COMPARISON OF RUTTING AND CRACKING PERFORMANCE ESTIMATES FOR HVEEM AND SUPERPAVE MIX DESIGNS UTILIZING *CALME*

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RESEARCH OBJECTIVES

Caltrans is shifting the HMA design method from Hveem to Superpave.

- Hypothesis tested:
  - Since Superpave mix design produces higher binder contents than Hveem mix design, Hveem mixes provide better rutting performance and worse cracking performance than Superpave mixes

- Use CalME to investigate the pros and cons of using Hveem and Superpave mix design

OUTLINE

- Background
  - Materials
  - Testing
- CalME simulations
- Conclusions

BACKGROUND

Mix types

- **Mix A**, dense graded HMA (NMAS=3/4”), conventional PG 64-16 binder (Refinery 1), crushed alluvial aggregate
- **Mix B**, dense graded HMA (NMAS=3/4”), conventional PG 64-16 binder (Refinery 2), crushed basalt aggregate
- **Mix I**, gap-graded HMA (NMAS=1/2”), rubberized binder with PG64-16 base binder (Refinery 2), crushed basalt aggregate

BACKGROUND

Mix types – Binder contents

- **Mix A**, Hveem binder content = 5.0 %

  Superpave binder content = 5.5 %
- **Mix B**, Hveem binder content = 5.2 %

  Superpave binder content = 6.3 %
- **Mix I**, Hveem binder content = 8.0 %

  Superpave binder content = 8.3 %

Testing Program

Rutting

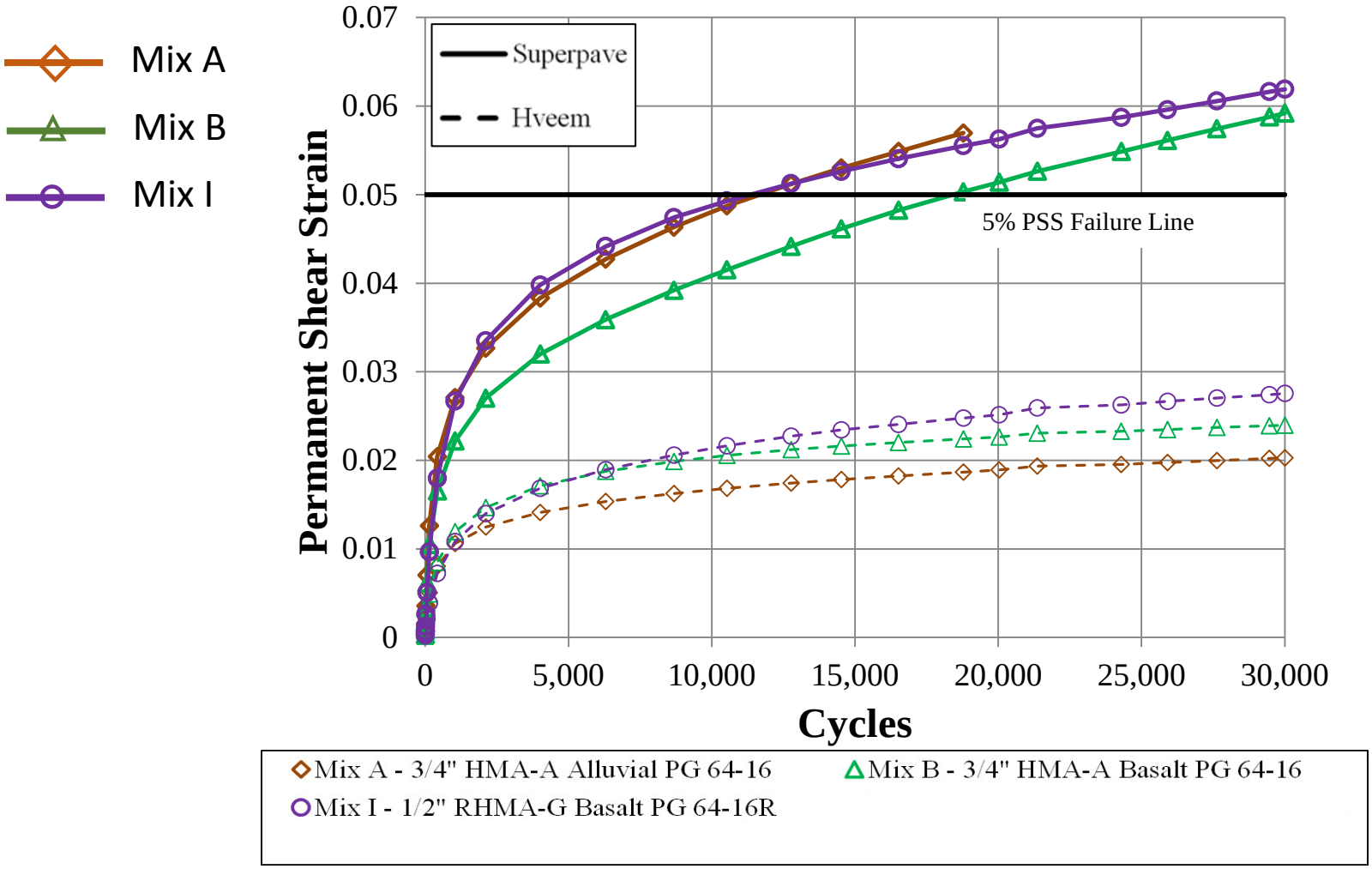
Repeated Simple Shear at Constant Height

100 kPa shear stress
Temperature: 45 and 55^{o}C

Test Results

Rutting

Repeated Simple Shear at Constant Height



Testing Program

Cracking

Flexural fatigue

200 and 400 micro strain
Temperature: 20^{o}C

Stiffness

Flexural frequency sweep

Temperature: 10, 20 and 30^{o}C
Various frequencies

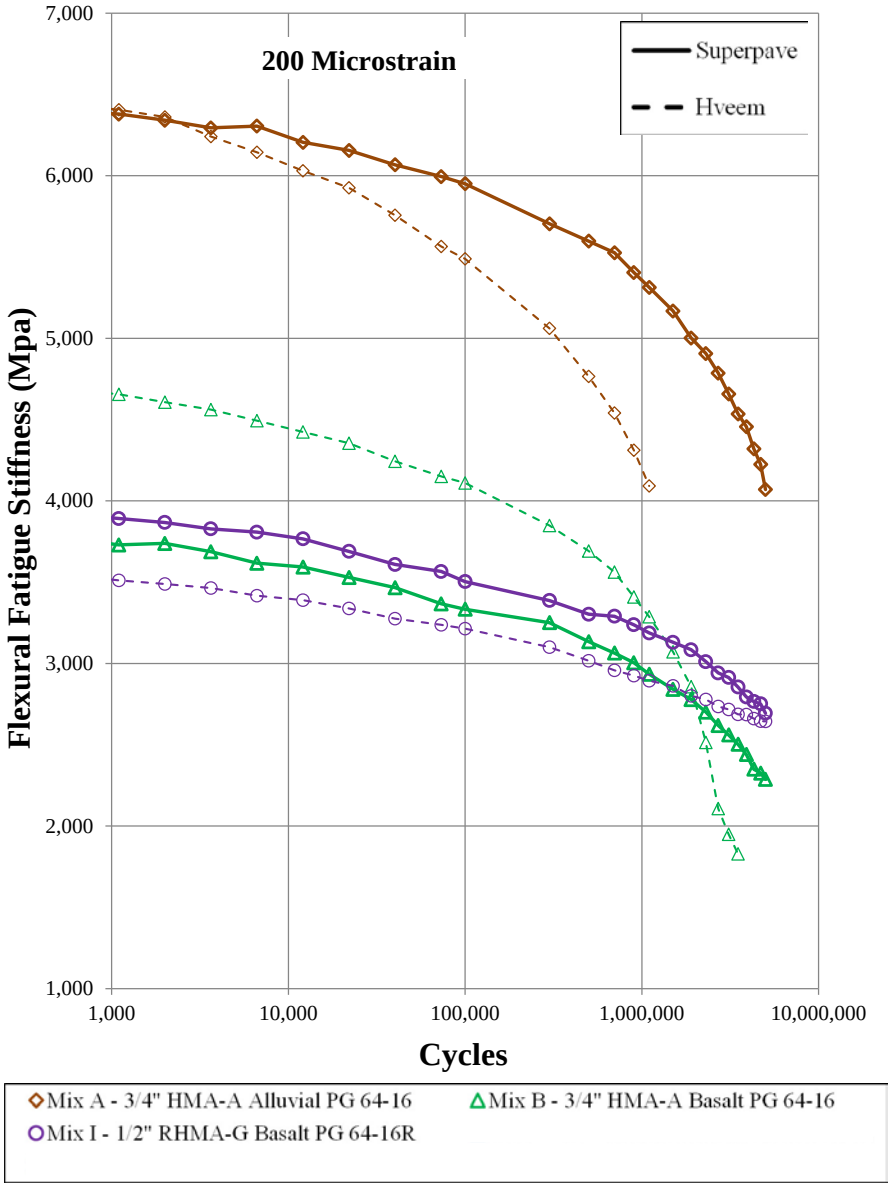
Test Results

Flexural fatigue

Mix A

Mix B

Mix I



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Rutting performance evaluation

Factorial to evaluate Hveem vs. Superpave mix design methods

2 structures x 2 traffic levels x 3 climates x 3 mixes

Structures: Structure 1: 125mm thick AC layer on top of 300mm thick AB (E_{ab}=250MPa) and a subgrade with 150MPa stiffness.

Structure 2: 175mm thick AC layer on top of 300mm thick AB (E_{ab}=250MPa) and a subgrade with 150MPa stiffness.

Traffic: Traffic 1: Axles 1st year = 3M with a 5% growth rate

Traffic 2: Axles 1st year = 6M with a 5% growth rate

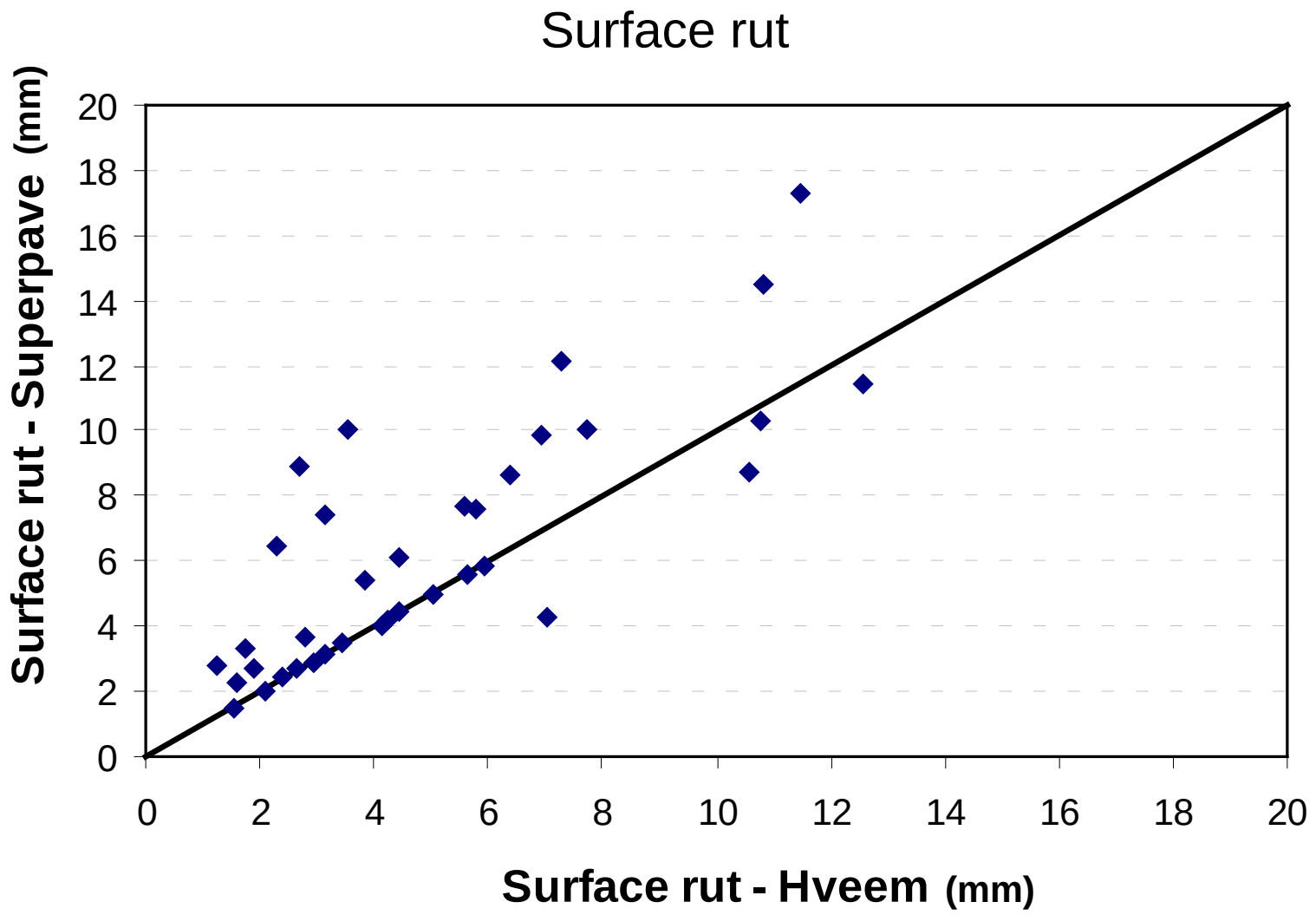
Climates: Inland Valley

High Desert

Low mountain

Mixes: Mix A; Mix B; Mix I

Rutting comparison Hveem vs. Superpave



Rutting comparison Hveem vs. Superpave

Welch modified two sample t-test for surface rut predicted for Hveem and Superpave mixes

F_1 and F_2 are two distributions, the possible hypotheses and alternatives concerning these distributions are:

H_0: $F_1(x) = F_2(x)$
H_A: $F_1(x) \neq F_2(x)$

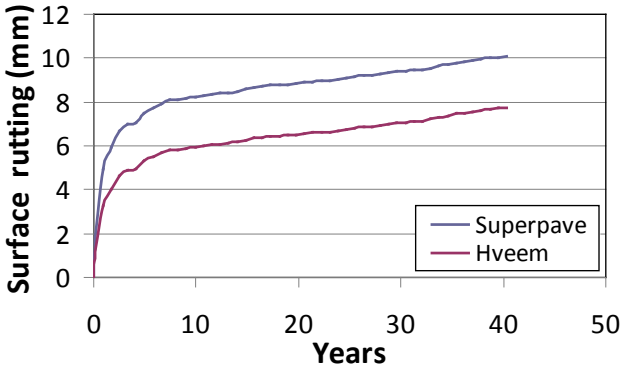
Decision rule: Reject H_0 if p-value < 0.10; accept H_0 if p-value ≥ 0.10

P-value = 0.09 for Hveem vs.Superpave

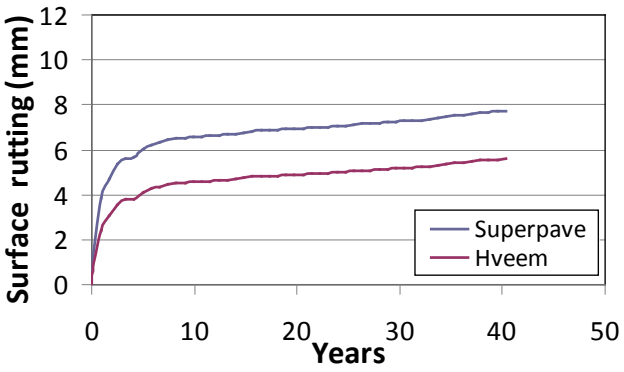
Predicted surface rutting for Hveem and Superpave mix design method are not equal. Superpave is higher.

Rutting comparison Hveem vs. Superpave

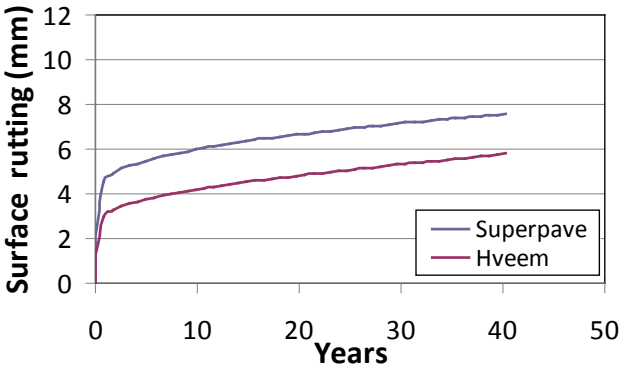
Surface rut for Mix A - Traffic level 1



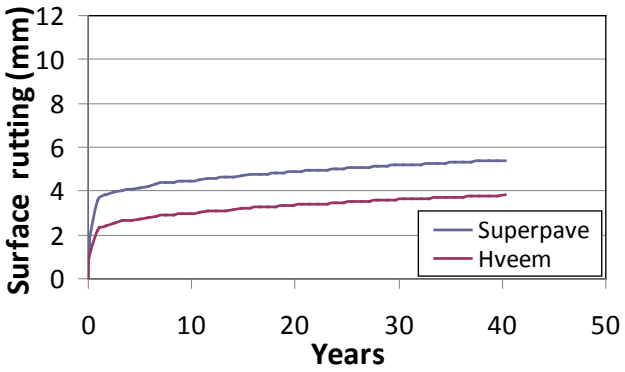
High Desert – Thin AC



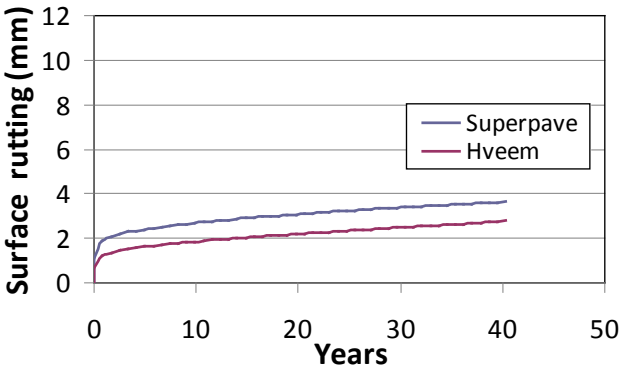
High Desert – Thick AC



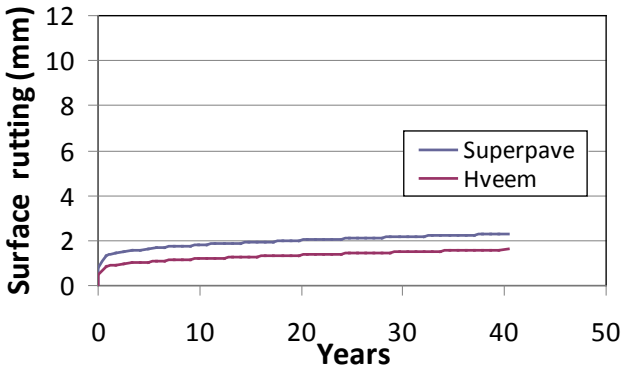
Inland Valley – Thin AC



Inland Valley – Thick AC



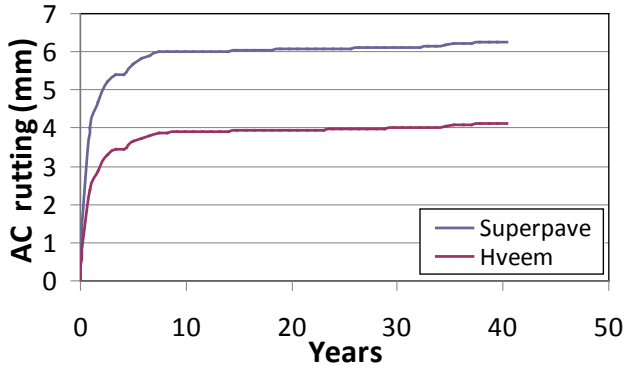
Low mountain – Thin AC



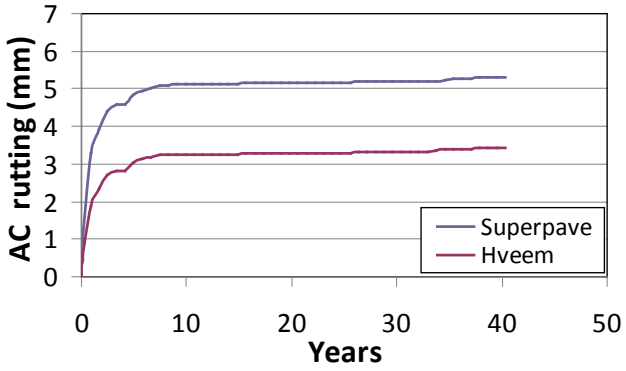
Low mountain – Thick AC

Rutting comparison Hveem vs. Superpave

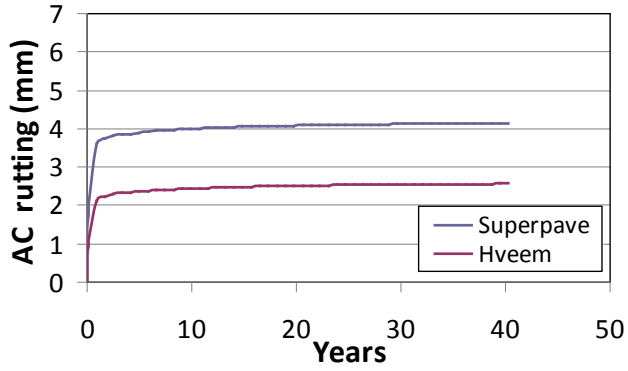
AC rut for Mix A - Traffic level 1



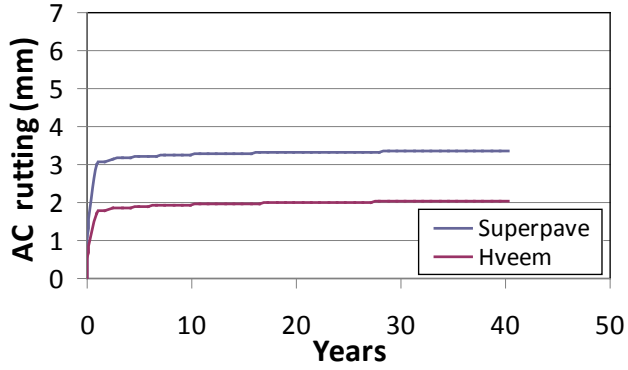
High Desert – Thin AC



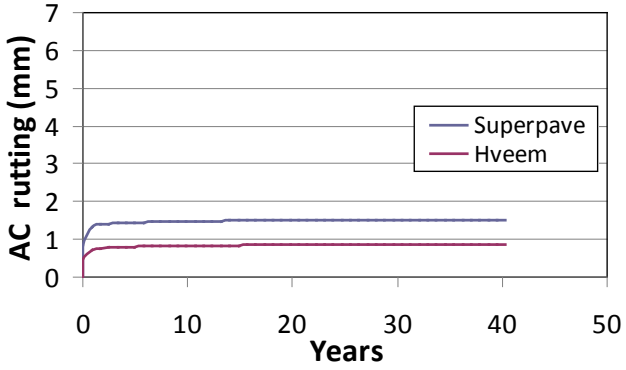
High Desert – Thick AC



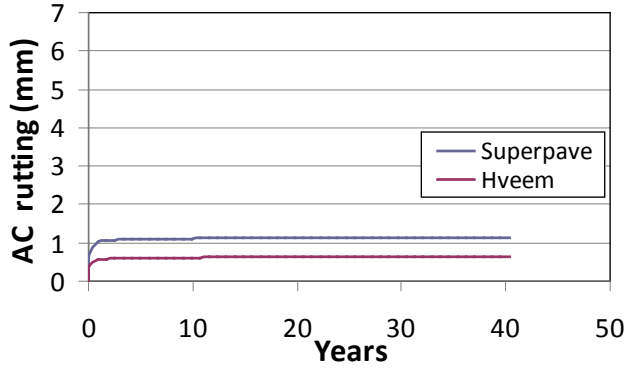
Inland Valley – Thin AC



Inland Valley – Thick AC



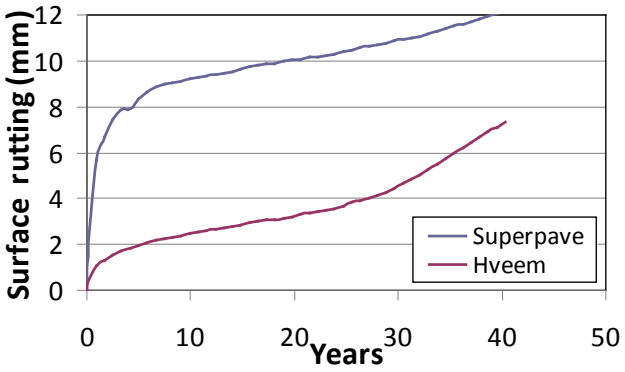
Low mountain – Thin AC



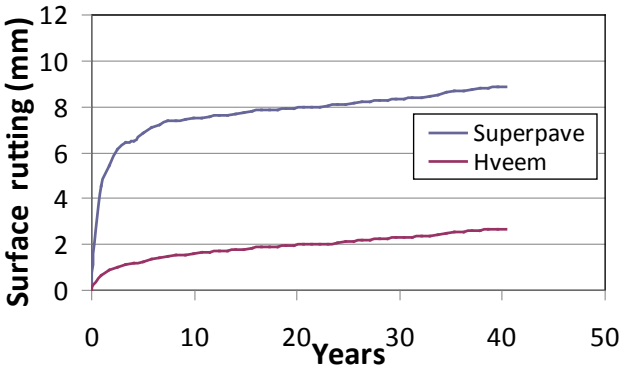
Low mountain – Thick AC

Rutting comparison Hveem vs. Superpave

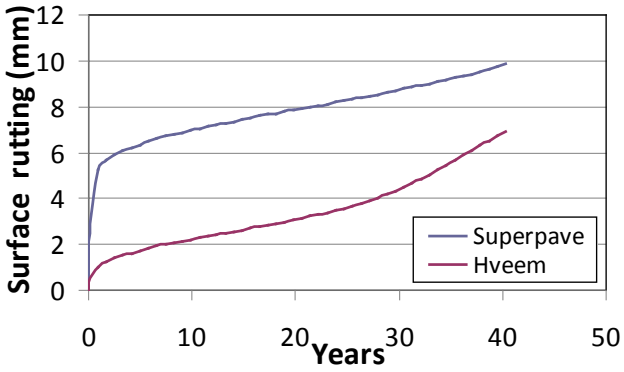
Surface rut for Mix B - Traffic level 1



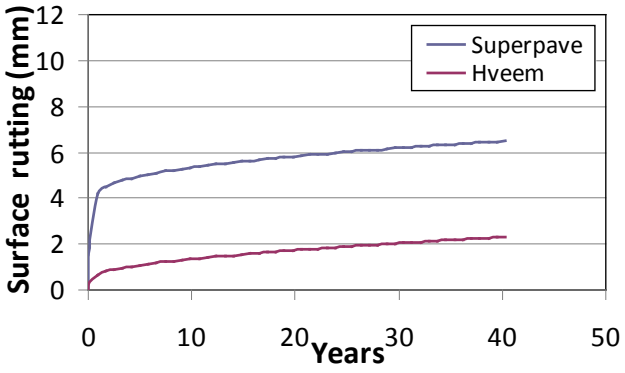
High Desert – Thin AC



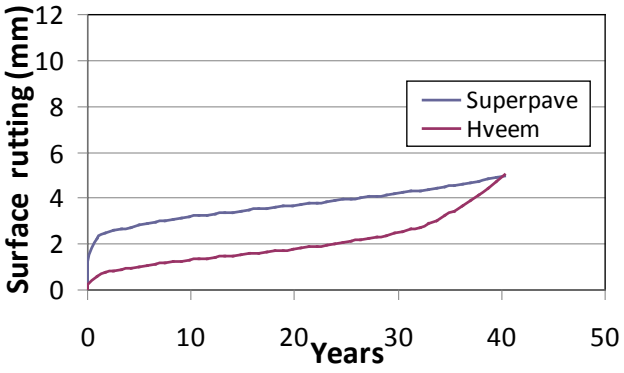
High Desert – Thick AC



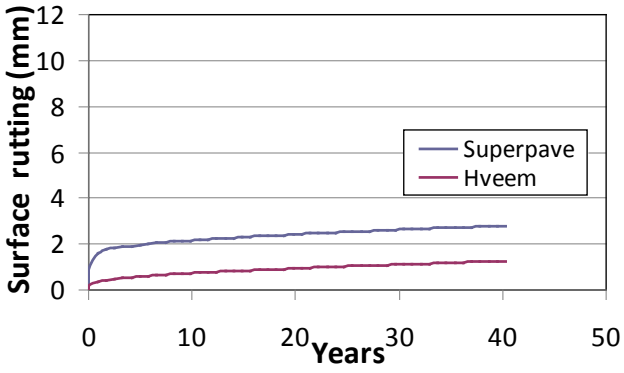
Inland Valley – Thin AC



Inland Valley – Thick AC



Low mountain – Thin AC



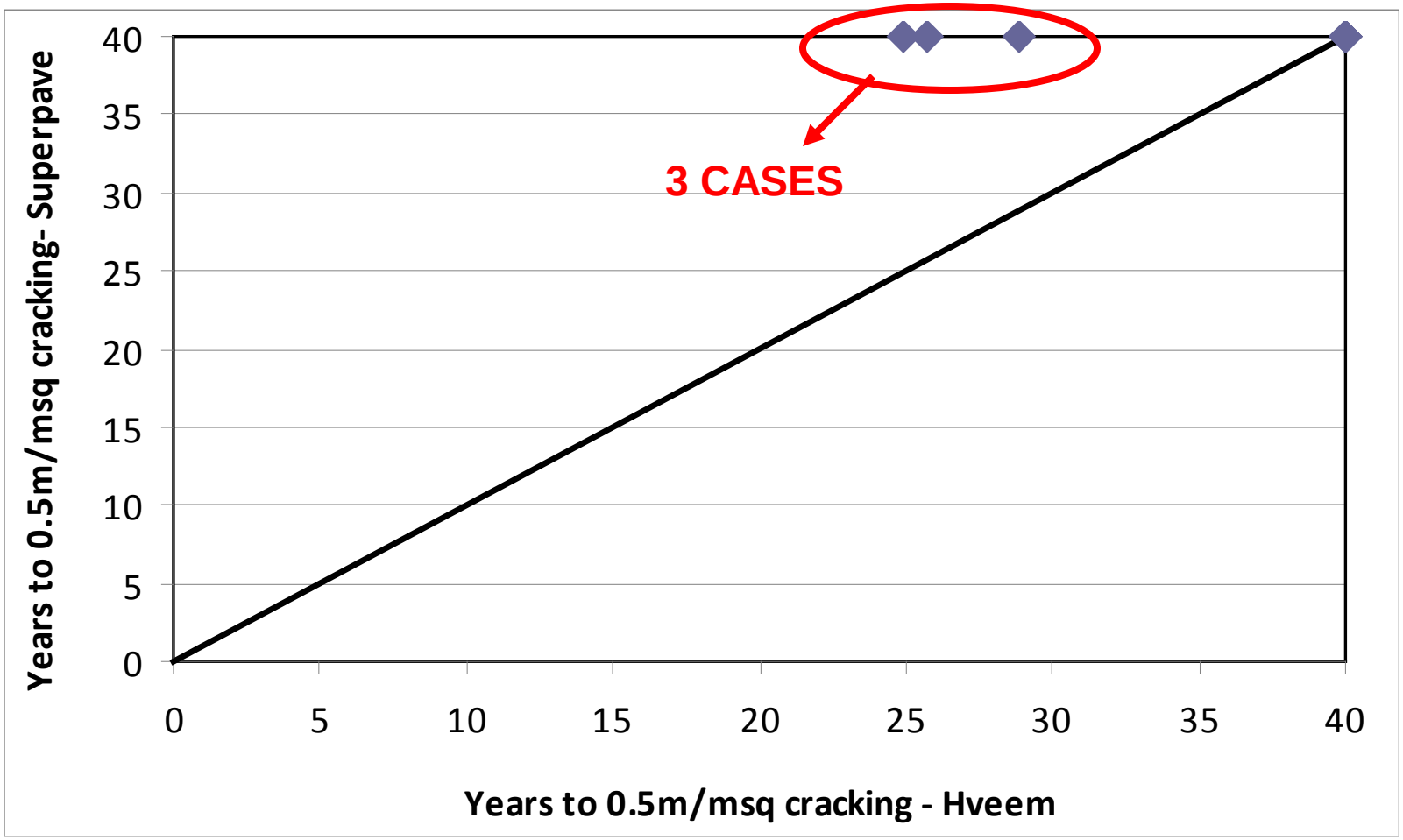
Low mountain – Thick AC

Cracking of thin layered structures is causing third stage rutting accumulation.

Cracking performance evaluation

Cracking comparison Hveem vs. Superpave

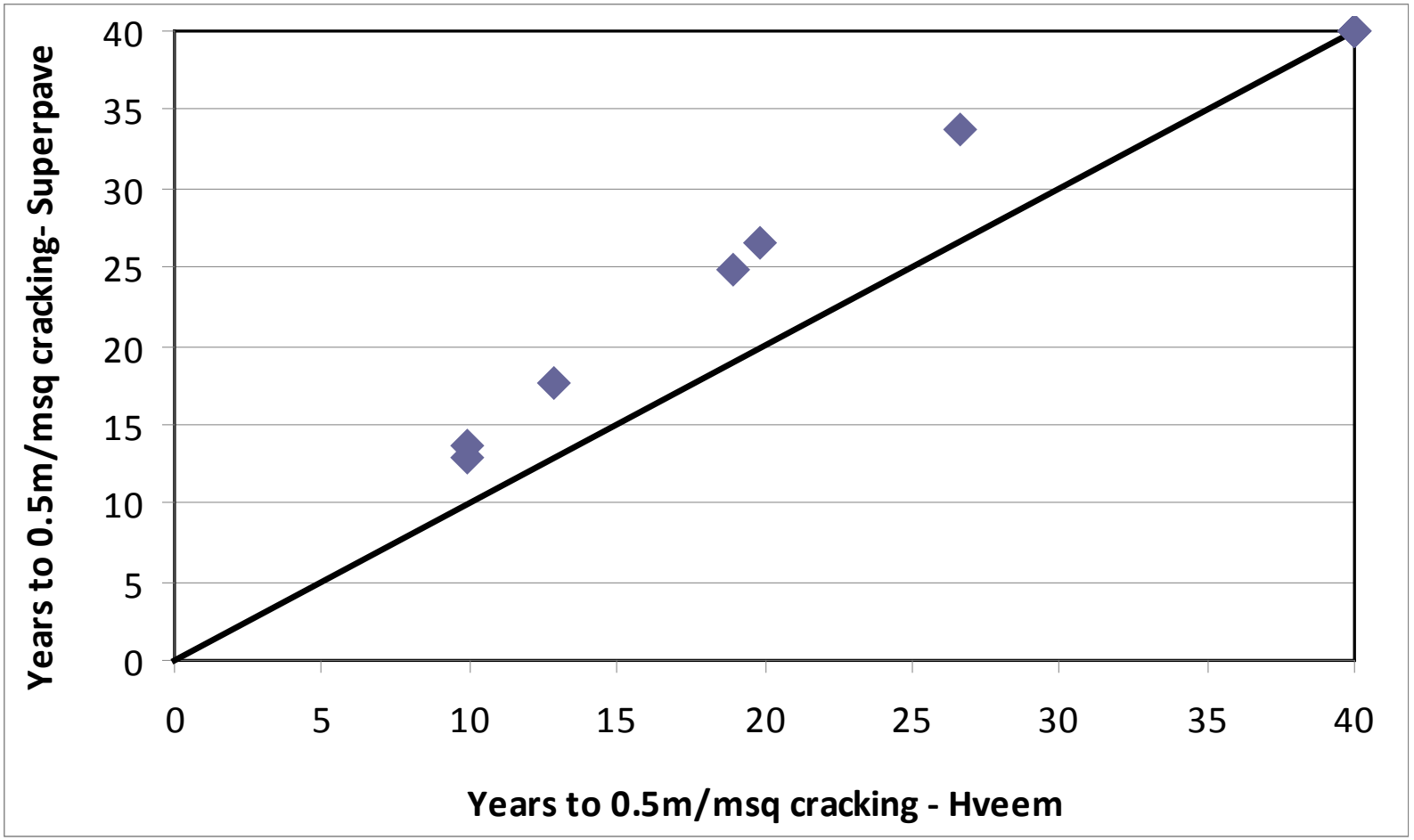
Years to 0.5m/msq cracking – Mix A



Year 40 means no cracking larger than 0.5m/msq in 40 years

Cracking comparison Hveem vs. Superpave

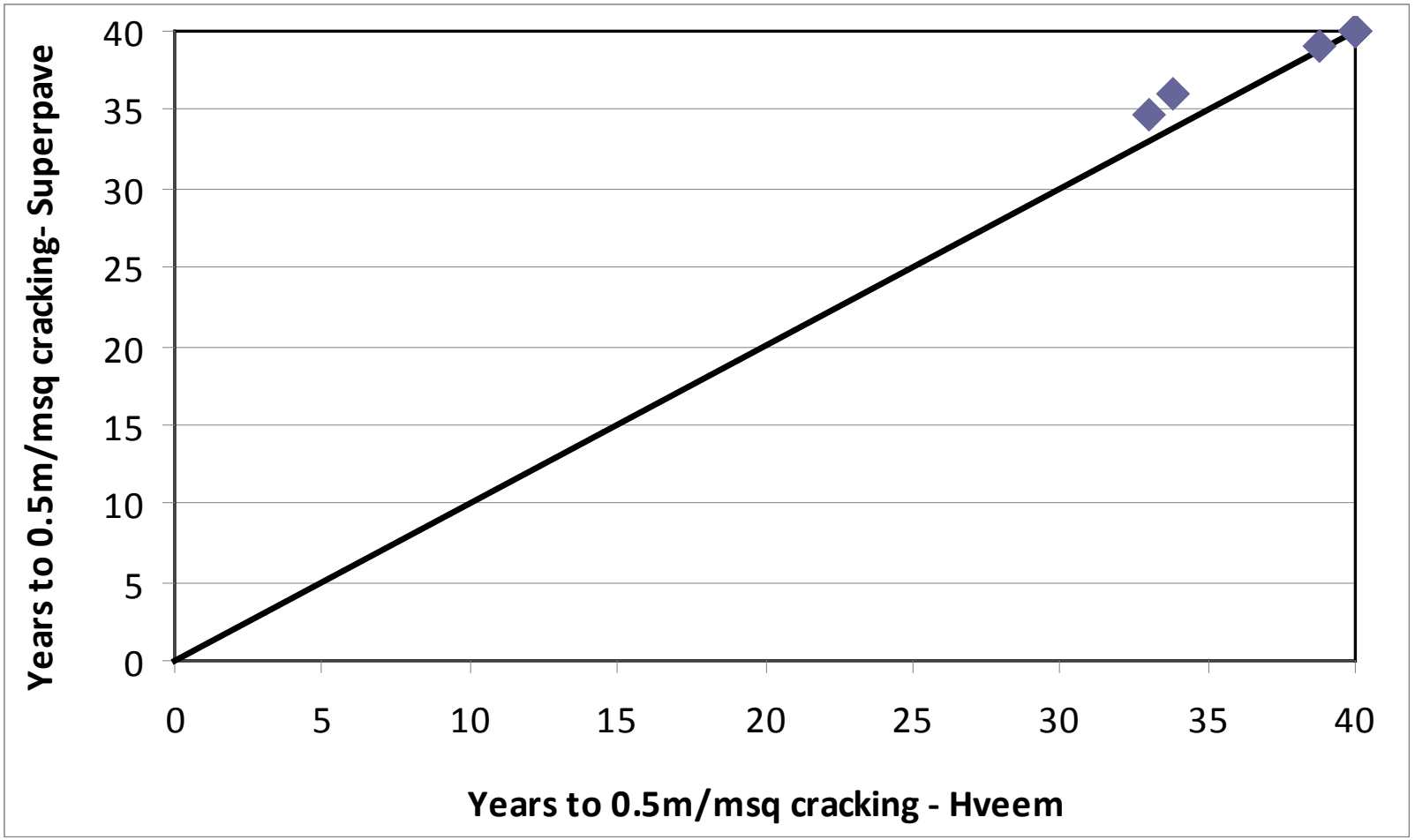
Years to 0.5m/msq cracking – Mix B



Year 40 means no cracking larger than 0.5m/msq in 40 years

Cracking comparison Hveem vs. Superpave

Years to 0.5m/msq cracking – Mix I



Year 40 means no cracking larger than 0.5m/msq in 40 years

Two cases to compare Hveem and Superpave:

1. Evaluate the reflection cracking resistance of thin Mix I (Rubber) layer on top of cracked PCC

2. Do thickness design for Hveem and Superpave mix designs and answer the question:

   What is the cost of using Hveem and Superpave mix designs to achieve equal performance?

   Superpave uses more binder but higher cracking performance reduces the material volume used for construction

Case 1:

1. 3.2M ESALS - 20 years (1)
2. High Desert; Low Mountain (2)
3. .

3 mixes – Mix A; Mix B; Mix I	**60 mm**
Cracked PCC - 35,000MPa	**125 and 175 mm**
AB-Class2 - 200MPa	**100 mm**
SG – CL - 100MPa	

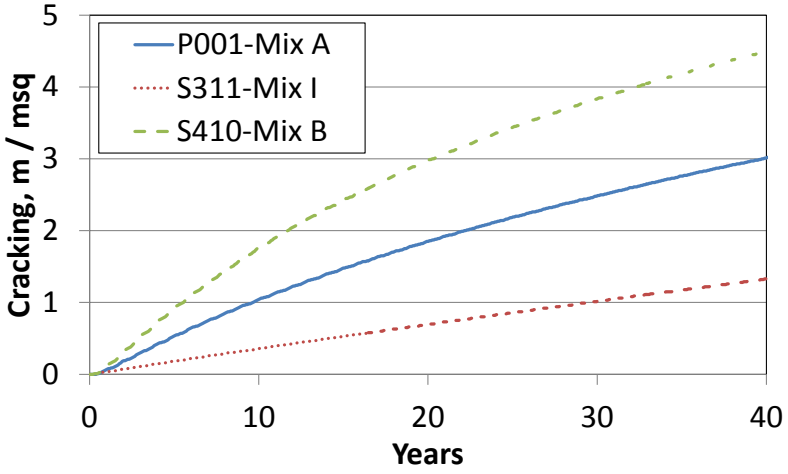
(6)

4. Hveem and Superpave (2)

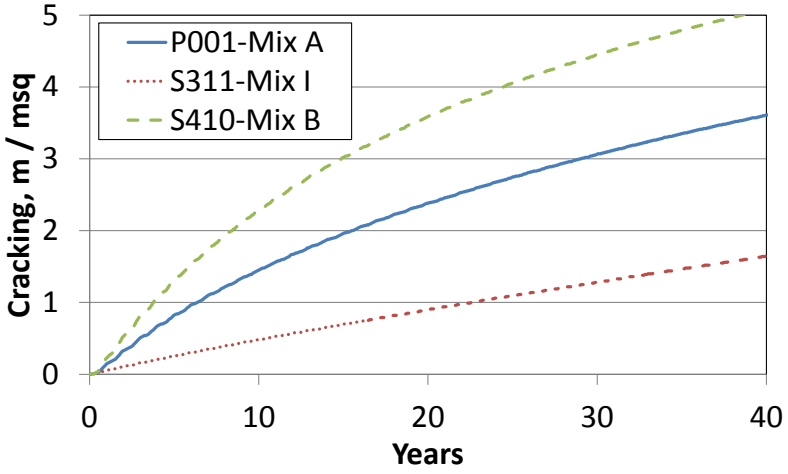
24 cases x 1 (with reflection cracking) = 24 Cases

Crack and seat –
Crack spacing 1.2m

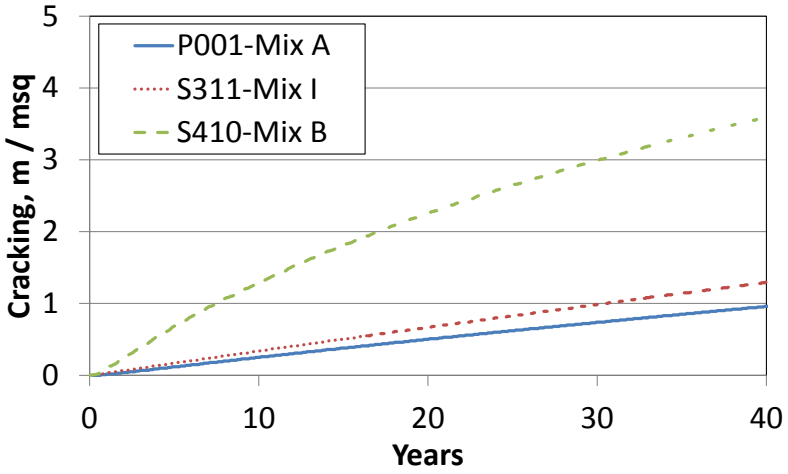
Low Mountain



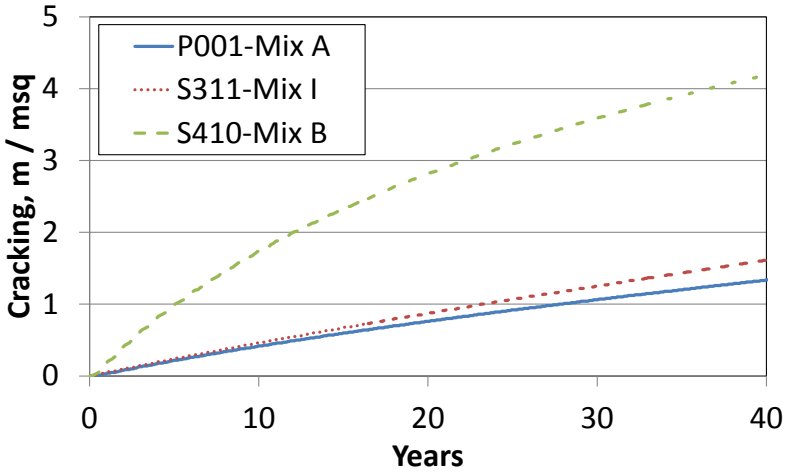
Structure 1 – Thin PCC - Hveem



Structure 2 – Thick PCC - Hveem



Structure 1 – Thin PCC - Superpave



Structure 2 – Thick PCC - Superpave

Case 2:

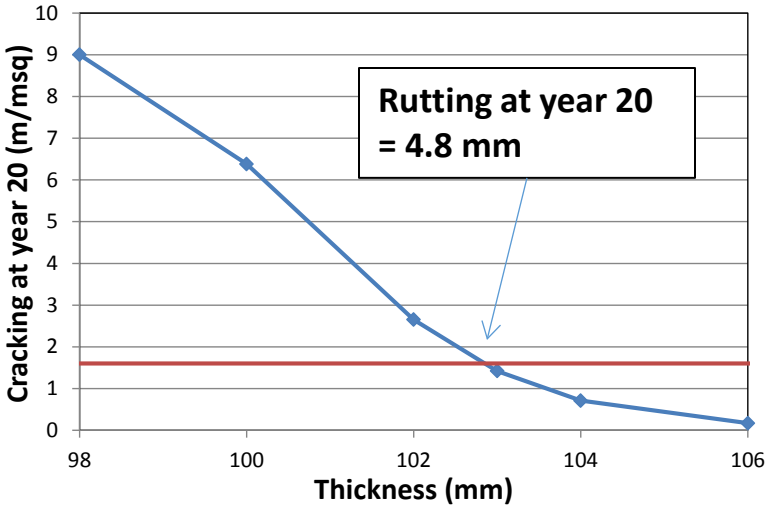
Amount of binder required for Hveem and Superpave mix designs to achieve equal performance

1. 2.5M ESALS - 20 years: TI10 & 40M ESALS – 20 years: TI14 (2)
2. Inland Valley (1)
3. .

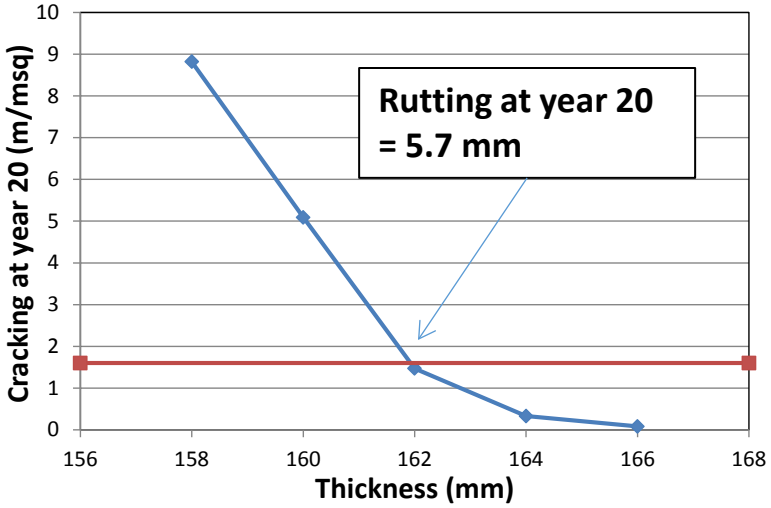
Mix A	**VARIABLE**	(multiple)
AB-Class2 - 200MPa	**150 mm**	
SG – CL - 100MPa		

4. Hveem and Superpave (2)

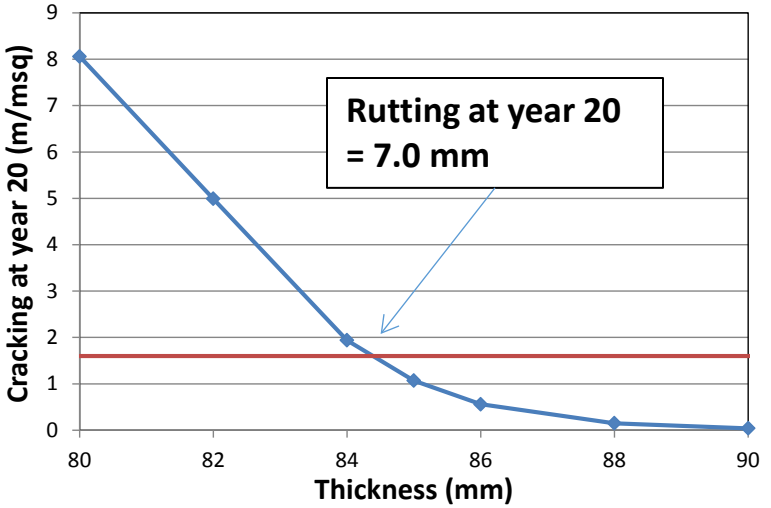
Design criteria: Cracking at year 20 = 1.6m/msq



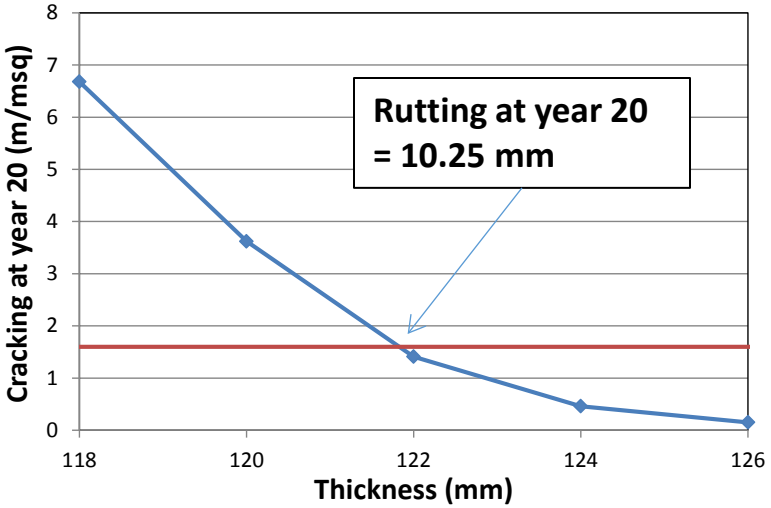
TI10 - Hveem **(103 mm)**



TI14 - Hveem **(162 mm)**



TI10 - Superpave **(84 mm)**



TI14 - Superpave **(122 mm)**

Amount of binder used for Hveem and Superpave

Volume of asphalt mix used for a 1 mile section for a 3.35m lane width

	TI 10 - V_{mix} (m^3)	TI 14 - V_{mix} (m^3)
Hveem	555.30	873.39
Superpave	452.87	657.74

	Design AC (%)	TI 10 - V_{binder} (m^3)	TI 14 - V_{binder} (m^3)
Hveem	5.00	27.77	43.67
Superpave	5.50	24.91	36.18

To get equal performance:

For TI 10 - The amount of binder required is 11.5 percent larger for the Hveem mix

For TI 14 - The amount of binder required is 20.7 percent larger for the Hveem mix

Conclusions

- Lower binder content for Hveem mix design results in
  - better rutting performance
  - worse cracking performance

- Difference in cracking resistance between Hveem and Superpave mix designs is not significant for the rubber mix (Mix I)

- For TI 10: The amount of binder required is 11.5 percent larger for the Hveem mix
  TI 14: The amount of binder required is 20.7 percent larger for the Hveem mix

  Superpave reduces cost for Mix A for the climate and traffic used in the simulations.

FUTURE STUDY:

WHAT HAPPENS IF RUTTING IS THE CONTROLLING FACTOR FOR DESIGN?

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Q & A

Thank you!

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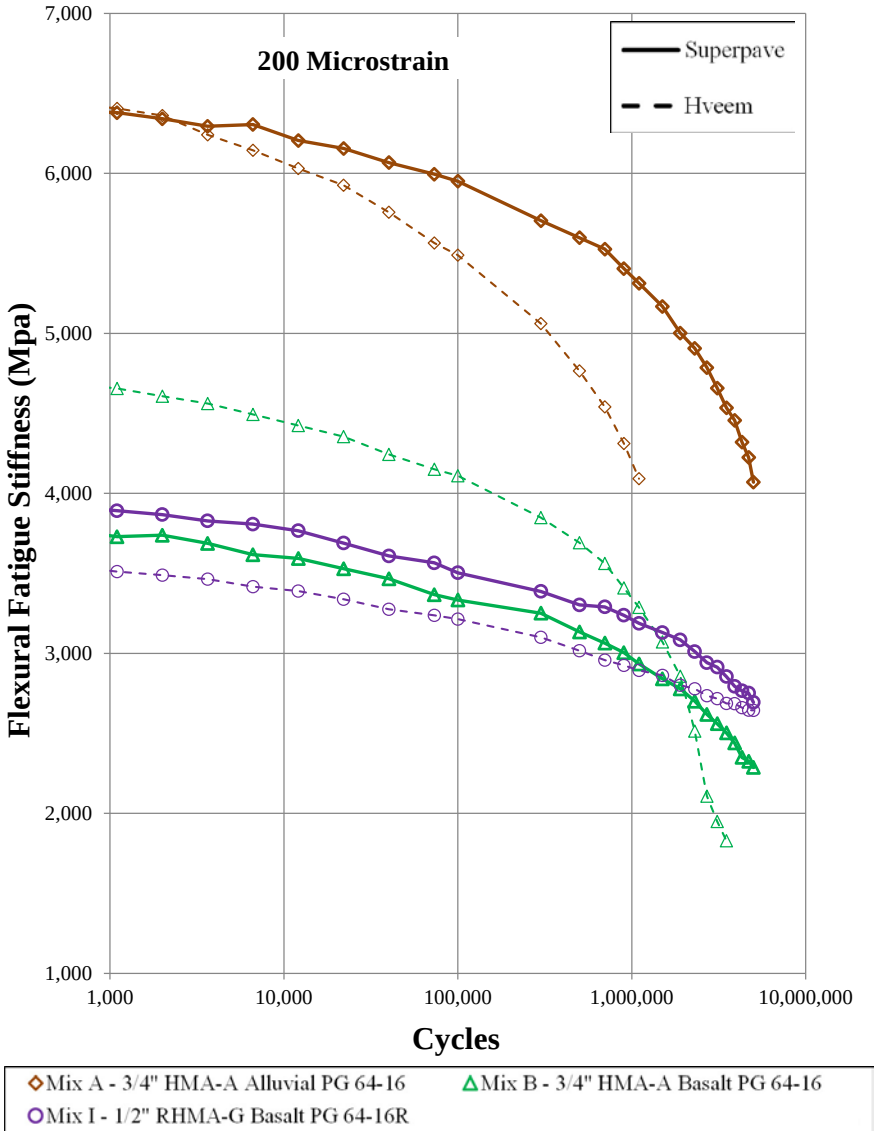
Results

- Mix I (Rubber) – Hveem vs Superpave: Close performance
- Mix A - Hveem vs Superpave: Superpave design~better perfor.



Case 1:

1. 76M ESALS - 20 years (1)
2. High Desert; Inland Valley; Low Mountain (3)

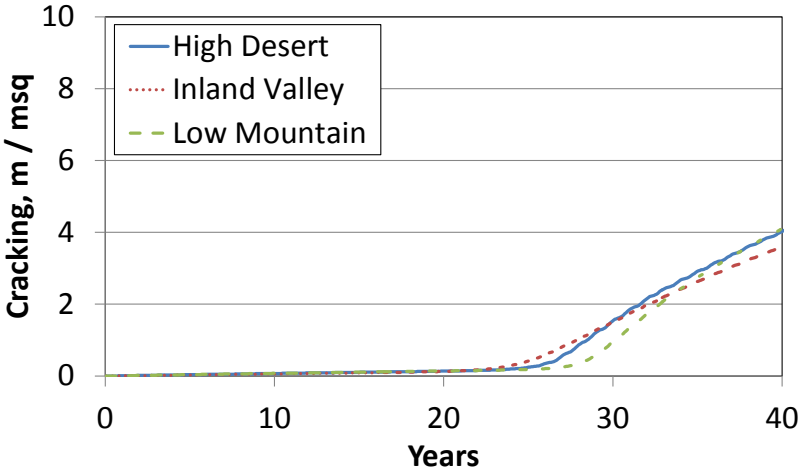
Mix I	**60 mm**
Mix A	**125 and 175 mm**
AB-Class2 - 200MPa	**100 mm**
SG – CL - 100MPa	

(2)

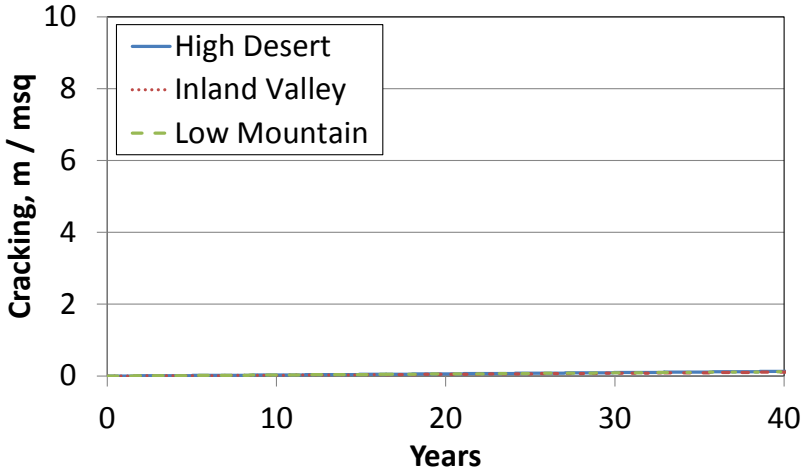
3. Hveem and Superpave (2)

12 cases x 2 (with and without reflection cracking) = 24 Cases

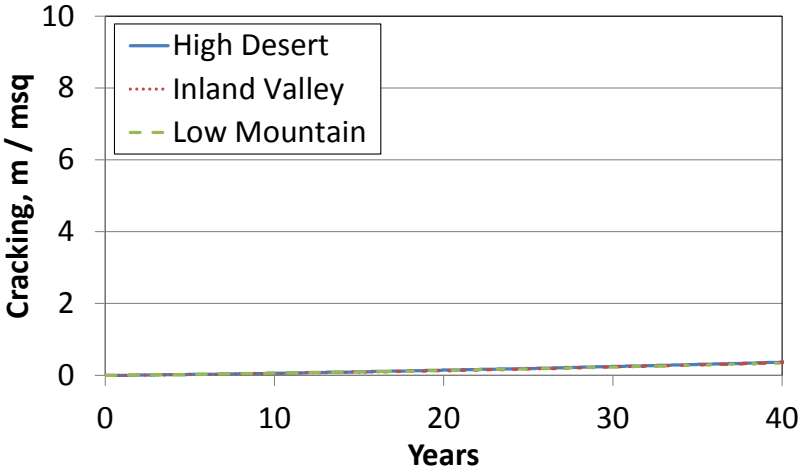
With reflection cracking



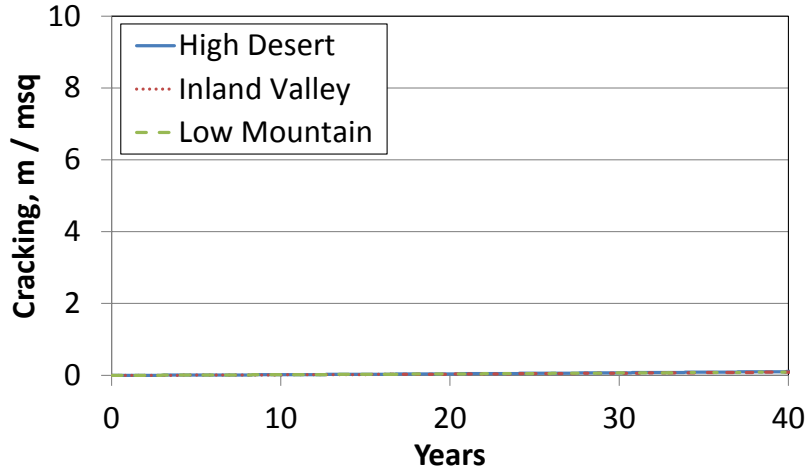
Structure 1 – Thin DGAC - Hveem



Structure 2 – Thick DGAC - Hveem



Structure 1 – Thin DGAC - Superpave



Structure 2 – Thick DGAC - Superpave

Future research

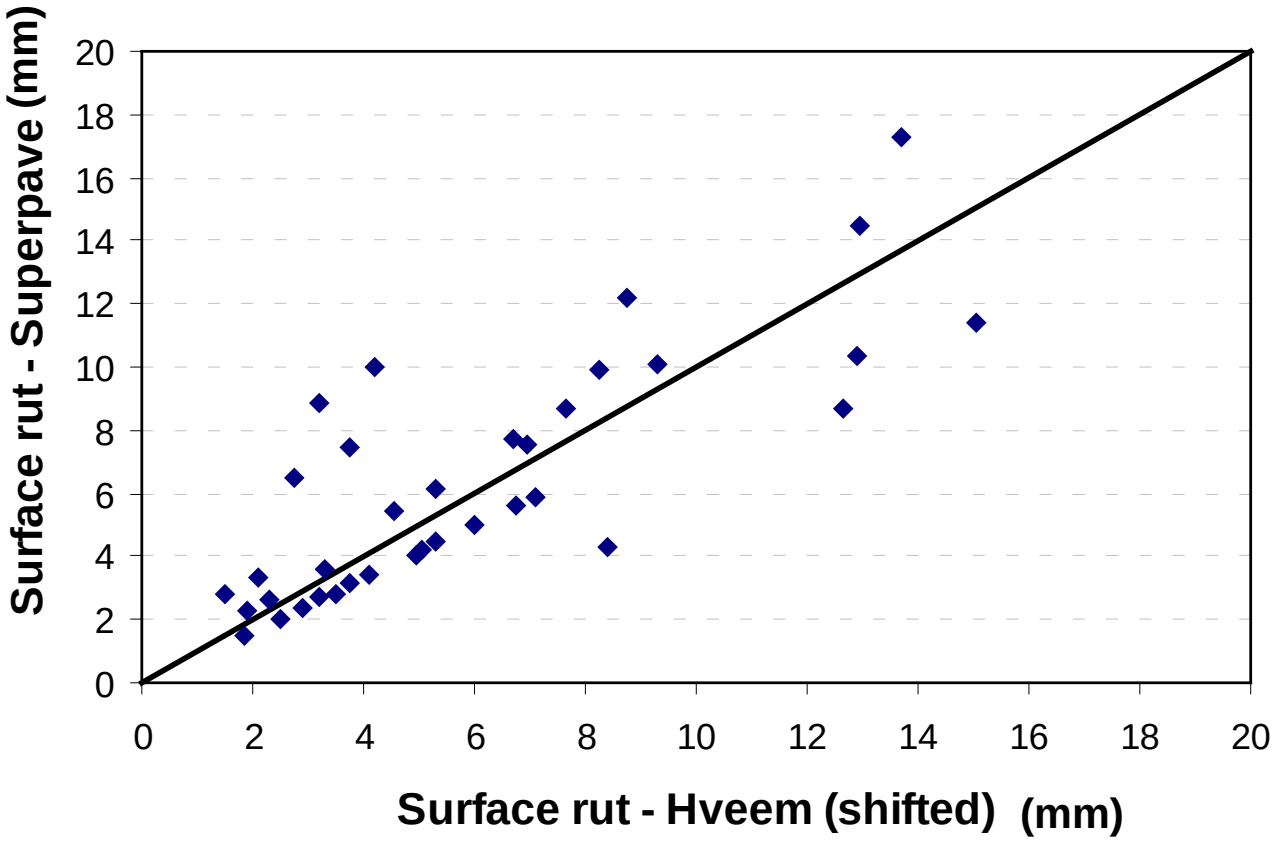
- Superpave improved cracking performance and reduced the cost WHEN CRACKING IS THE CONTROLLING DESIGN CRITERIA.

  HVEEM mix design might be more cost effective
  WHEN RUTTING IS THE CONTROLLING DESIGN CRITERIA

  WARMER CLIMATES AND HEAVY LOADS

Rutting comparison Hveem vs. Superpave

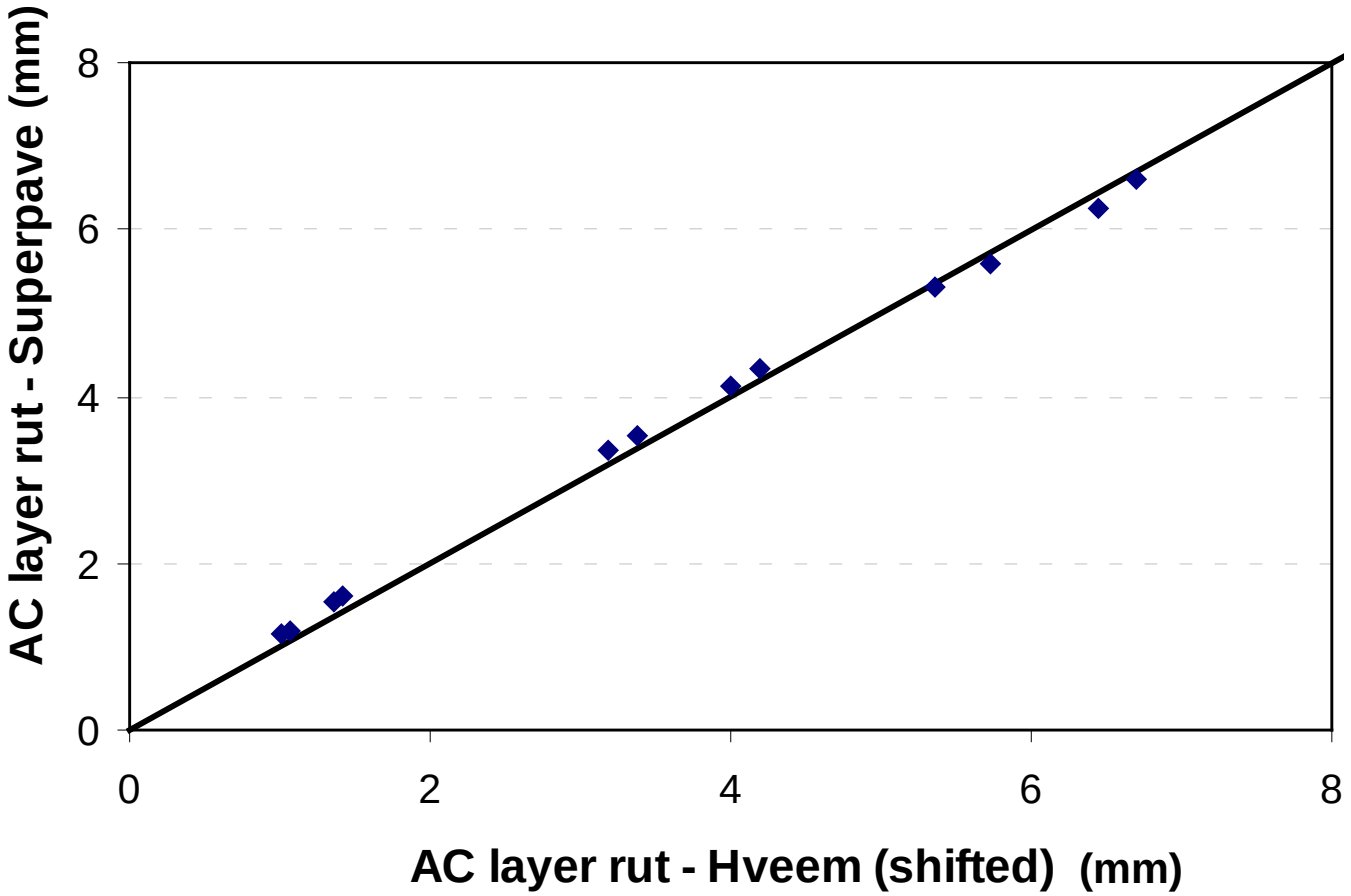
Shift factor between predicted surface rutting for Hveem and Superpave mix design methods



Surface rutting predicted for Superpave mixes is 20% larger than rutting for Hveem mixes.

Rutting comparison Hveem vs. Superpave

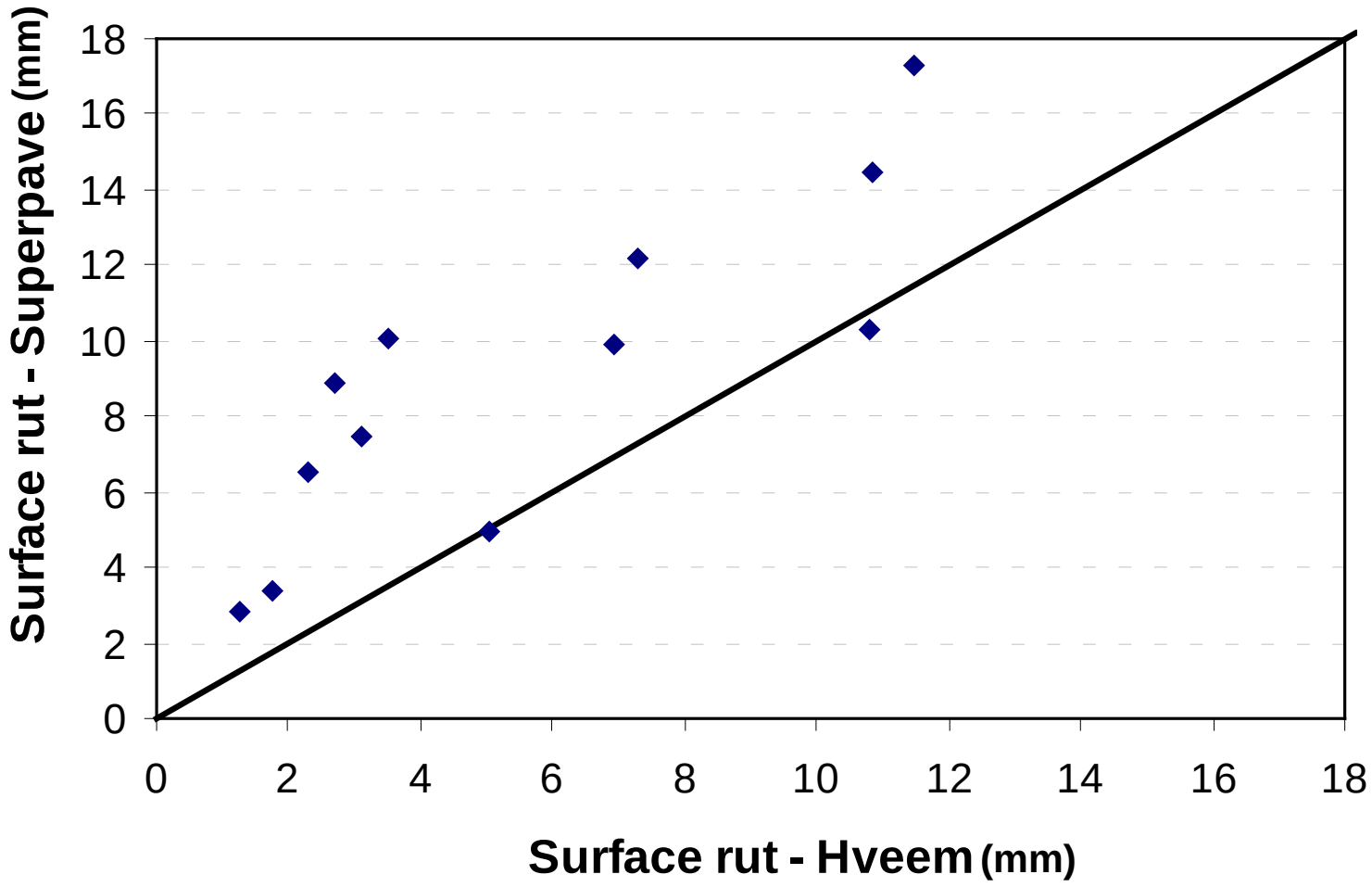
Shift factor between predicted AC rutting for Hveem and Superpave mix design methods



AC layer rutting predicted for Superpave mixes is 56% larger than rutting for Hveem mixes.

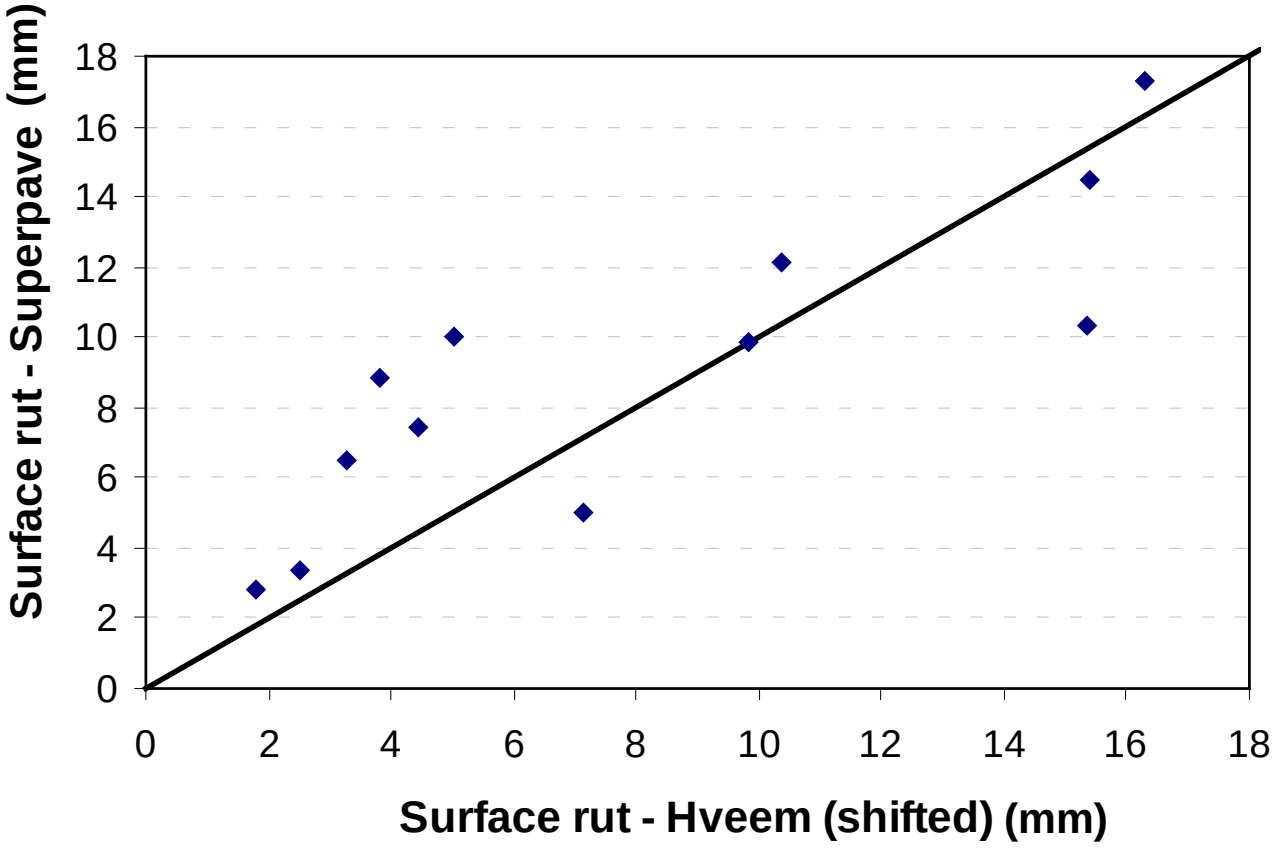
Rutting comparison Hveem vs. Superpave

Surface rut for S410 – Mix B



Rutting comparison Hveem vs. Superpave

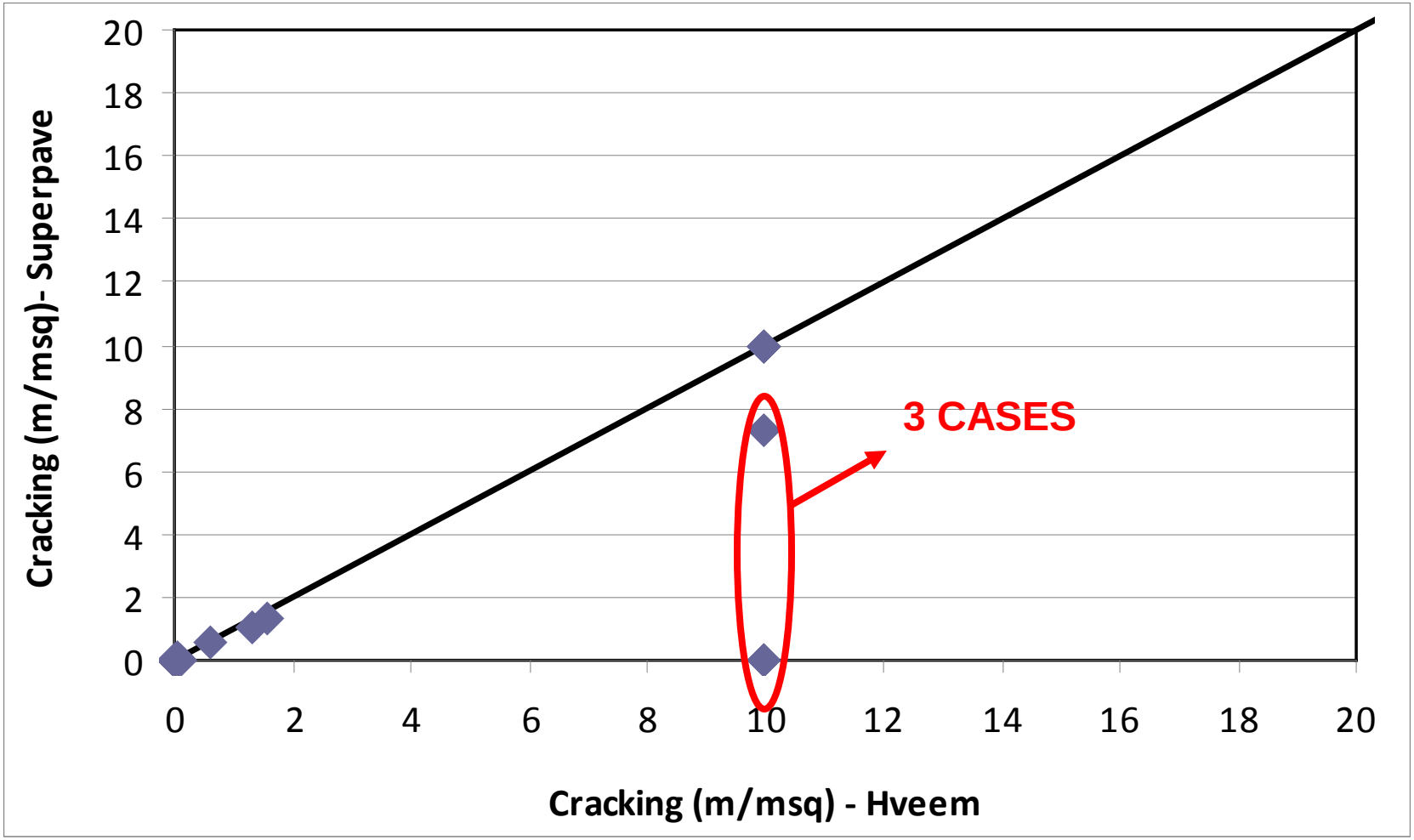
Shift factor between predicted surface rutting for Hveem and Superpave mix design methods



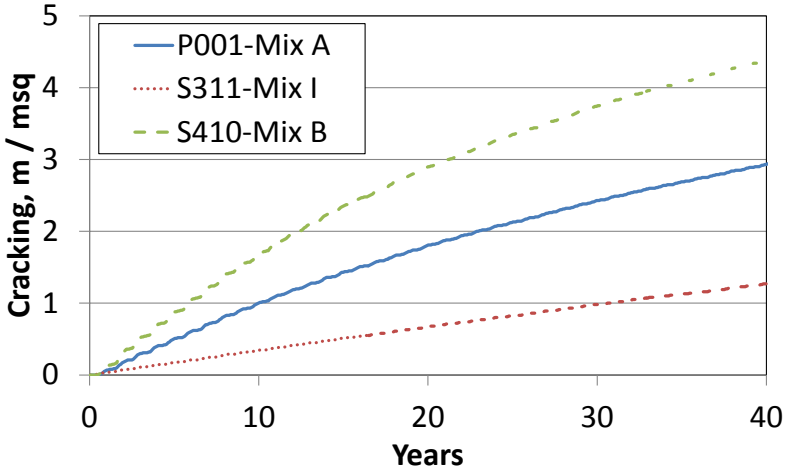
Surface rutting predicted for Superpave mixes is 42% larger than rutting for Hveem mixes.

Cracking comparison Hveem vs. Superpave

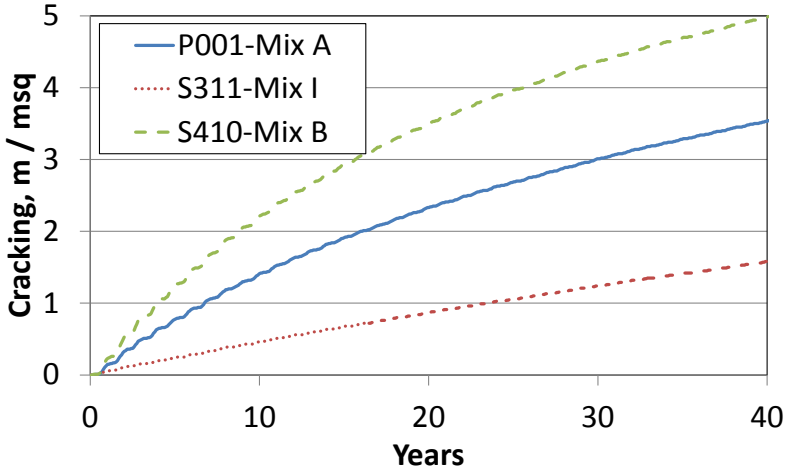
Surface cracking for all mixes



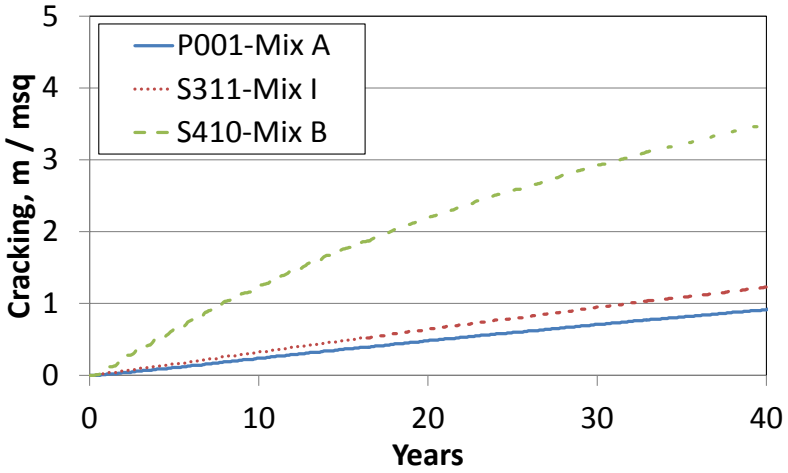
High Desert



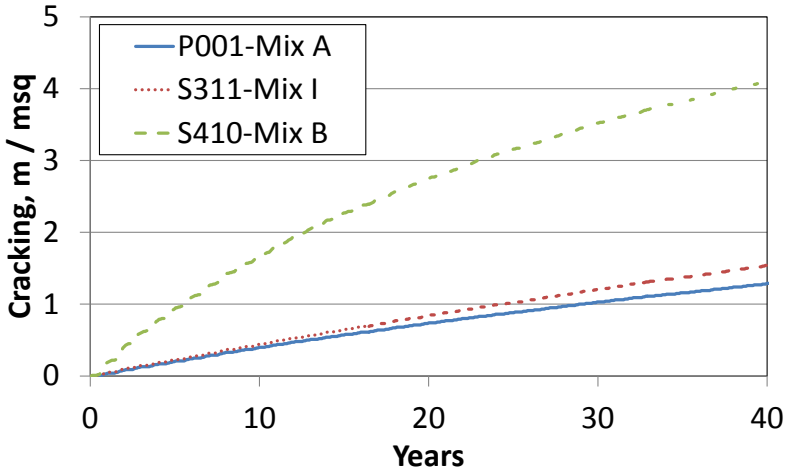
Structure 1 – Thin PCC - Hveem



Structure 2 – Thick PCC - Hveem



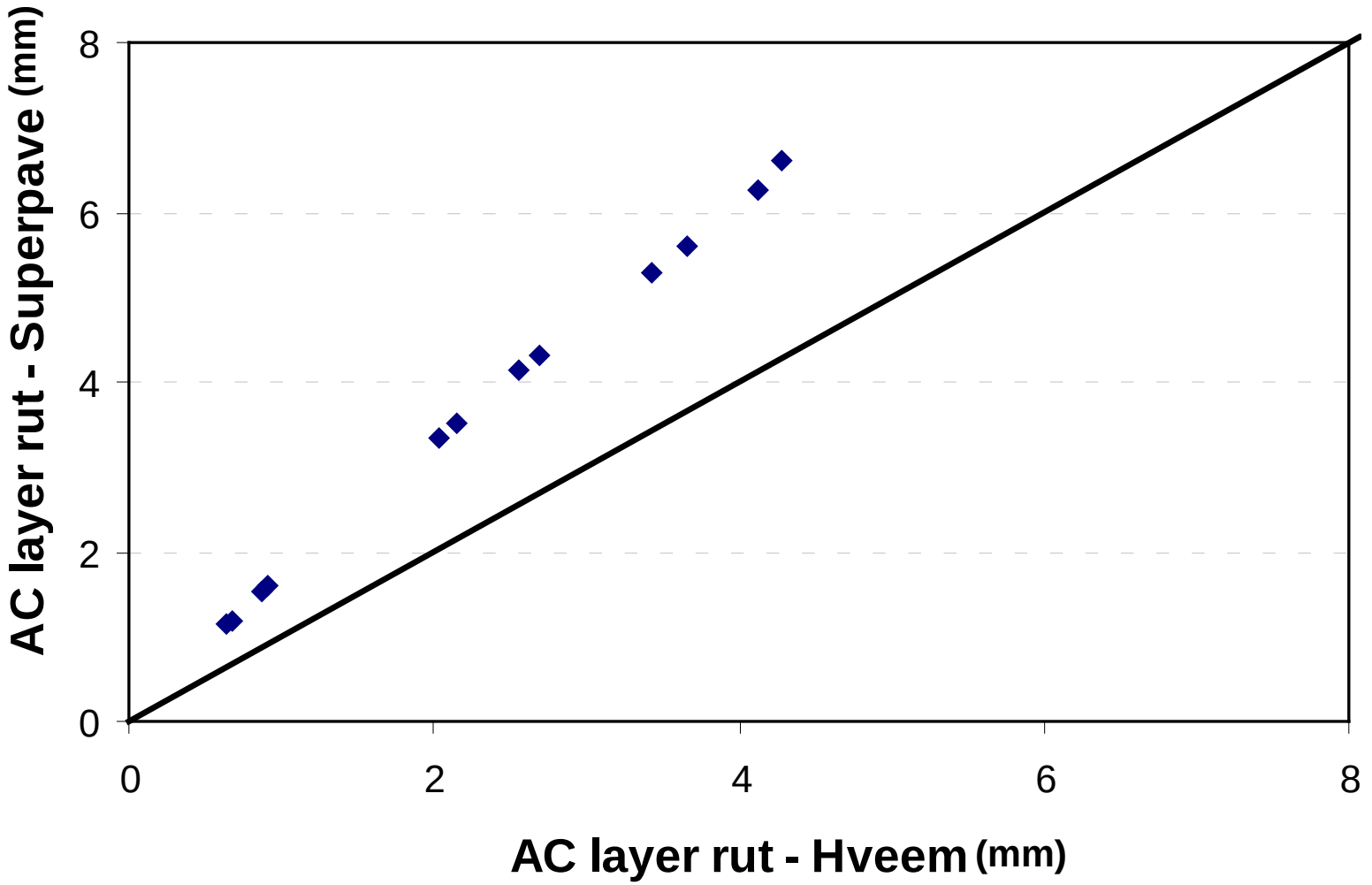
Structure 1 – Thin PCC - Superpave



Structure 2 – Thick PCC - Superpave

Rutting comparison Hveem vs. Superpave

AC rut for Mix A



Rutting comparison Hveem vs. Superpave

Welch modified two sample t-test for AC rut predicted for Hveem and Superpave mixes

F_1 and F_2 are two distributions, the possible hypotheses and alternatives concerning these distributions are:

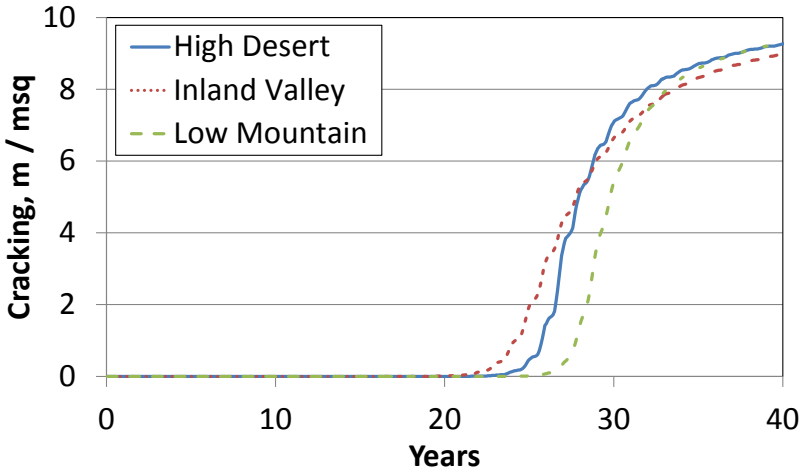
H_0: $F_1(x) = F_2(x)$
H_A: $F_1(x) \neq F_2(x)$

Decision rule: Reject H_0 if p-value < 0.10; accept H_0 if p-value ≥ 0.10

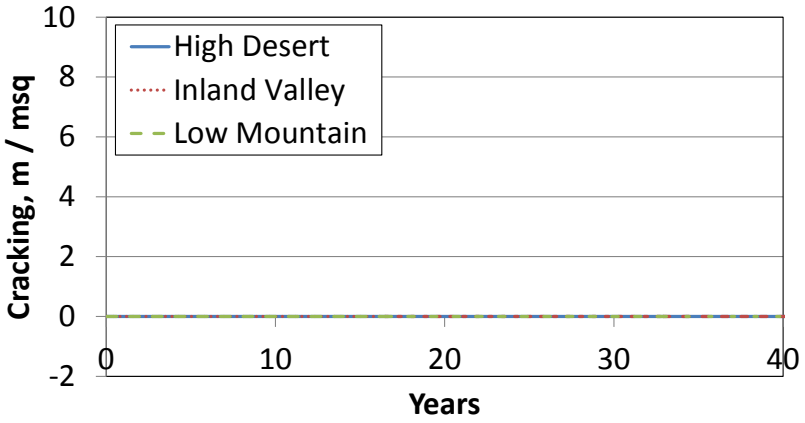
P-value = 0.05 for Hveem vs.Superpave

Predicted AC rutting for Hveem and Superpave mix design method are not equal. Superpave rutting is higher.

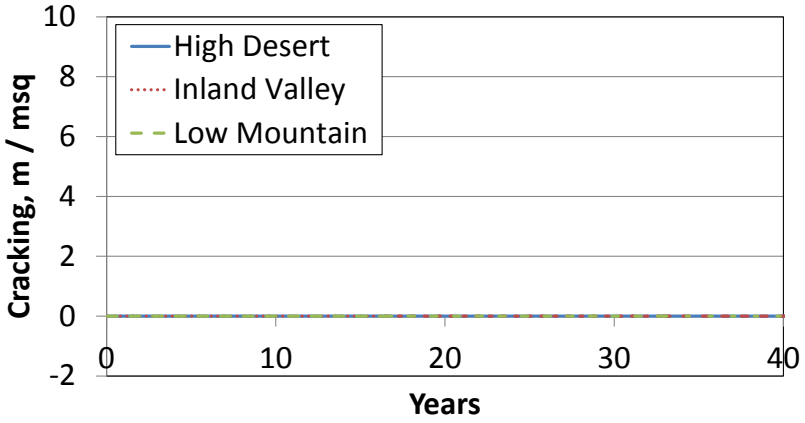
Without reflection cracking



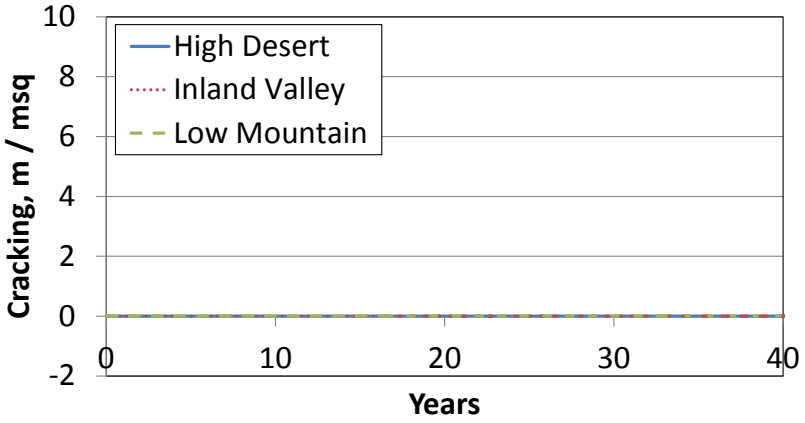
Structure 1 – Thin DGAC - Hveem



Structure 2 – Thick DGAC - Hveem



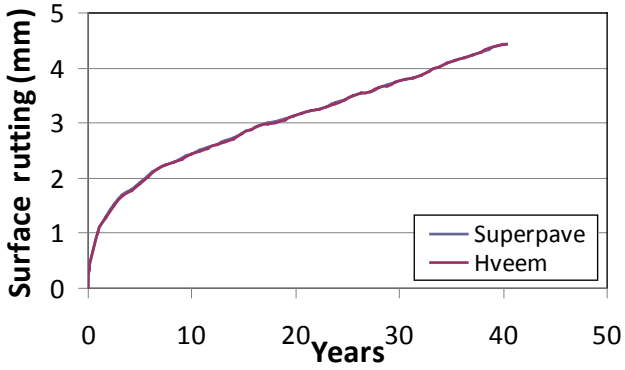
Structure 1 – Thin DGAC - Superpave



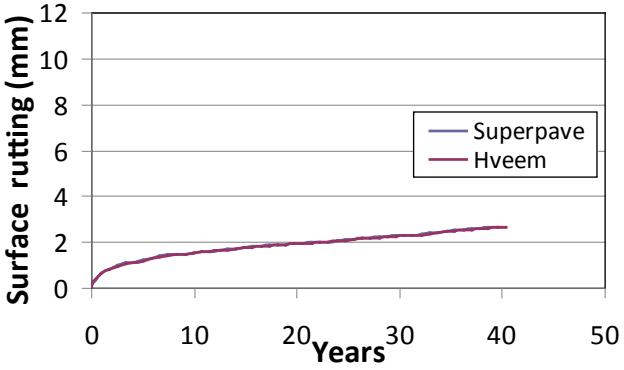
Structure 2 – Thick DGAC - Superpave

Rutting comparison Hveem vs. Superpave

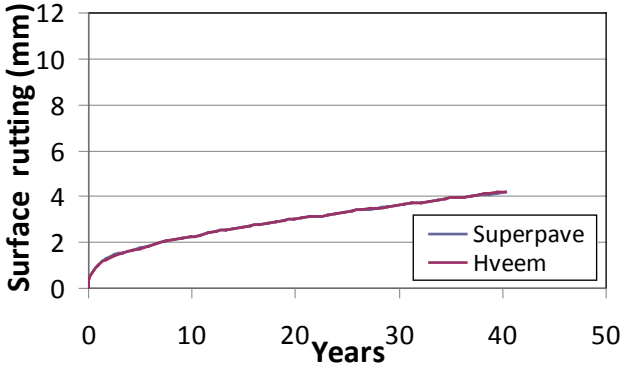
Surface rut for Mix I - Traffic level 1



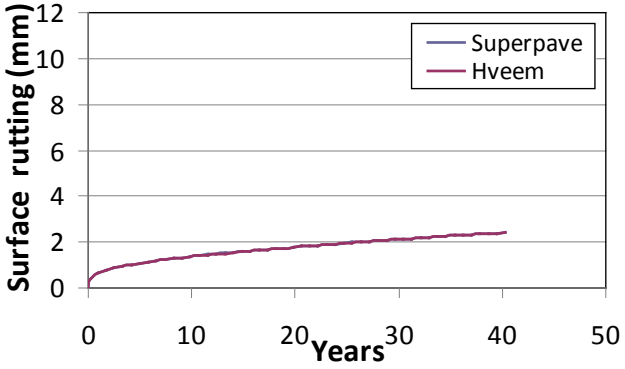
High Desert – Thin AC



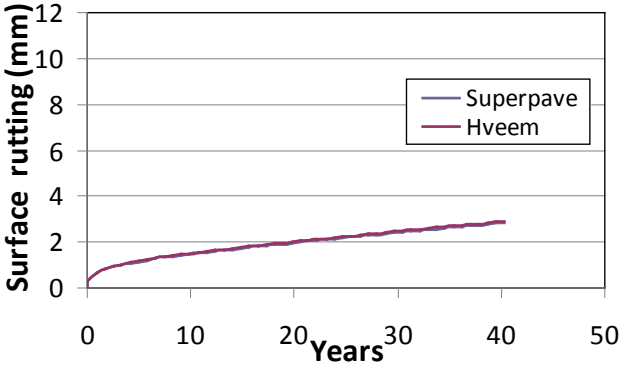
High Desert – Thick AC



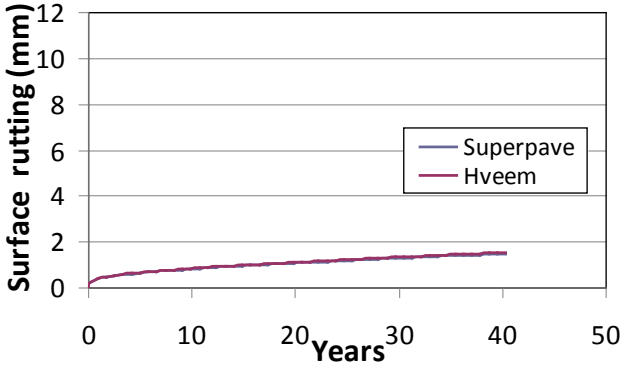
Inland Valley – Thin AC



Inland Valley – Thick AC



Low mountain – Thin AC



Low mountain – Thick AC

AC layer does not rut. All rutting is accumulated in the unbound layers.