Recycled Asphalt Shingles in Hot Mix Asphalt

Mihai Marasteanu, Adam Zofka, Jim McGraw,
Dan Krivit, Roger Olson,

Background

- Using recycled asphalt shingles in HMA a developing technology for more than two decades
- Increasing pressure to find acceptable recycled supplements to virgin materials
- State of Minnesota has sponsored several research studies on the use of recycled shingles in HMA over the past 15 years

Recycling Shingles into MN Mixtures

- HMA-shingle mixtures since 1990's in Minnesota
  - ✓High asphalt content ~ 30%
- 1996 HMA-shingle specification – Mn/DOT
  - ✓5% Manufacturer Scrap in certain mixes
  - ✓Performance – proper binder content is critical

- Tear-Off Scrap Shingles
  - ✓Guidelines under development

Shingles Mixture Specifications

- Mn/DOT 2360.2A2h
  - ✓Allows manufacturer scrap shingles
    - -5 percent of total mix weight
    - -Wear and non-wear
    - -Percent scrap shingles is considered part of the maximum allowable RAP percentage
    - -Binder selected using 2360.2 G1, same as mixtures having > 20% RAP
- Tear-Off Scrap Shingles
  - ✓Field trials
  - ✓Guidelines under development

Introduction

- Recent study investigated the use of both tear-off shingle scrap and manufacturer shingle scrap combined with traditional reclaimed asphalt pavement materials
- Two projects
  - ✓Missouri samples
    - -Mixture testing
  - ✓Minnesota samples
    - -Mixture and binder testing

Missouri Samples

- Pace Construction Company's Quality Control team designed 3 different MoDOT SP190C asphalt mixes with the following characteristics:
  - ✓19.0 mm (3/4 inch) nominal aggregate
  - ✓Design level 3,000,000 to <30,000,000 ESAL's
  - ✓N design 100 gyrations (gyratory compactor)
  - ✓VMA minimum 13.0
  - ✓TSR @ 7% ± 0.5% air voids greater than 80 % using AASHTO T 283

Missouri Samples

- First mixture - all virgin materials
- Second mixture - 20% recycled asphalt pavement (RAP)
- Third mixture - 15% recycled asphalt pavement (RAP) and 5% ground takeoff shingles
  - ✓Takeoff shingles came from single-family dwellings
    - -Tested for asbestos - oversight by St. Louis County Department of Health

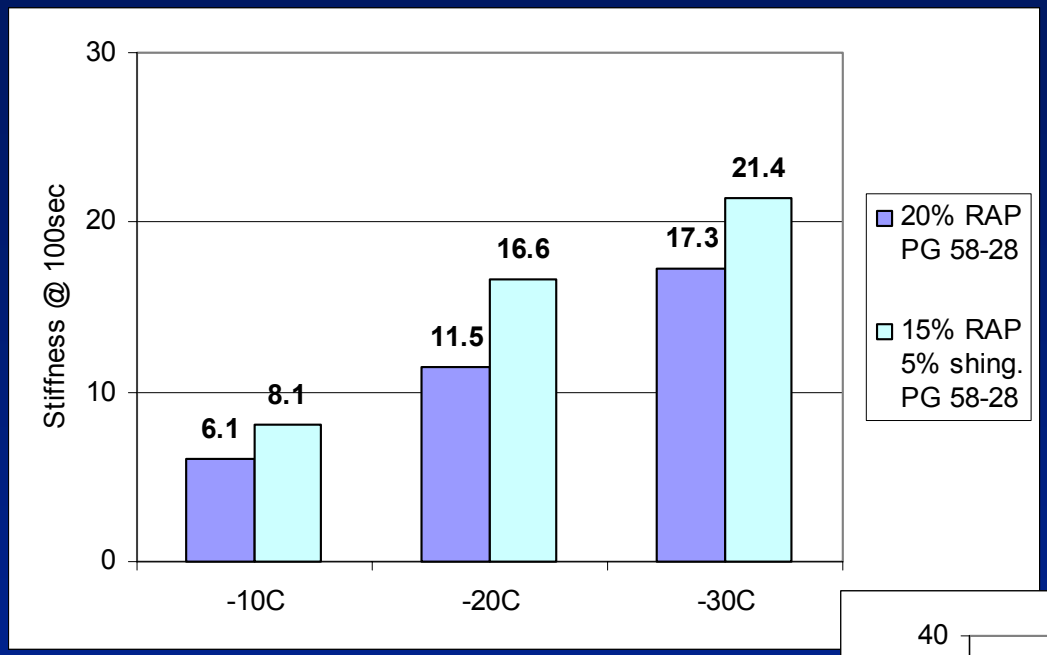
Missouri Samples

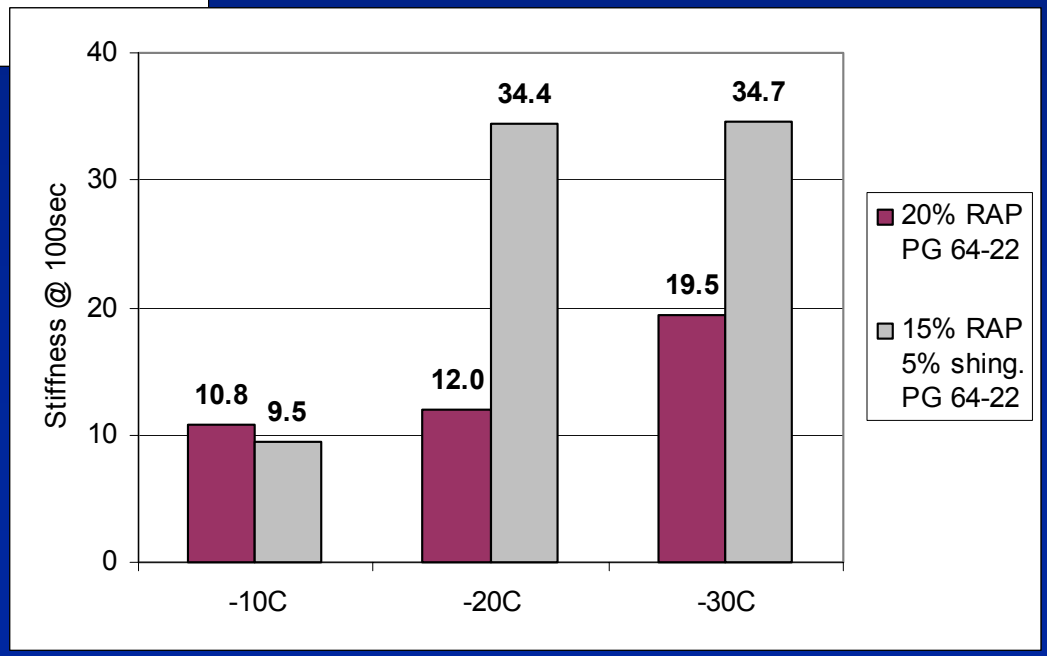
- ✓ Shingles were ground and screened so that 100% passed a $\frac{3}{4}$" opening screen
- A PG 64-22 and a PG 58-28 binder used in each separate mixture
- Each mixture designed with 0.25% anti-strip additive (Pave Bond Lite)

Missouri Samples

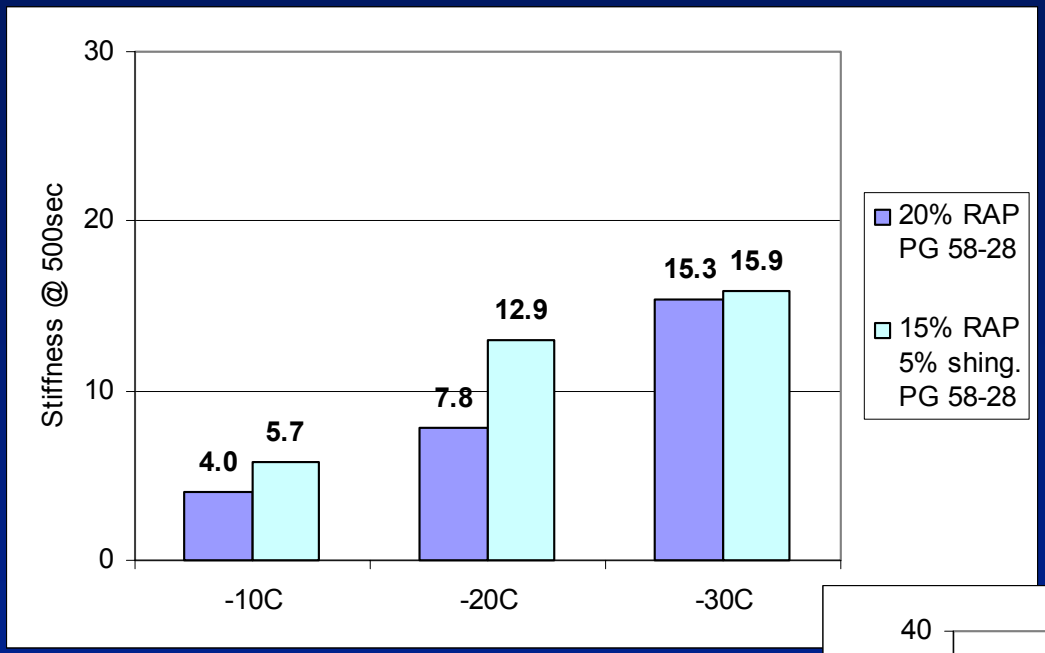
- Tests performed on 4 mixtures
  - ✓20% RAP (PG 64-22)
  - ✓20% RAP (PG 58-28)
  - ✓15% RAP + 5% shingles (PG 58-28)
  - ✓15% RAP + 5% shingles (PG 64-22)
- Tested (IDT creep and strength) at three temperatures
  - ✓-10°C, -20°C, -30°C

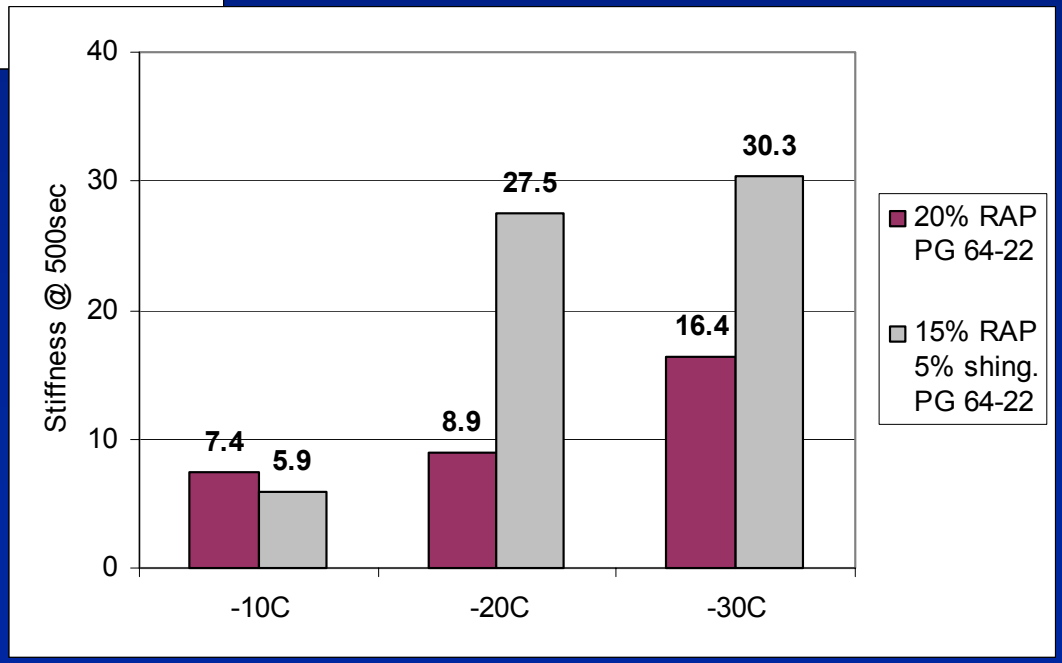
Creep Stiffness Results (100s)



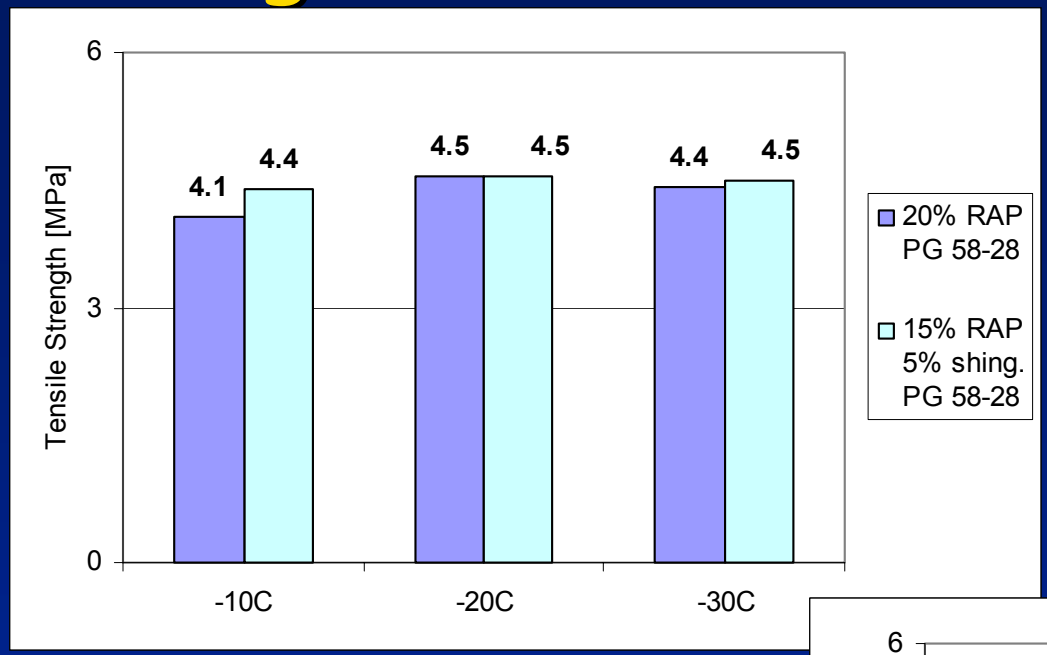


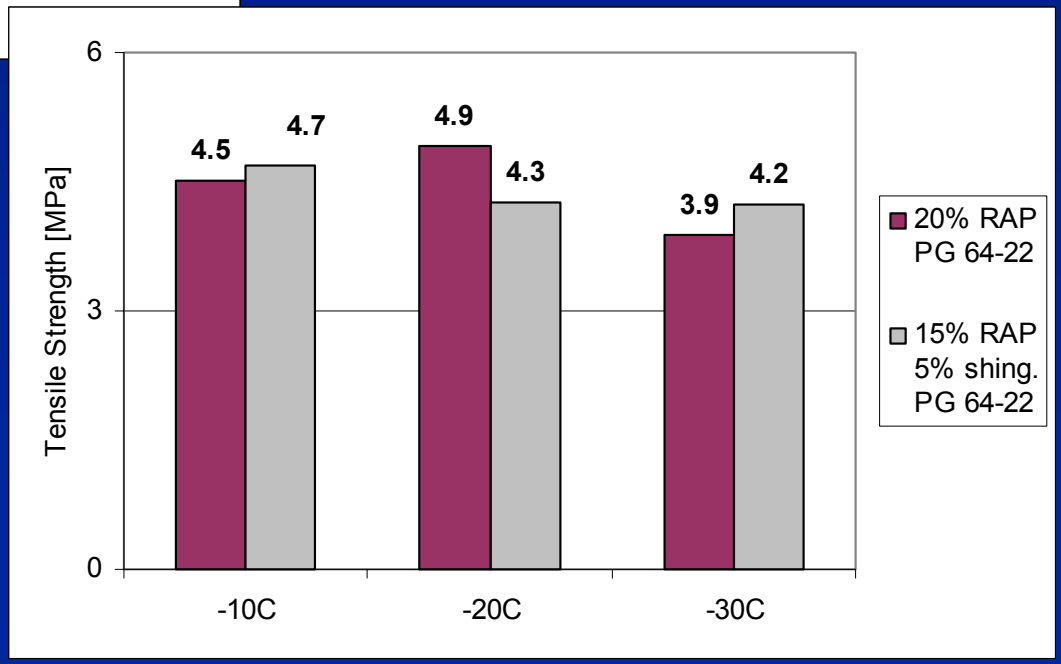
Creep Stiffness Results (500s)





Strength Results





Conclusions Missouri Specimens

- For PG-22 mixture, at temperatures below -10°C, the addition of shingles increases the mixture stiffness considerably
  - ✓Most likely results in increased thermal cracking and fatigue cracking occurrence
  - ✓Also in PG-28 mixtures but to a much lesser extent
- Strength properties were not significantly affected by the addition of shingles for both the PG-22 and PG-28 mixtures.

Conclusions Missouri Specimens

- During cutting process, the saw shutoff automatically due to the intense heat generated when cutting the specimens prepared with shingles
  - ✓This did not occur for the specimens prepared only with RAP

Minnesota Specimens

- Dan Krivit and Associates (DKA) secured participation of Dem-Con Landfill and Resource Recovery in Shakopee, Minnesota
  - ✓Mixed roofing waste into approximately 50 tons of clean, sorted tear-off shingles only
- Loads were redirected to a transfer station tipping area inside an enclosed building
- The clean, shingles only material was re-piled, loaded and then shipped to the Bituminous Roadways, Inc. (BRI) shingle recycling plant in Inver Grove Heights

Minnesota Specimens

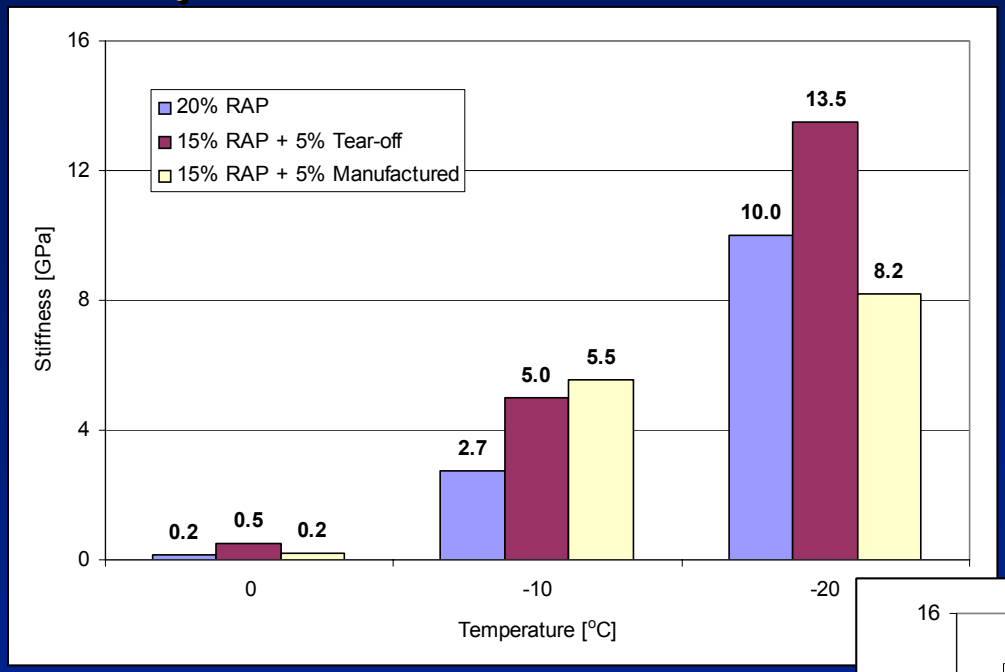
- BRI ground and screened the clean, tear-off shingles into a recycled asphalt shingles (RAS) product
- Three mixes designed for Dakota County Project 19-626-15
  - ✓Bituminous Roadways Inc (BRI) did the mix designs
  - ✓Provided gyratory test specimens and loose mix for the Indirect Tensile Testing (IDT) and Performance-Grade (PG) testing

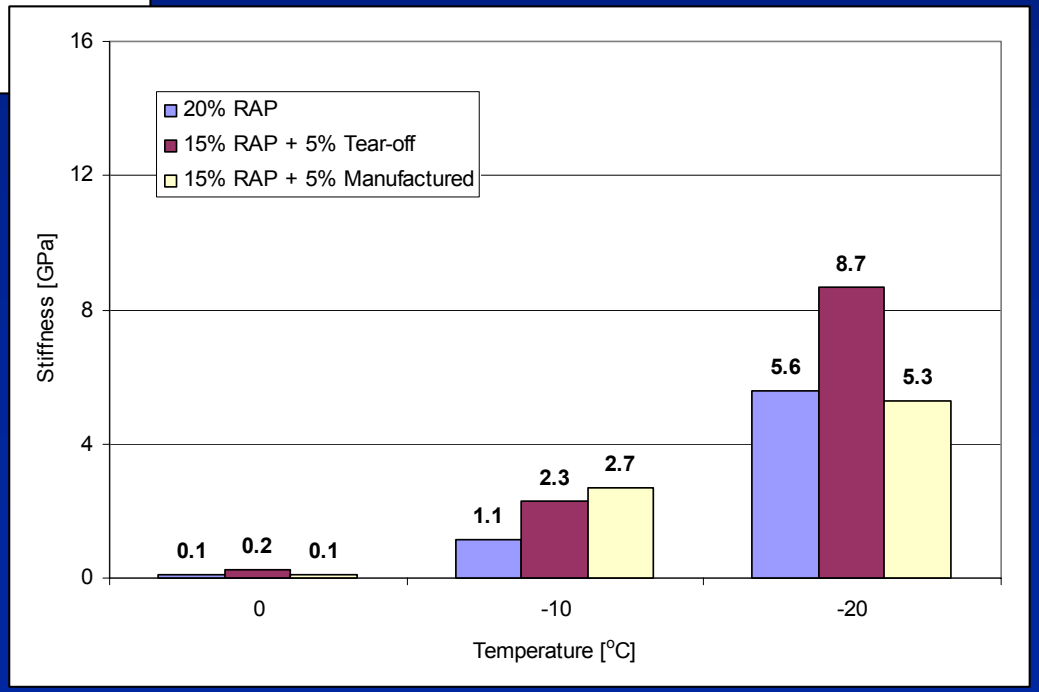
Minnesota Specimens

- Three mixes
  - ✓20% reclaimed asphalt pavement (RAP),
  - ✓15% RAP + 5% Tear-off recycled asphalt shingles (RAS),
  - ✓15% RAP + 5% Manufactured RAS
- All three mixtures contain the same virgin asphalt binder PG 58-28

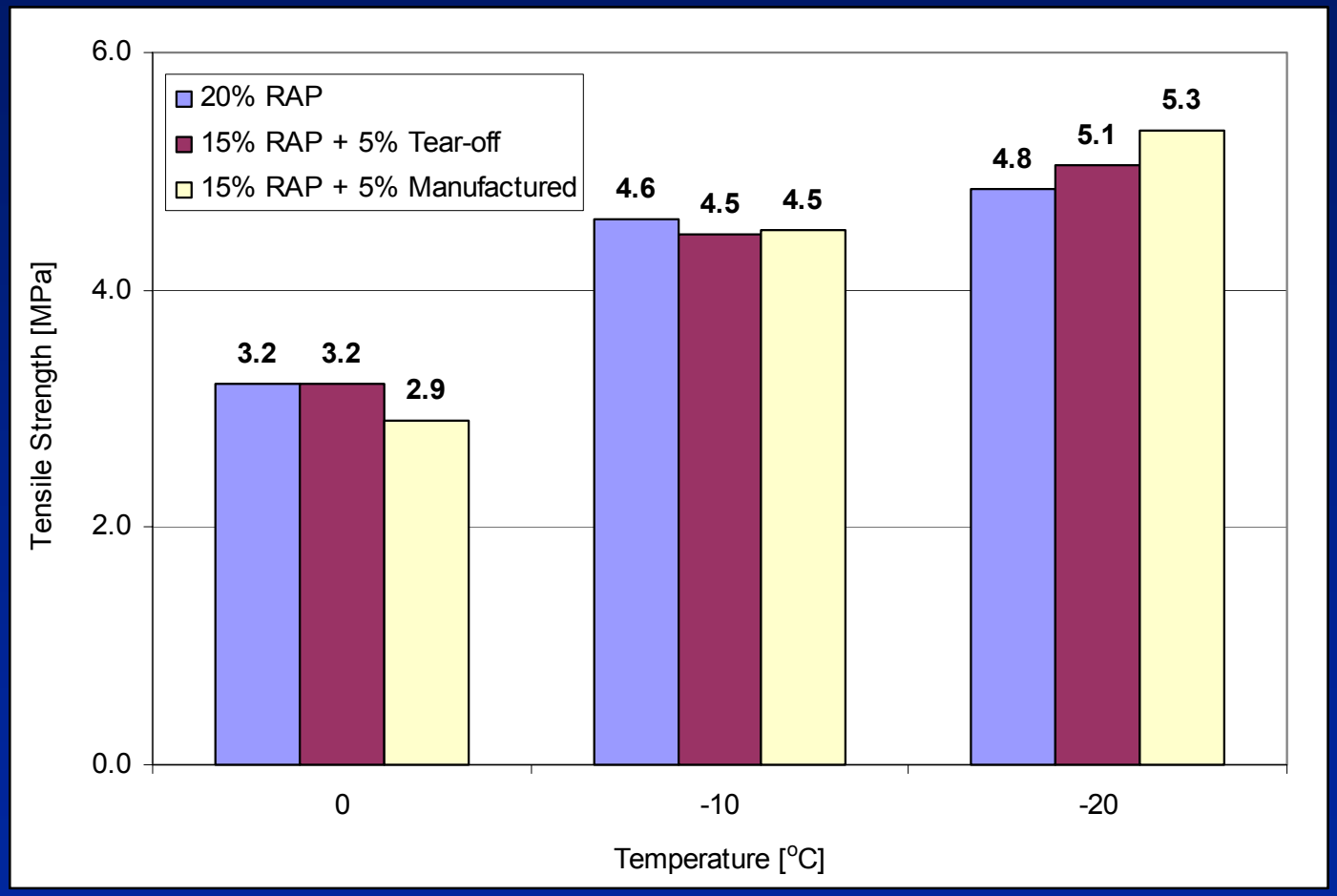
- Binders were chemically extracted (MnDOT) and tested (MnDOT + UMN)

Asphalt Mixture Creep Stiffness

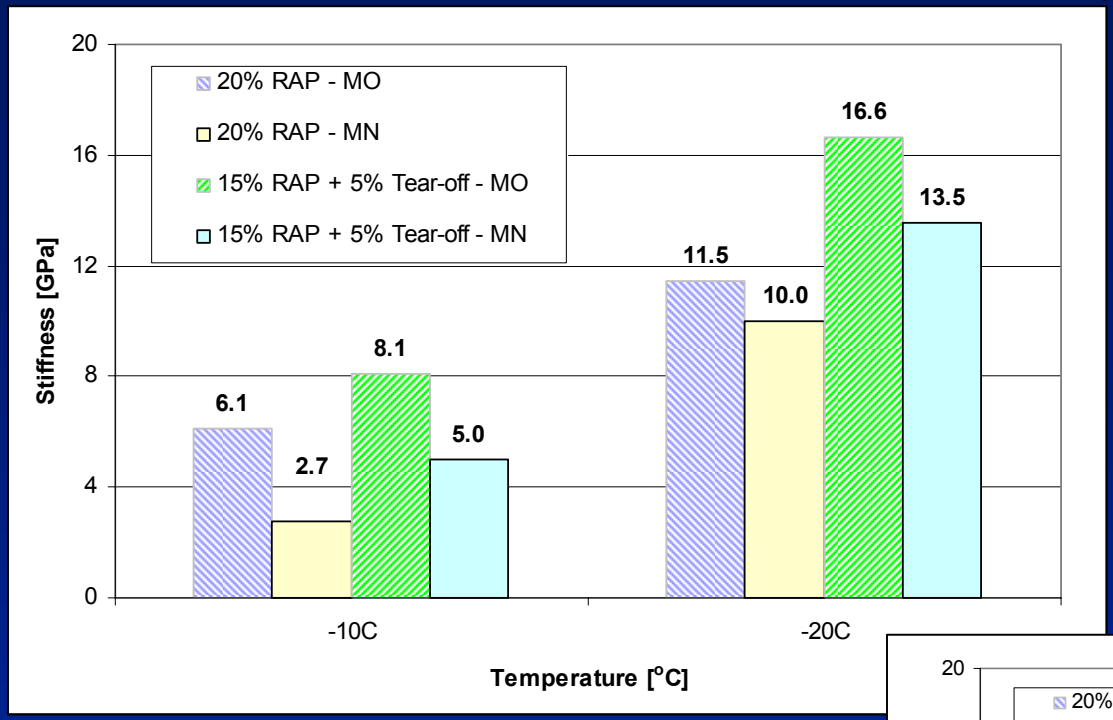


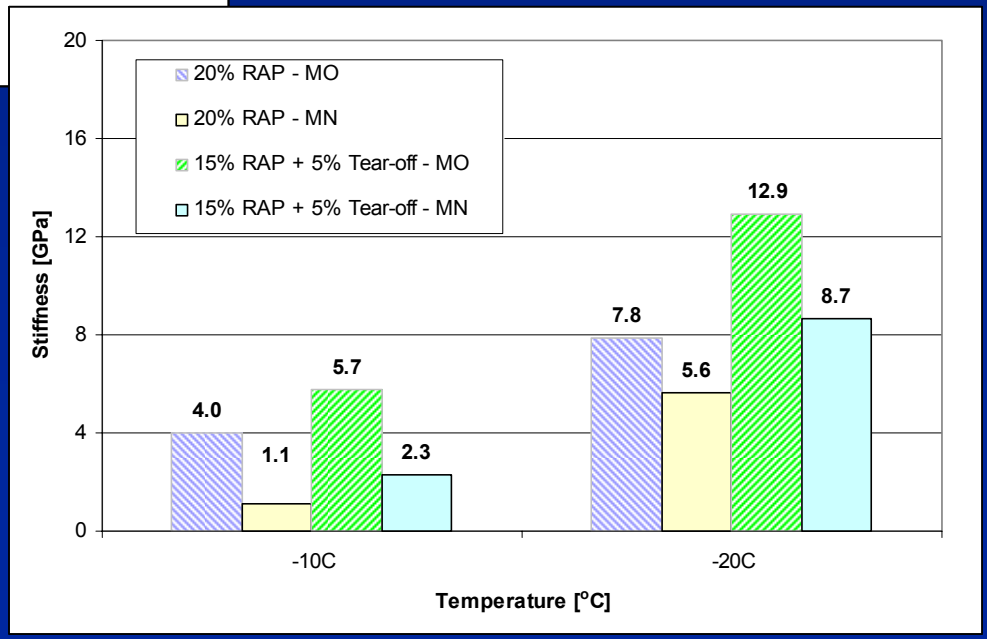


Asphalt Mixture Strength



Missouri vs. Minnesota (58-28 binder)





Conclusions Minnesota Mix Specimens

- Addition of tear-off RAS material increases the stiffness of the mixtures at all test temperatures
  - ✓Largest increase at -20°C
- Addition of manufactured RAS material increased stiffness only at 0°C and -10°C
  - ✓Stiffness at -20°C reached the lowest observed value from all tested materials
- Strength properties were not significantly affected by the addition of shingles

Conclusions Minnesota Mix Specimens

- Results indicate lower stiffness values for the Minnesota RAP mixtures compared to Missouri mixtures
- Similar observation for the combinations of RAP + RAS
  - ✓Suggests differences in the tear-off RAS materials used in the two studies

Minnesota Specimens – Extracted Binders

- The following tests were performed on the extracted materials
  - ✓"PG grading" for shingles and RAP binders
  - ✓Bending Beam Rheometer (BBR) tests
  - ✓Direct Tension Tests (DTT) performed at temperatures similar to the temperature at which S(60s) = 300MPa

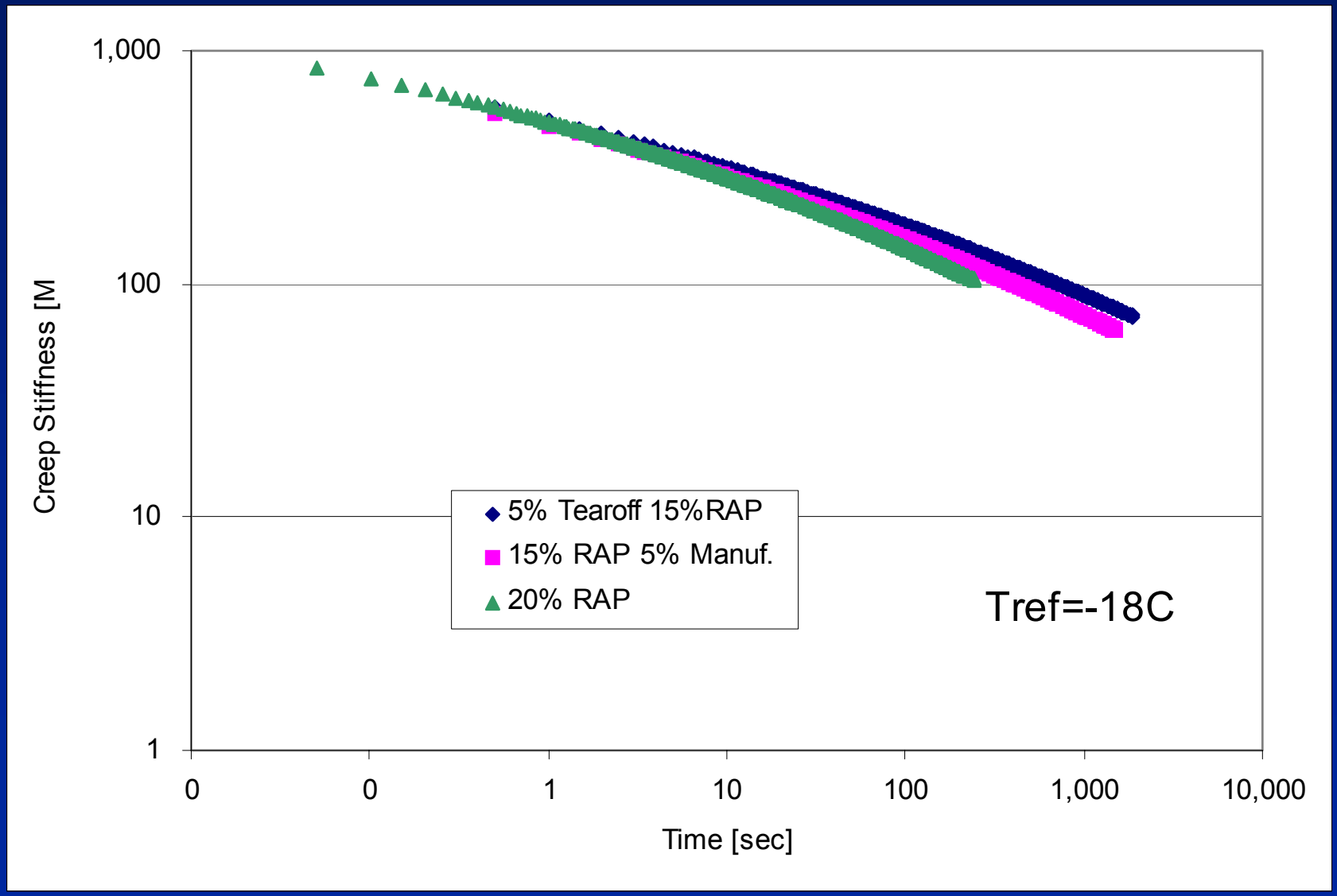
S and m-value for Extracted Binders

Temp	Binder	S(60s)	Average	m(60s)	Average
-12	15%RAP + 5% Tear-off	107	115	0.303	0.307
		123		0.311	
-18		206	206	0.264	0.264
		206		0.264	
-12	15% RAP + 5% Manufacture waste	99	103	0.329	0.326
		106		0.322	
-18		182	182	0.289	0.289
-18	20% RAP	173	170	0.325	0.324
		166		0.322	
-24		313	329	0.237	0.250
		384		0.236	
		331		0.263	
		288		0.264	

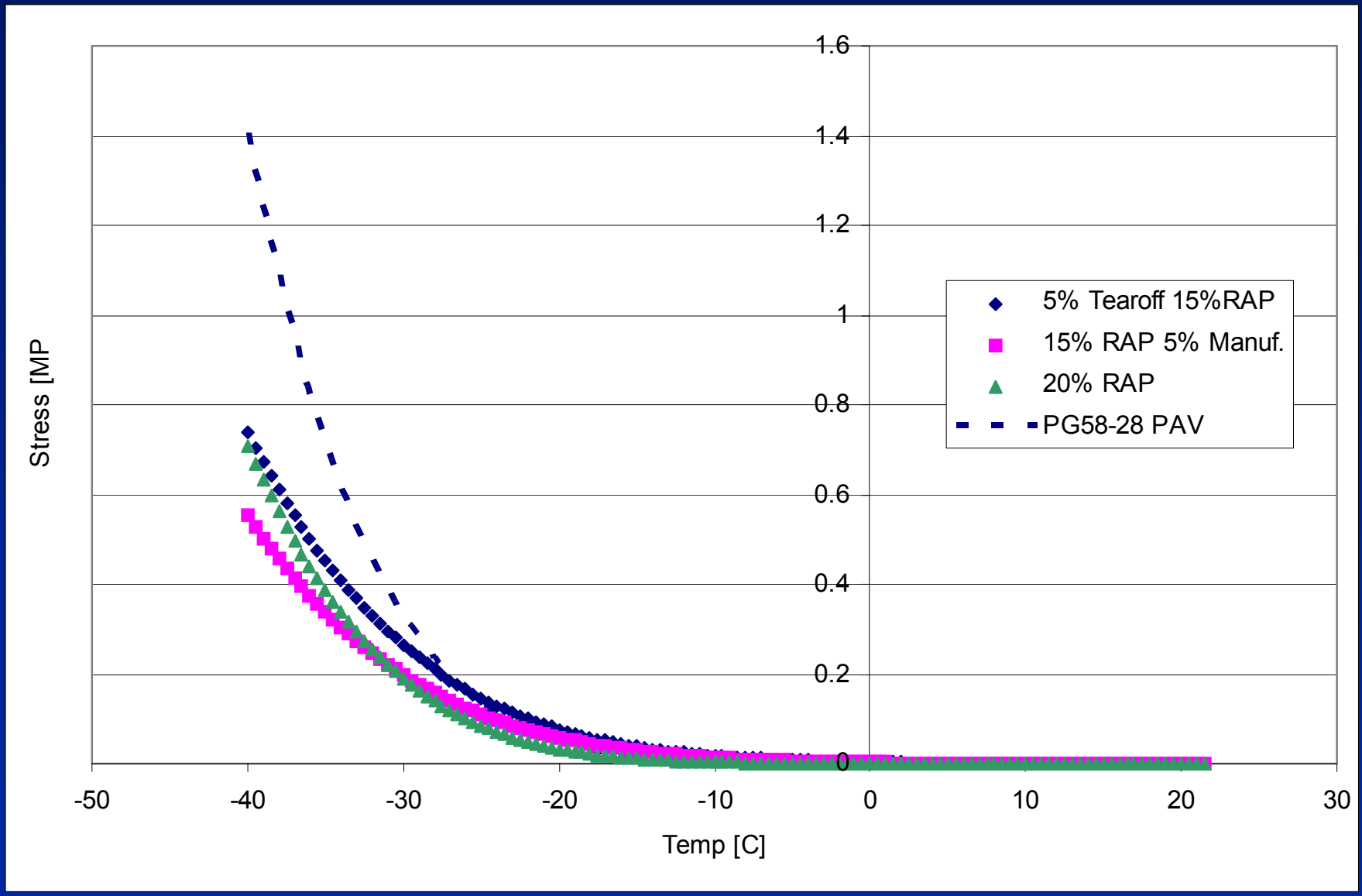
BBR Results

- Comparison of results at -18°C indicates that addition of shingles changes the properties
  - ✓Slightly increases stiffness
  - ✓Significantly lowers the m-values
    - -Changes the relaxation properties
- Need to look at master curve
- Need to look at thermal stresses
  - ✓Small m-values (RAP, shingles) results in less stress accumulation?

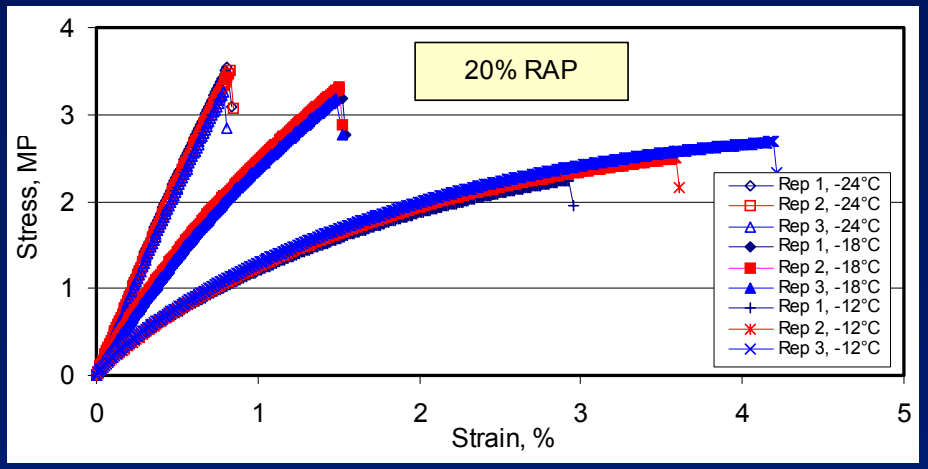
BBR Master Curves

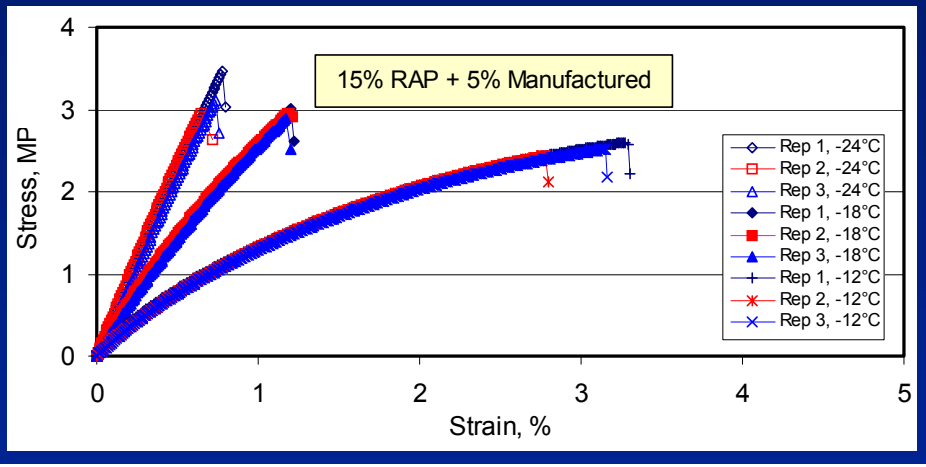


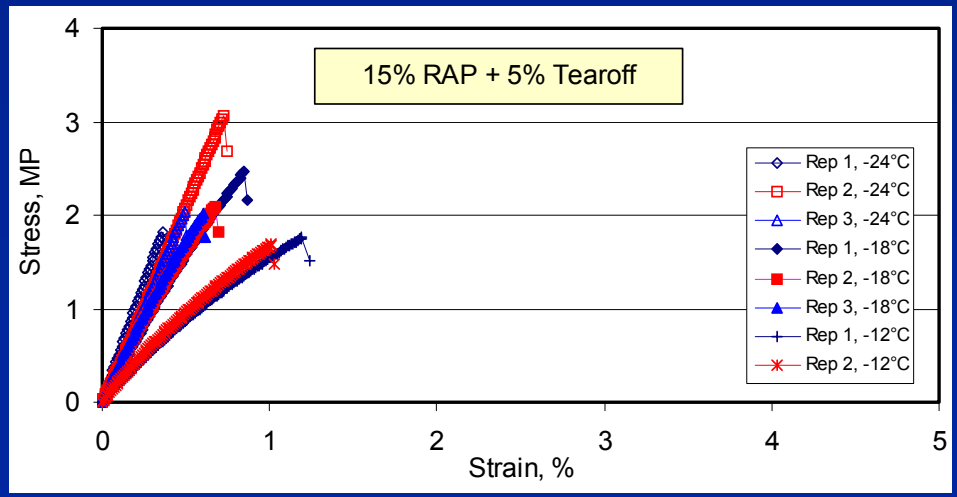
Thermal Stresses



Direct Tension Results







Conclusions - Binder Results

- The two types of shingles perform differently
  - ✓The manufactured material seems to be beneficial
    - -Not significant increase in stiffness
    - -Does not affect strength
    - -Reduces critical temperature very little
  - ✓The tear off affects properties in a negative way (although it increases stiffness slightly)
    - -Lowers strength significantly
    - -Increases critical temperature

General Conclusions

- Missouri study
  - ✓Two binders, PG58-28 and PG 64-22
  - ✓Single source of RAP
  - ✓Single source of tear off shingles
- Test results indicate that
  - ✓For PG-22 mixture addition of shingles increased mixture stiffness considerably below -10°C
  - ✓Less significant in PG-28 mixtures
- Not clear if using a softer grade is a cost effective solution

General Conclusions

- Minnesota study
  - ✓One binder PG58-28
  - ✓Single source of RAP
  - ✓Two sources of shingles
    - -Manufacture reject
    - -Tear-off
- Both mixture and binder experimental data

General Conclusions

- Mix and binder results indicated that the two types of shingles perform differently
  - ✓Manufacture reject
    - -Decreased mix stiffness
    - -Slightly increased binder stiffness
    - -Did not affect mix and binder strength
  - ✓Tear-off
    - -Decreased mix stiffness
    - -Slightly increased binder stiffness
    - -Did not affect mix strength but considerably decreased binder strain at failure

General Conclusions

- ✓ Addition of shingles lowers the m-values significantly
  - -Lowers binders temperature susceptibility
  - -Stiffer than conventional and RAP modified binders at intermediate temperatures more characteristic of fatigue cracking distress
  - - However, lower m-values result in less thermal stress accumulation

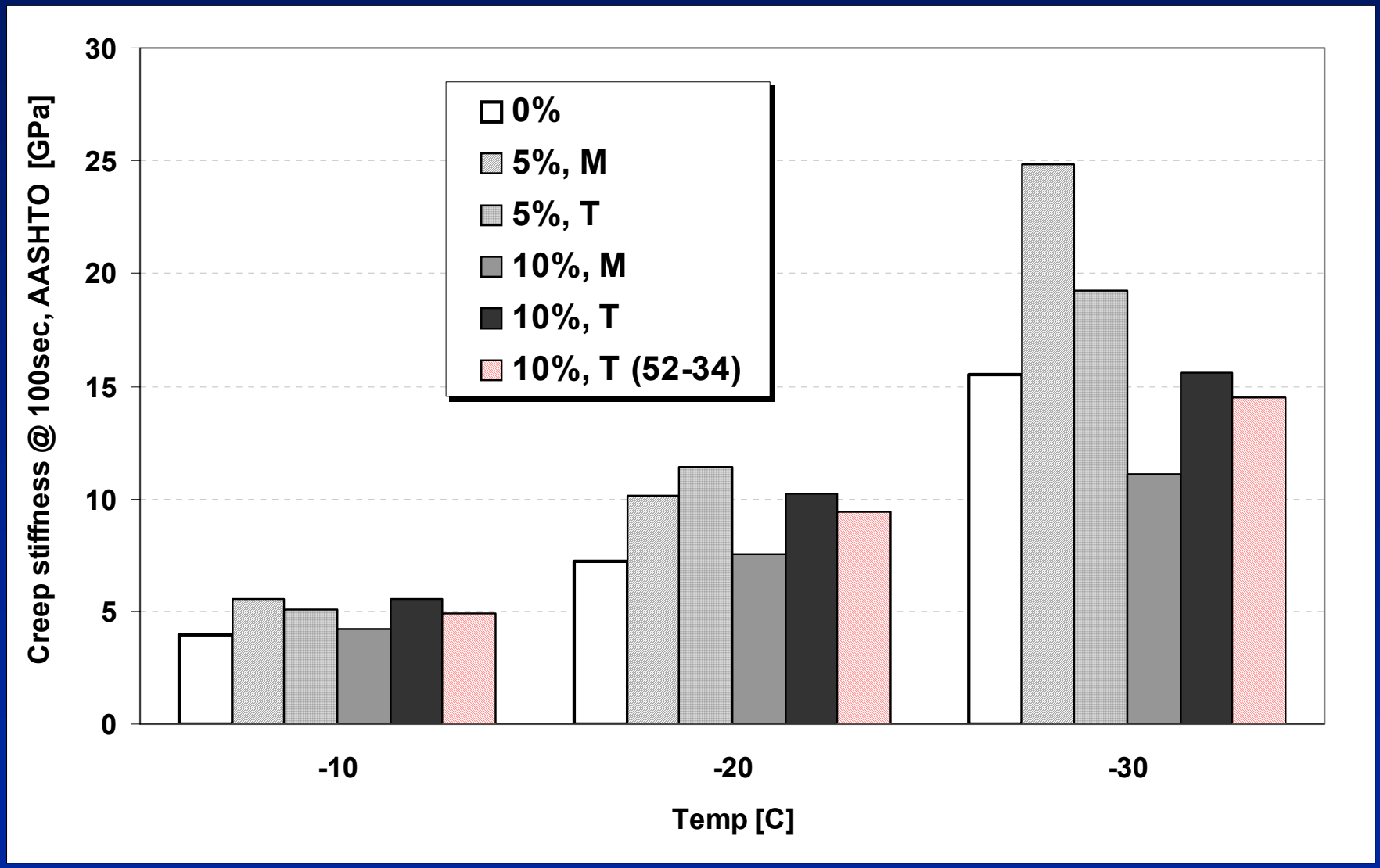
General Conclusions

- The limited data also shows that binder and mixture results do not always agree
  - ✓Most likely due to other parameters from mixture preparation (gradation, air voids, etc)
- To validate the results of this study it becomes important to expand the analysis to more sources of materials and to build pavement sections that offer critical field evaluation of these products

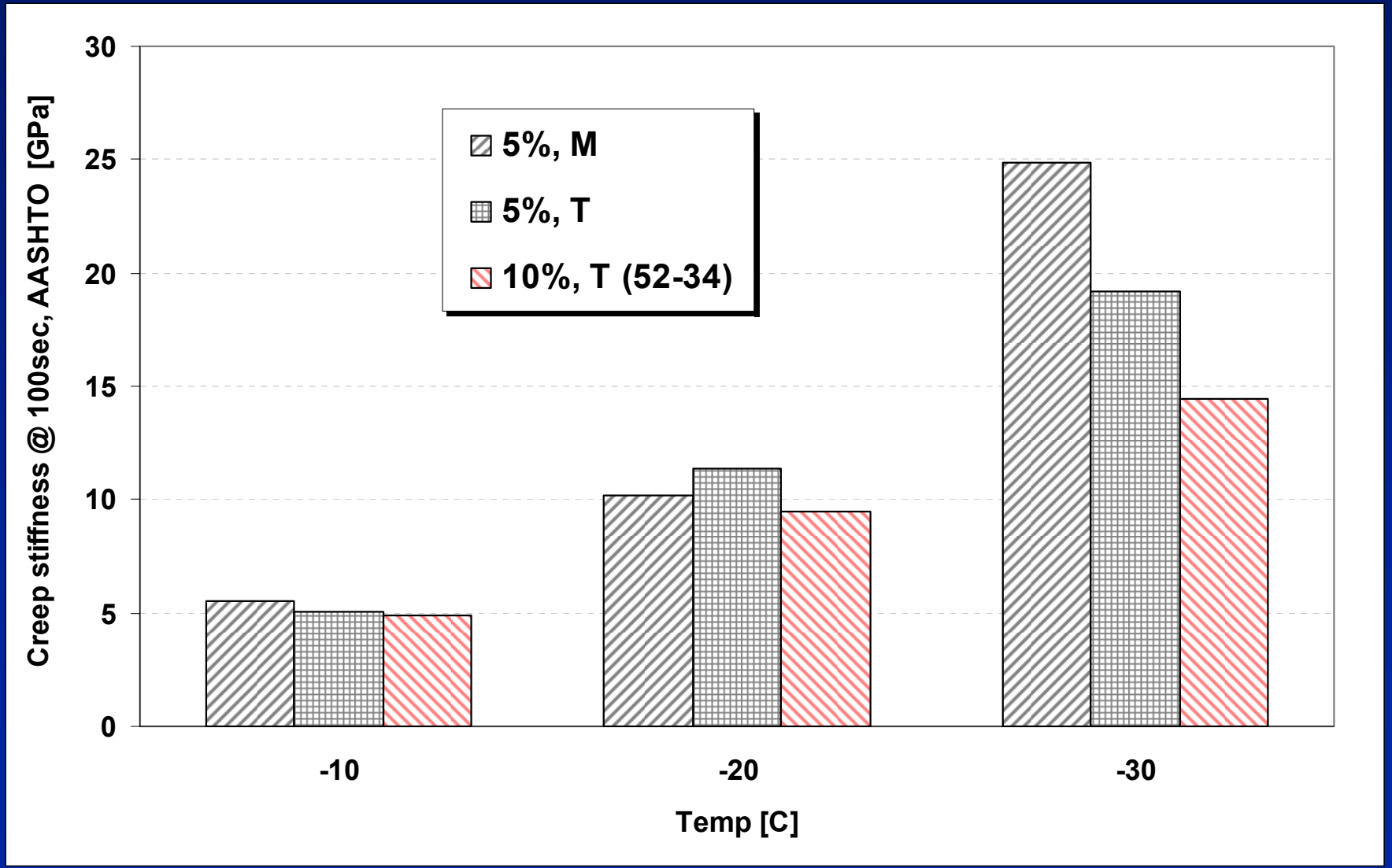
Hassan / Omann Demonstration Project

- Tested (IDT creep and strength) at three temperatures
  - ✓-10°C, -20°C, -30°C
- Tests performed on 6 mixtures
  - ✓Virgin asphalt, no shingles (PG58-28)
  - ✓5% manufacturer reject shingles (PG58-28)
  - ✓5% tear-off shingles (PG58-28)
  - ✓10% manufacturer reject shingles (PG58-28)
  - ✓10% tear-off shingles (PG58-28)
  - ✓10% tear-off shingles (PG52-34)

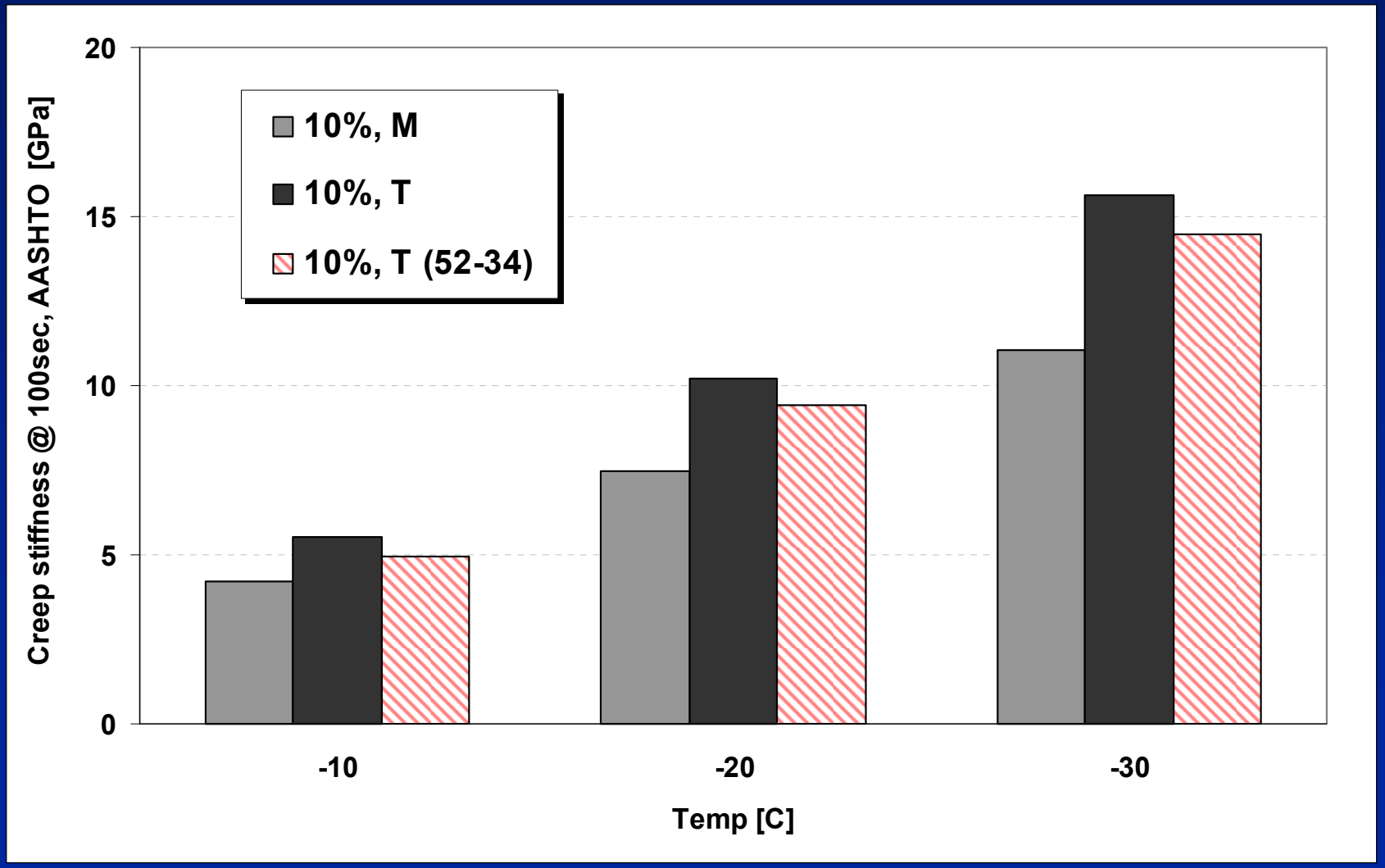
Creep Stiffness at 100s



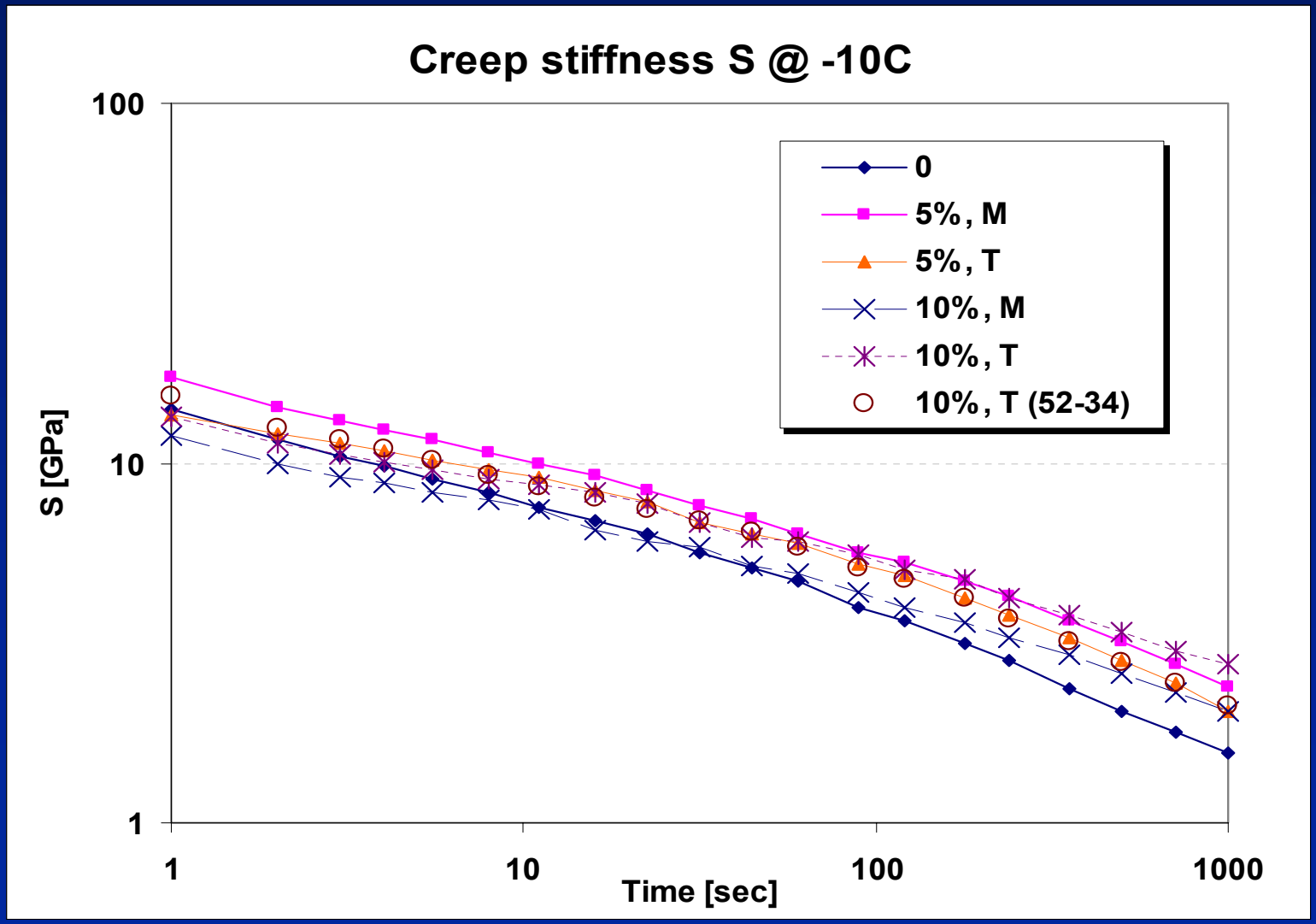
PG58-28 with 5% M and T vs. PG52-34 with 10% T



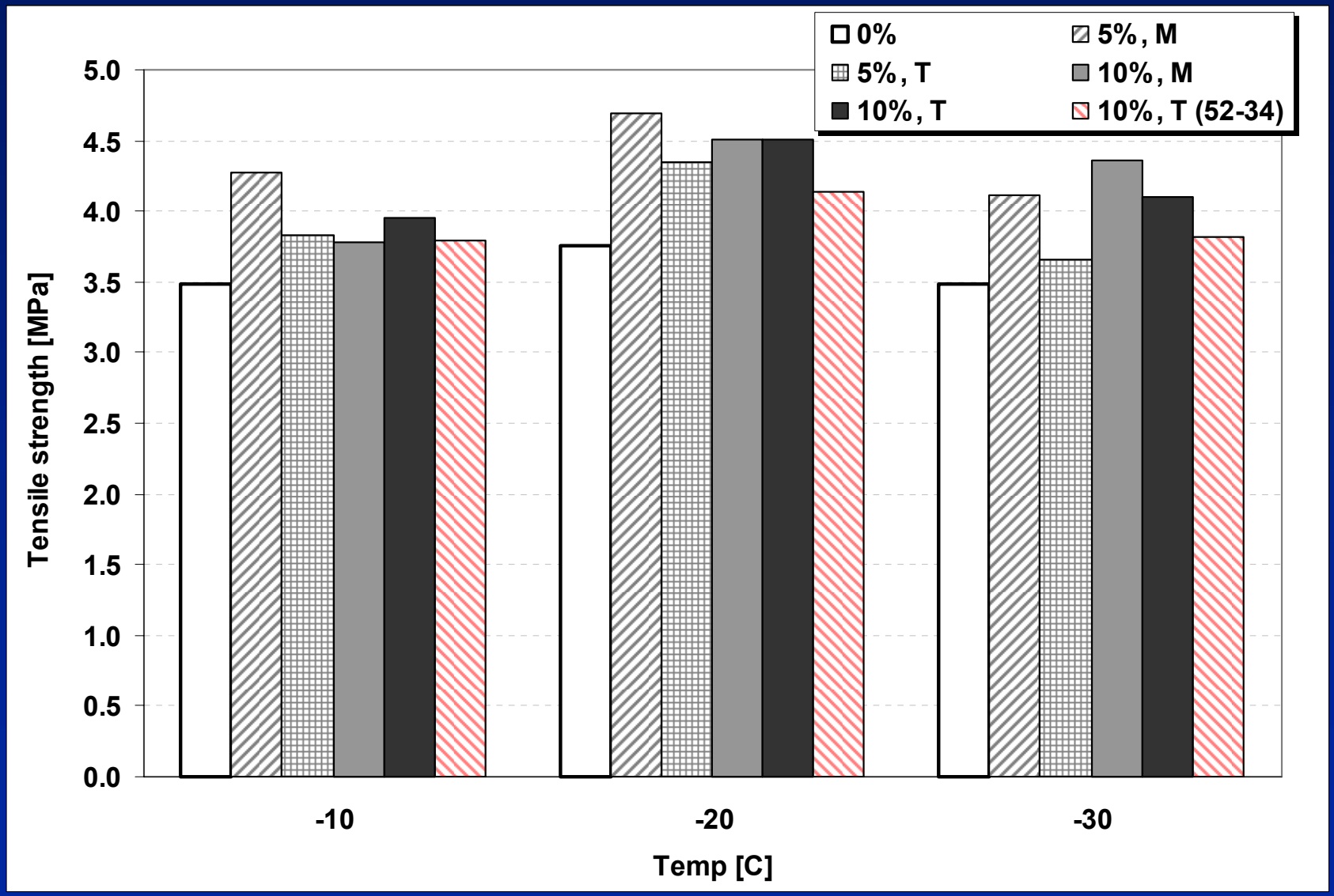
PG58-28 with 10% M and T vs. PG52-34 with 10% T



Change in Stiffness Slope (Relaxation Properties)



Tensile Strength – All Mixtures



Conclusions Hassan / Omann Project

- Creep stiffness (S) results indicate that:
  - ✓Adding more M or T shingles decreases S compared to control mix
  - ✓At 10% level, T shingles give higher S than M shingles but at 5% amount level the trend is the opposite!
  - ✓PG 52-34 with 10% T has slightly lower S that PG 52-28 with also 10% T
- S curves indicate that in terms of thermal stresses development, best performer would be PG 58-28 with 10% M

Conclusions Hassan / Omann Project

- Difficult to interpret results
  - ✓Addition of shingles and their interaction with virgin aggregate and binder not well understood
  - ✓Mix design not as straight forward
  - ✓Small number of samples
- Need to investigate mixture fracture properties!
  - ✓Most likely the property that controls performance
    - -Low temperature and fatigue cracking

Thank you!