

# Impact of Loose Mix Aging Time and Temperature on the Mechanistic Performance of Hot and Warm Bituminous Mixtures

A STUDY CONDUCTED BY MTE SERVICES FOR THE WARM MIX TWG  
MAY 14-15, DARTMOUTH, MA

by

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# **OVERVIEW OF LAB STUDY-1**

- 1. HOT MIX PRODUCED WITH 0% & 20% RAP USING PG 58-28 BINDER**
- 2. MIXED & CURED AT 275°F**
- 3. LOOSE MIX CURED FOR 0.5, 2 AND 4 HRS**
- 4. HAMBURG RUT PILLS FOR DRY & WET TESTING PRODUCED**
- 5. AMPT PILLS PRODUCED FOR E\* AND FLOWNUMBER TESTING**

# OVERVIEW OF LAB STUDY-2

- 1. WARM MIX PRODUCED WITH 0% & 20% RAP USING PG 58-28 BINDER**
- 2. USED 0.5% EVOTHERM 3G IN BINDER**
- 3. MIXED @ 230°F & CURED AT 220°F**
- 4. LOOSE MIX CURED FOR 2, 4 AND 8 HRS**
- 5. HAMBURG RUT PILLS FOR DRY & WET TESTING PRODUCED**
- 6. AMPT PILLS PRODUCED FOR E\* AND FLOWNUMBER TESTING**

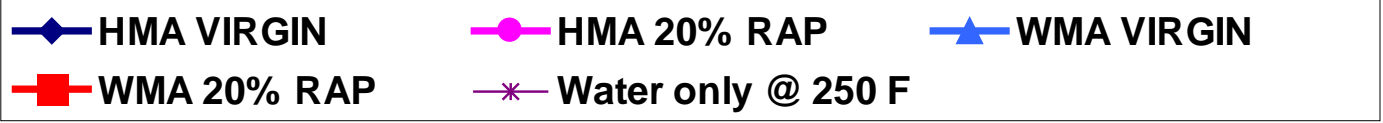
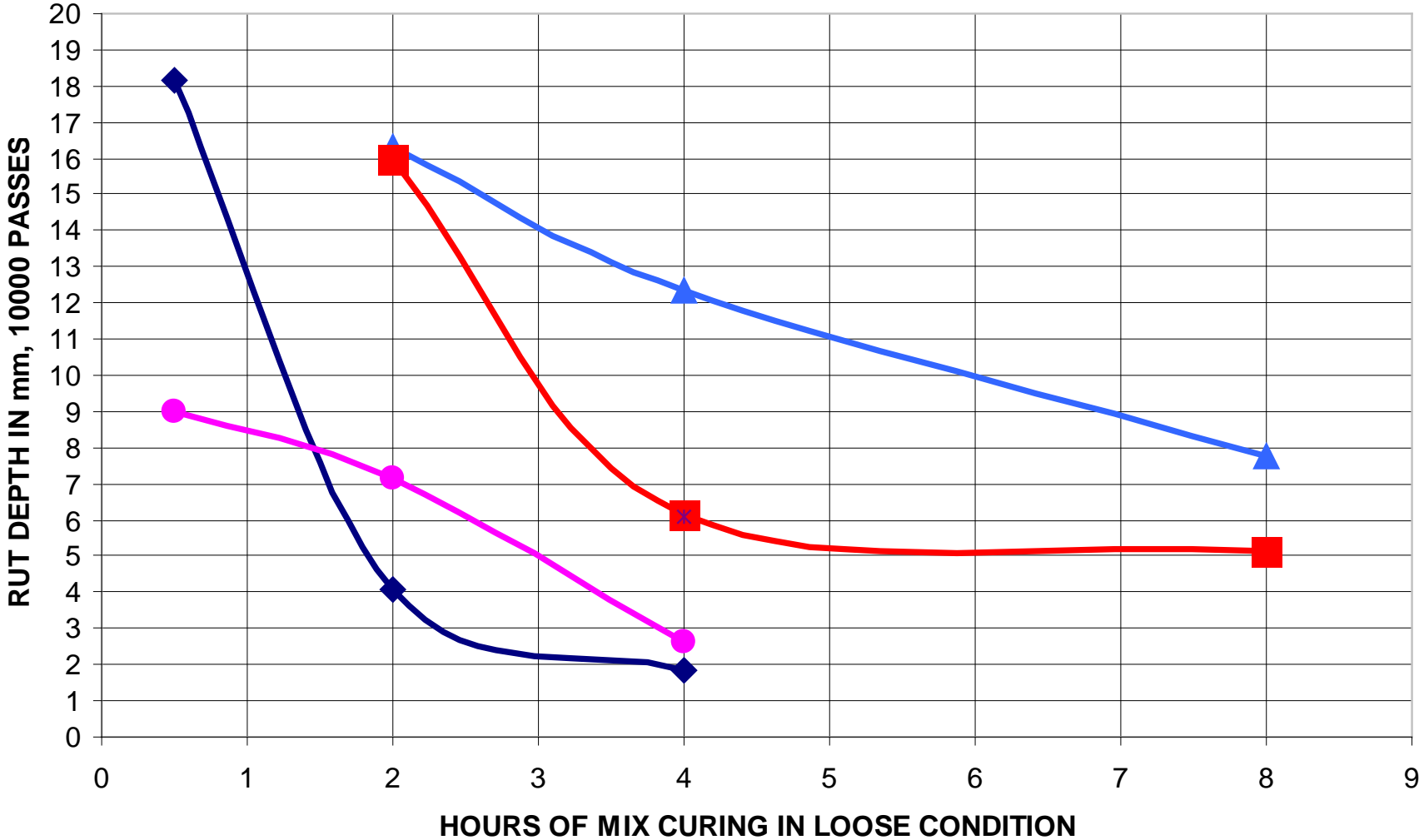
# OVERVIEW OF LAB STUDY-3

1. BINDER EXTRACTED FROM DRY HAMBURG RUT PILLS, RECOVERED, PG GRADED
2. ADDITIONAL SPECIMENS PRODUCED WARM AT 4 HRS CURING TIME USING
  - a) WATER ONLY (250°F, 235°F)
  - b) WAX (220°F)
  - c) HAMBURG TESTING @ 58°C DRY
  - d) BINDER RECOVERED,  $G^*/\text{SIN}(\delta)$ ,  $J_{nr}$

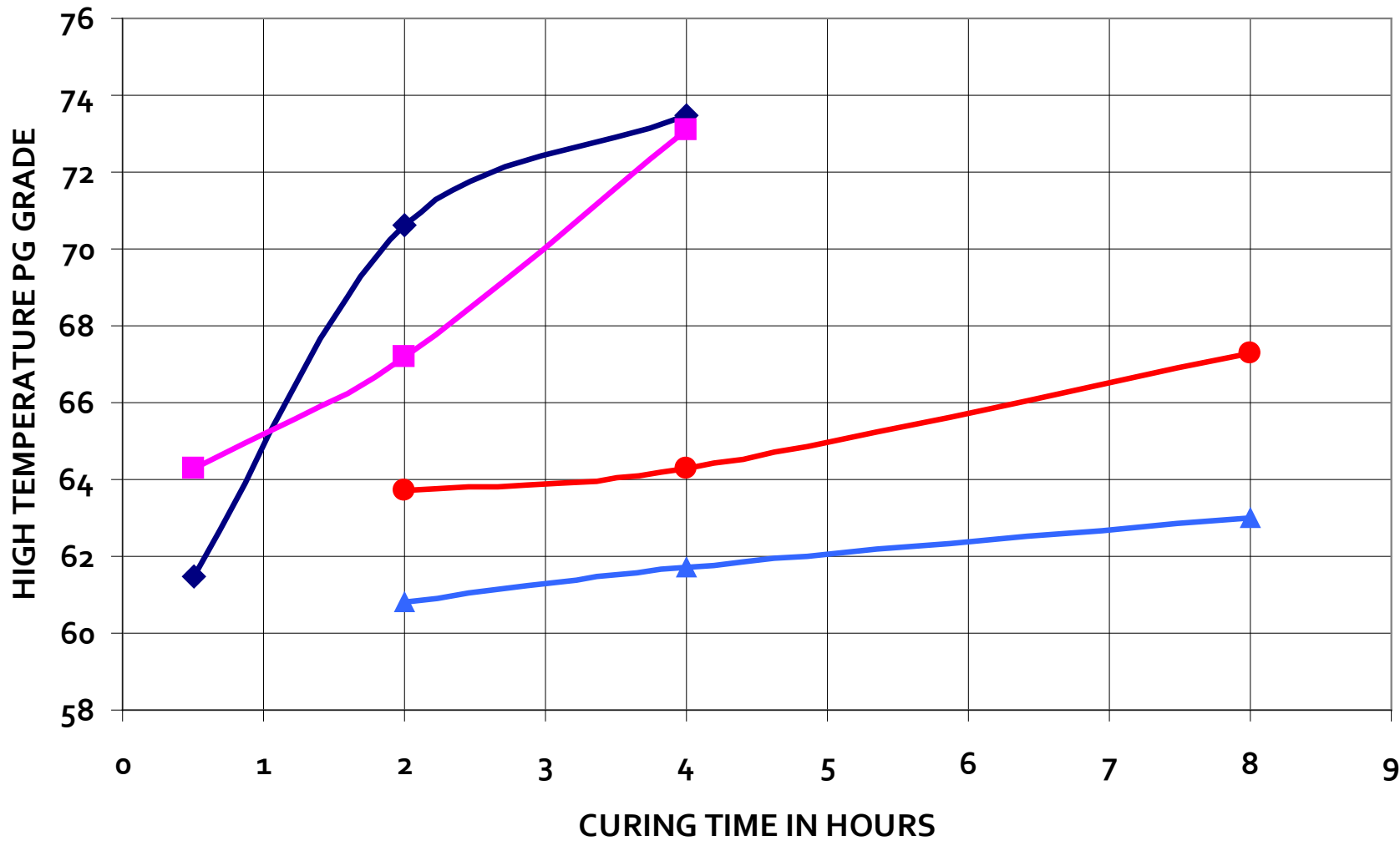
# OVERVIEW OF LAB STUDY-4

1. **ADDITIONAL STUDIES USING 64-22  
FOLLOWING ABOVE TESTING PROGRAM  
BEING CONDUCTED BY PARAGON  
TECHNICAL SERVICES AND THE  
ASPHALT INSTITUTE**
  - a) **Mike Hemsley of Paragon has some data to  
report today**
  - b) **AI is just getting their work started**

**RUT DEPTH AT 10000 PASSES @ 58C  
HOT MIX @ 275F, WARM MIX @ 220F**

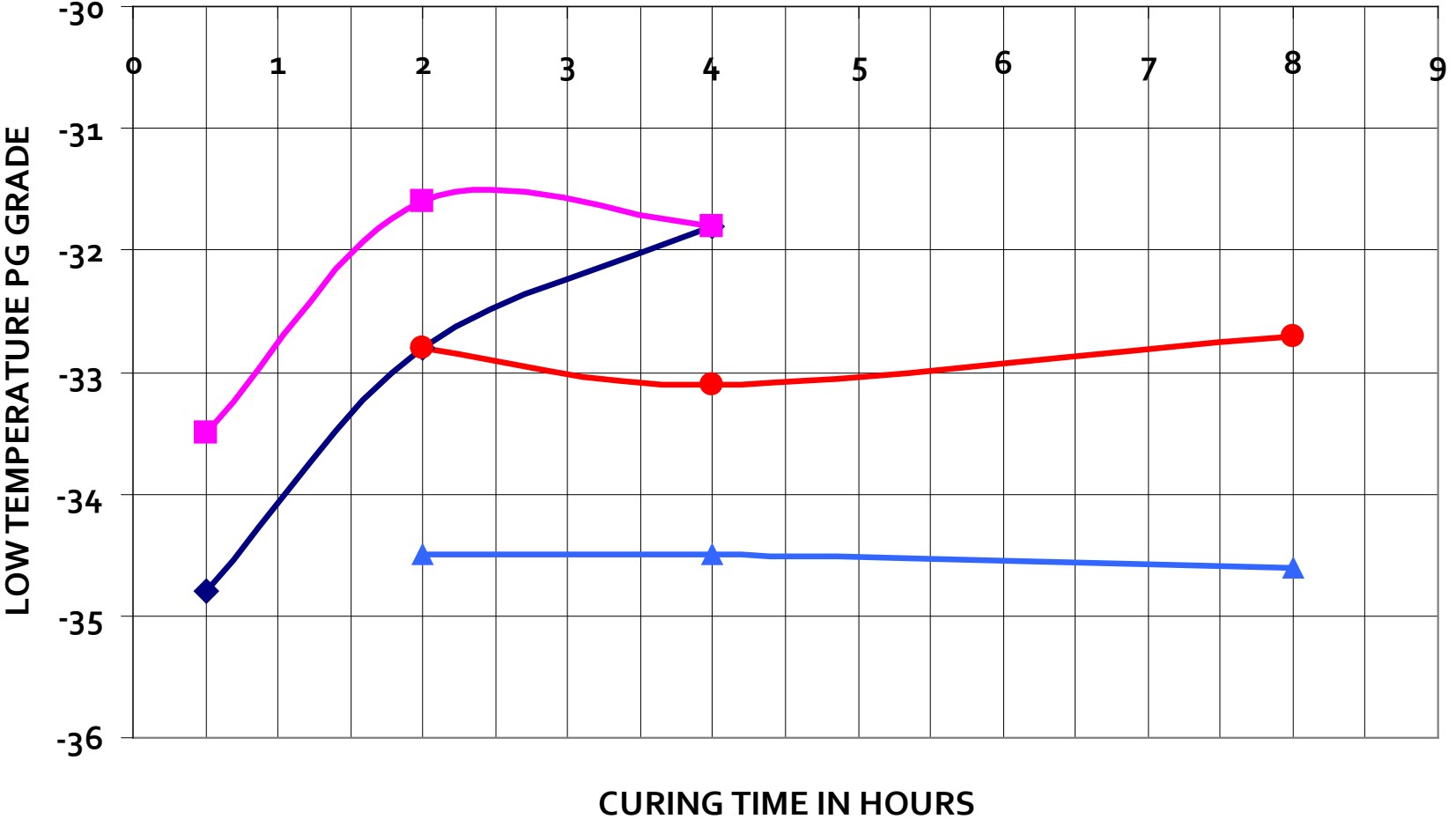


# HIGH TEMPERATURE PG GRADE VS MIX CURE TIME [HOT MIX @ 275F, WARM MIX @ 220F]



◆ HOT MIX VIRGIN MIX    ■ HOT MIX 20% RAP    ▲ WARM MIX VIRGIN    ● WARM MIX 20% RAP

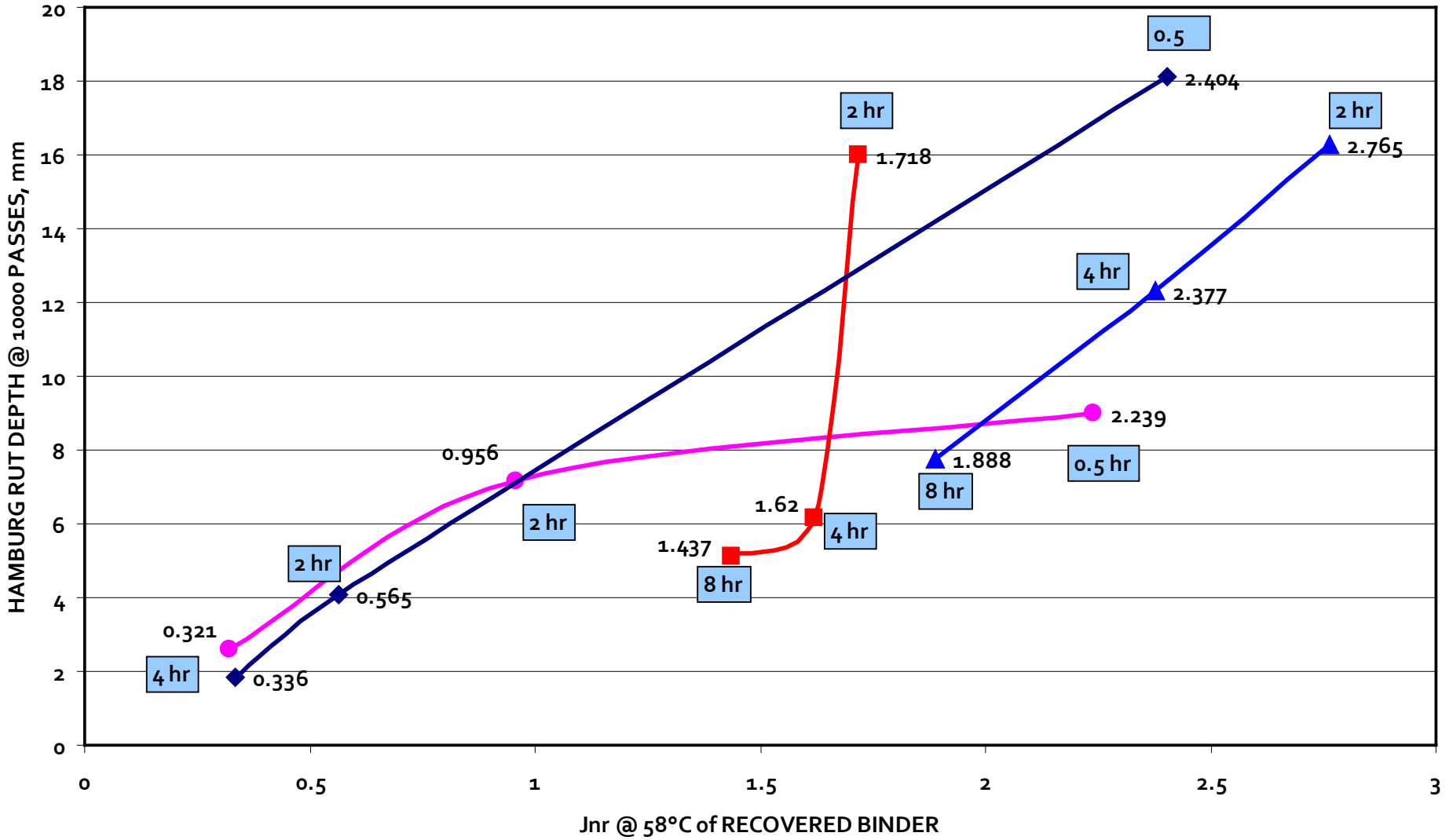
# LOW TEMPERATURE PG GRADE VS MIX CURE TIME [HOT MIX @ 275F, WARM MIX @ 220F]



◆ HOT MIX VIRGIN MIX    ■ HOT MIX 20% RAP    ▲ WARM MIX VIRGIN    ● WARM MIX 20% RAP

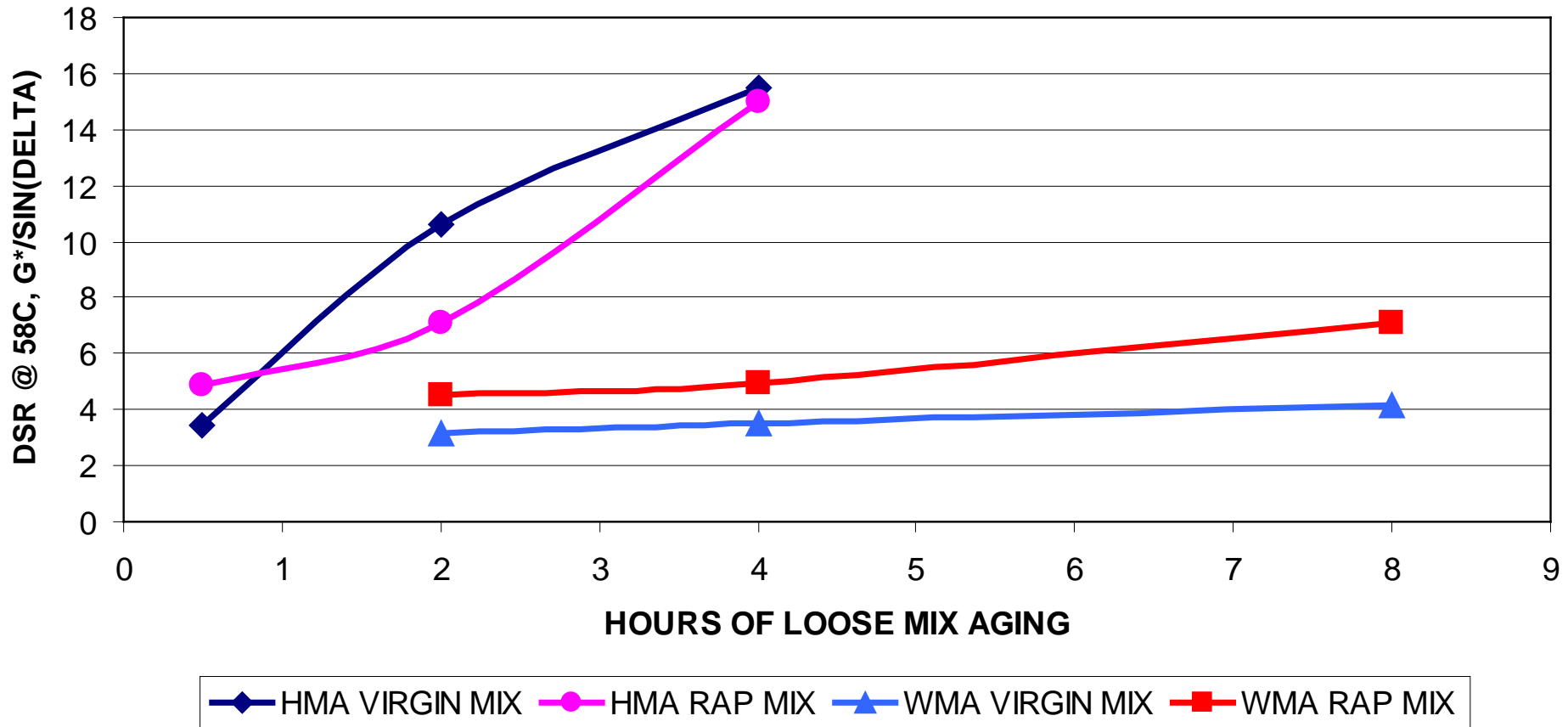
# RUT DEPTH @ 10000 PASSES @ 58°C HMA @ 275°F, WMA @ 220°F

X hr= LOOSE MIX CURING TIME AT EITHER 275°F OR 220°F

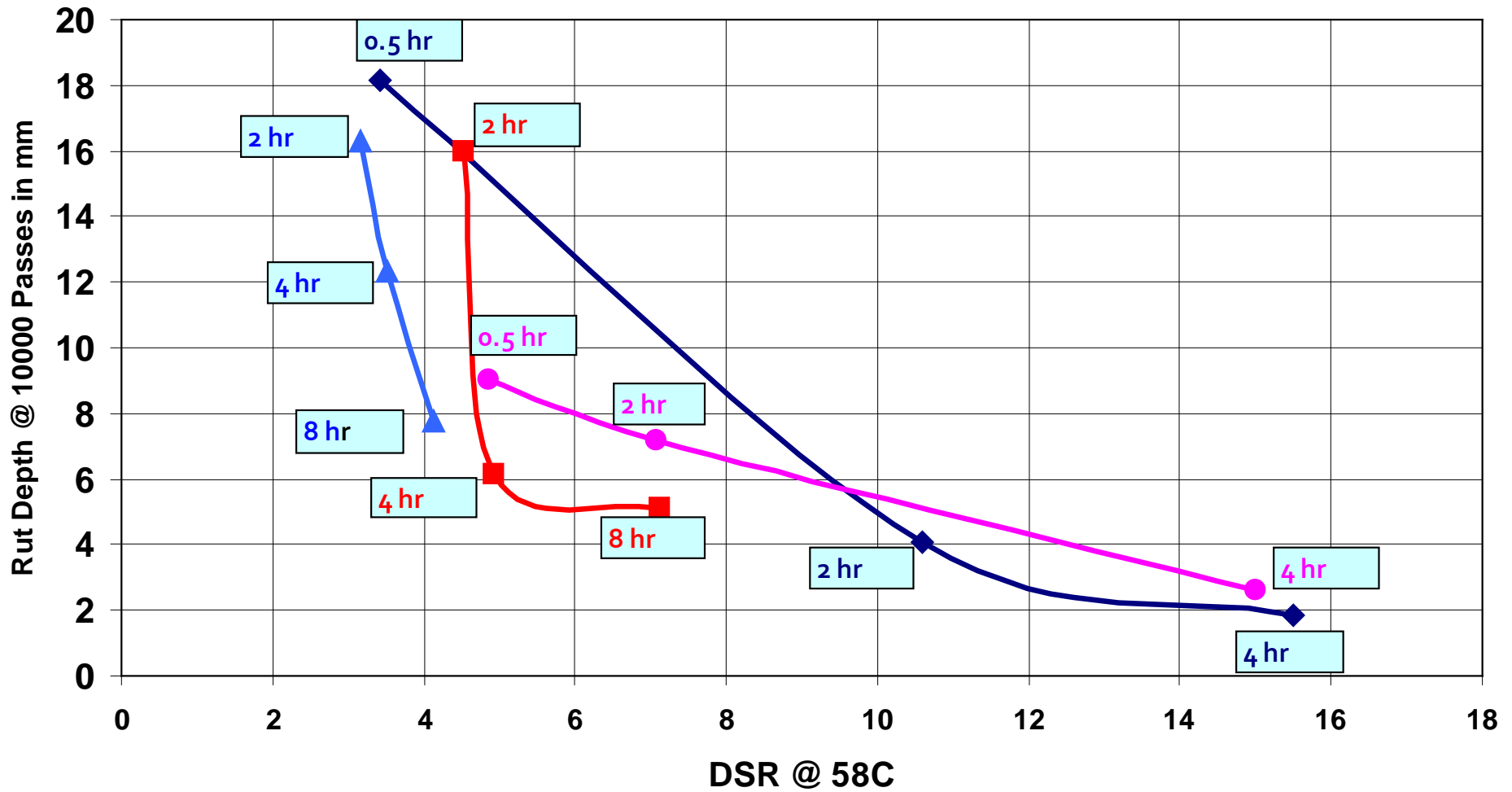


● HMA 20% RAP MIX   
 ▲ WMA VIRGIN MIX   
 ■ WMA 20% RAP MIX   
 ◆ HMA VIRGIN MIX

# RECOVERED BINDER DSR AS A FUNCTION OF HOURS OF LOOSE MIX AGING



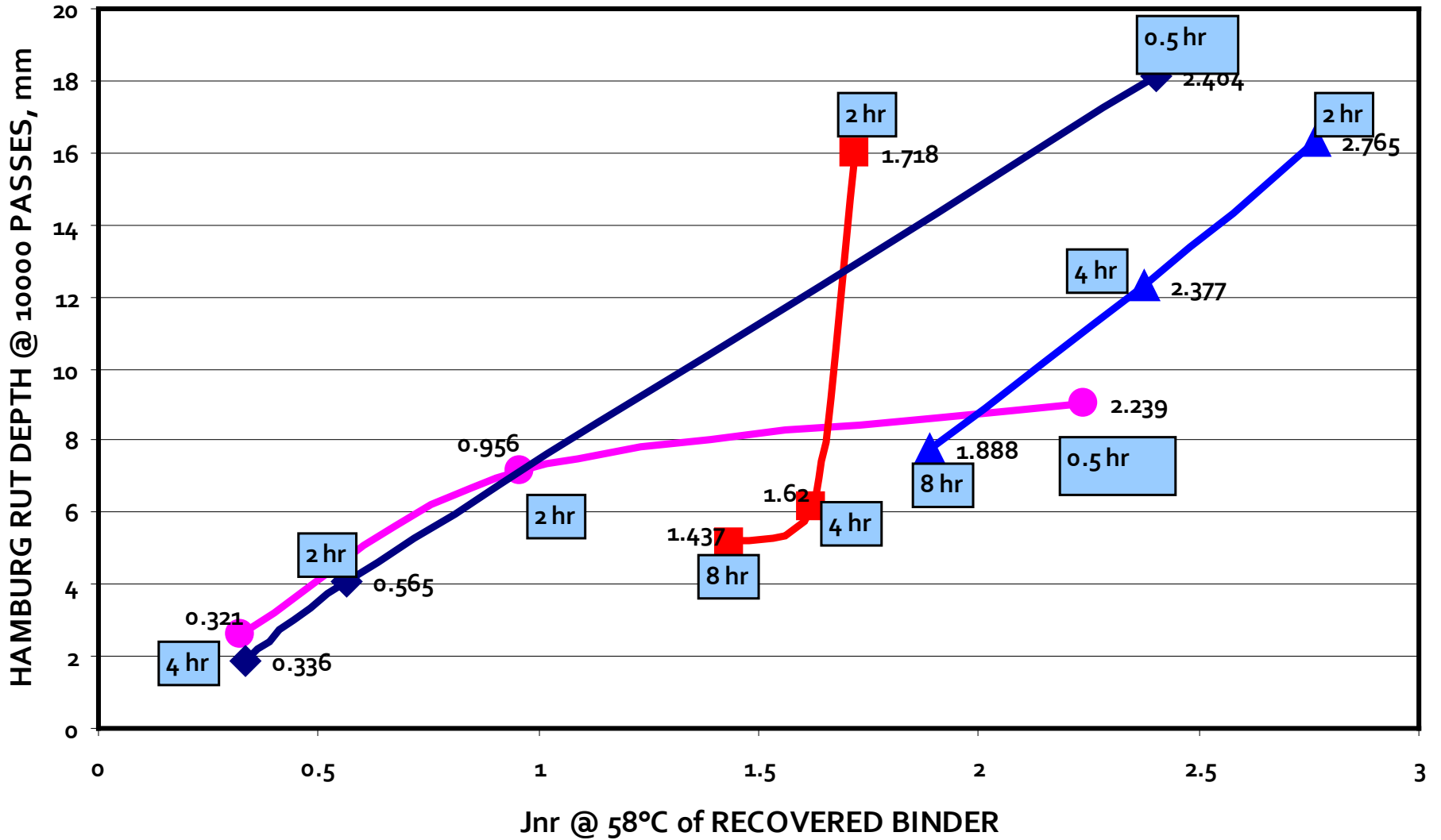
# RUT DEPTH (mm) @ 58°C AS A FUNCTION OF G\*/SIN(DELTA) @ 58°C OF RECOVERED BINDER



◆ HMA VIRGIN MIX   
 ● HMA RAP MIX   
 ▲ WMA VIRGIN MIX   
 ■ WMA RAP MIX

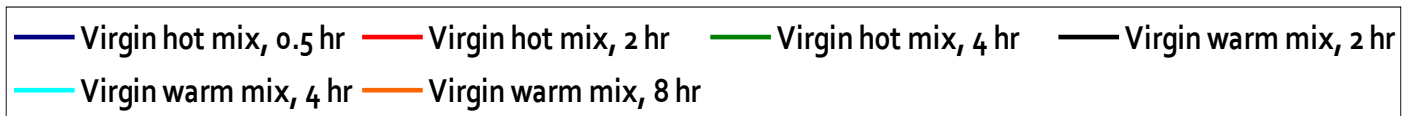
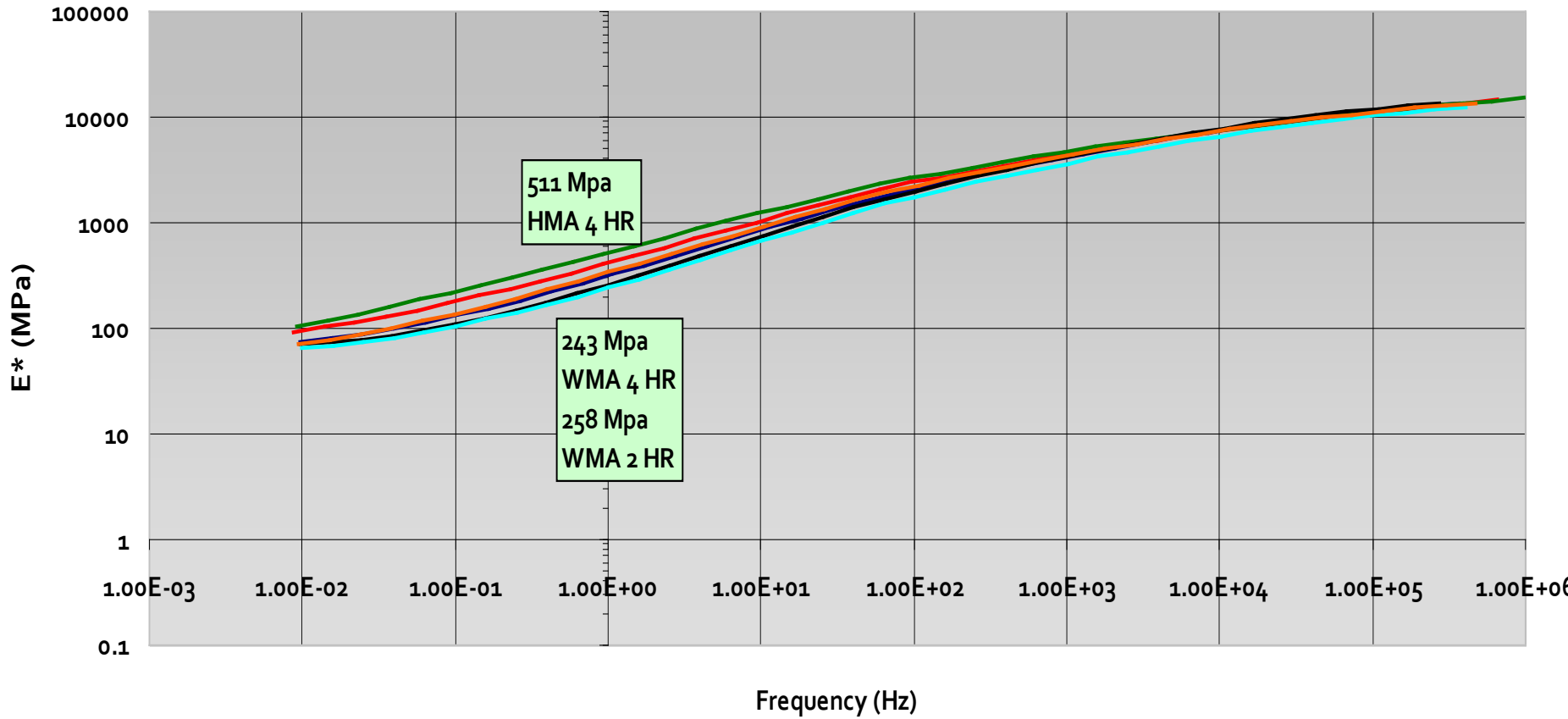
RUT DEPTH @ 10000 PASSES @ 58°C HMA @ 275°F, WMA @ 220°F

X hr= LOOSE MIX CURING TIME AT EITHER 275°F OR 220°F

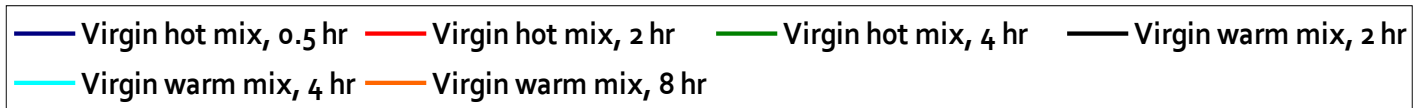
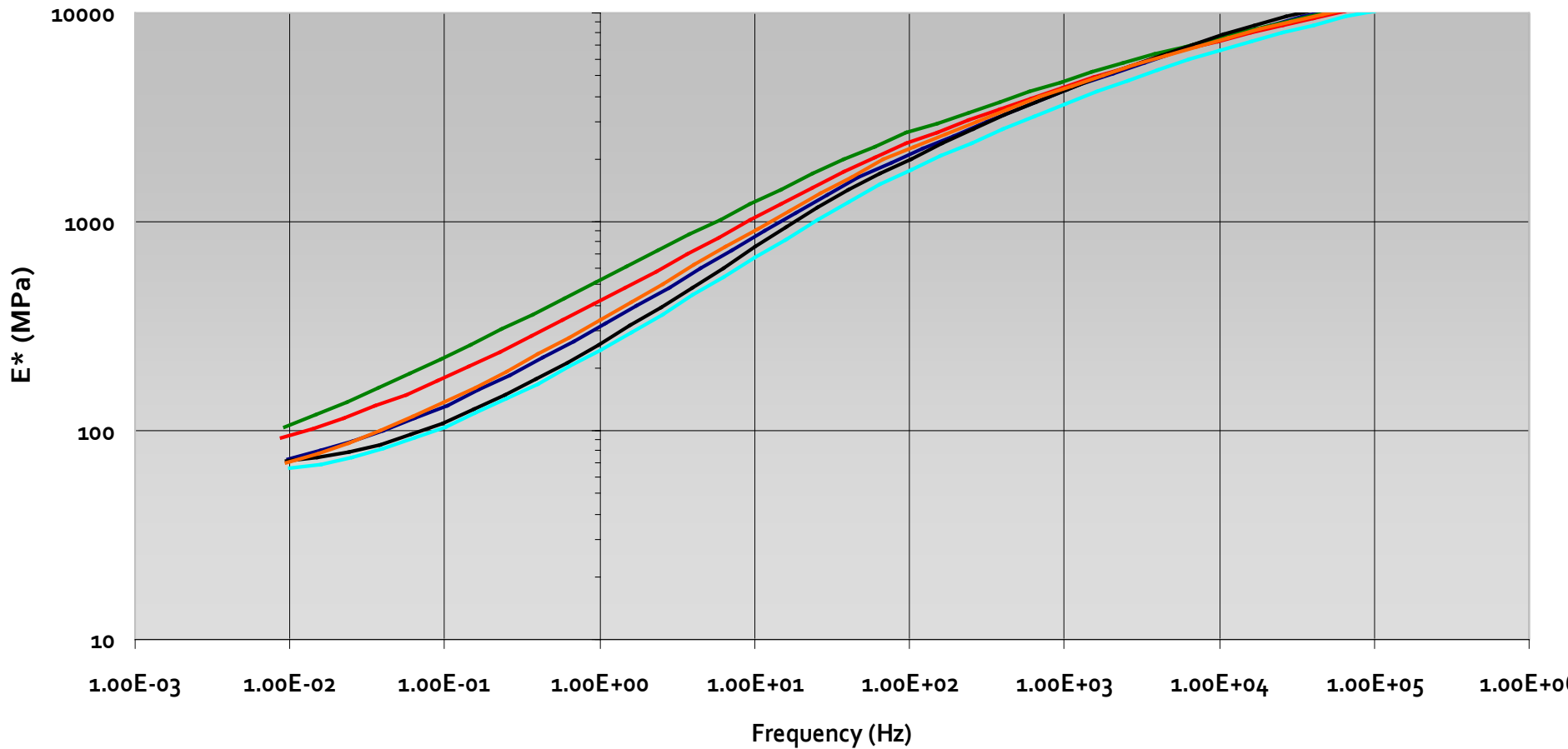


● HMA 20% RAP MIX   
 ▲ WMA VIRGIN MIX   
 ■ WMA 20% RAP MIX   
 ◆ HMA VIRGIN MIX

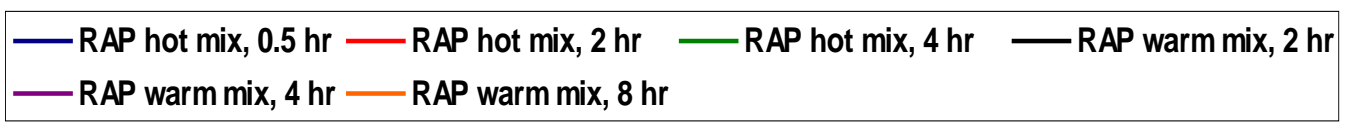
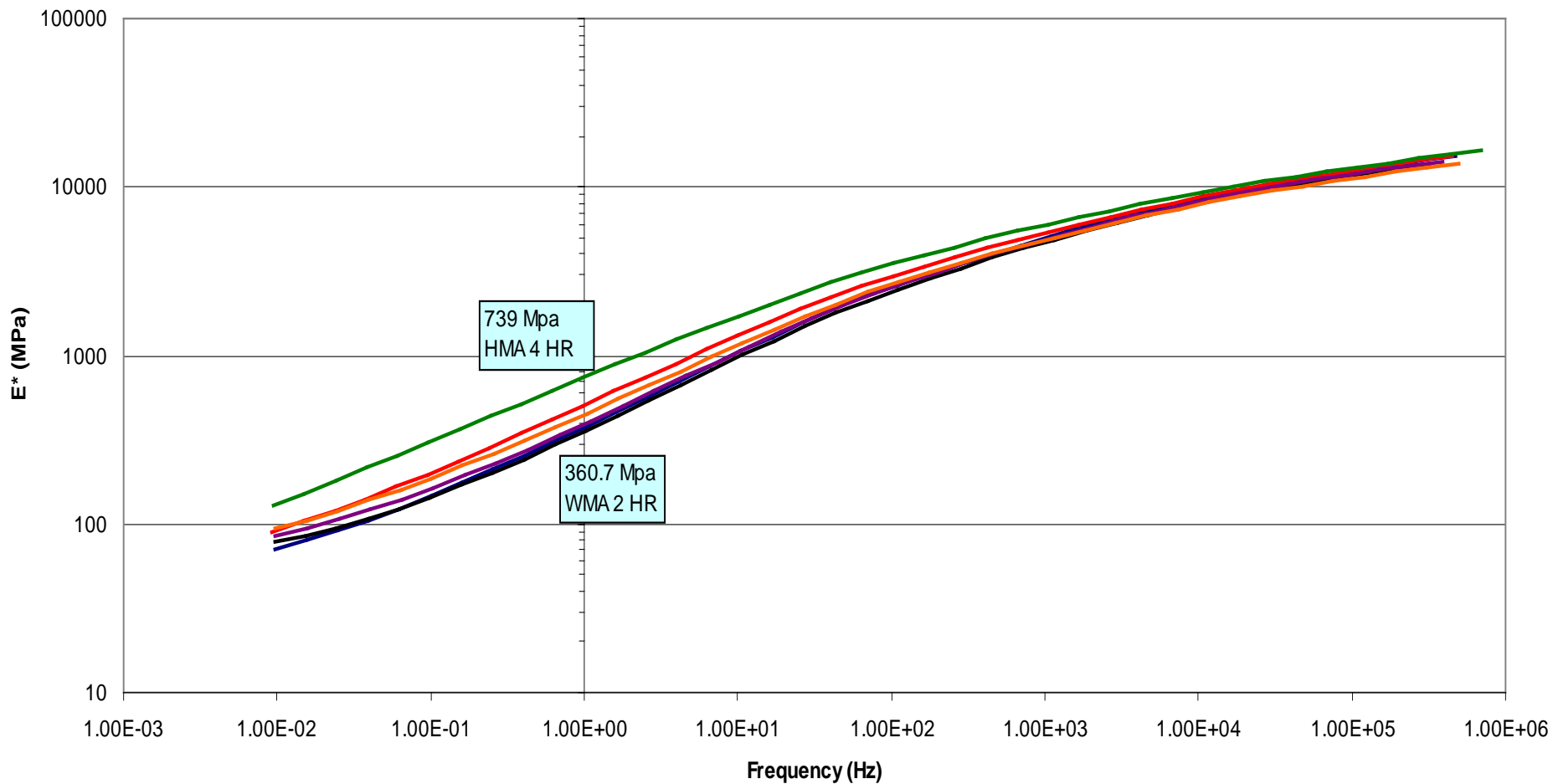
# Comparison of Stiffness Mastercurves of Virgin Hot & Warm Mixes at Tr=40°C



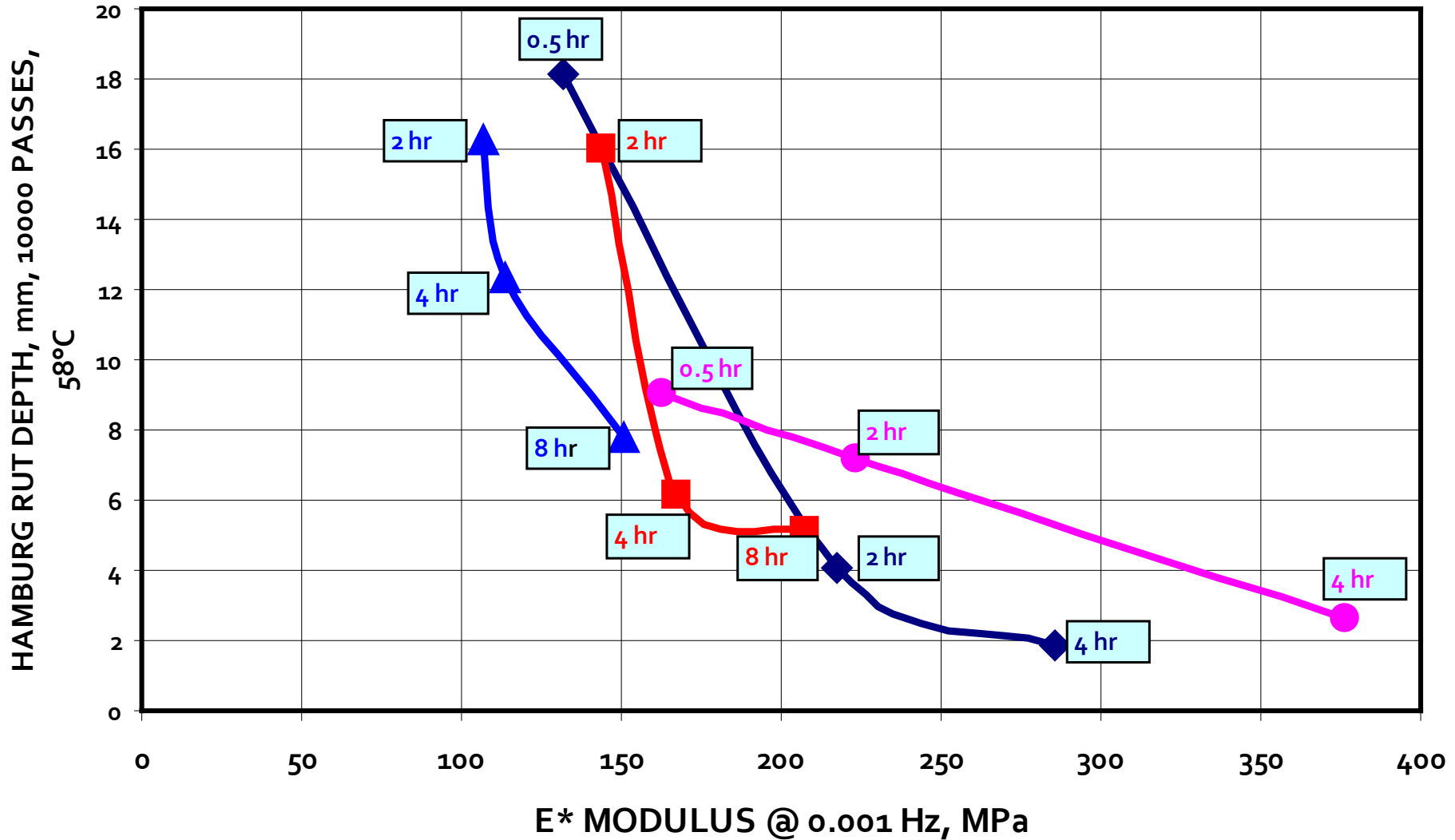
# Comparison of Stiffness Mastercurves of Virgin Hot & Warm Mixes at $T_r=40^\circ\text{C}$



### Stiffness Comparison at $T_r=40^\circ\text{C}$

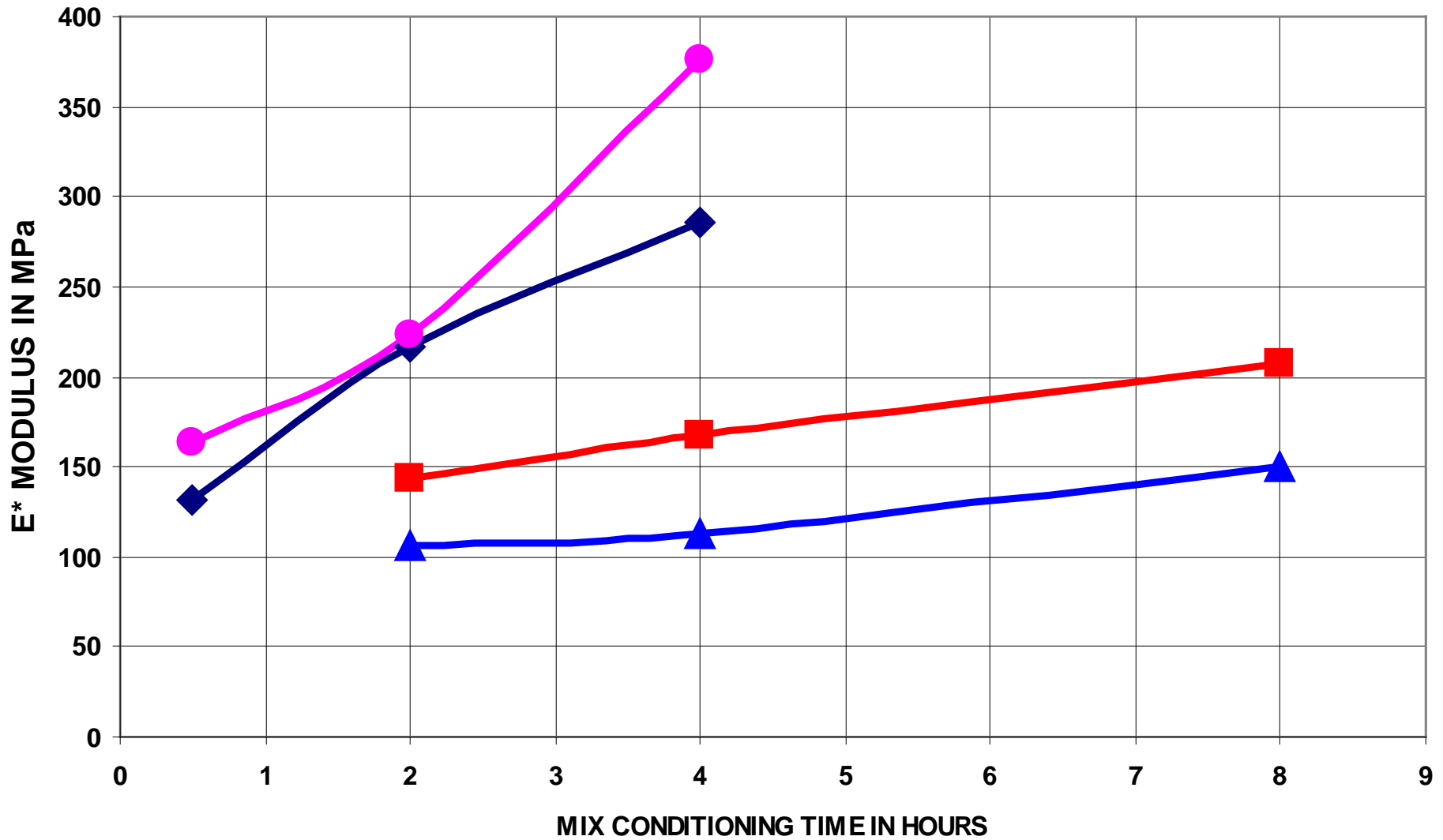


RUT DEPTH (mm) AT 10000 PASSES @ 58°C VS E\* (MPa) @ 0.001 Hz



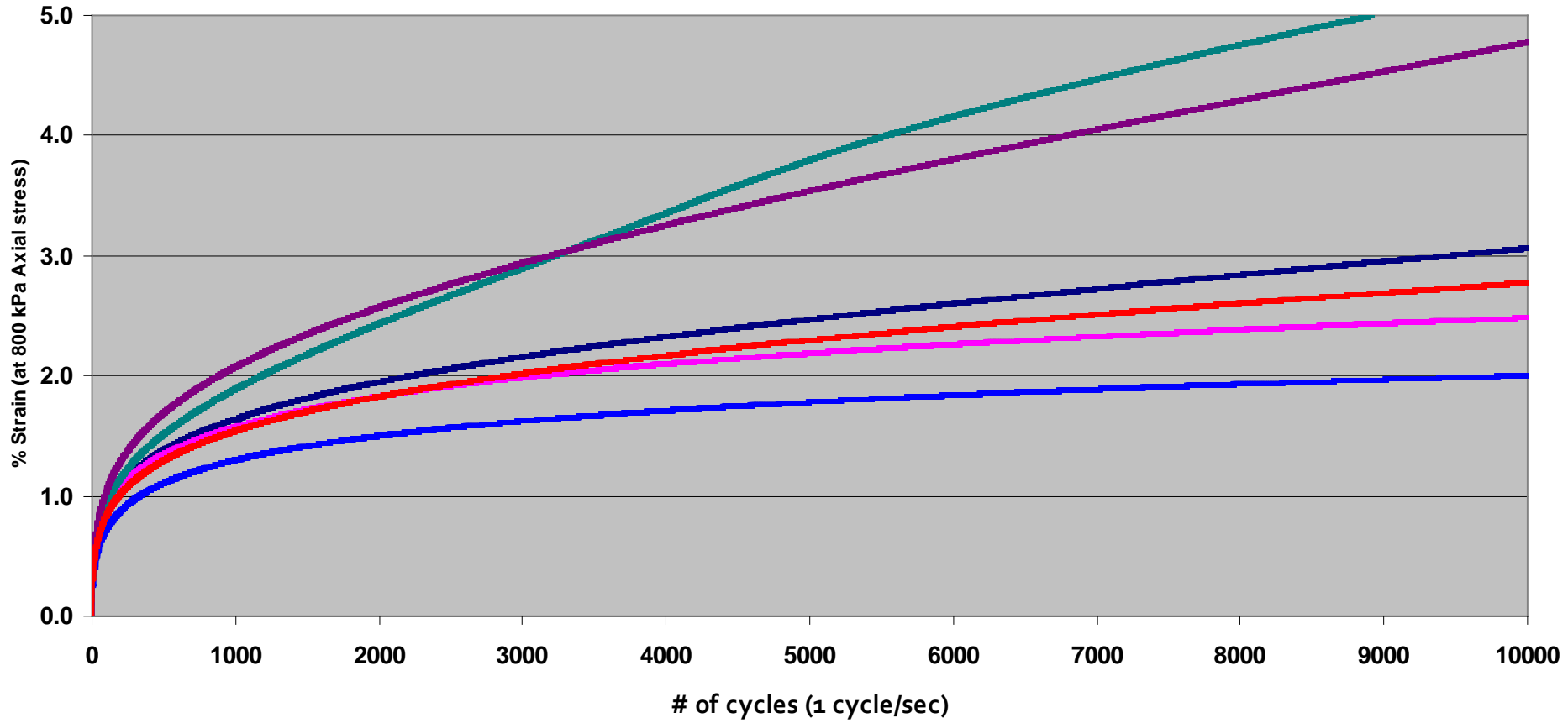
◆ HMA VIRGIN MIX   
 ● HMA 20% RAP MIX   
 ▲ WMA VIRGIN MIX   
 ■ WMA 20% RAP MIX

# E\* MODULUS @ 0.001 Hz REF FREQ FROM 20°C MASTER CURVE



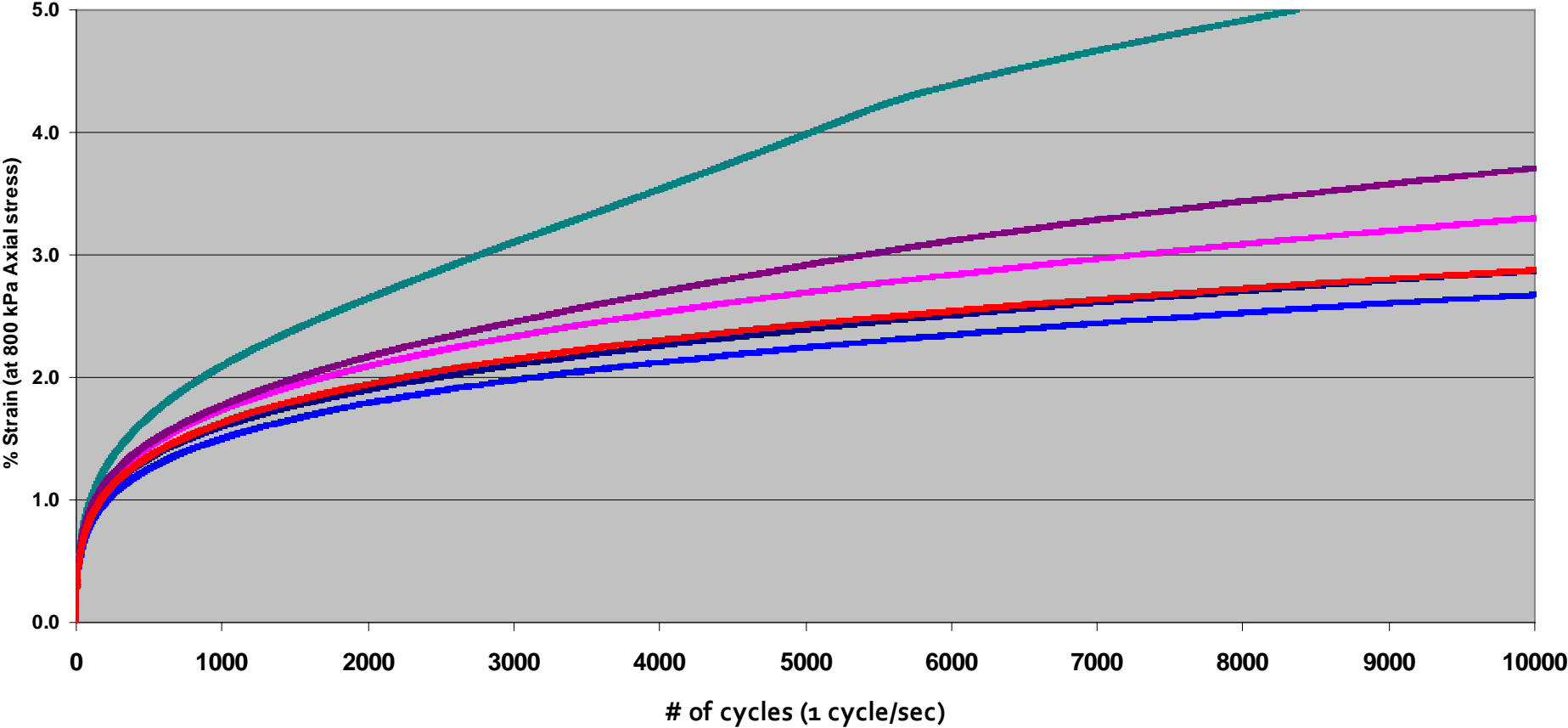
—◆— HMA VIRGIN MIX    —●— HMA 20% RAP MIX    —▲— WMA VIRGIN MIX    —■— WMA 20% RAP MIX

Strain vs. Time Comparison (Virgin mixes) from FLOWNUMBER TEST



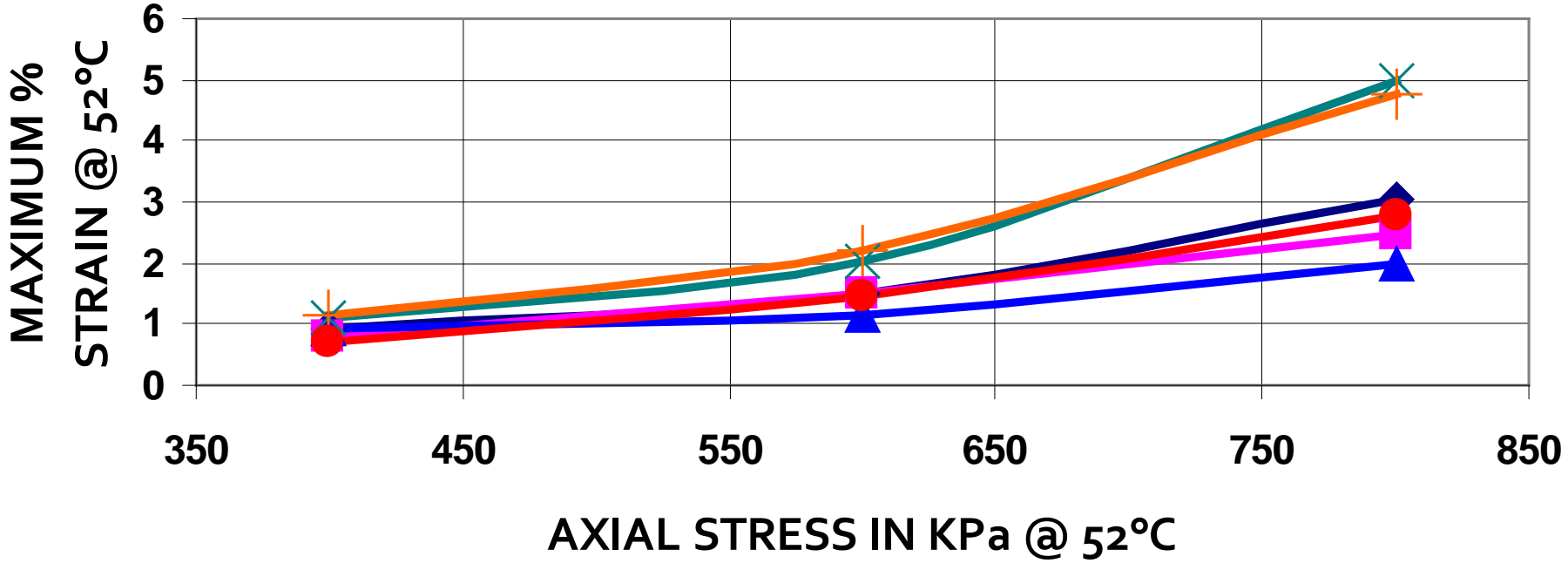
Hot mix (1/2 hr) Hot mix (2 hr) Hot mix (4 hr) Warm mix (2 hr) Warm mix (4 hr) Warm mix (8 hr)

Strain vs. Time Comparison (RAP mixes) from FLOWNUMBER TEST



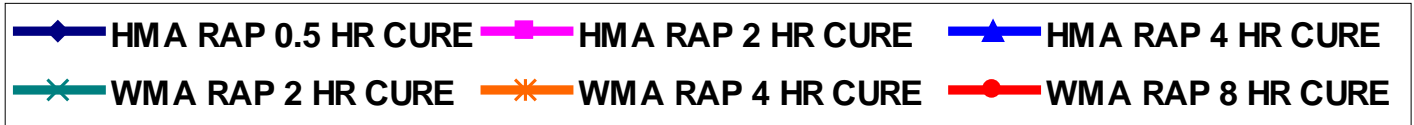
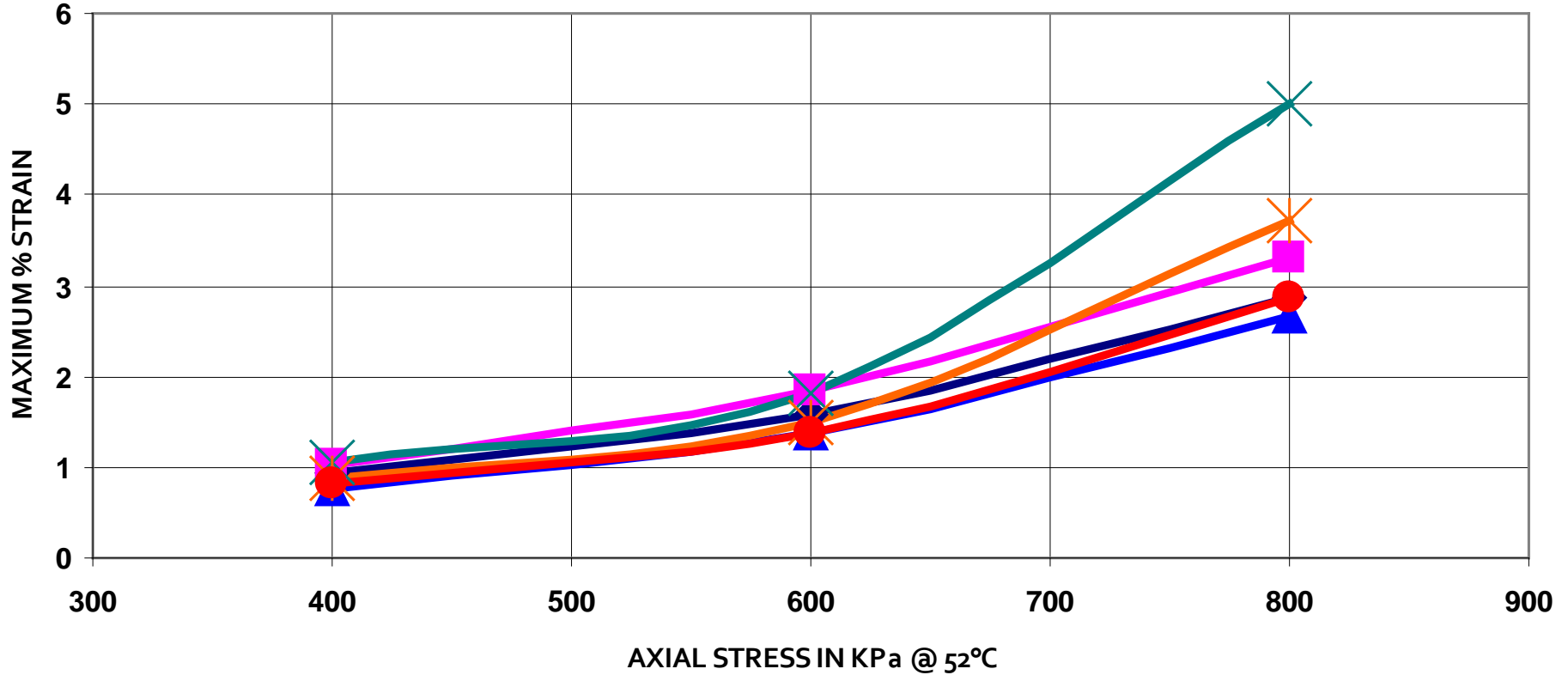
Hot mix (1/2 hr) Hot mix (2 hr) Hot mix (4 hr) Warm mix (2 hr) Warm mix (4 hr) Warm mix (8 hr)

# MAXIMUM % STRAIN IN FLOWNUMBER TEST @ 52°C FOR VIRGIN MIXES

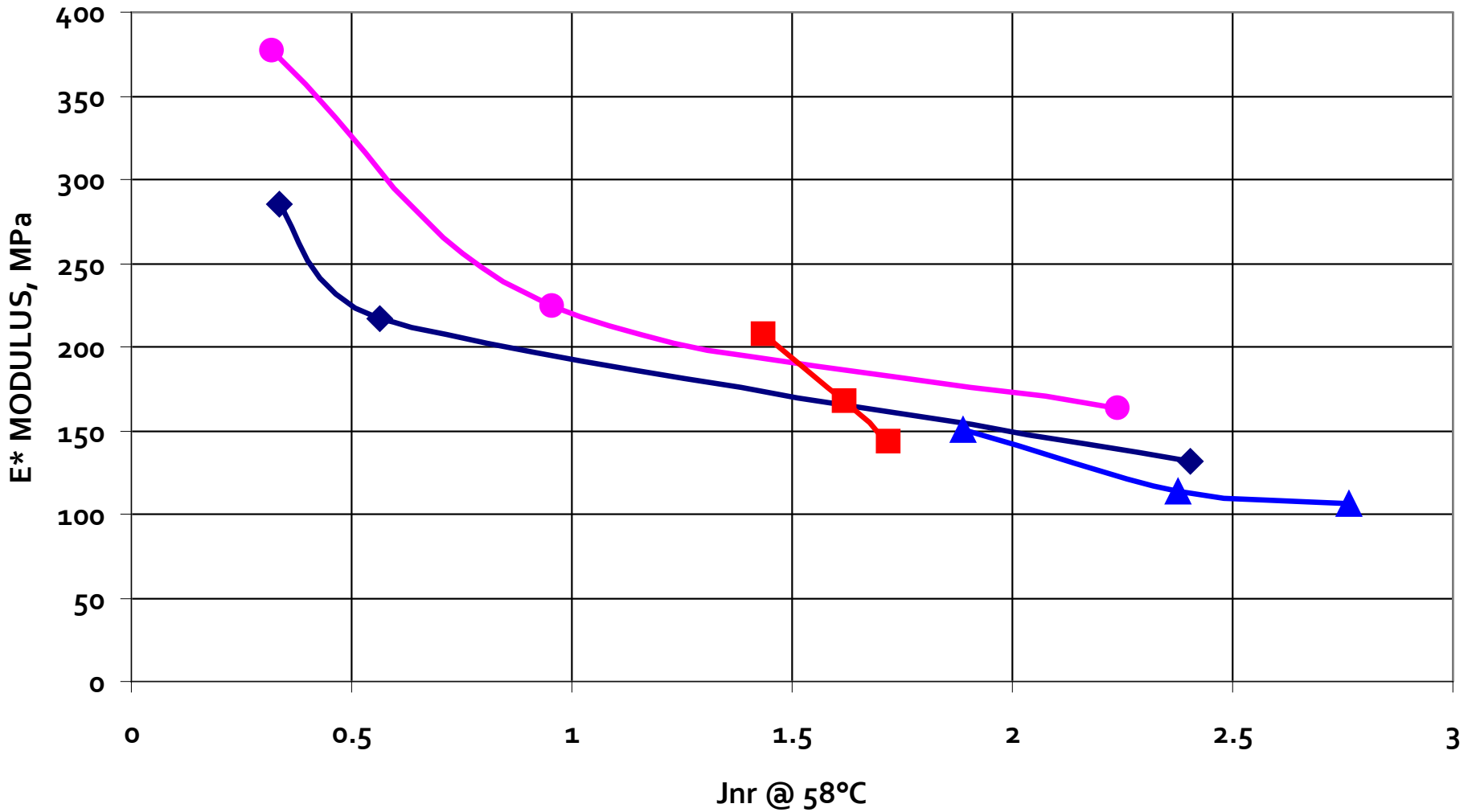


- ◆ HMA VIRGIN 0.5 HR CURE
- HMA VIRGIN 2 HR CURE
- ▲ HMA VIRGIN 4 HR CURE
- ✕ WMA VIRGIN 2 HR CURE
- ✚ WMA VIRGIN 4 HR CURE
- WMA VIRGIN 8 HR CURE

MAXIMUM % STRAIN IN FLOWNUMBER TEST @ 52°C FOR 20% RAP MIXES



E\* MODULUS @ 0.001 Hz VS Jnr @ 58°C



◆ HMA VIRGIN MIX    ● HMA 20% RAP MIX    ▲ WMA VIRGIN MIX    ■ WMA RAP MIX

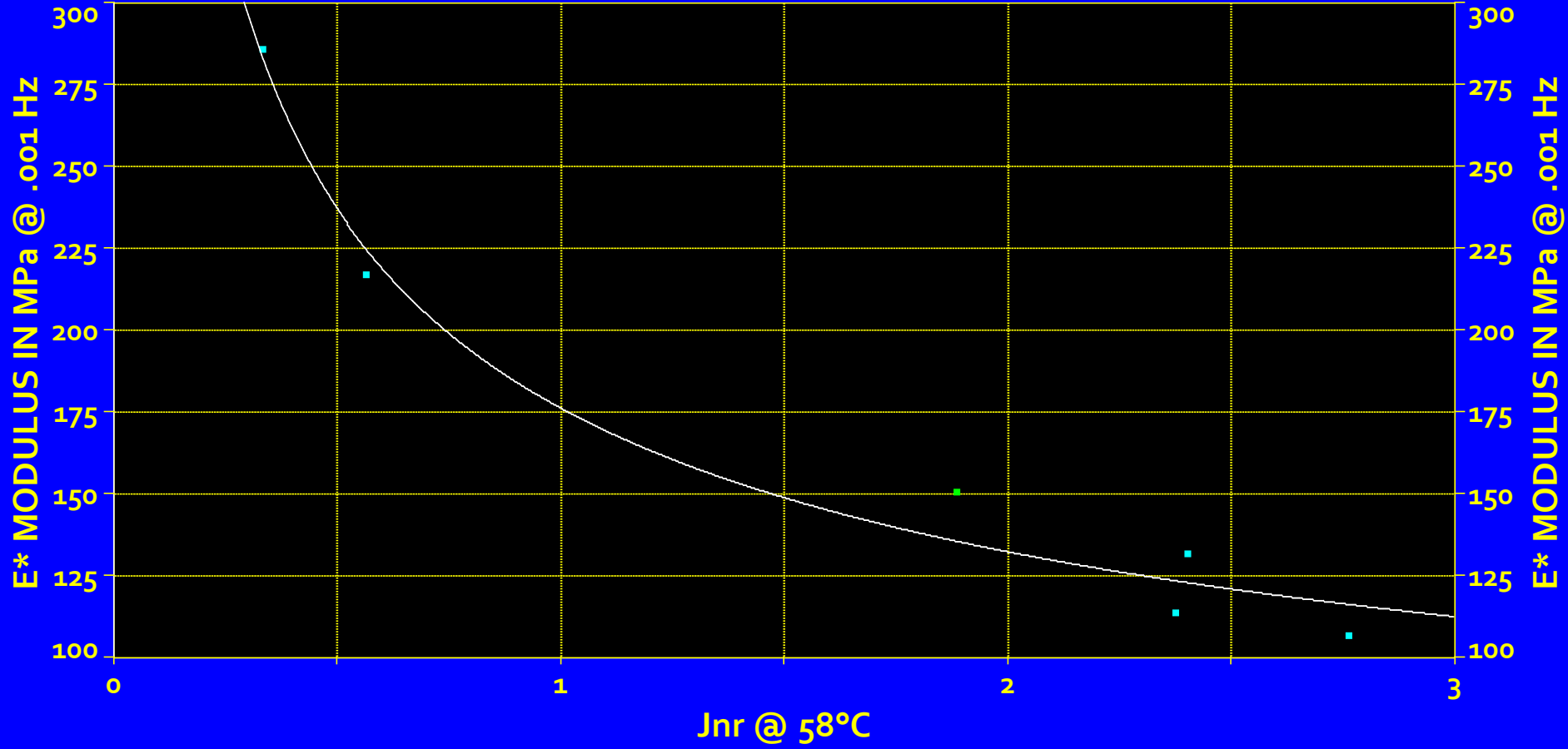
# E\* MODULUS OF VIRGIN MIXES (HMA & WMA DATA COMBINED)

$$Y=A+B*X^C$$

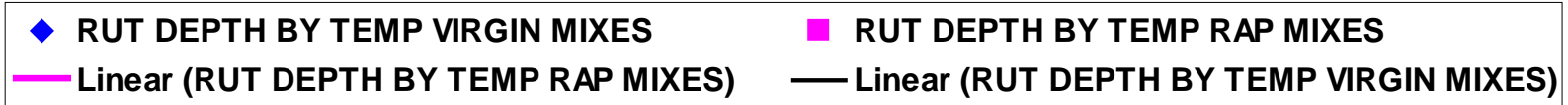
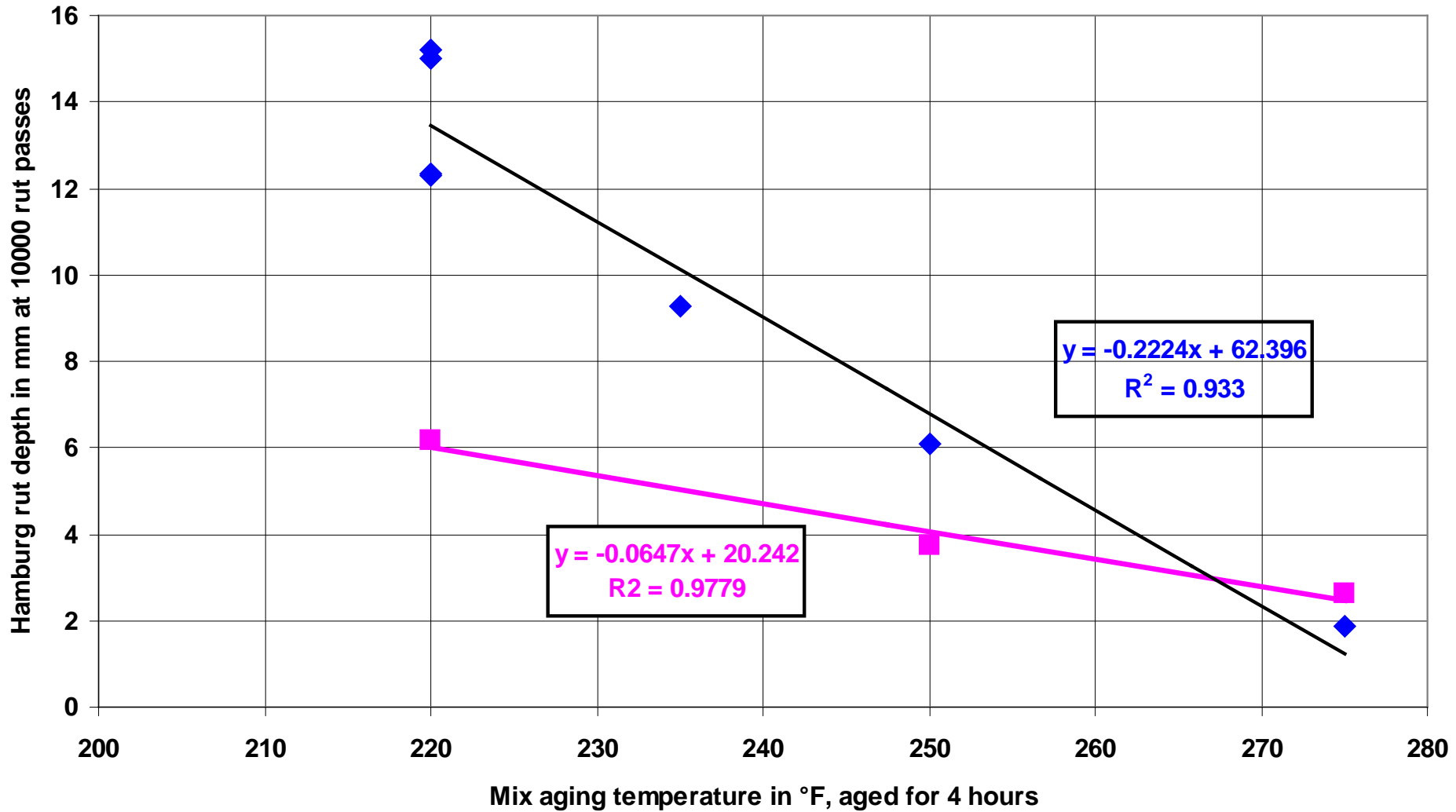
$r^2=0.97679798$  DF Adj  $r^2=0.94199495$  FitStdErr=13.796385 Fstat=63.149547

a=17.170161 b=159.29495

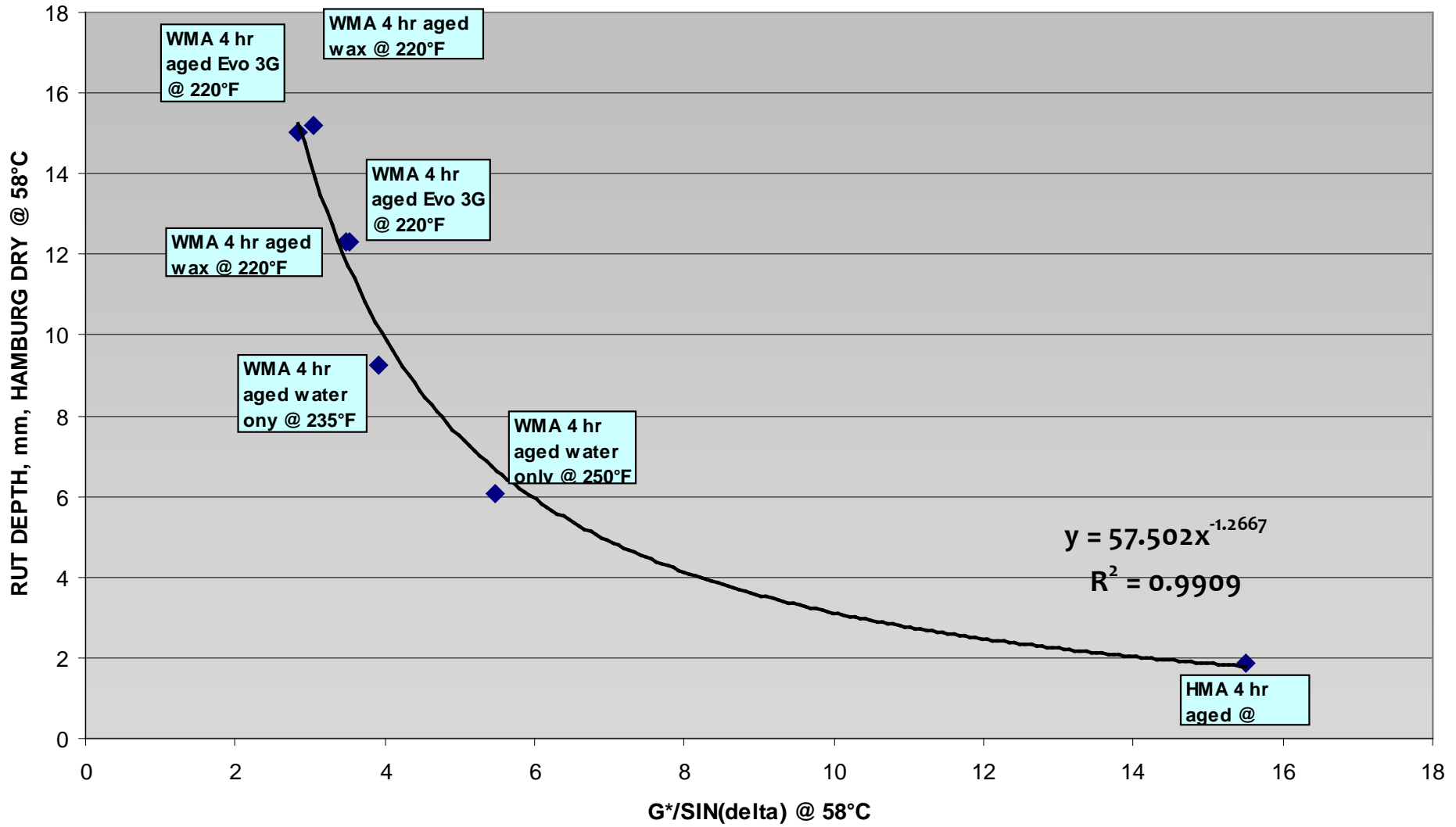
c=-0.46677165



### Hamburg rut depth at 58°C test temperature--E-10 fine mix based on Plant 86 design

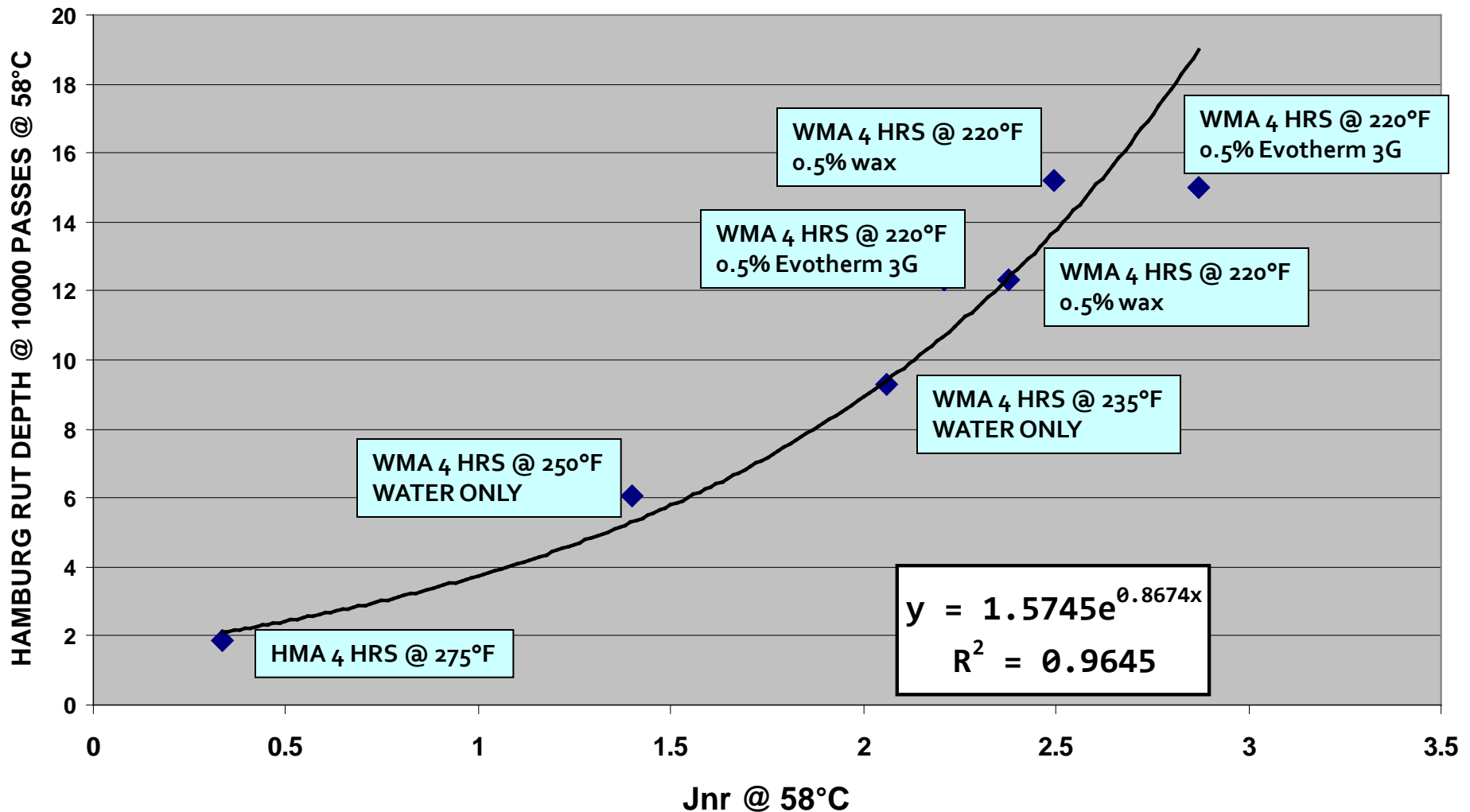


# RUT DEPTH AS A FUNCTION OF G\*/SIN(Delta) @ 58°C FOR VIRGIN MIXES AGED AT 4 HOURS



◆ RUT DEPTH = F(DSR@58°C) — Power (RUT DEPTH = F(DSR@58°C))

# HAMBURG RUT DEPTH @ 10000 PASSES FOR 4 HOUR AGED MIXES HMA & WMA (NO RAP)



◆ RUT DEPTH VS Jnr 4 HR AGED MIXES — Expon. (RUT DEPTH VS Jnr 4 HR AGED MIXES)

# CONCLUSIONS

1. MECHANISTIC RESULTS DRIVEN BY AGING TEMPERATURE AND AGING TIME FOR VIRGIN MIXES
2. 4 HOURS AGING AT 220°F WITH RAP WAS ROUGHLY SIMILAR TO 2 HOURS AGING AT 275°F WITH RAP
  - a) Takes twice as long at warm mix vs. hot mix temperature to activate RAP???

# CONCLUSIONS

3. **50°F REDUCTION IN CONDITIONING TEMPERATURE RESULTED IN:**
  - a) **~11°C INCREASE IN HIGH TEMPERATURE PG GRADE WHEN CONDITIONING AT 275°F FROM 0.5, 2, TO 4 HOURS**
  - b) **~2°C INCREASE IN HIGH TEMPERATURE PG GRADE WHEN CONDITIONING AT 220°F FROM 2, 4, TO 8 HOURS**

# CONCLUSIONS

## 4. 50°F REDUCTION IN CONDITIONING TEMPERATURE RESULTED IN:

- a) ~3°C INCREASE IN LOW TEMPERATURE PG GRADE WHEN CONDITIONING AT 275°F FROM 0.5, 2, TO 4 HOURS FOR VIRGIN MIX
- b) ~2.5°C INCREASE IN LOW TEMPERATURE PG GRADE WHEN CONDITIONING AT 275°F FROM 0.5, 2, TO 4 HOURS
- c) ~0°C INCREASE IN LOW TEMPERATURE PG GRADE WHEN CONDITIONING AT 220°F FROM 2, 4, TO 8 HOURS

# CONCLUSIONS

5. 4 HOURS OR 220°C AGING OF RAP MIX PRODUCES RUTTING RESULTS SIMILAR TO 2 HOURS OF AGING OF HMA AT 275°F
6. FLOWNUMBER STRAIN RESULTS WITH 10 PSI CONFINING PRESSURE SHOW THAT 8 HOURS OF WARM MIX CONDITIONING TIME IS EQUIVALENT TO 2 TO 4 HOURS OF HOT MIX CONDITIONING

**G**

- **HH**

