Oregon Department of Transportation

Oregon State University

Binder-Grade Bumping and High Binder Content to Improve Performance of RAP-RAS Mixtures

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Other contributors

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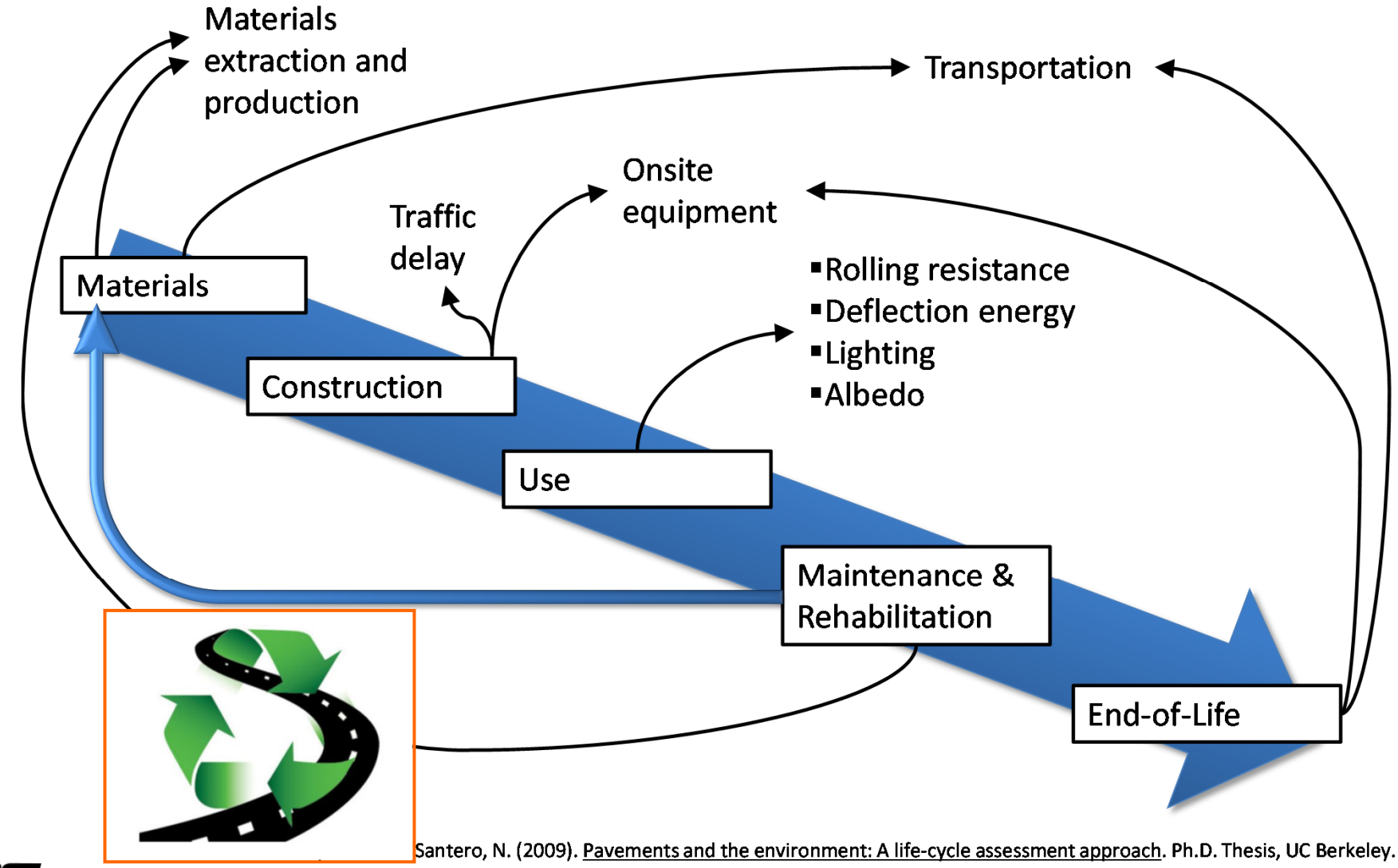
- Terri Zahler from McCall Oil
- Mike Miller from Oldcastle Materials

Outline

- Introduction and Literature review
- Experiment types
- Objectives and Experimental plan
  - Binder grade and binder content
  - Blending evaluation
- Initial results
- Summary

INTRODUCTION AND LITERATURE REVIEW



Santero, N. (2009). Pavements and the environment: A life-cycle assessment approach. Ph.D. Thesis, UC Berkeley.

INTRODUCTION AND LITERATURE REVIEW

An EPD (Environmental Product Declarations) is a third-party certified label that discloses the quantified environmental impacts of producing a product.

- Primary energy (MJ)
- Global warming potential
- Ozone depletion
- Acidification potential etc.

Summary of
Environmental Product Declaration

Central Concrete

Mix 340PG9Q1

San Jose Service Area

EF V2 Gen Use P4000 3" Line 50% SCM

Performance Metrics

28-day compressive strength	4,000 psi
Slump	4.0 in

Environmental Impacts

Impact name	Unit	Impact per m3	Impact per cyd
Total primary energy consumption	MJ	2,491	1,906
Concrete water use (batch)	m3	6.66E-2	5.10E-2
Concrete water use (wash)	m3	8.56E-3	6.55E-3
Global warming potential	kg CO2-eq	271	207
Ozone depletion	kg CFC-11-eq	5.40E-6	4.14E-6
Acidification	kg SO2-eq	2.26	1.73
Eutrophication	kg N-eq	1.31E-1	1.00E-1
Photochemical ozone creation	kg O3-eq	46.6	35.7

A sample EPD for a concrete mix design by Central Concrete Supply Co.

Credit: Central Concrete Supply

NAPA EPD Program

http://www.asphaltpavement.org/EPD

INTRODUCTION AND LITERATURE REVIEW

- Hansen and Copeland (2014)
  - In 2014, the use of RAP/RAS on U.S. roads displaced 20M barrels of oil and 68M tons of aggregate
  - A savings of $2.8B based on binder cost of $550/ton and aggregate cost of $9.50/ton

- NCAT – Willis (2015)
  - Utilizing recycled asphalt results in a 9-26% energy savings and a 5-29% reduction in CO_2 emissions
  - A 19-42% energy savings and a 6-39% reduction in CO_2 emissions were realized when using RAP along with locally sourced materials

INTRODUCTION AND LITERATURE REVIEW

HOW CAN WE INCREASE RAP CONTENT?

- Softer virgin binder grade (binder-grade bumping)
- Increased binder content
- Recycling agents
- Polymer and rubber modifiers
- Warm mix asphalt

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EXPERIMENTS USED IN THIS STUDY
SEMI CIRCULAR BEND TEST

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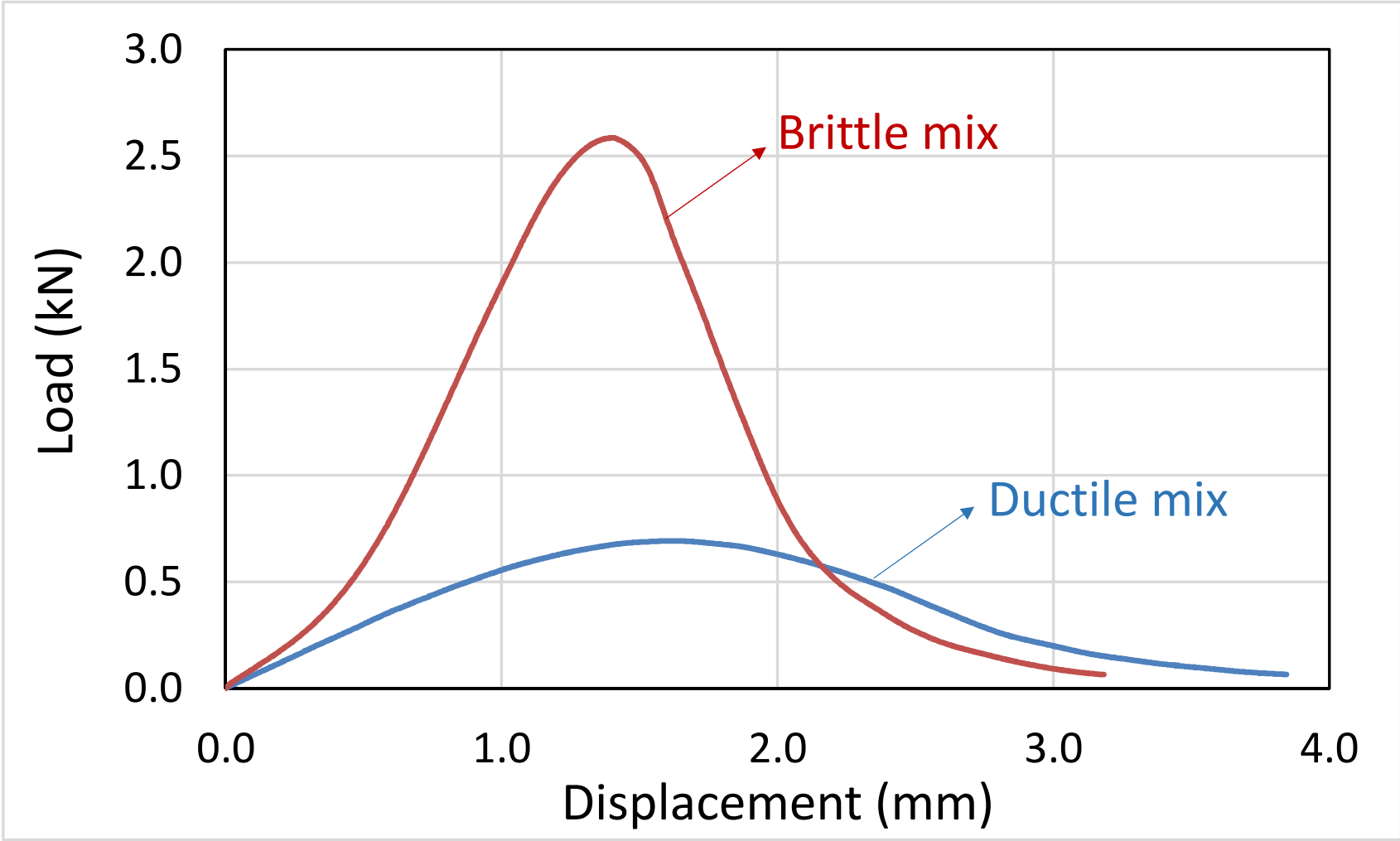
SEMI CIRCULAR BEND TEST – OUTPUT PARAMETERS



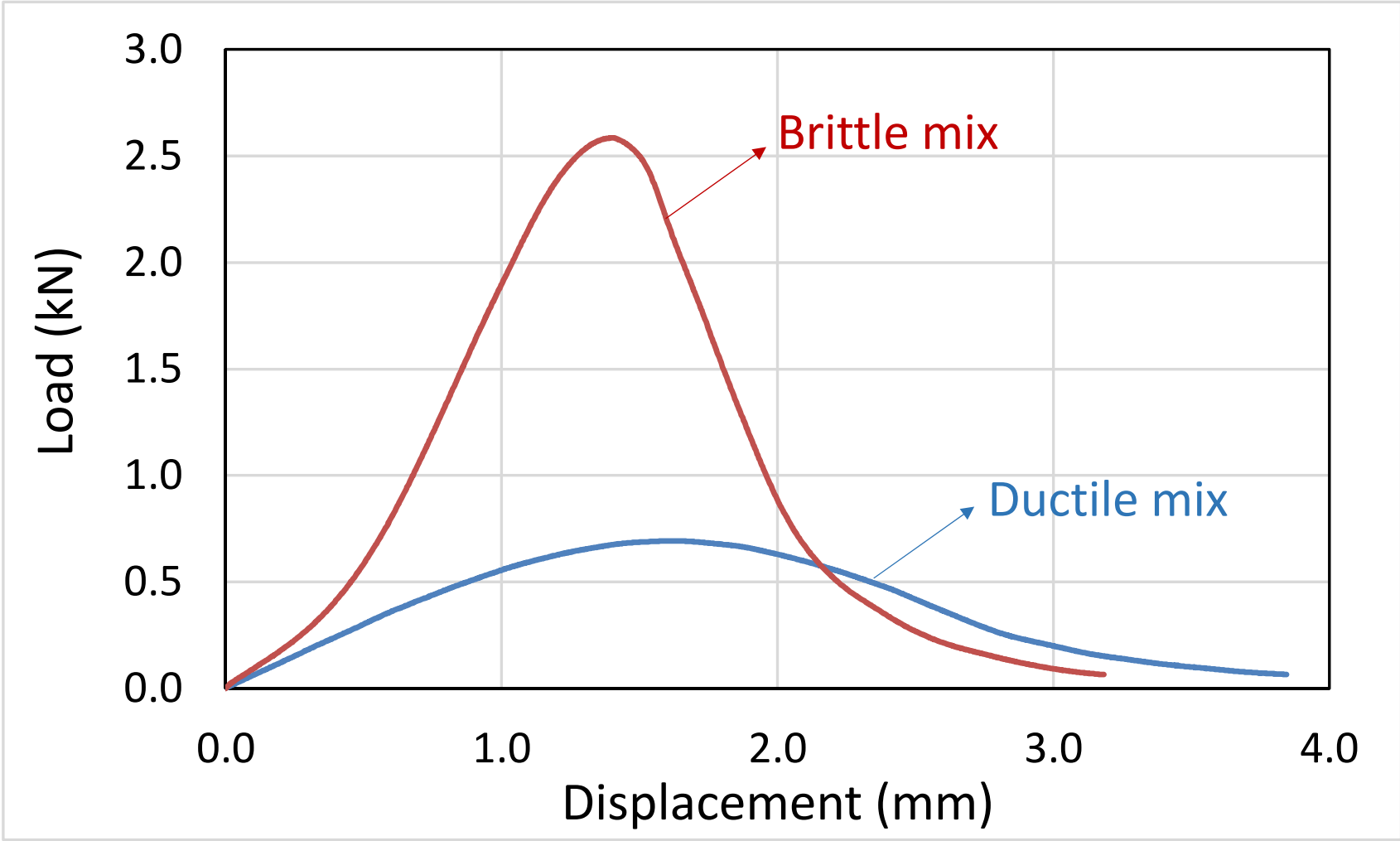
EXPERIMENTS USED IN THIS STUDY
SEMI CIRCULAR BEND TEST – OUTPUT PARAMETERS

Fracture energy: is calculated by dividing the work of fracture (the area under the load vs. the average load-line displacement curve) by the ligament area (the product of the ligament length and the thickness of the specimen) of the test specimen prior to testing.

Flexibility index: is calculated by dividing the fracture energy by the slope at the inflection point.

EXPERIMENTS USED IN THIS STUDY

SEMI CIRCULAR BEND TEST – OUTPUT PARAMETERS



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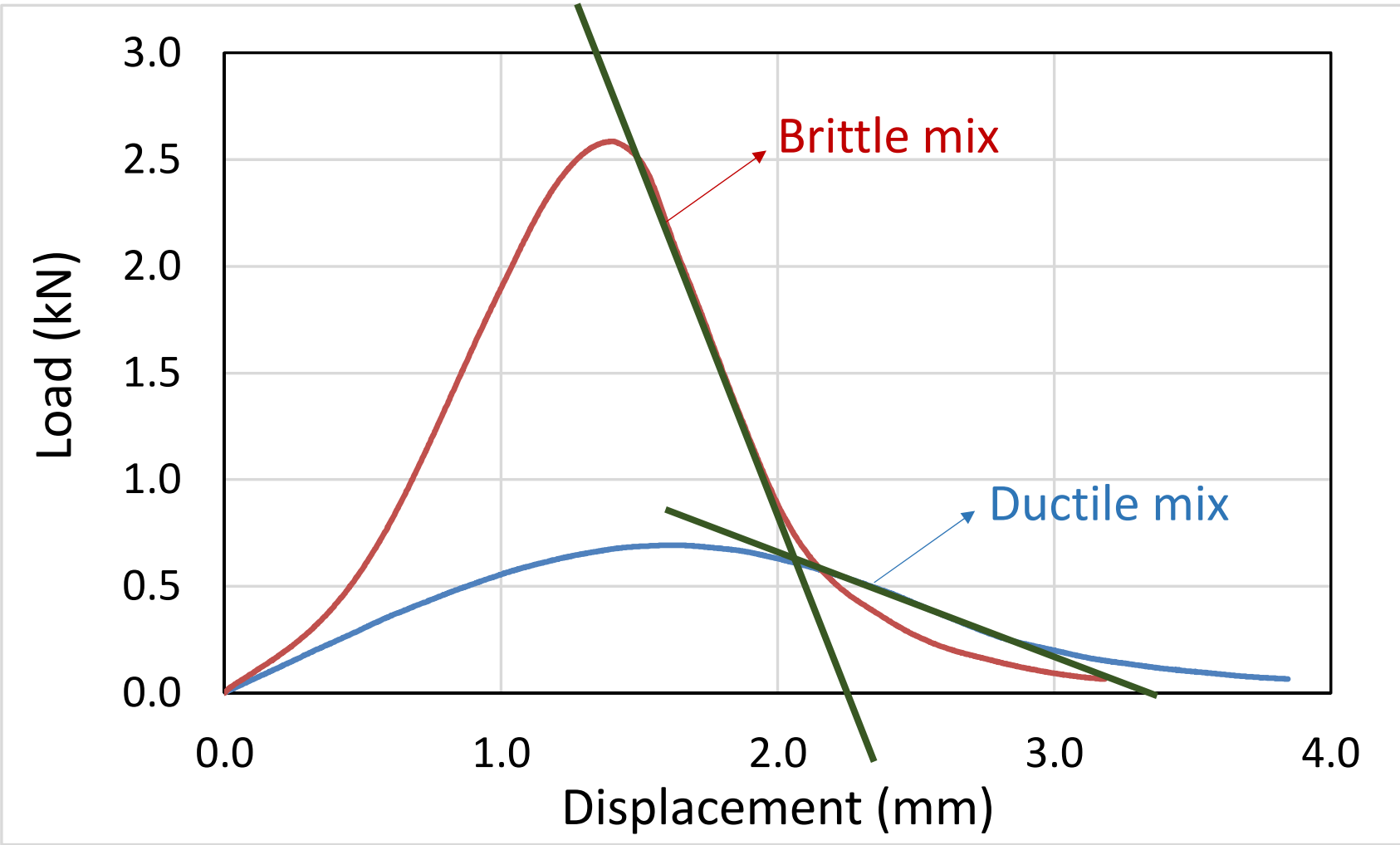
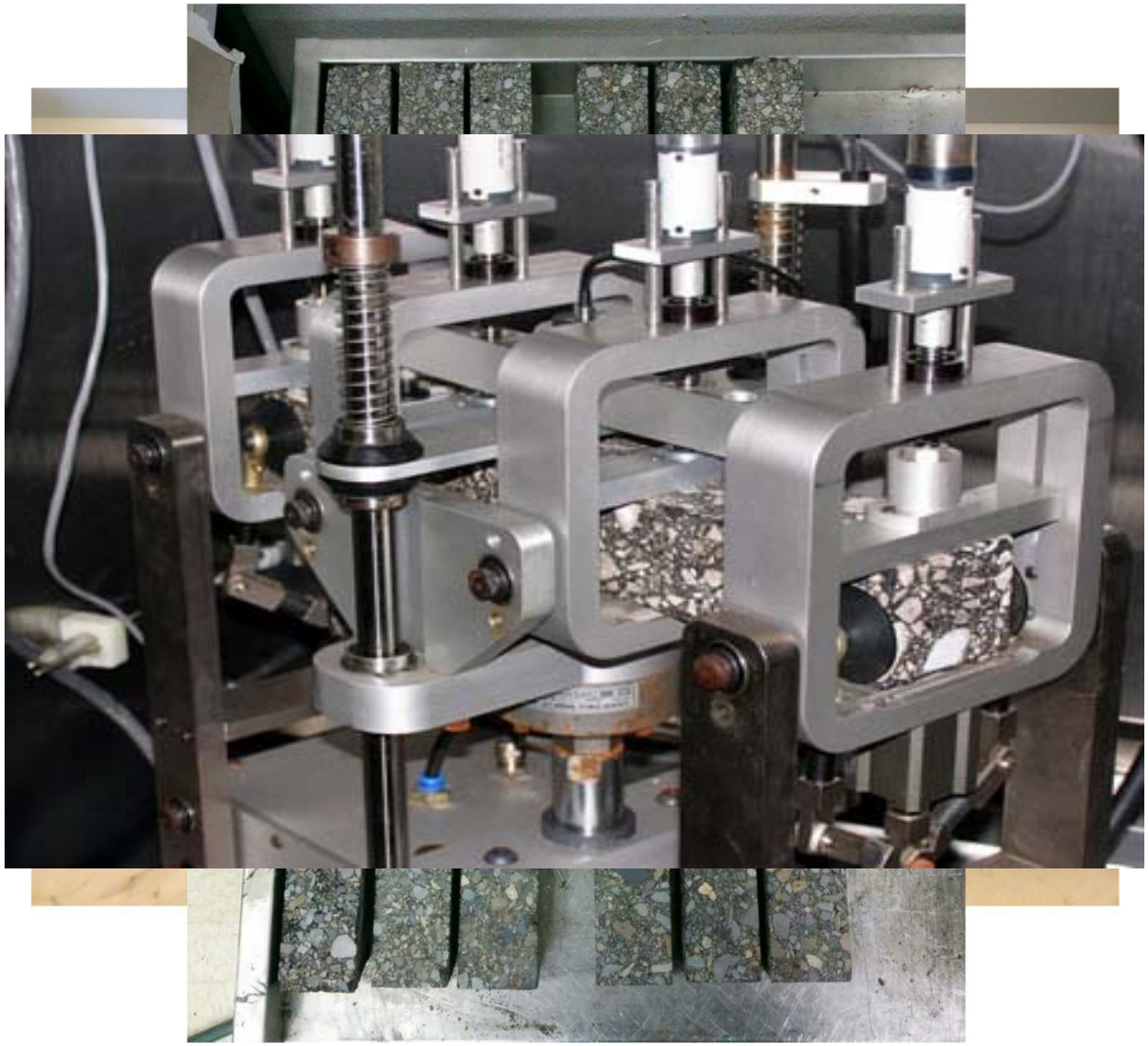


EXPERIMENTS USED IN THIS STUDY
BEAM FATIGUE TEST



EXPERIMENTS USED IN THIS STUDY
DYNAMIC MODULUS AND FLOW NUMBER TESTS

Dynamic modulus: Determine mix stiffness at different temperatures and load frequencies

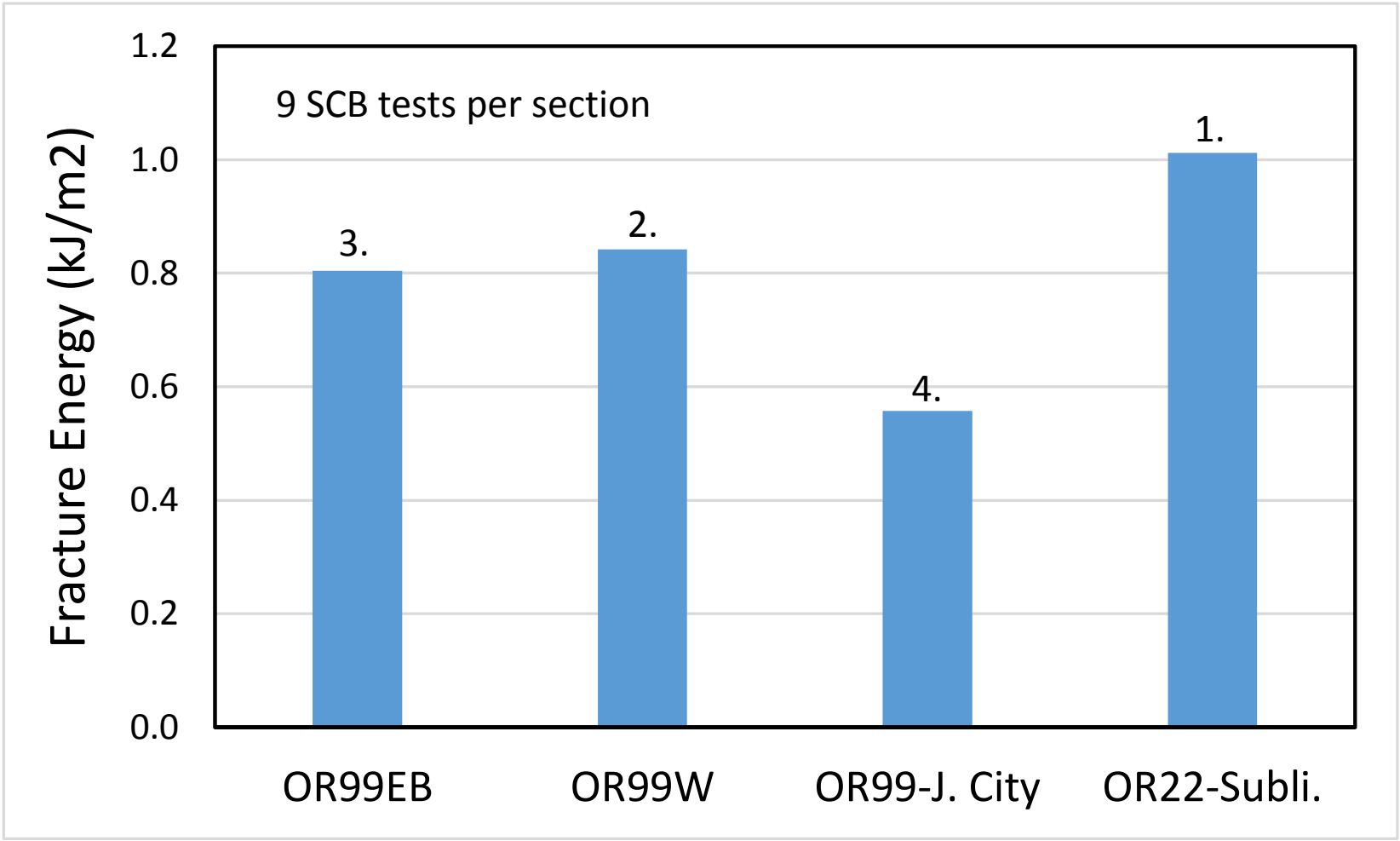
Conduct flow number experiment at high temperatures to determine rutting resistance

EXPERIMENTS USED IN THIS STUDY
WHICH EXPERIMENT IS THE BEST?

***ODOT Research Project*: Adjusting Asphalt Mixes for Increased Durability and Implementation of a Performance Tester to Evaluate Fatigue Cracking of Asphalt Concrete**

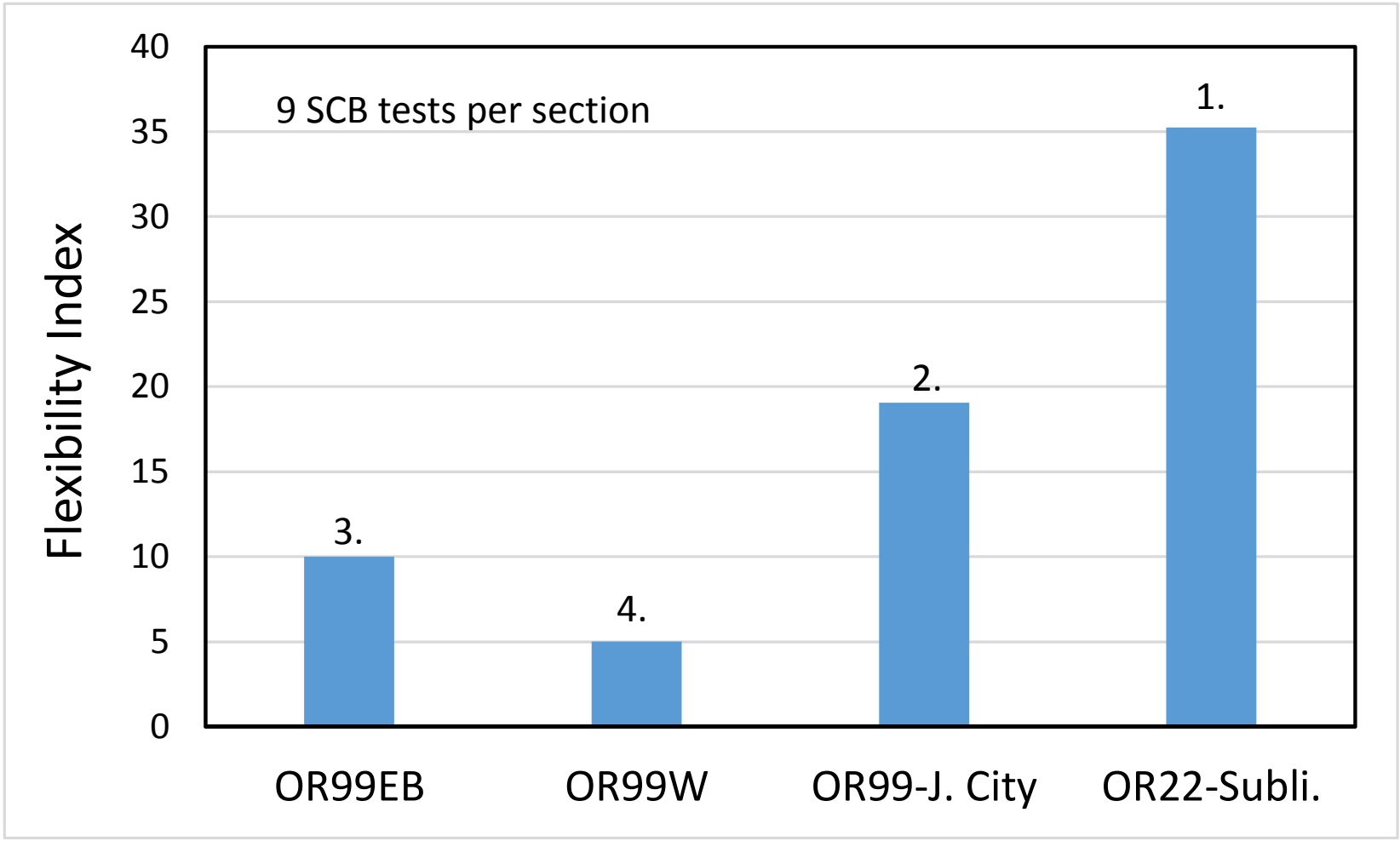
Experiments evaluated in ODOT-OSU research:
SVECD, SCB, IDT, Beam fatigue

EXPERIMENTS USED IN THIS STUDY
PRELIMINARY SCB TEST RESULTS FROM ODOT CRACKING PROJECT



ODOT PMS	Cracked	Cracked	NO Cracking	NO Cracking

EXPERIMENTS USED IN THIS STUDY
PRELIMINARY SCB TEST RESULTS FROM ODOT CRACKING PROJECT



ODOT PMS	Cracked	Cracked	NO Cracking	NO Cracking

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OBJECTIVES
RAP CONTENT, BINDER GRADE, AND BINDER CONTENT

- Identify the effects of binder-grade bumping and higher binder content on RAP/RAS performance
- Determine the impact of these alternatives on increasing RAP/RAS contents
- Evaluate the effect of blending on mixture performance
- Evaluate the cost and benefits of using binder-grade bumping and higher binder content to increase RAP/RAS.

EXPERIMENTAL PLAN
RAP CONTENT, BINDER GRADE, AND BINDER CONTENT

Phase I – High RAP mixes:

Test type	Binder grade	RAP content	Binder content	Air-void content	Replicates	Total Tests
Beam fatigue	PG58-34 PG64-22 PG76-22	30% 40%	6.0% 6.4% 6.8%	7%	3	54
SCB	PG58-34 PG64-22 PG76-22	30% 40%	6.0% 6.4% 6.8%	7%	4	72
Dynamic modulus	PG58-34 PG64-22 PG76-22	30% 40%.	6.0% 6.4% 6.8%	7%	2	36
Flow number	PG58-34 PG64-22 PG76-22	30% 40%.	6.0% 6.4% 6.8%	7%	2	36

EXPERIMENTAL PLAN
RAP CONTENT, BINDER GRADE, AND BINDER CONTENT

Phase II – Low – No RAP and RAP-RAS mixes:

Test type	Binder grade	RAP content	Binder content	Air-void content	Replicates	Total Tests
Beam fatigue	PG58-34 PG76-22	0% 15% RAP/RAS	6.0% 6.8%	7%	3	36
SCB	PG58-34 PG76-22	0% 15% RAP/RAS	6.0% 6.8%	7%	4	48
Dynamic modulus	PG58-34 PG76-22	0% 15% RAP/RAS	6.0% 6.8%	7%	2	24
Flow number	PG58-34 PG76-22	15% RAP/RAS	6.0% 6.8%	7%	3	24

BLENDING EVALUATION

Phase III – Blending Evaluation:

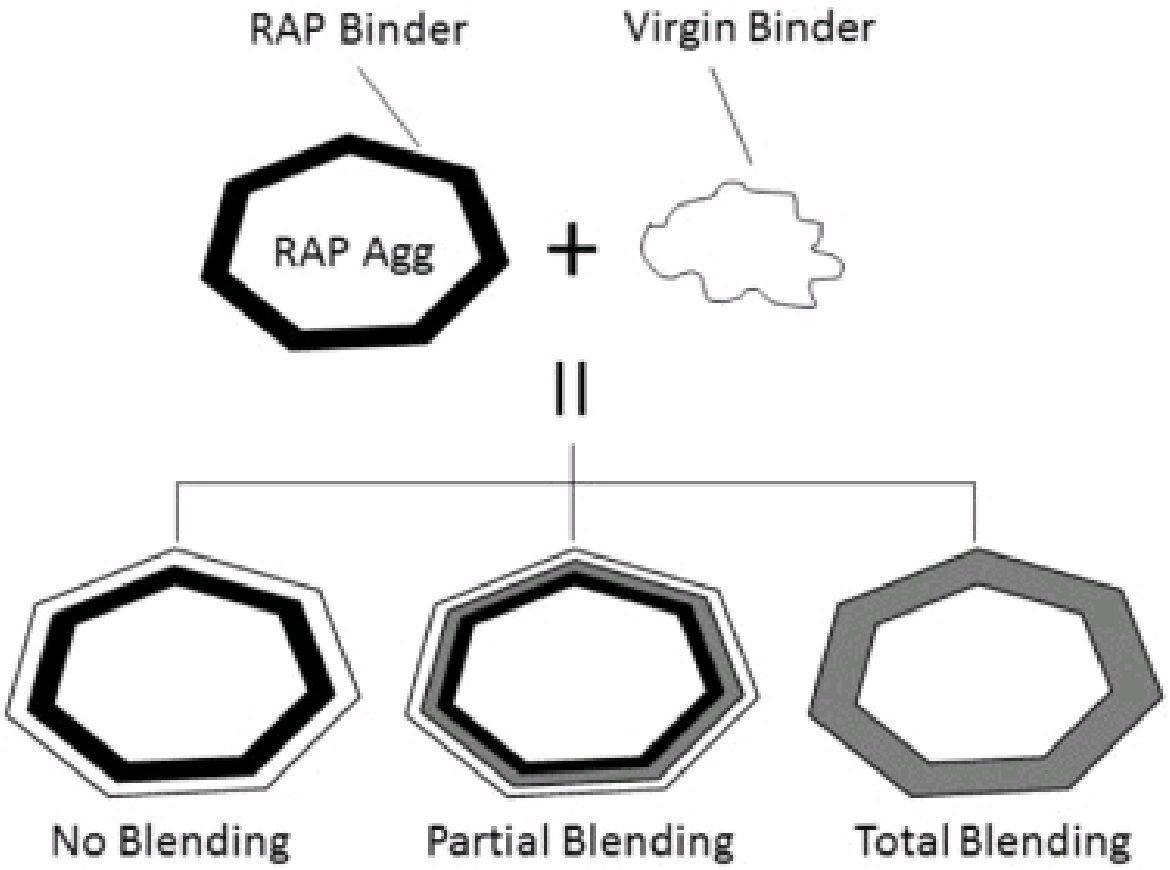


Image: Zhao et al. (2016) Materials and Design

BLENDING EVALUATION

Phase III – Blending Evaluation:

Test type	Mix Type	RAP Content	Blending	RAP mixing temp.	Repl.	Total Tests
SCB	PG58-34	15% 40%	0% Actual 50% 100%	2 temps	4	64

BLENDING EVALUATION

Phase III – Blending Evaluation:

Binder extraction

Binder recovery

BLENDING EVALUATION

Phase III – Blending Evaluation:

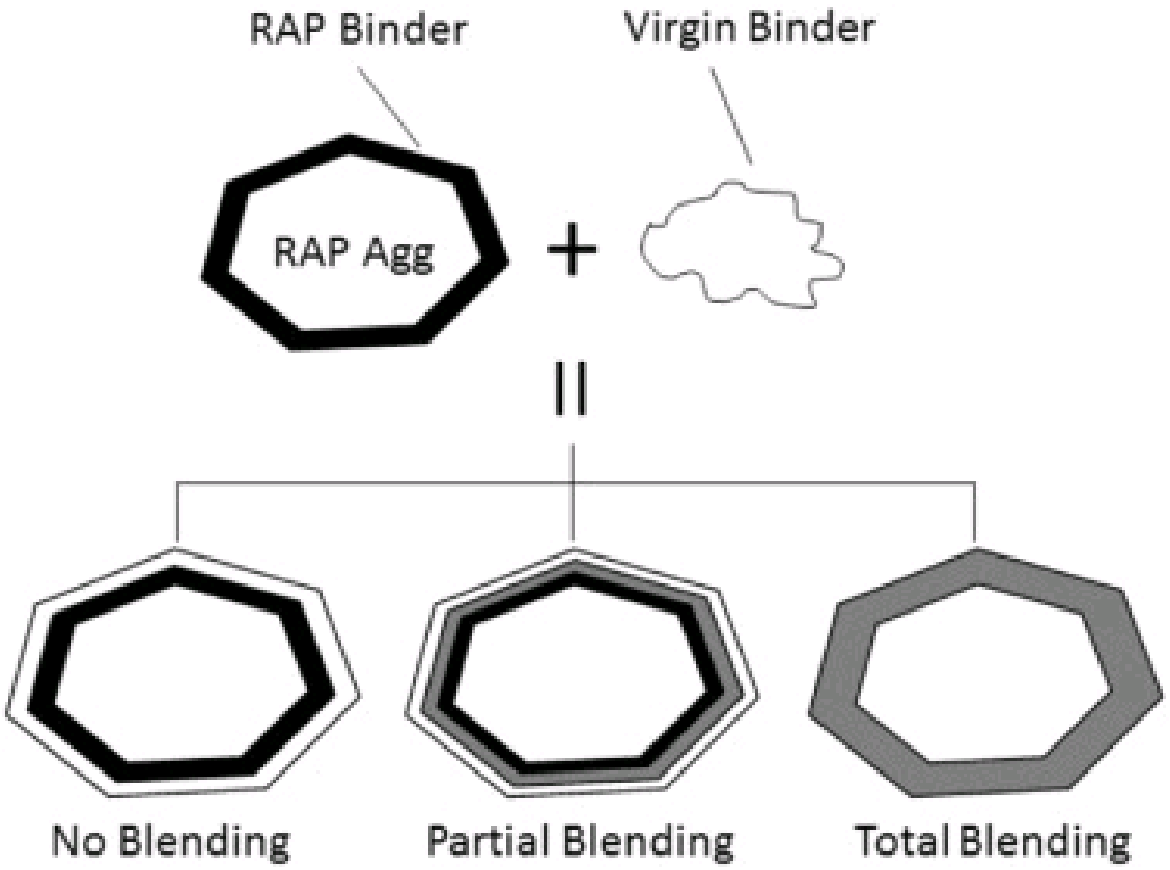
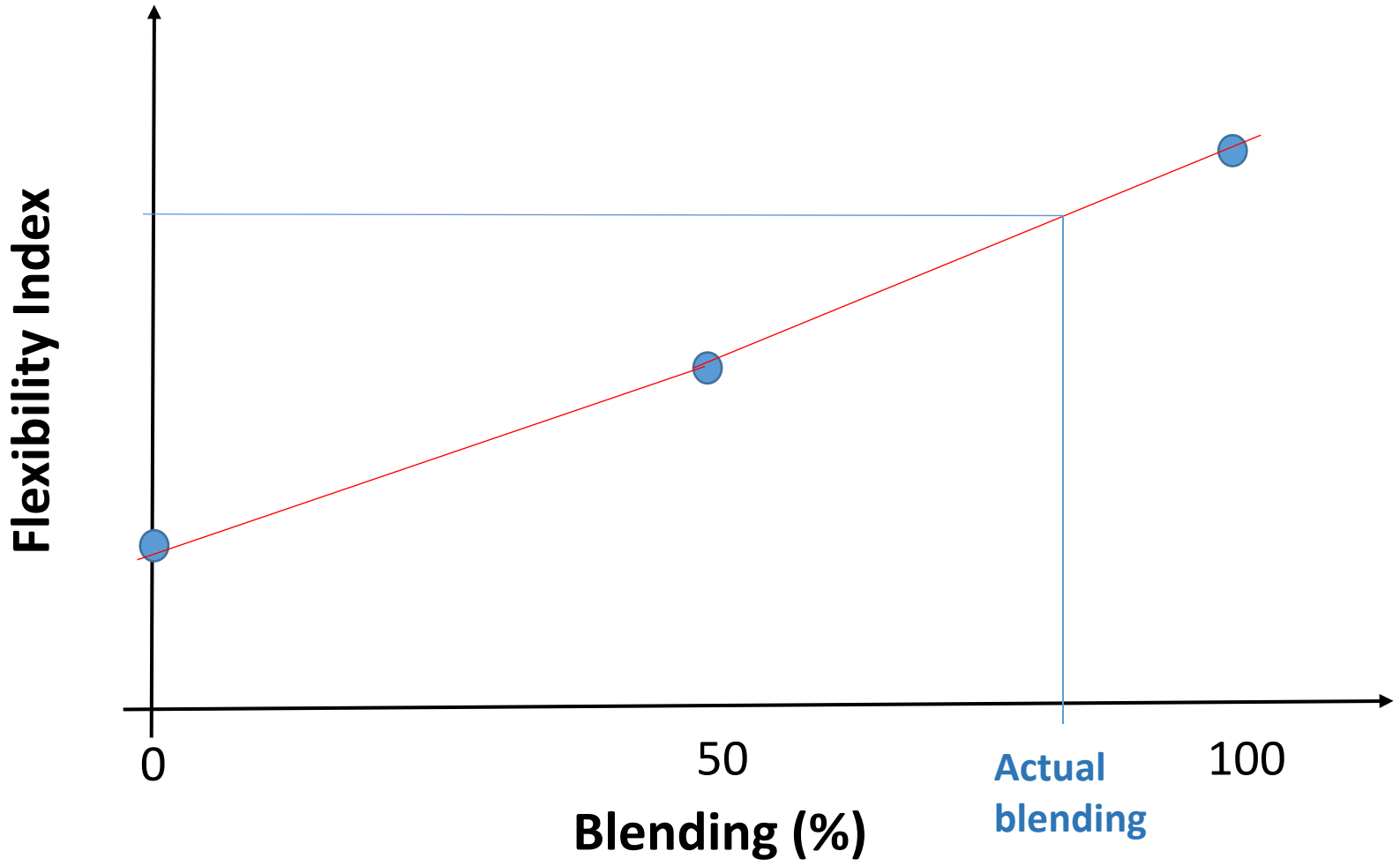


Image: Zhao et al. (2016) Materials and Design

BLENDING EVALUATION

Phase III – Blending Evaluation: Theoretical curve



OBJECTIVES AND EXPERIMENTAL PLAN

- A total of 364 experiments
- All Phase I samples prepared
- Majority of Phase I experiments completed
- Phase II samples are currently being prepared

- **SCB RESULTS FROM PHASE I**

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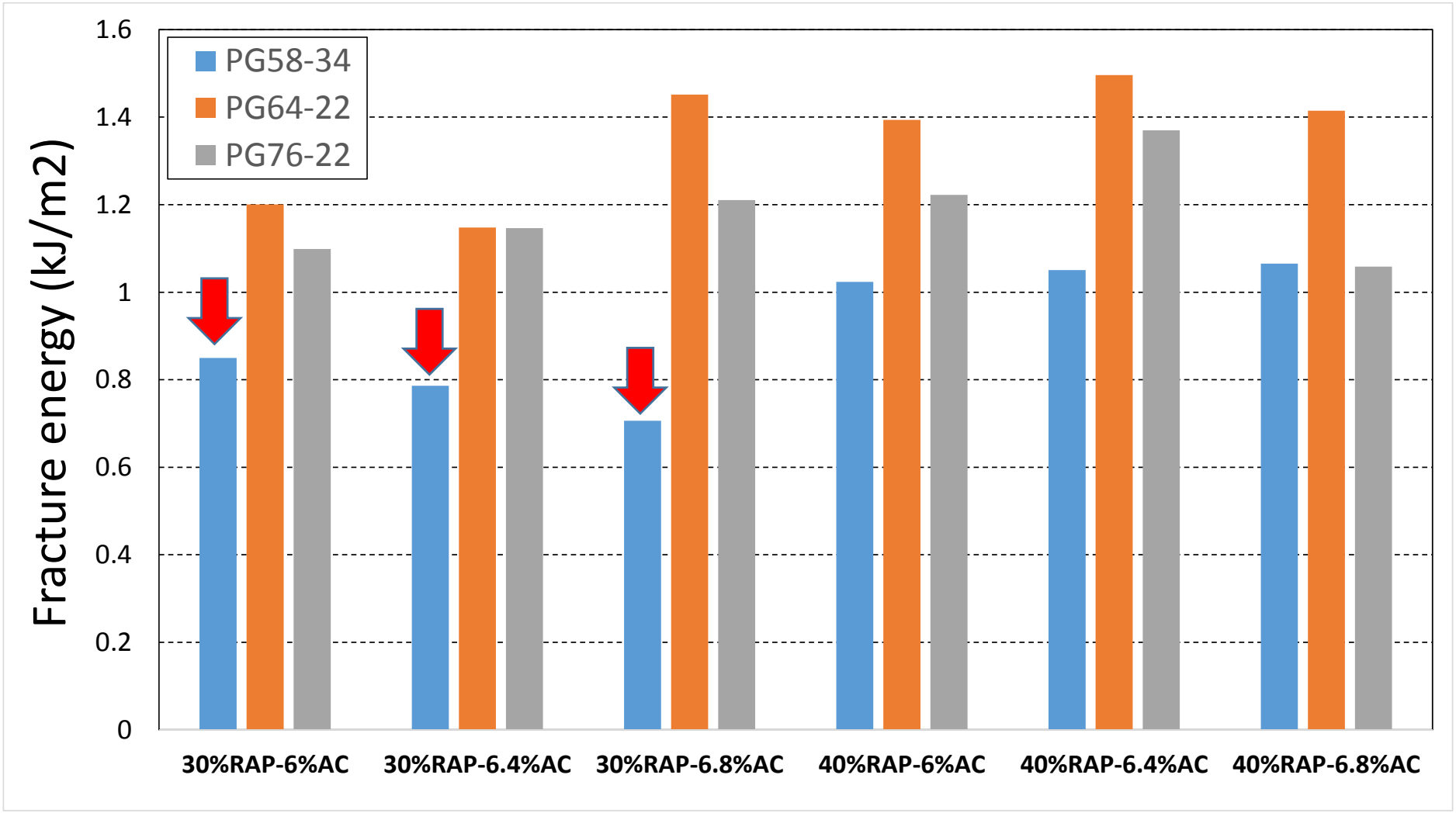
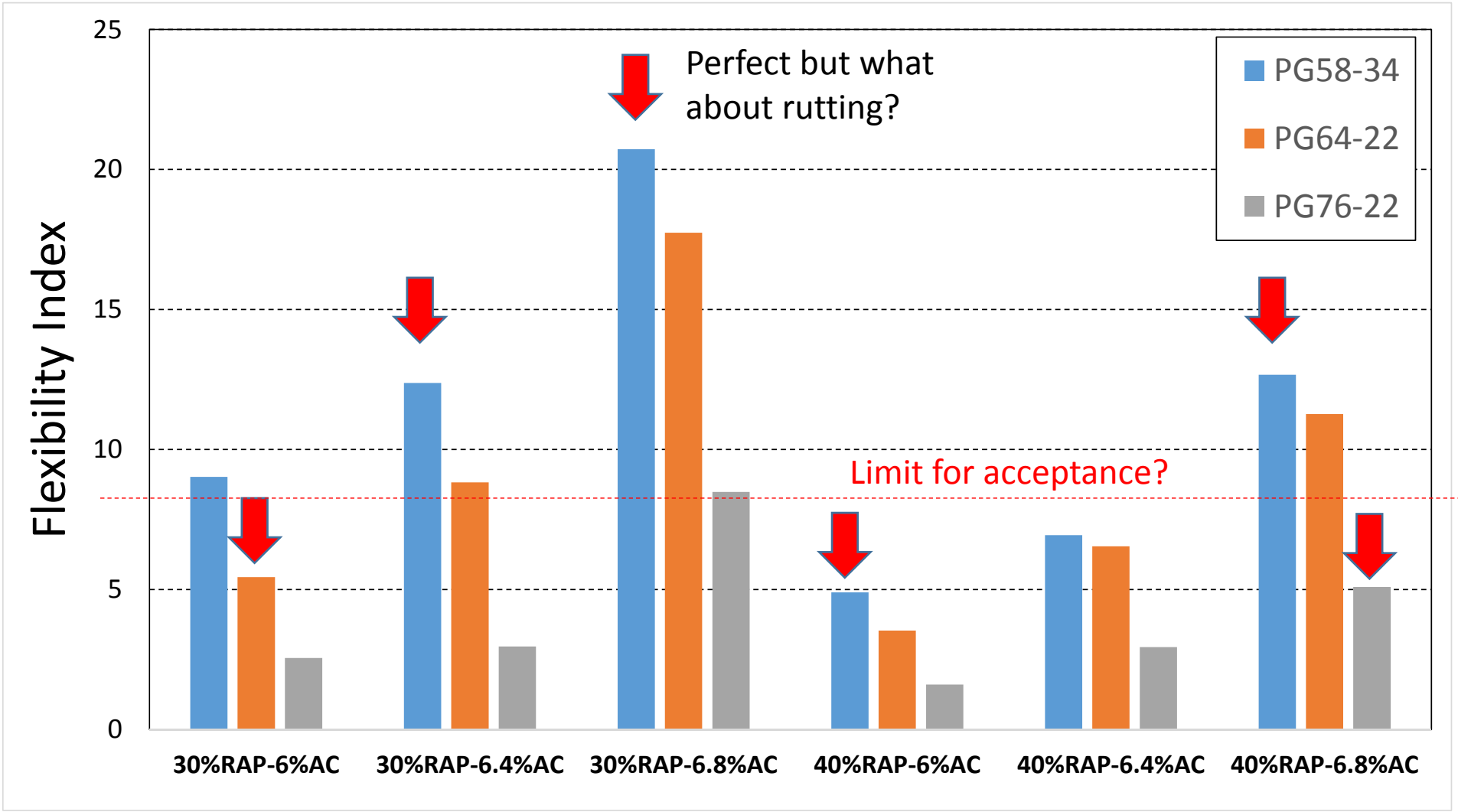
INITIAL TEST RESULTS – SCB – FRACTURE ENERGY



INITIAL TEST RESULTS – SCB – FLEXIBILITY INDEX



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SUMMARY

- SCB and Flexibility Index are promising
- Sample preparation and testing will be completed soon
- MEPDG modeling and cost analysis will follow
- Planning to repeat Phase I SCB experiments with specimens aged with new long-term aging protocols (6-7 days of aging loose-mix at 85^{o}C)
- Do mix designs for critical mixes

GO BEAVS!

Q & A

Thank you!

Oregon Department of Transportation

OSU Oregon State University

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