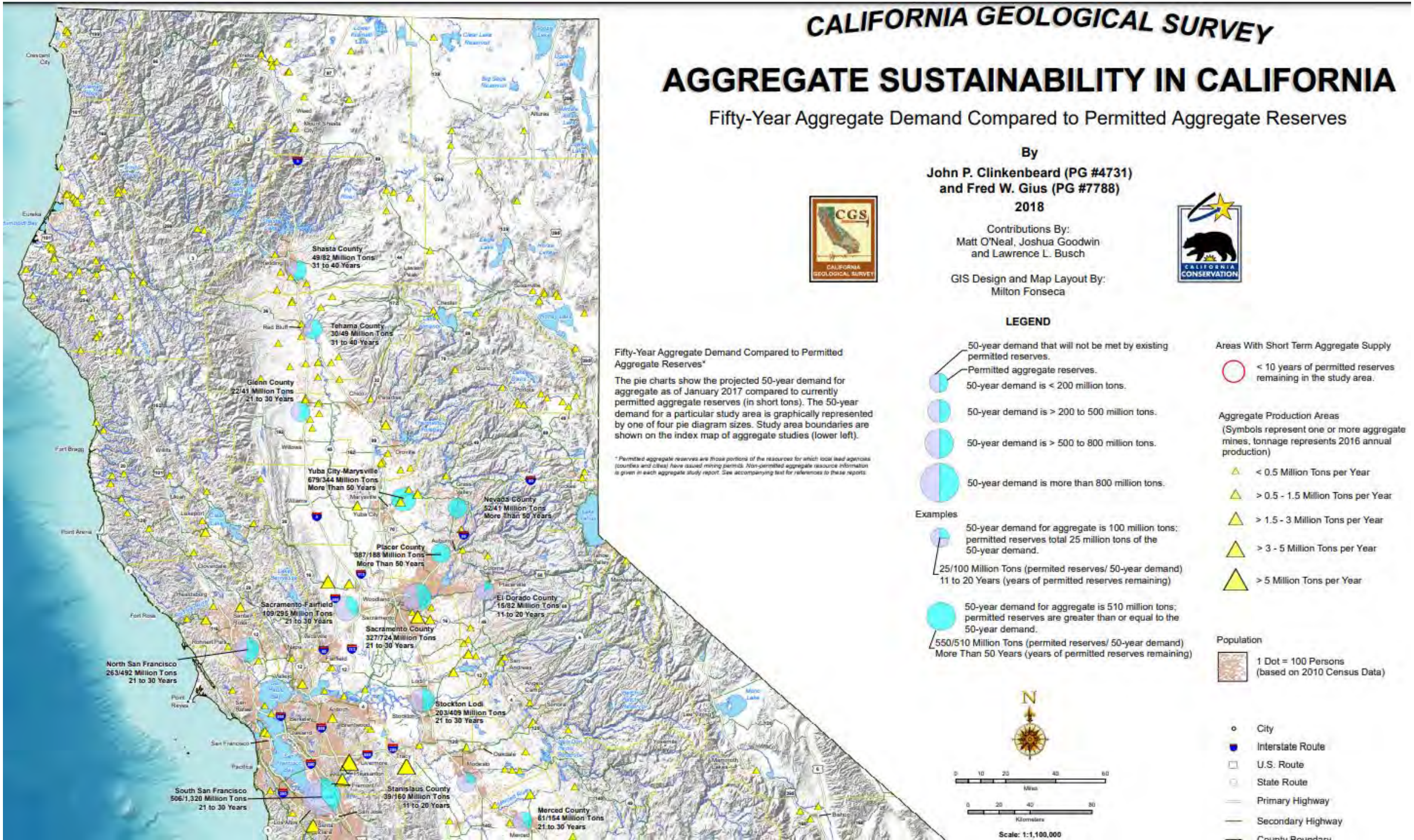
Environmental Benefits

- **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, Los Angeles County (San Fernando/Saugus/Newhall, Palmdale areas), San Bernardino County, 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



CALIFORNIA GEOLOGICAL SURVEY

AGGREGATE SUSTAINABILITY IN CALIFORNIA

Fifty-Year Aggregate Demand Compared to Permitted Aggregate Reserves

By

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and Fred W. Gius (PG #7788)

2018

Contributions By:
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and Lawrence L. Busch

GIS Design and Map Layout By:
Milton Fonseca

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.*

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 (permited 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 (permited 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

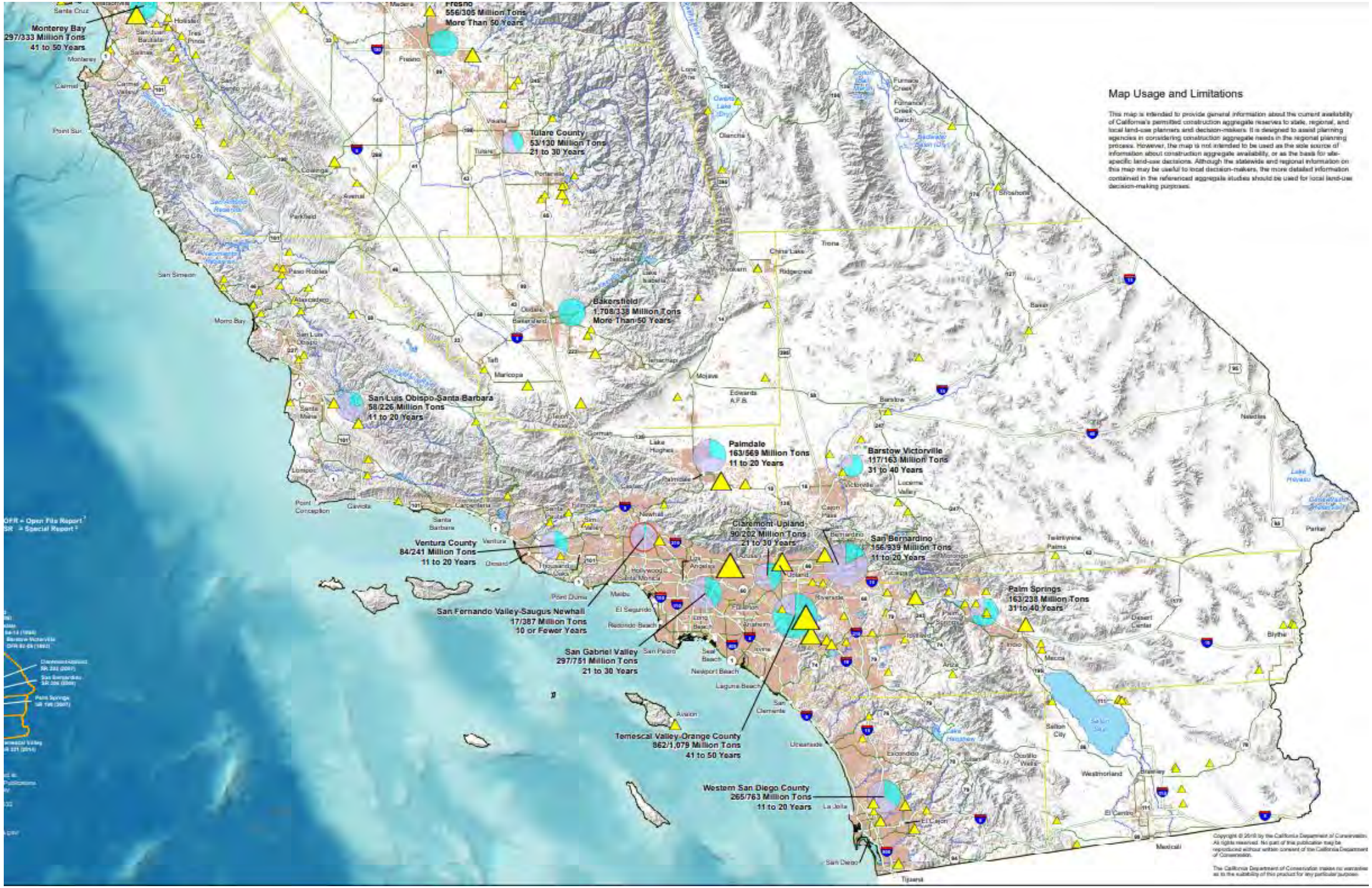
- 1 Dot = 100 Persons (based on 2010 Census Data)

N

0 10 20 40 60
Miles
0 20 40 80
Kilometers

Scale: 1:1,100,000

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

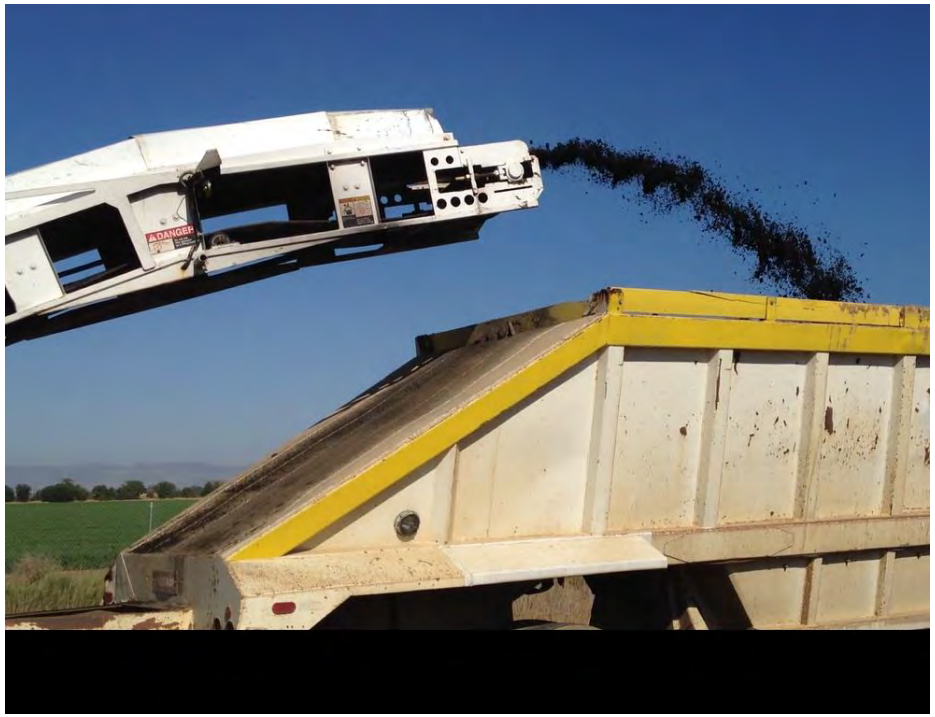


Map Usage and Limitations

This map is intended to provide general information about the current availability of California's permitted construction aggregate reserves to state, regional, and local land-use planners and decision-makers. It is designed to assist planning agencies in considering construction aggregate needs in the regional planning process. However, the map is not intended to be used as the sole source of information about construction aggregate availability, or as the basis for site-specific land-use decisions. Although the statewide and regional information on this map may be useful to local decision-makers, the more detailed information contained in the referenced aggregate studies should be used for local land-use decision-making purposes.

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?**



How is RAP Processed and Added to the Mix?

- **RAP can be in one stockpile**
- **RAP generally "fractionated" i.e. sieved into coarse and fine stockpiles as mix RAP contents increase**
  - Fine stockpile has higher binder content than coarse stockpile
- **RAP piles often have very good consistency**
- **Different RAP sources have different binder contents and stiffnesses**
  - Fractionating gives more consistent properties throughout each pile

Images FHWA
https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/11021/003.cfm

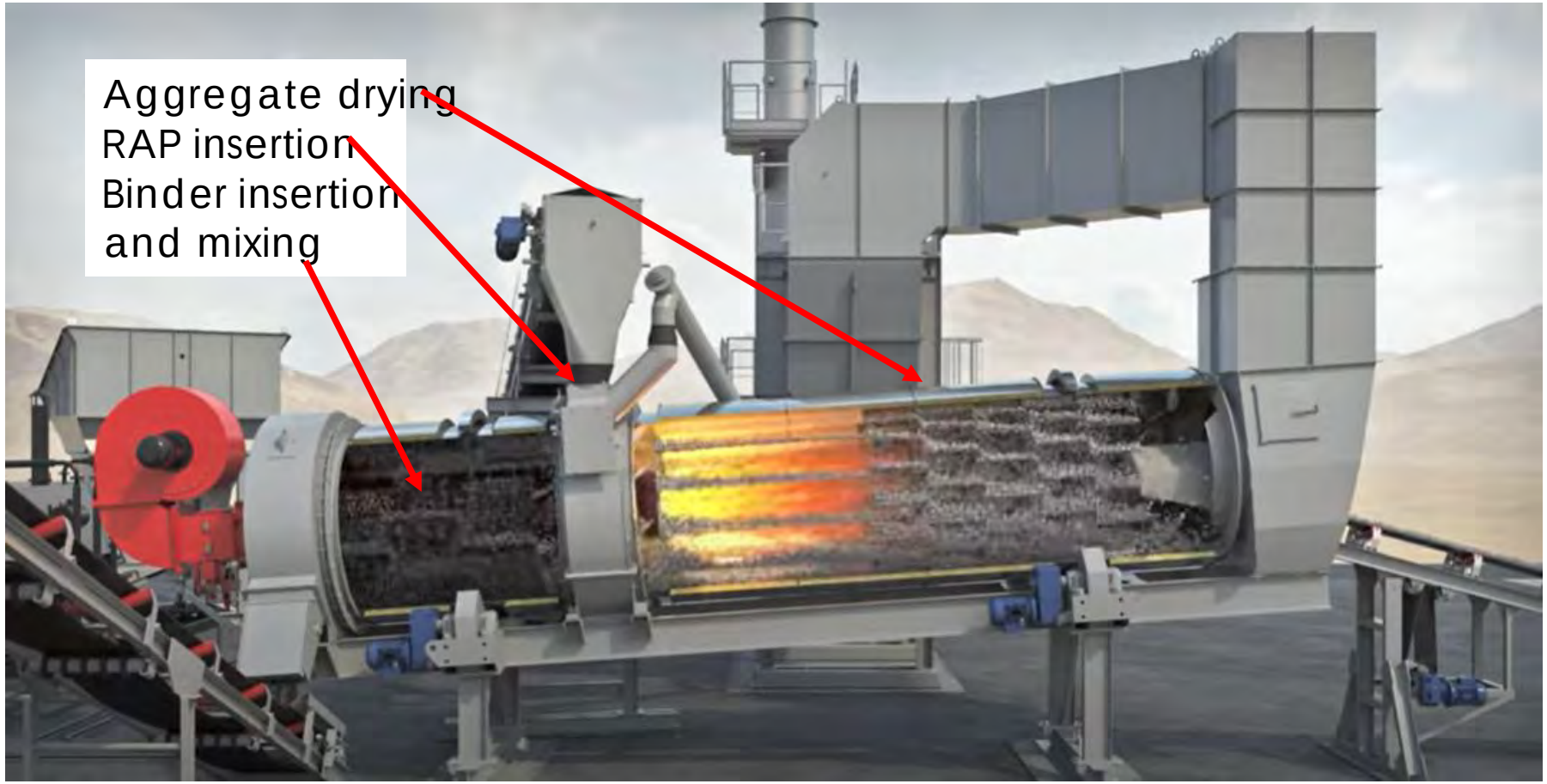
Coarse RAP

Fine RAP

How is RAP processed and added to the mix?

Image Amman Group
https://www.youtube.com/watch?app=desktop&v=QllO7McSpP4

- RAP is added to the drum after the aggregate heating flame through the “RAP collar”
- Aggregate is superheated to compensate for cooler RAP



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 a 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 one grade softer virgin binder still results in too stiff a mix
  - Adding too much RA or when not needed can result in rutting and compaction issues (too soft)

Is it beneficial to include RAP in new mixes?

- **Age-related cracking leading to block cracking;** all asphalt pavements everywhere
- Want mix that is 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 for asphalt pavement with heavy vehicle loading
- Want softer if total new asphalt thickness ≤ 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 for 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

- **In other words: want not too stiff and not too soft, which is different for different layers in the new asphalt**

Examples Under Current Caltrans Spec 39-2.02B(2)

- New asphalt layer(s) are ≤ 2.4 inches thick
  - Maximum 25% RAP substitution by dry weight of aggregate (updated statement)
  - If 15 to 25% RAP substitution then reduce binder grade by one grade
  - Use PG58-22 instead of PG64-16
  - *Comment: specification is an interim solution as Caltrans develops better engineering approaches for RAP*
- If new asphalt layer(s) are > 2.4 inches thick, example 6 inches
  - Same as above applies to top 2.4 inches
  - Below 2.4 inches (bottom 3.6 inches)
    - Can include up to 40% RAP binder replacement
    - No requirements on adjusting binder grade or other means to engineer binder
- ***Comment: Caltrans and industry with UCPRC support are working on updated engineering approaches for mixes with RAP***
- ***We will cover those in next slides***

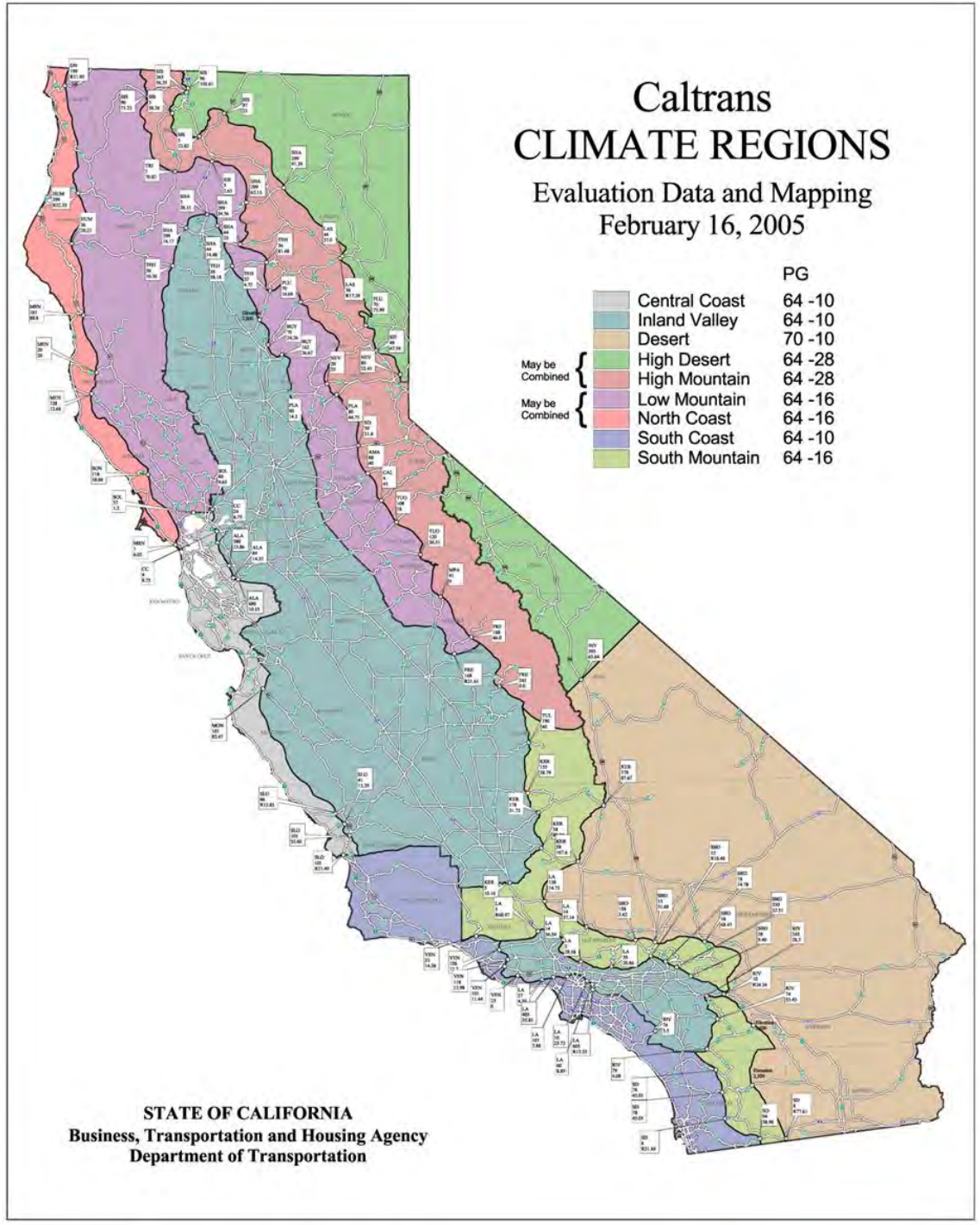
Engineering the Performance of New Mixes using RAP

- **RAP is one of the tools that can be used to engineer the Goldilocks stiffness of the mix**
- **Engineering the mix means ensuring that the stiffnesses of the mix at high, intermediate and low temperatures maximize its life**
  - Stiffness primary property, there are other properties, and must be constructable and cost-effective
- **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

RAP Substitution vs. Binder Replacement

- **RAP substitution means the percent of RAP in the mix**
  - RAP substitution = mass of RAP in mix/total dry weight of aggregate (Superpave mix design, Caltrans Std. Specs.) or weight of RAP/weight of dry weight of aggregate (Hveem mix design, Greenbook)

- **Binder replacement means how much of the total binder comes from the RAP binder**
  - Binder replacement % = % binder from RAP in the mix/total % binder in the mix (virgin + RAP)
  - For mix/total mass of mix calculation, it is the same as RAP substitution % if RAP and virgin part of the mix have the same binder %
  - If RAP has more or less binder % then have to do calculation
  - For Greenbook dry weight of aggregate, there is another calculation



UCPRC Recommendation for Blended Binders for the Future:

- Engineer the properties of blended binder (virgin+RAP+ recycling agent) to meet the PG binder spec requirements for each climate region
- Example: PG 64-10 regions
  - PG High Temp ≥ spec limits at (64C)
  - PG Int Temp ≤ spec limits at (28C for a 64-16)
  - PG Low Temp ≤ spec limits at (-10)

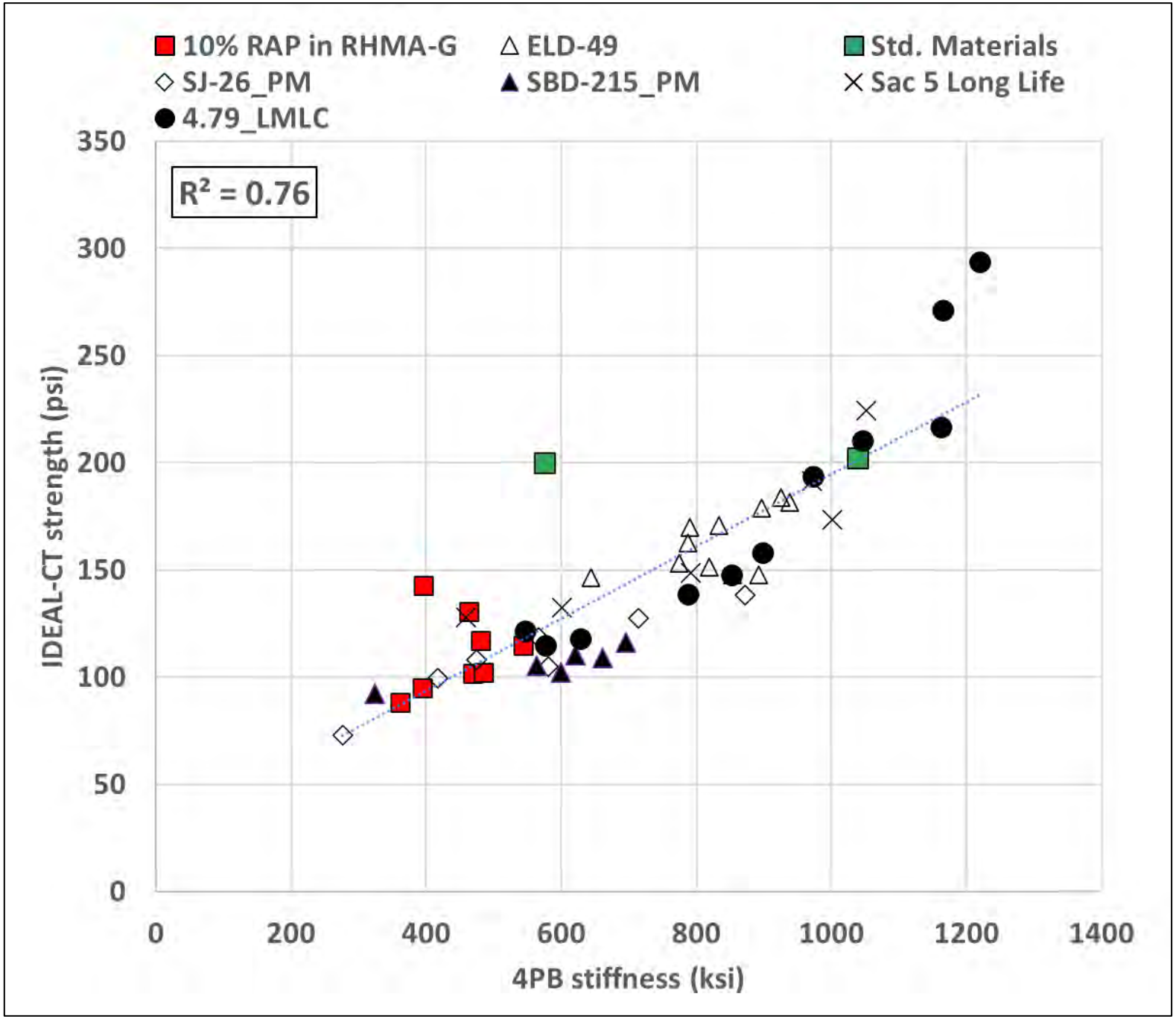
Potential Future Test in Specs: IDEAL-CT test

- **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

ImageUCPRC, https://escholarship.org/uc/item/52d1d1q5

IDEAL-CT Strength is a good indicator of mix stiffness at intermediate temperature

Can likely help indicate if getting good blending of RAP and virgin binders at high RAP contents



Rejuvenating/Recycling Agents

- Chemicals that help with blending of virgin and RAP binders
- Several types: tail oil, vegetable oil, petroleum distillate
- Included in binder blend when doing blending charts
- Contractors will consider use when > 25% RAP or highly-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 Asphalt 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**
- **RAP improves rutting resistance but can hurt age related cracking; Caltrans specs address through binder replacement limits and use of step-down binder**
  - 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**

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

Federal Highway Administration Low Carbon Transportation Materials Program


U.S. Department of Transportation
Federal Highway Administration

Low-Carbon Transportation Materials Grants Program

Home / Programs / Low-Carbon Transportation Materials Grants Program

Low-Carbon Transportation Materials Grants Program

NEW! On March 12, 2024, FHWA announced $2 billion available to fund low carbon materials that create less pollution by reducing the levels steel. In FHWA's Low Carbon Transportation Materials (LCTM) Program $1.2 Billion is available to State Departments of Transportation (incl activities and projects that advance the use of low carbon materials and products. This RFA approach will allow FHWA to quickly provide reir materials on construction projects now. In the coming months FHWA will also make available $800 million to target non-State applicants, inc tribes, Federal Lands Management Agencies, and other agencies through a Notice of Funding Opportunity (NOFO). FHWA encourages non-

- $0.8 billion incentive to local governments; announcement likely in next weeks
- Templates for proposals will be available soon at SPPCC website: https://sppcc.sf.ucdavis.edu/
- $1.2 billion incentive to state DOTs to use LCTM; were due 10 June 2024

More info at https://sppcc.sf.ucdavis.edu/

AB 2953: Analysis and Recommendations

Legislation, Recycled Materials Content, and RAP in AC/HMA

Details for all applicable pavement materials

With Greenbook change recommendations

City and County
Pavement Improvement Center

Reclaimed Asphalt Pavement and Other Materials in Asphalt:

- **Caltrans, Section 39:** Based on the Superpave Mix Design Method
- **Greenbook, Subsection 203-6:** Based on the Hveem Mix Design Method
- **Note:** *Mix design methods and corresponding requirements are not interchangeable*.
- The following focuses on Caltrans provisions that, for Greenbook users, either must be included as Special Provisions to satisfy AB 2853, or are other related provisions recommended for inclusion as Special Provisions.

Reclaimed Asphalt Pavement and Other Materials in Asphalt:

- ***Recommendations:***
  - If using the 2024 Greenbook, review 203-6 for inclusion of required and recommended provisions. Prepare and include Special Provisions for missing provisions.
  - If using the 2021 or earlier Greenbook: Prepare and include Special Provisions. See Sample Special Provisions developed for the City of San Diego.
  - Review Job Mix Formula submittals:
    - Analyze for compliance with limitation on virgin binder replacement. See sample analysis.
  - Perform on-site (“plant”) inspection and quality assurance testing during production

Reclaimed Asphalt Pavement and Other Materials in Asphalt:

39-2.02B(2) Type A Hot Mix Asphalt Mix Design

For Type A HMA mixtures using RAP, ***the maximum allowed binder replacement*** is 25.0 percent in the upper 0.2 foot exclusive of OGFC and 40.0 percent below. The binder replacement is calculated as a percentage of the approved JMF target asphalt binder content. ***203-6.3.1***

For RAP substitution of ***15 percent or less***, the grade of the virgin binder must be the ***specified grade of asphalt binder*** ~~for Type A HMA~~. ***203-6.2.1 (2021 and earlier)***

For RAP substitution ***greater than 15 percent and not exceeding 25 percent***, the grade of the virgin binder must be the specified grade of asphalt binder ~~for Type A HMA~~ with the ***upper and lower temperature classification reduced by 6 degrees C***. ~~Hamburg wheel track requirements are based on the grade of asphalt binder specified for Type A HMA.~~ ***203-6.2.1 (2021 and earlier, included in 2024)***

- *Note: the provisions above are recommended for inclusion as Special Provisions to the Greenbook, but not required to satisfy AB 2953.*

Reclaimed Asphalt Pavement and Other Materials in Asphalt:

39-2.02B(5) Reclaimed Asphalt Pavement

You may substitute RAP for part of the virgin aggregate in a quantity up to 25 percent of the aggregate blend. ***203-6.2.5.1 (2021 and earlier)***

- *Note: inclusion of the above as a Special Provision to the Greenbook is required to satisfy AB 2953.*

If RAP is from multiple sources, blend the RAP thoroughly and completely before fractionating. ***203-6.2.5.3***

For RAP substitution *greater than 15 percent* of the aggregate blend, *fractionate* RAP stockpiles into 2 sizes, a coarse fraction RAP retained on 3/8-inch sieve and a fine fraction RAP passing 3/8-inch sieve. ***203-6.2.5.3***

For RAP substitution of *15 percent* of the aggregate blend *or less*, *fractionation is not required*. The RAP fractionation must comply with the requirements shown in the following table: [include table] ***203-6.2.5.3***

- *Note: the provisions above are recommended for inclusion as Special Provisions to the Greenbook, but not required to satisfy AB 2953. The Greenbook, all editions, does not require fractionation.*

Reclaimed Asphalt Pavement and Other Materials in Asphalt:

39-2.02B(5) Reclaimed Asphalt Pavement

You may use the coarse fractionated stockpile, the fine fractionated stockpile, or a combination of the coarse and fine fractionated stockpiles. ***203-6.2.5.3***

Isolate the processed RAP stockpiles from other materials. Store processed RAP in conical or longitudinal stockpiles. Processed RAP must not be agglomerated or be allowed to congeal in large stockpiles. ***203-6.2.5.2***

- *Note: the above are recommended for inclusion as Special Provisions to the Greenbook, but not required to satisfy AB 2953.*

Reclaimed Asphalt Pavement and Other Materials in Asphalt:

39-2.02B(11) Type A Hot Mix Asphalt Production

If RAP is used, the asphalt plant must automatically adjust the virgin asphalt binder to account for RAP percentage and RAP binder. ***203-6.7.1***

During production, you may adjust hot- or cold-feed proportion controls for virgin aggregate and RAP. For RAP substitution of 15 percent or less, RAP must be within ±3 of RAP percentage shown in your Contractor Job Mix Formula Proposal form without exceeding 15 percent. For RAP substitution of greater than 15 percent, RAP must be within ±3 of RAP percentage shown in your Contractor Job Mix Formula Proposal form without exceeding 25 percent. ***203-6.7.1***

- *Note: the above are recommended for inclusion as Special Provisions to the Greenbook, but not required to satisfy AB 2953.*

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, (520) 235-0480

References

- **AB 2953**
  - https://legiscan.com/CA/text/AB2953/id/2609286
- **AB 661**
  - https://legiscan.com/CA/text/AB661/id/2292479
- **NAPA 2022 Survey on Recycled Materials and Warm-Mix Asphalt Usage:**
  - https://go.asphaltpavement.org/is-138
- **San Diego County Building Better Roads:** https://www.sandiegocounty.gov/content/dam/sdc/dpw/COUNTY_ROADS/bbr-documents/R-1_25Percent_RAP%20v5%2002202023.pdf

Summary of Takeaways

Questions?

- **John Harvey**: jtharvey@ucdavis.edu
- **Erik Updyke:** eupdyke@ucdavis.edu

Additional Detail Slides

Caltrans Standard Specifications
39-2.02B(2) Type A Hot Mix Asphalt Mix Design

- For Type A HMA mixtures using RAP, the maximum allowed binder replacement is 25.0 percent in the upper 0.2 foot exclusive of OGFC and 40.0 percent below. The binder replacement is calculated as a percentage of the approved JMF target asphalt binder content. For RAP substitution of 15 percent or less, the grade of the virgin binder must be the specified grade of asphalt binder for Type A HMA. *(Note: the Greenbook does not have a similar requirement.)*

- For RAP substitution greater than 15 percent and not exceeding 25 percent, the grade of the virgin binder must be the specified grade of asphalt binder for Type A HMA with the upper and lower temperature classification reduced by 6 degrees C. Hamburg wheel track requirements are based on the grade of asphalt binder specified for Type A HMA. *(Note: similar requirement included in the 2024 Greenbook.)*

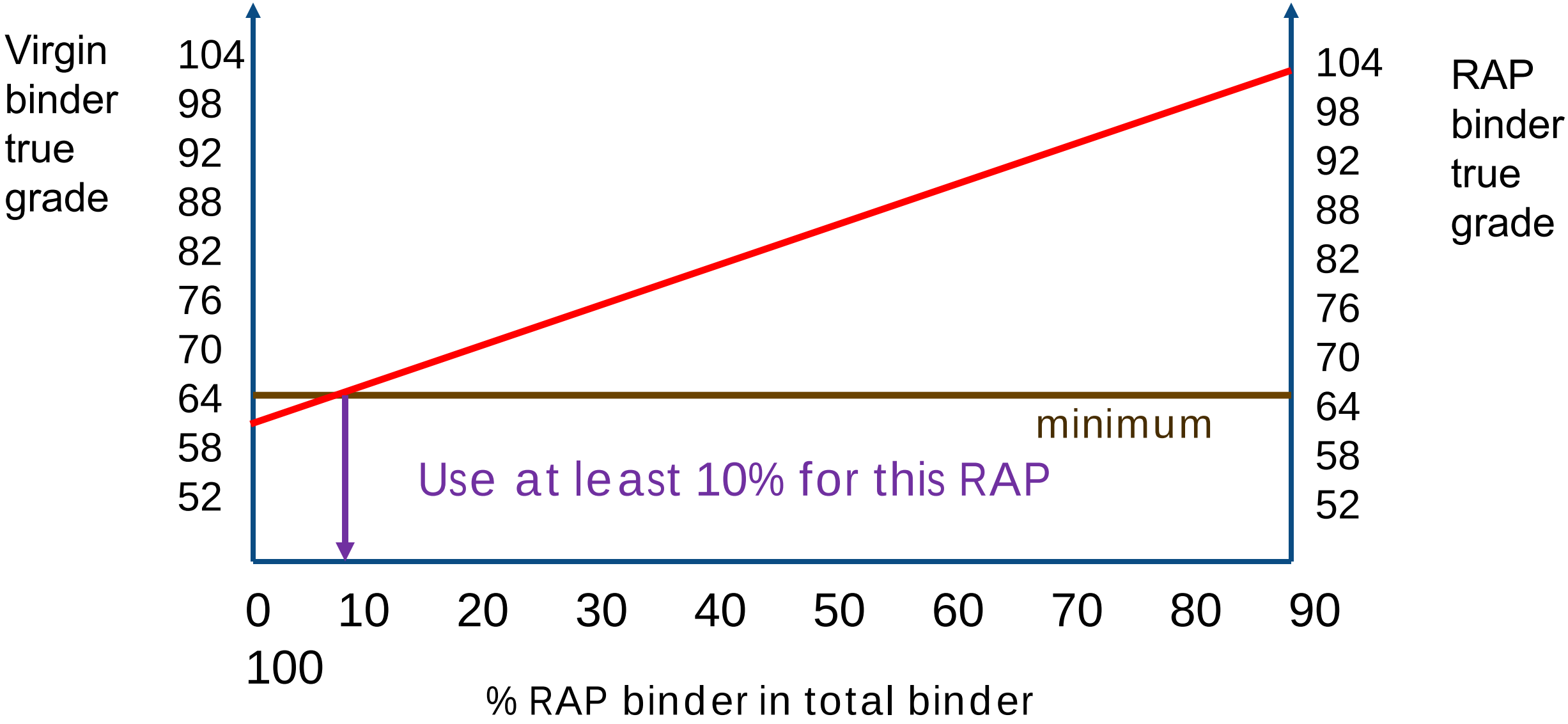
Blended Binder PG Grading

- **"True PG grade" the RAP and the virgin binder**
  - Assumes complete blending between RAP and virgin binders
- **Find the ranges of RAP that meet 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 specifications require one "step down" lower v
    PG binder for 15 to 25% RAP without doing the testing
  - Example: use PG 58-22 instead of PG 64-16

Image: Rutgers Univ

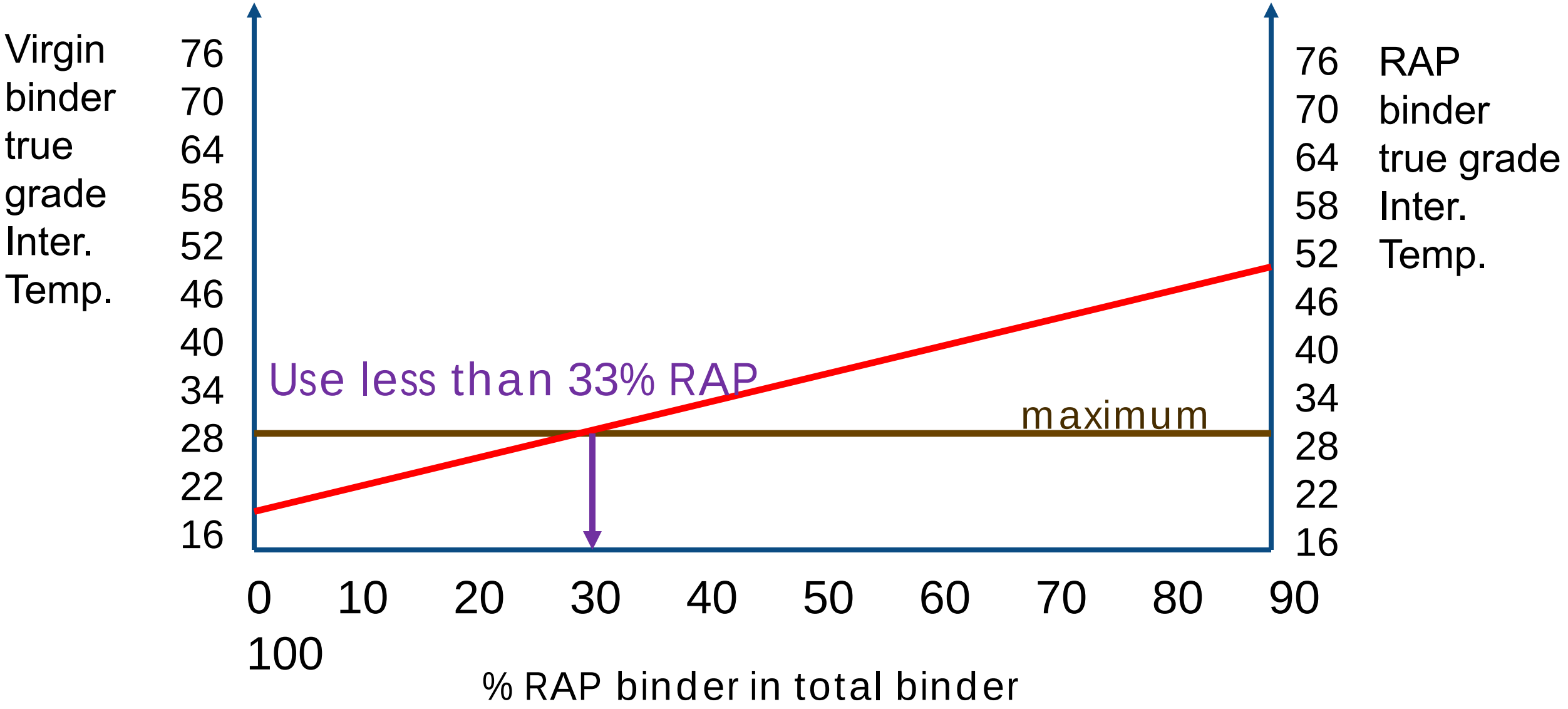
Blended Binder PG Grading: High Temperature

PG 64-16 requires minimum 64°C, how much RAP if use PG 58-22?



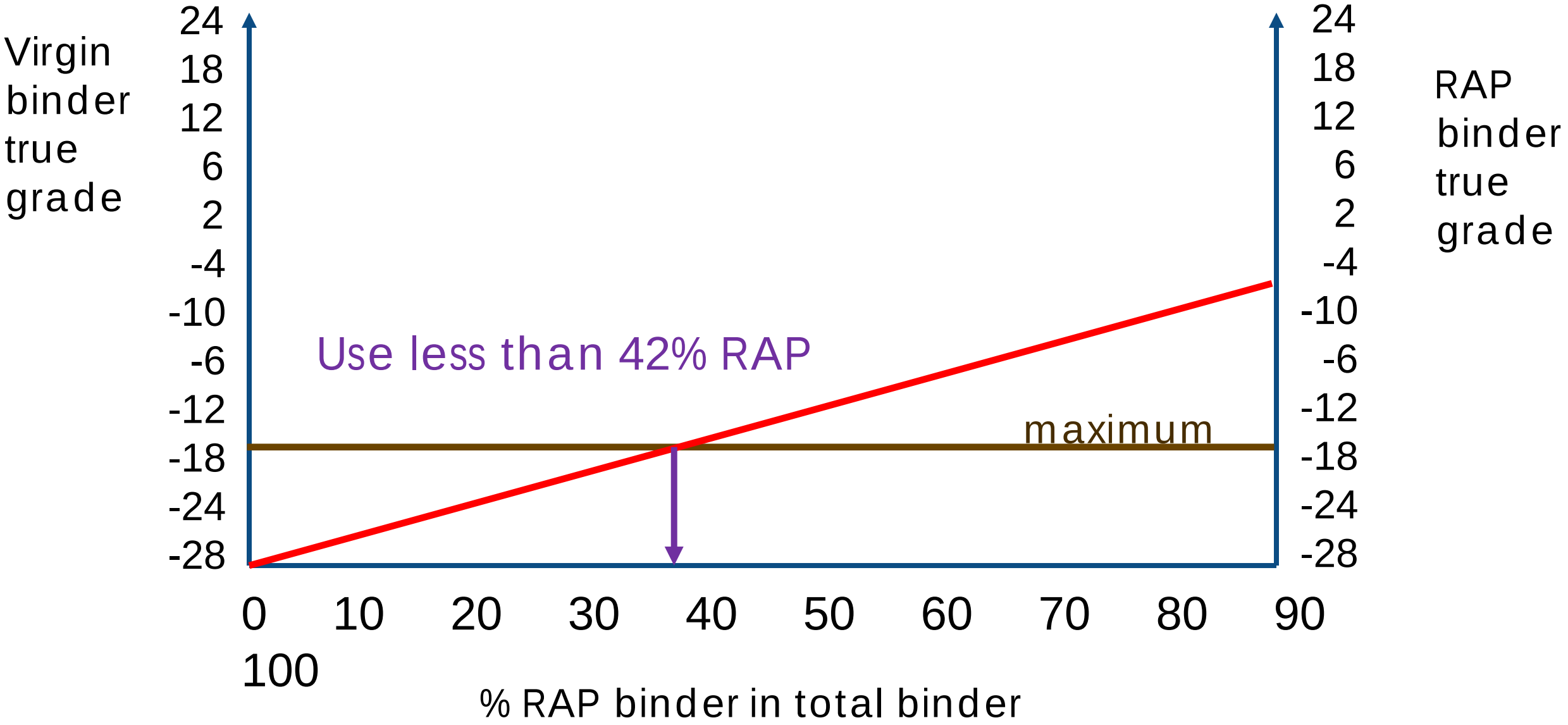
Blended Binder PG Grading: Intermediate Temperature

PG 64-16 requires maximum 28°C; , how much RAP if use PG 58-22?



Blended Binder PG Grading: Low temperature

PG 64-16 requires maximum -16°C for critical property (m, S); how much RAP if use PG 58-22?



AB 2953: Analysis and Recommendations

Legislation, Recycled Materials Content, and RAP in AC/HMA

Details for all materials and Greenbook changes recommended ```in additional slides

City and County
Pavement Improvement Center

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

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