Test Methods for Mineral Filler Used in HMA

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International Workshop on Asphalt
Binders and Mastics
September 16th and 17th, 2010
Madison-Wisconsin

NCHRP 9-45

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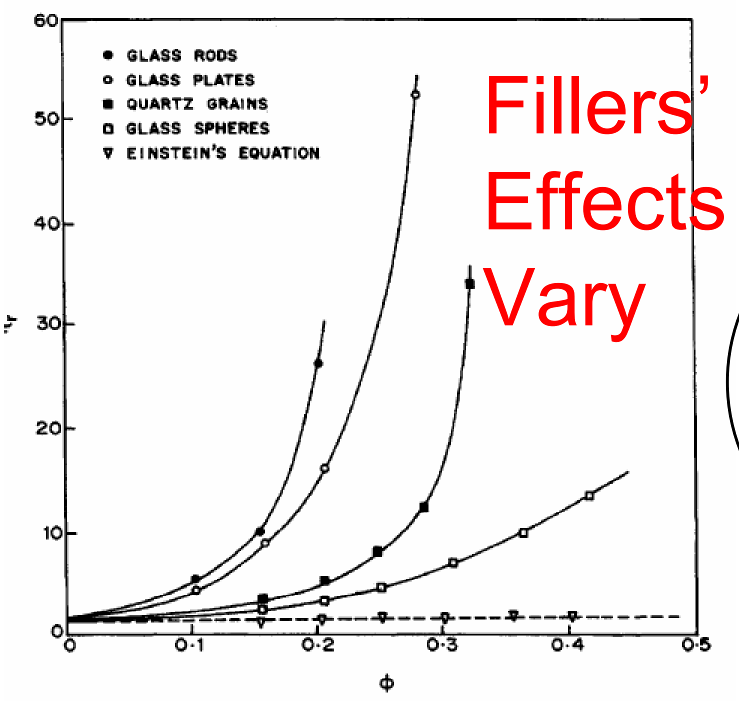
Objectives of the Study

(1) Identify or develop test methods for mineral filler that characterize its mechanical and chemical effects on the performance of :

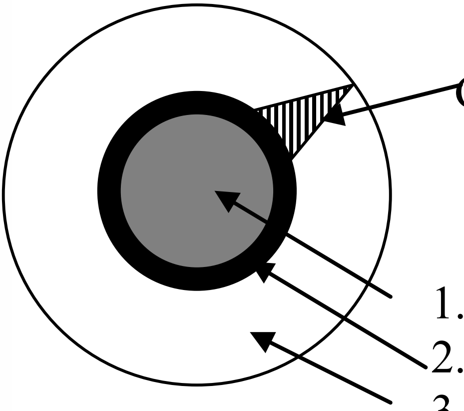
- (a) mastics and
- (b) hot mix asphalt (HMA)

(2) Recommend specification criteria for mineral filler that optimize HMA performance

Basic Concept of Study: Fillers' Interaction with Binders(**Tunnicliff in 1960)**



Fillers' Effects Vary



Gradient of stiffening

1. Filler
2. Asphalt adsorbed layer
3. Asphalt layer affected by adsorption

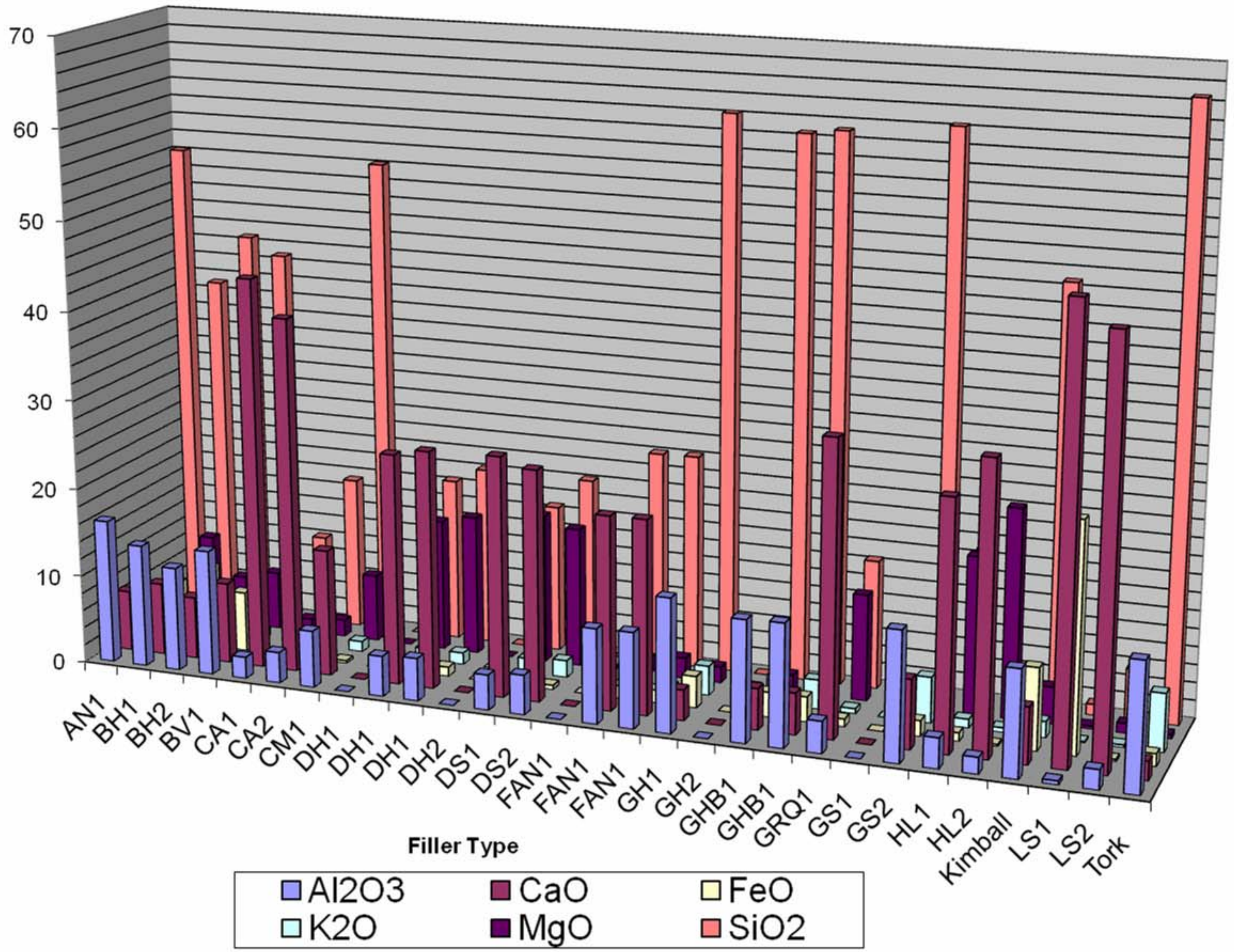
Important Properties: Geometry & Composition

Fillers Collected

- Natural & Imported
- Soft and Hard
  - LA = 25%
- Many from 2 sources

No.	Code	Filler Type
1	LH1	**Hard Limestone**
2,3	LS1, LS2	**Soft Limestone**
4,5	DH1, DH2	**Hard Dolomite**
6,7	DS1, DS2	**Soft Dolomite**
8, 9	GH1, GH2	**Hard Granite**
10	GHB1	**Hard Granite**
11,12	GS1, GS2	**Soft Granite**
13,14	BH1,BH2	**Hard Basalt**
15	BV1	**Vesicular Basalt**
16, 17	GRQ1, GRQ2	**Siliceous Gravel Quartzite**
18, 19	CA1, CA2	**Soft Caliches**
20	AN1	**Andesite**
21, 22	FAC1, FAC2	**Fly Ash Type C**
23	FAF1	**Fly Ash Type F**
24, 25	FAN1, FAN2	**Fly Ash Non Spec**
26, 27	HL1, HL2	**Hydrated Lime**
28	CM1	**Cement**
29, 30	FS1, FS2	**Steel Furnace Slag**
31	CBC1	**Carbon Black Coarse**
32	CBF1	**Carbon Black Fine**

Composition vs Filler type



Best Filler Tests for Geometry/ Physical Properties

1. Physical Property	Test Protocol	Remarks
- Fractional voids	Rigden Voids EN 1097-4	No development is necessary.
- Size Distribution	Laser Diffracti ASTM D4464	Type of surfactant and time of agitation will be studied.
- Specific Gravity	AASHTO T-133 & CoreLok	Both methods will be used to evaluate the possibility of measuring apparent and bulk SG
- Absorption	Bitumen Number (EN13179-2) & Laser Diffraction with Time	Not a standard method and some development is needed.
- Shape and Texture	Microscopy using AIMS or UIAIA software	Not a standard method and some development is needed.

RV

FM

Best Filler Tests for Composition/Chemical Properties

2. Chemical Property	Test Protocol	Remarks
- Calcium Compounds CaO	X-ray Fluorescence, EN 196-21, EN 495-2 ASTM D3042 MN/DOT	Initial testing is needed to determine the appropriate test.
- Water Solubility	EN 1744-1:1998	No development is necessary.
- Methylene Blue / MBV Plasticity Index	AASHTO TP57 AASHTO T90	Limited development for TP 57 will be needed.
- Organic Content- Loss on Ignition	EN 1744-1:1998 C17, AASHTO 267-86	Need to determine testing temperature.

Range in Filler Properties

	RV	FM	CaO	MBV	SG*
Fillers Max	49.1	6.3	50.3	31.6	2.402
Fillers Min	26.2	3.0	1.0	0.0	2.787

RV: Rigden Voids

FM: Fineness Modulus

CaO: Calcium Oxide

MBV: Methylene Blue Value

* Natural Fillers only

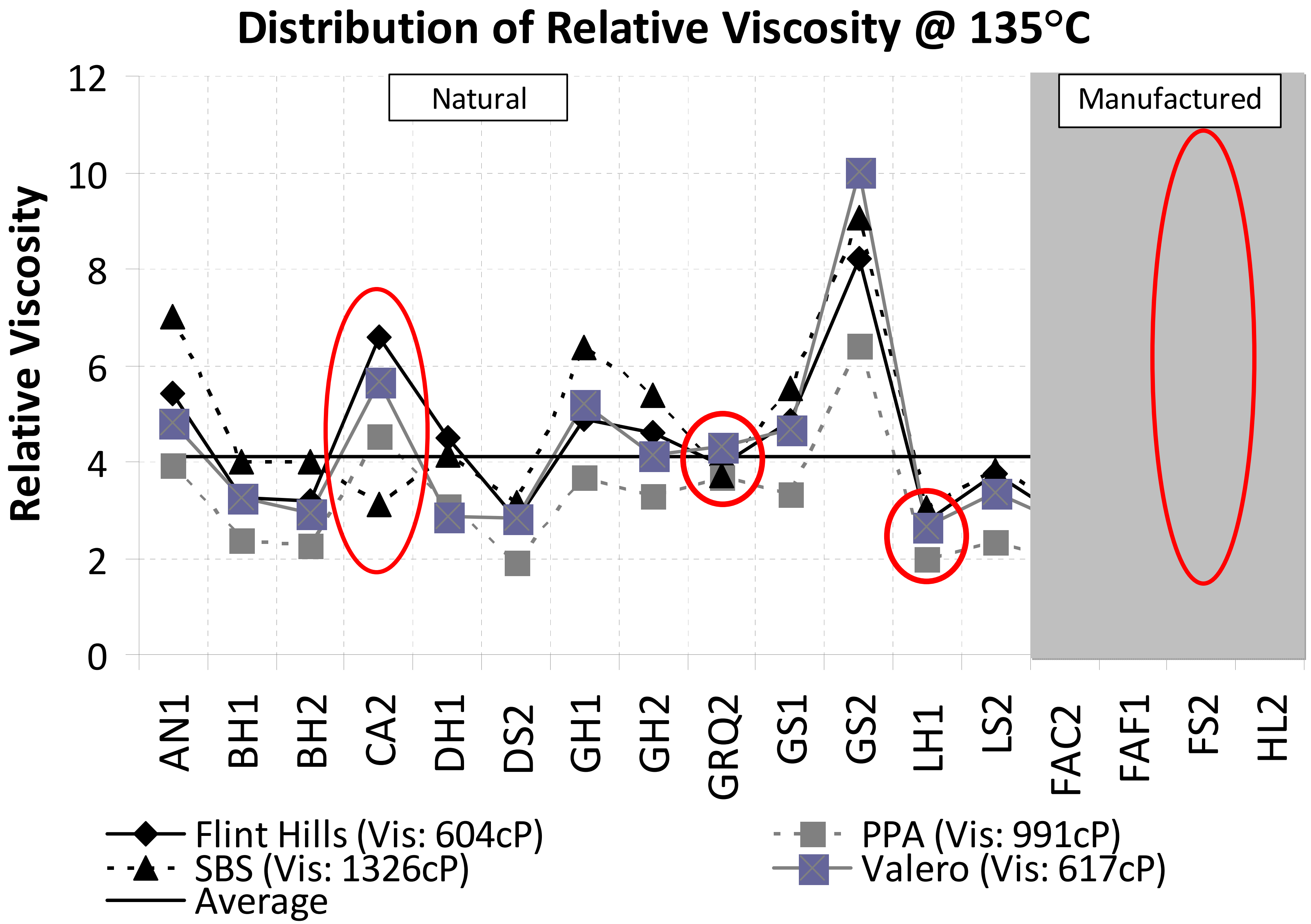
Mastic Testing

Workability:	Mastic: Viscosity - 135°C &20RPM.
Rutting:	Mastic: Jnr - 58°C &3.2,10kPa.
Fatigue:	Mastic: G*.Sinδ, and Time Sweep, 25°C and 10Hz.
Low Temp:	Mastic: S, m, at -12°C, Cracking temperature (ABCD)
Moisture Damage	Mastic: Pull Off Test, 24hr moisture conditioning at 60°C

Mastic Testing and Results

4 binders x 17 fillers

Viscosity

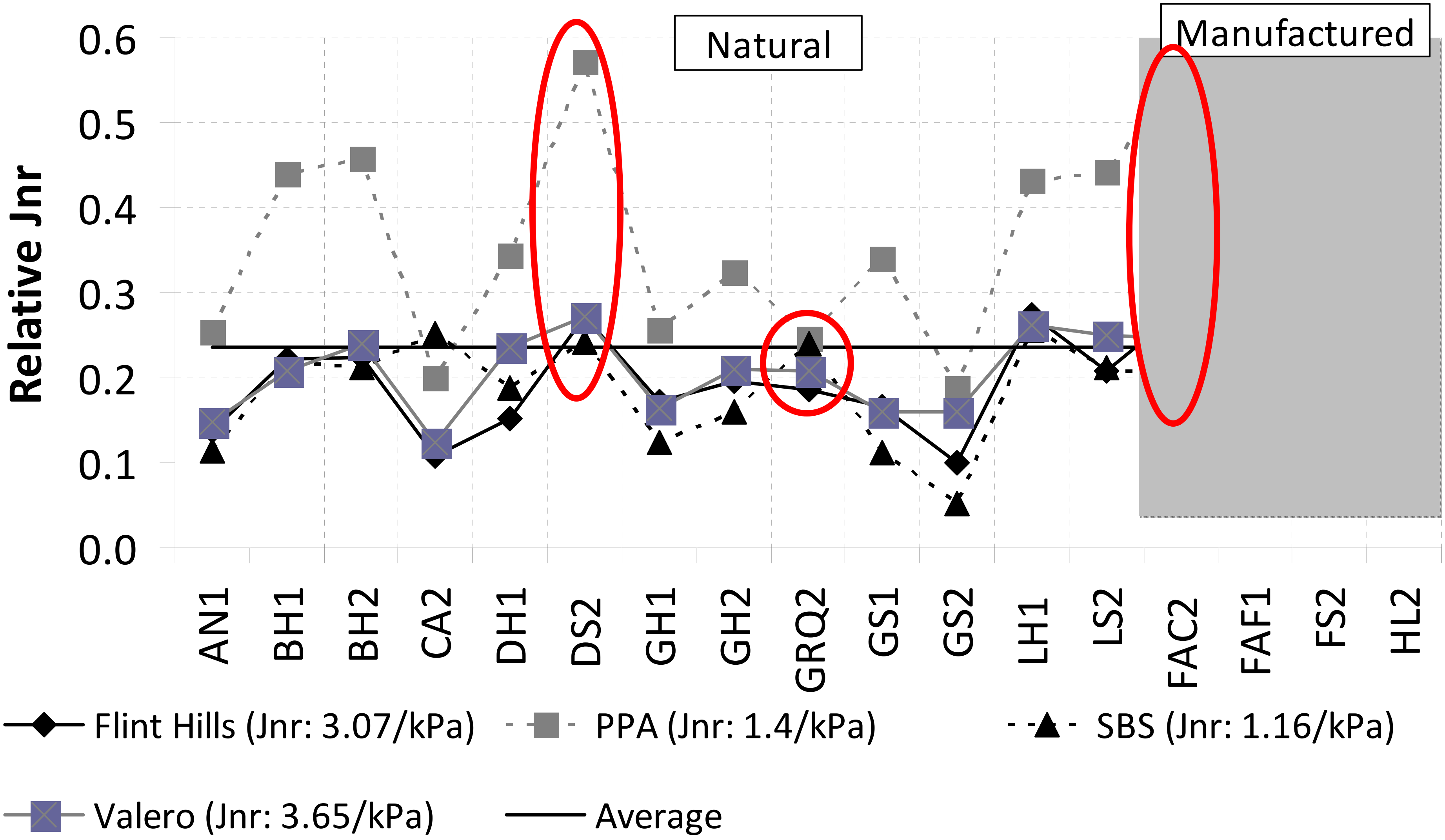

Distribution of Relative Viscosity @ 135°C
Relative Viscosity
12
10
8
6
4
2
0
Natural
Manufactured
AN1
BH1
BH2
CA2
DH1
DS2
GH1
GH2
GRQ2
GS1
GS2
LH1
LS2
FAC2
FAF1
FS2
HL2
Flint Hills (Vis: 604cP)
SBS (Vis: 1326cP)
Average
PPA (Vis: 991cP)
Valero (Vis: 617cP)

Effect of Filler on Mastic Viscosity

```
Mastic Viscosity =  - 12891 + 148xRigden Voids
                    + 25653xVolume Fraction
                    + 4.23xBinder Viscosity


Predictor              T      P
Constant           -4.54  0.000
Rigden Voids        6.89  0.000
Volume Fraction     2.79  0.007
Binder Viscosity   10.29  0.000


S = 964.614   R-Sq = 71.7%   R-Sq(adj) = 70.3%
```

Permanent Deformation

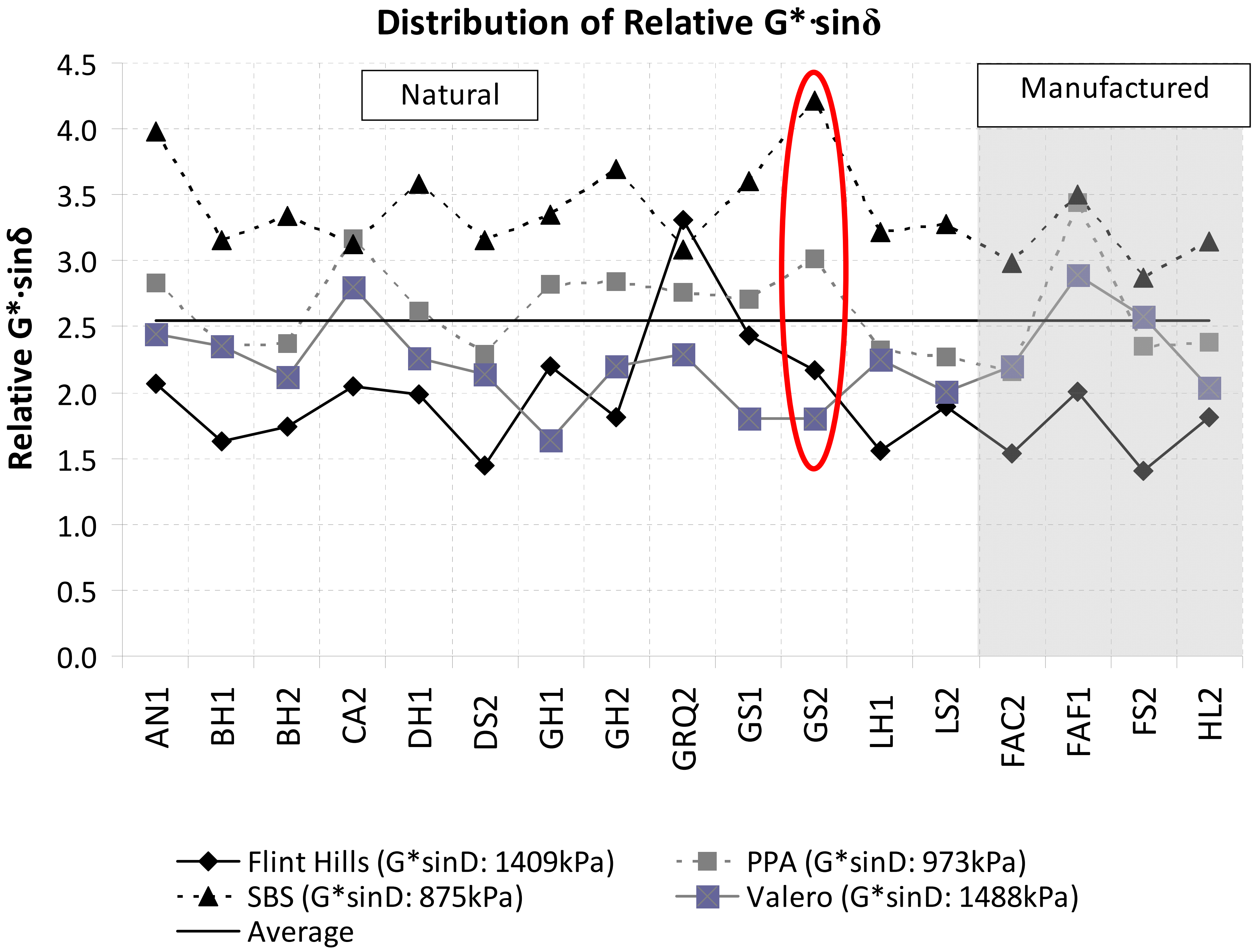
Distribution of Relative Jnr @ 58°C



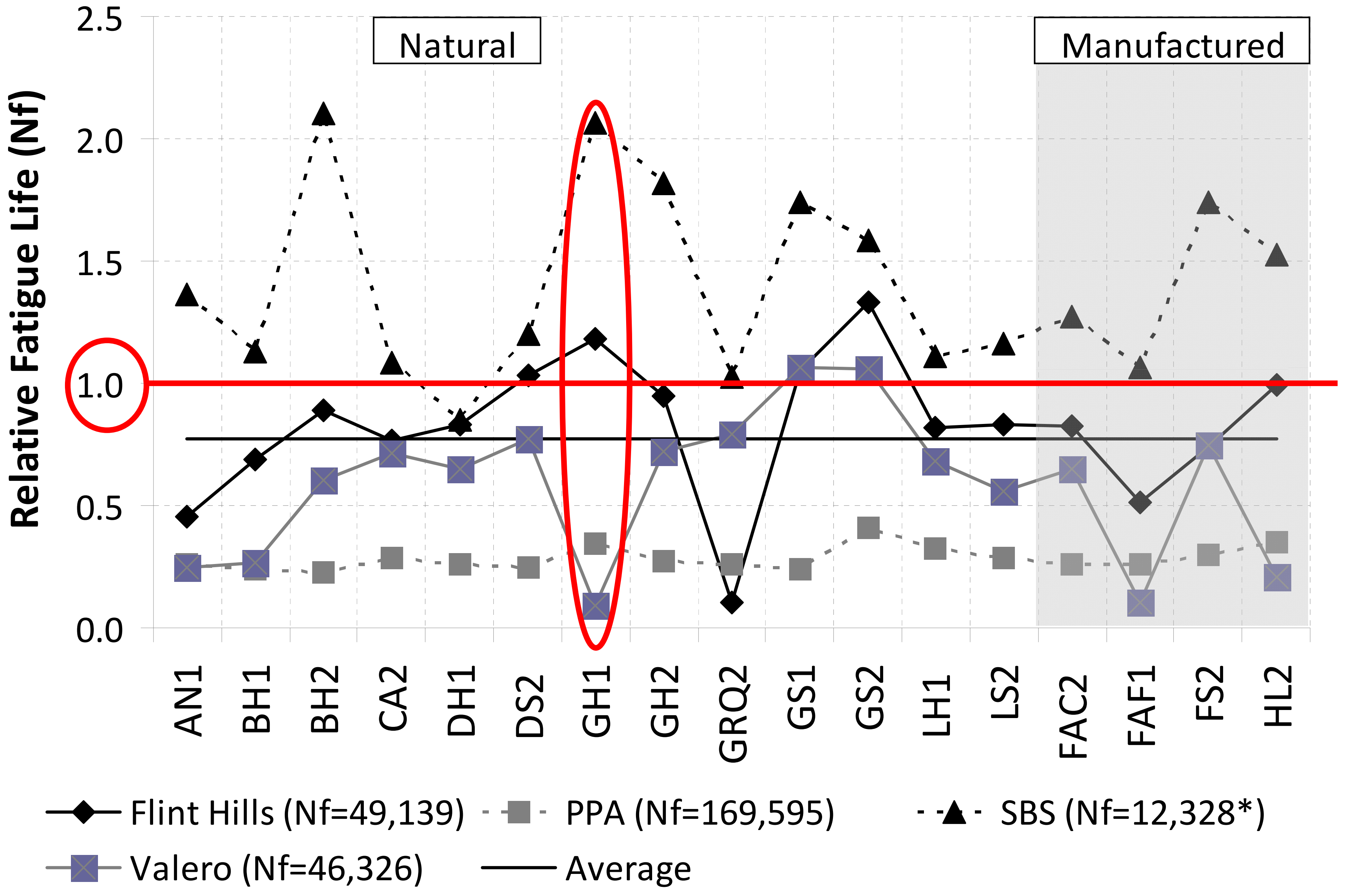
Effect of Filler on Mastic Jnr

```
Jnr = 2.05 + 0.166 Binder Jnr
       - 0.0162 Rigden Voids
       - 4.67 Volume Fraction


Predictor             T      P
Constant           5.38  0.000
Binder Jnr        10.71  0.000
Rigden Voids      -5.97  0.000
Volume Fraction   -3.84  0.000


S = 0.136097   R-Sq = 70.9%   R-Sq(adj) = 69.5%
```

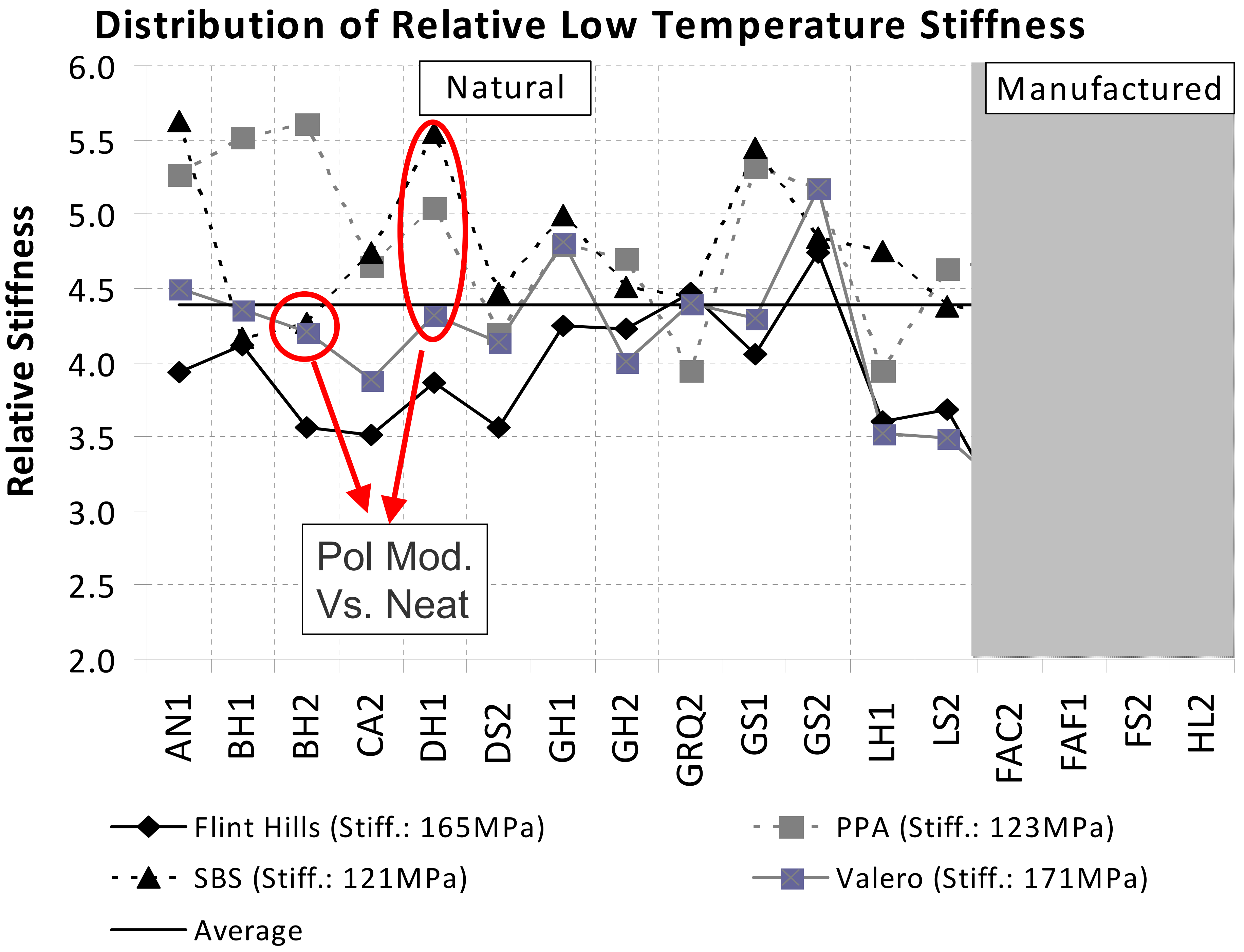
Mastic Fatigue Resistance


Distribution of Relative G*·sinδ
Relative G*·sinδ
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Natural
Manufactured
AN1
BH1
BH2
CA2
DH1
DS2
GH1
GH2
GRQ2
GS1
GS2
LH1
LS2
FAC2
FAF1
FS2
HL2
Flint Hills (G*sinD: 1409kPa)
PPA (G*sinD: 973kPa)
SBS (G*sinD: 875kPa)
Valero (G*sinD: 1488kPa)
Average

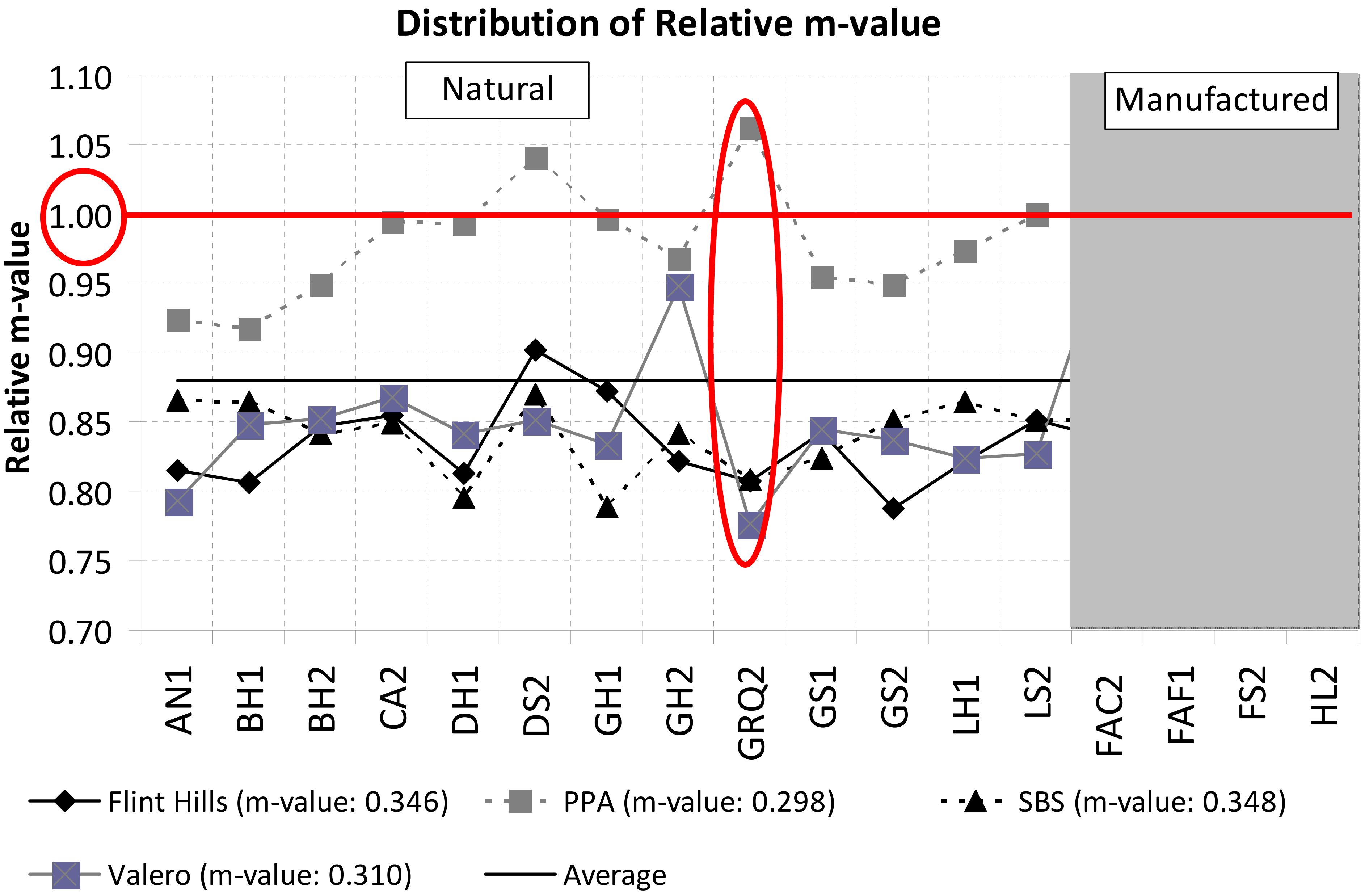
Distribution of Relative Fatigue Life

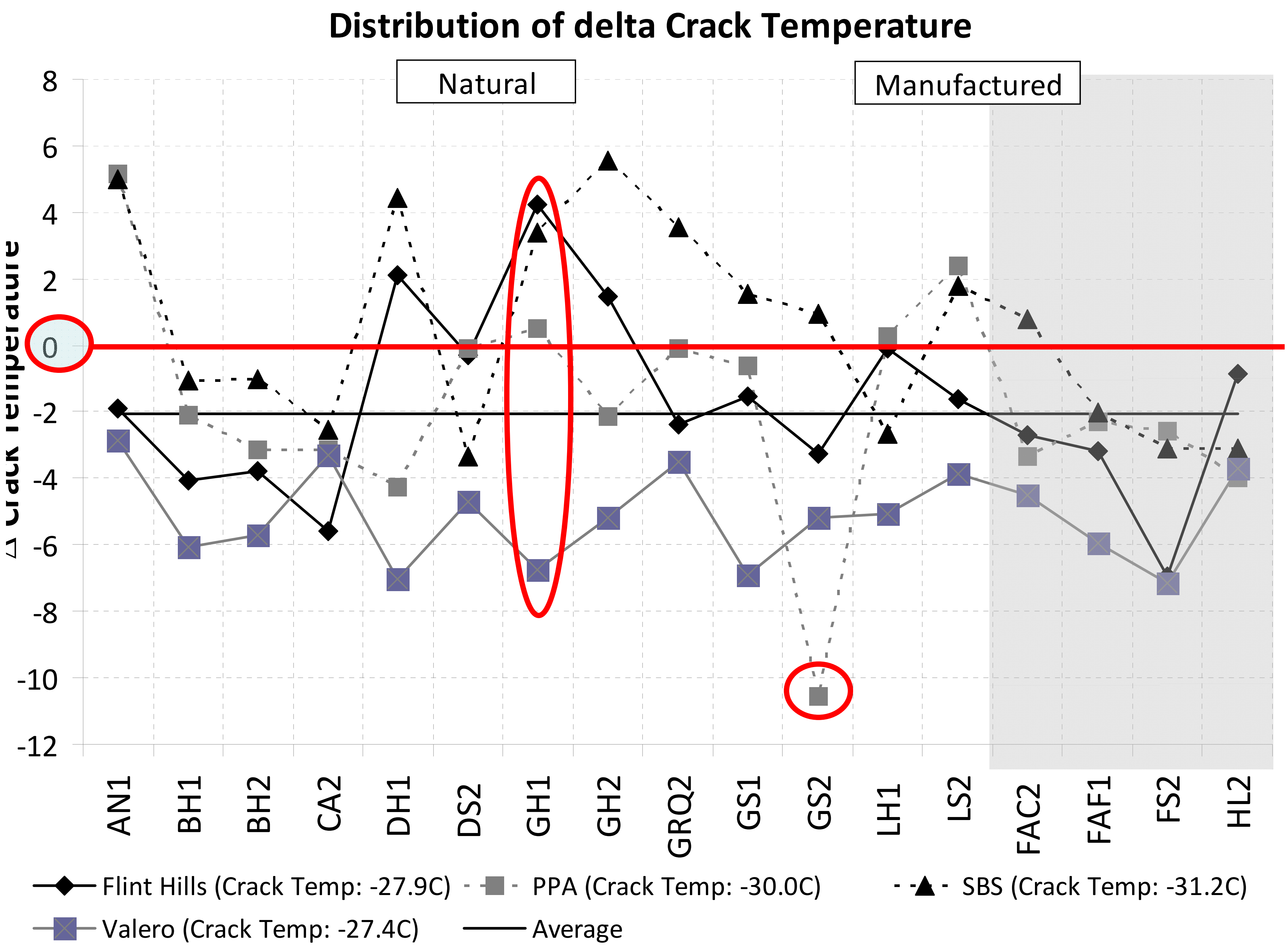


Mastic Low Temperature Performance



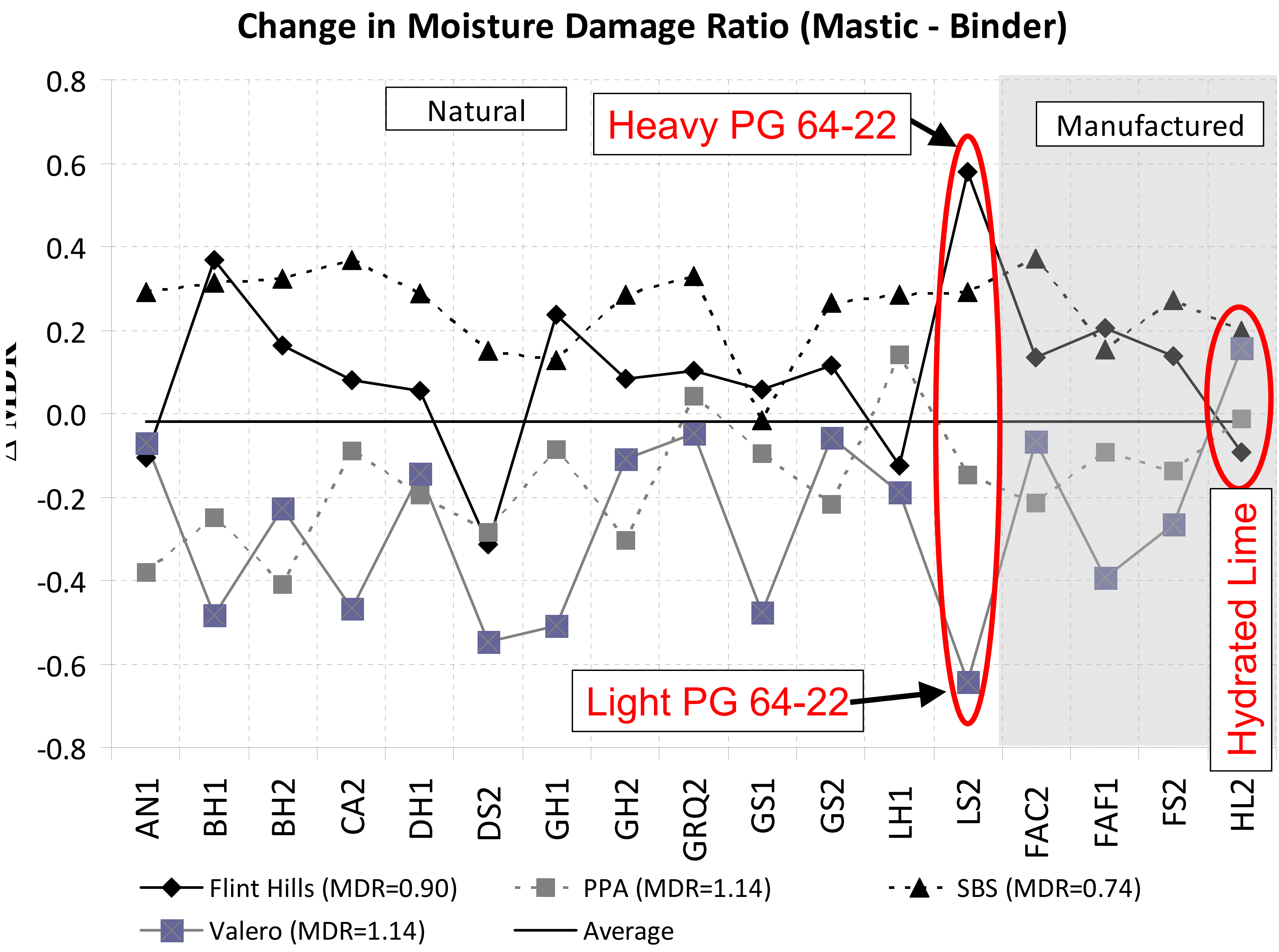
Pol Mod.
Vs. Neat


Distribution of Relative m-value
Natural
Manufactured
Relative m-value
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
AN1
BH1
BH2
CA2
DH1
DS2
GH1
GH2
GRQ2
GS1
GS2
LH1
LS2
FAC2
FAF1
FS2
HL2
Flint Hills (m-value: 0.346)
PPA (m-value: 0.298)
SBS (m-value: 0.348)
Valero (m-value: 0.310)
Average



Distribution of delta Crack Temperature

Mastic Moisture Damage Resistance


Change in Moisture Damage Ratio (Mastic - Binder)
Δ MDR
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
Natural
Manufactured
Heavy PG 64-22
Light PG 64-22
Hydrated Lime
AN1
BH1
BH2
CA2
DH1
DS2
GH1
GH2
GRQ2
GS1
GS2
LH1
LS2
FAC2
FAF1
FS2
HL2
Flint Hills (MDR=0.90)
PPA (MDR=1.14)
SBS (MDR=0.74)
Valero (MDR=1.14)
Average

Mixture Testing and Results

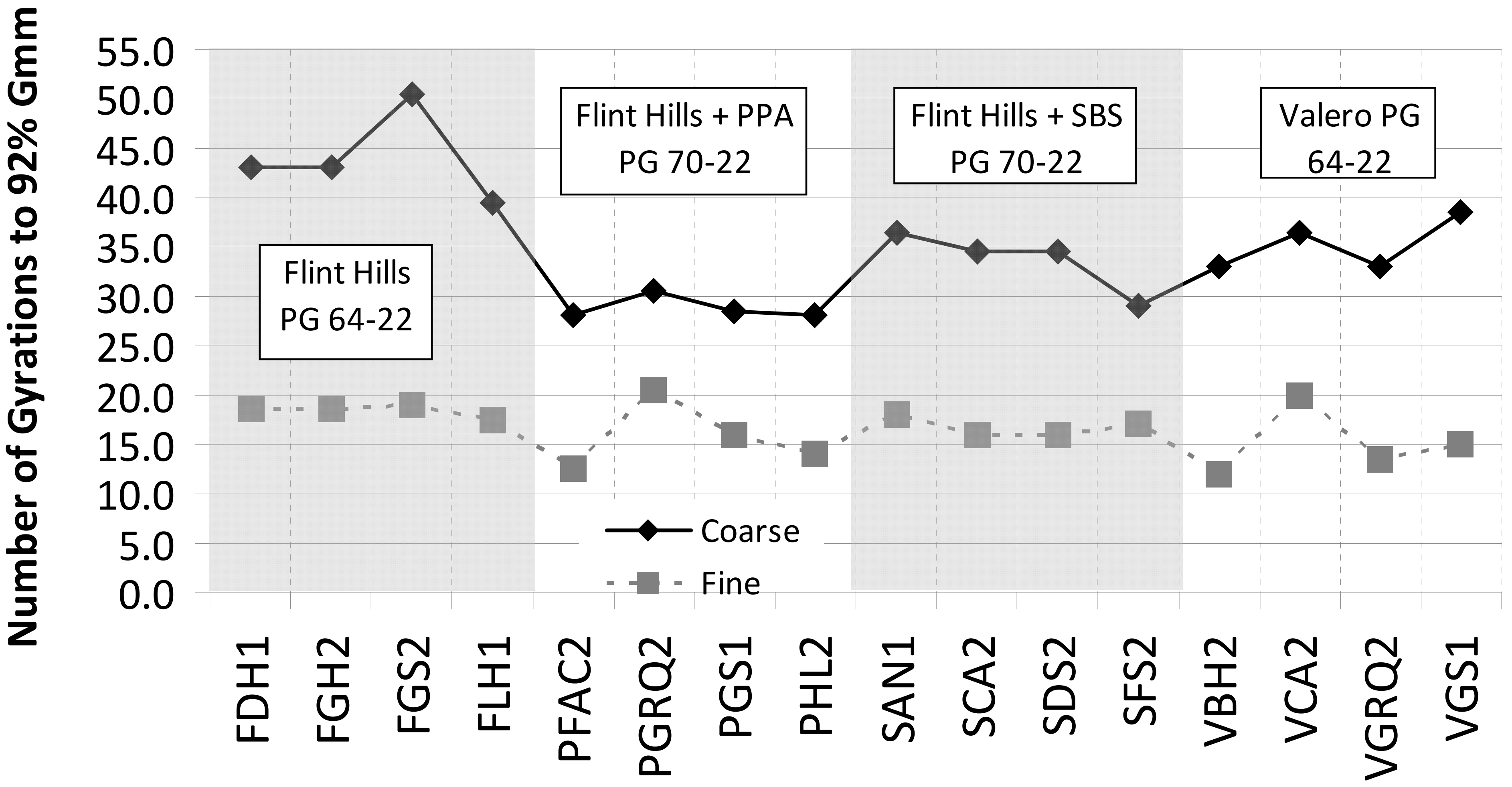
Mixture Testing

Workability:	Mixture: Gyrations to 92%Gmm
Rutting:	Mixture: Flow Number, 200kPa, 58°C
Fatigue:	Mixture: IDT, Oscillatory load of 3.25kN , 25°C, and 10 Hz.
Low Temp:	Mixture: Fracture Strength, -12°C
Moisture Damage	Mixture: Hamburg Wheel (discontinued)

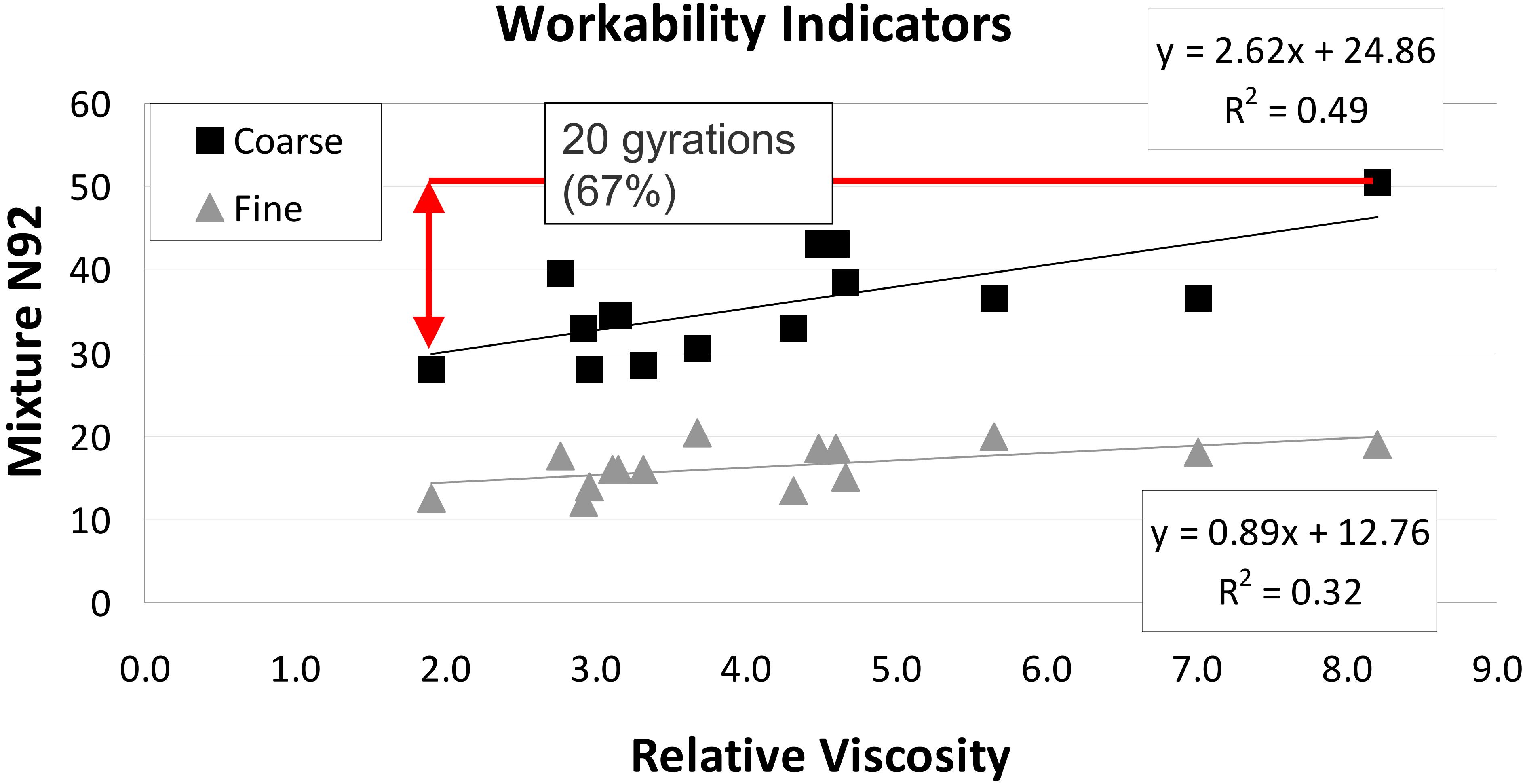
Mixture Workability

Mixture Workability

Distribution of the Number of Gyrations to 92% Gmm



Correlation between Mixture and Mastic Workability Indicators



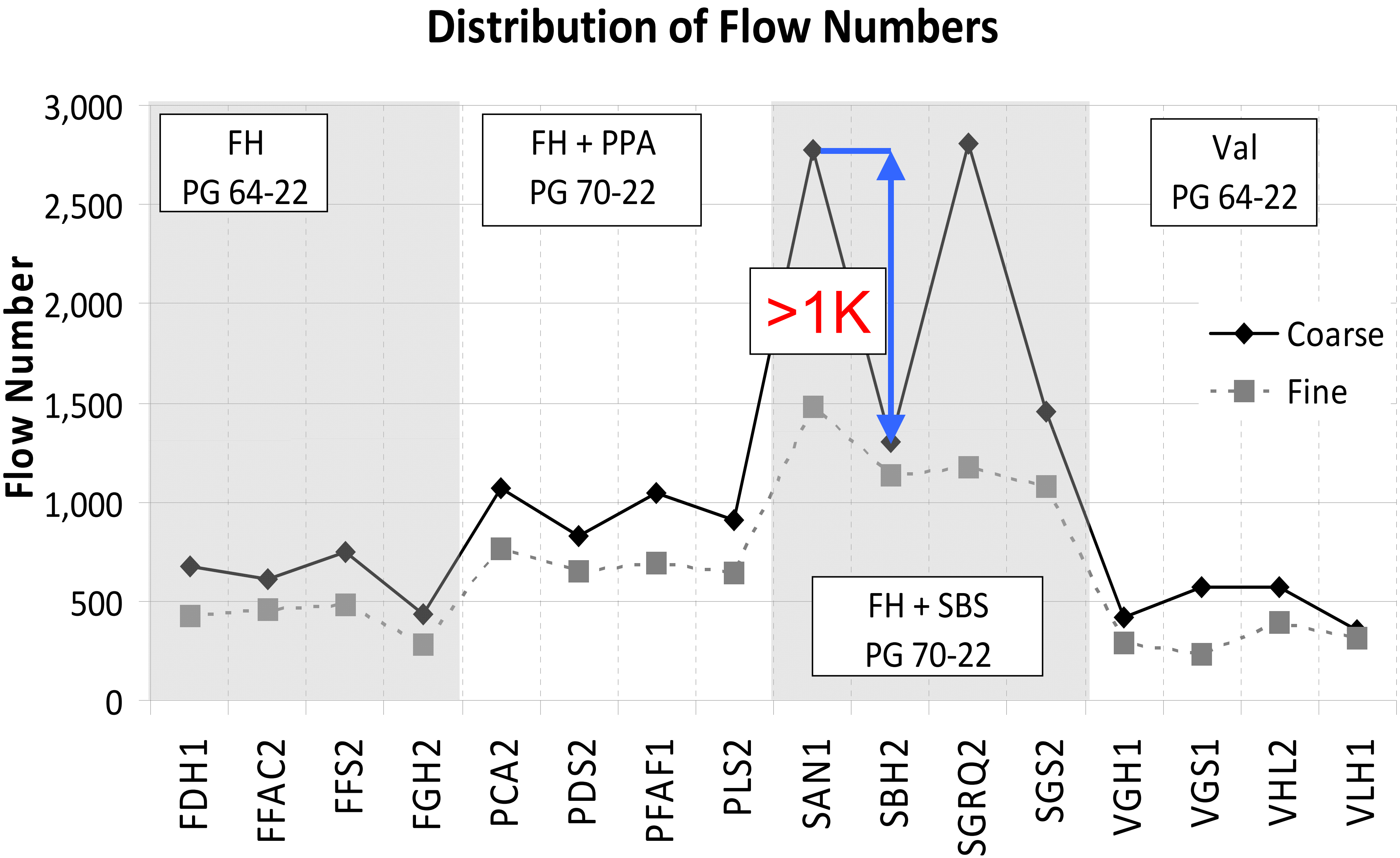
Factors Affecting Mixture Workability

Variable	F-Value	P-Value
Gradation	454.34	0.000
Binder Source	7.39	0.009
Binder Modification	15.12	0.000
Filler Mineralogy	1.87	0.072

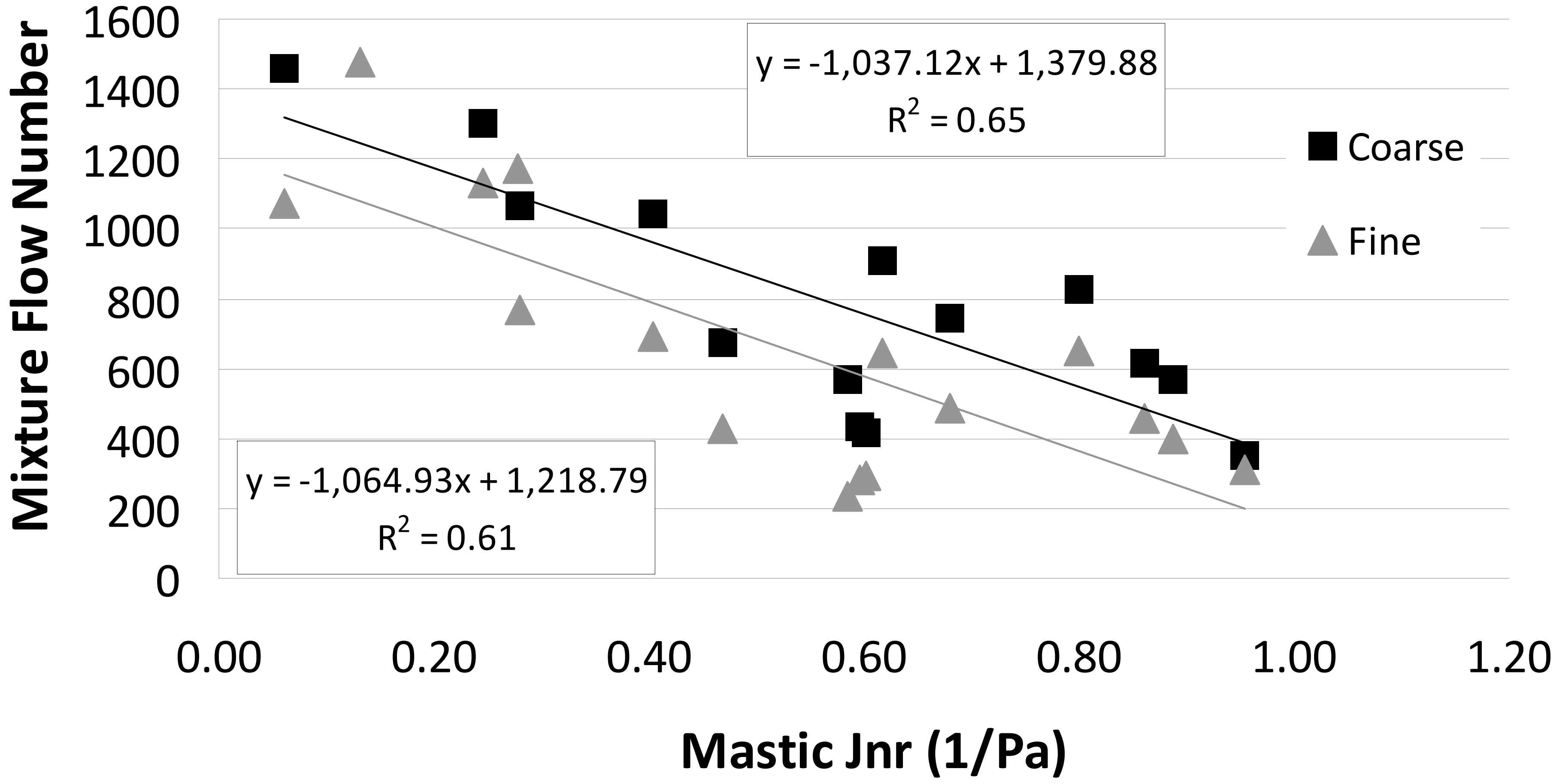
- Gradation is the most influential factor.
- For Binders of the same grade, the source have significant influence on the workability

Mixture Permanent Deformation

Mixture Flow Number



Correlation between Mixture and Mastic Rutting Indicators



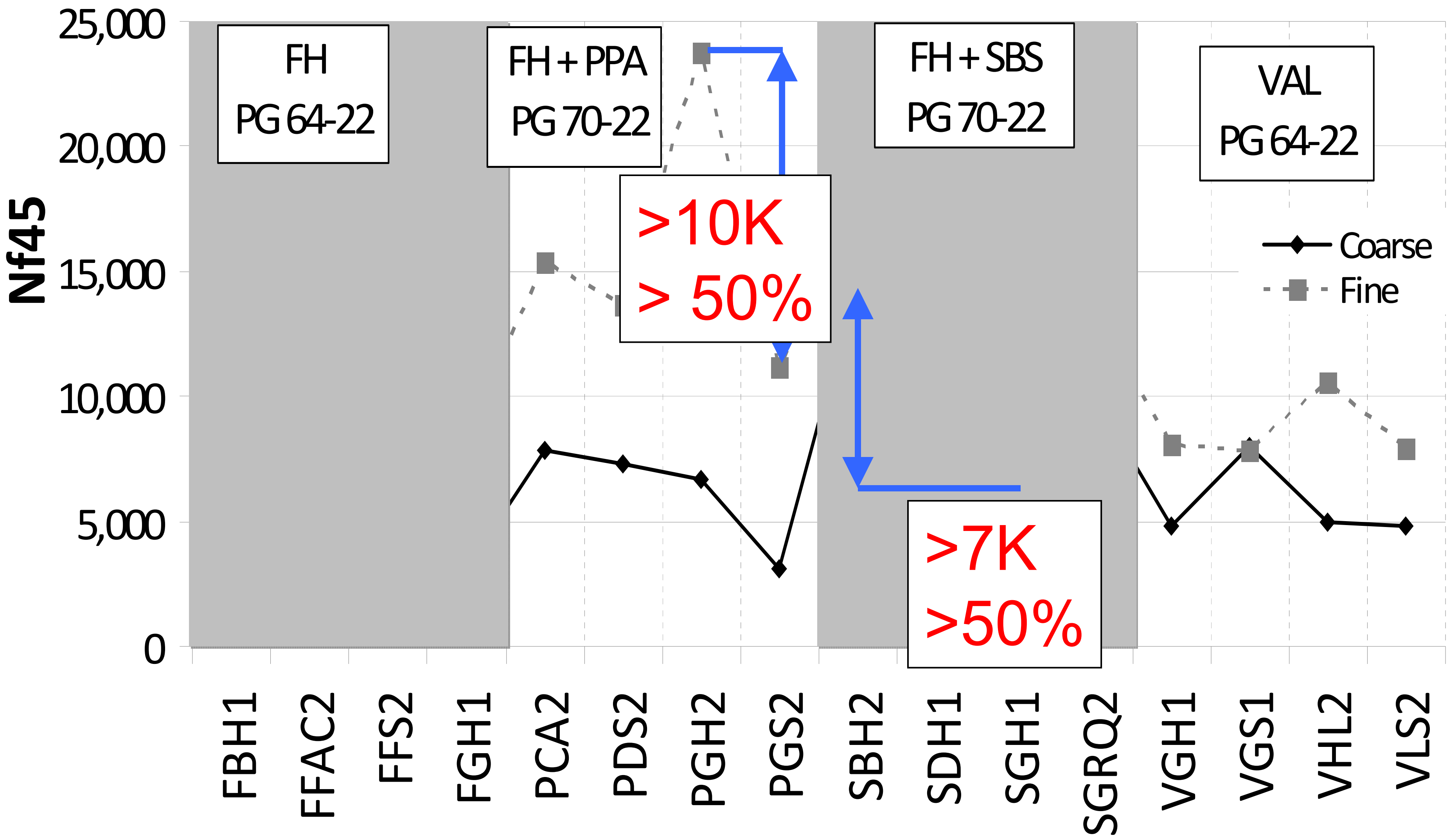
Factors Affecting Mixture Flow Number

Variable	F-Value	P-Value
Gradation	21.9	0.000
Binder Source	0.09	0.765
Binder Modification	22.63	0.000
Filler Mineralogy	2.25	0.038

- Binder Modification and Gradation are equally as influential.

Other Mixture Properties

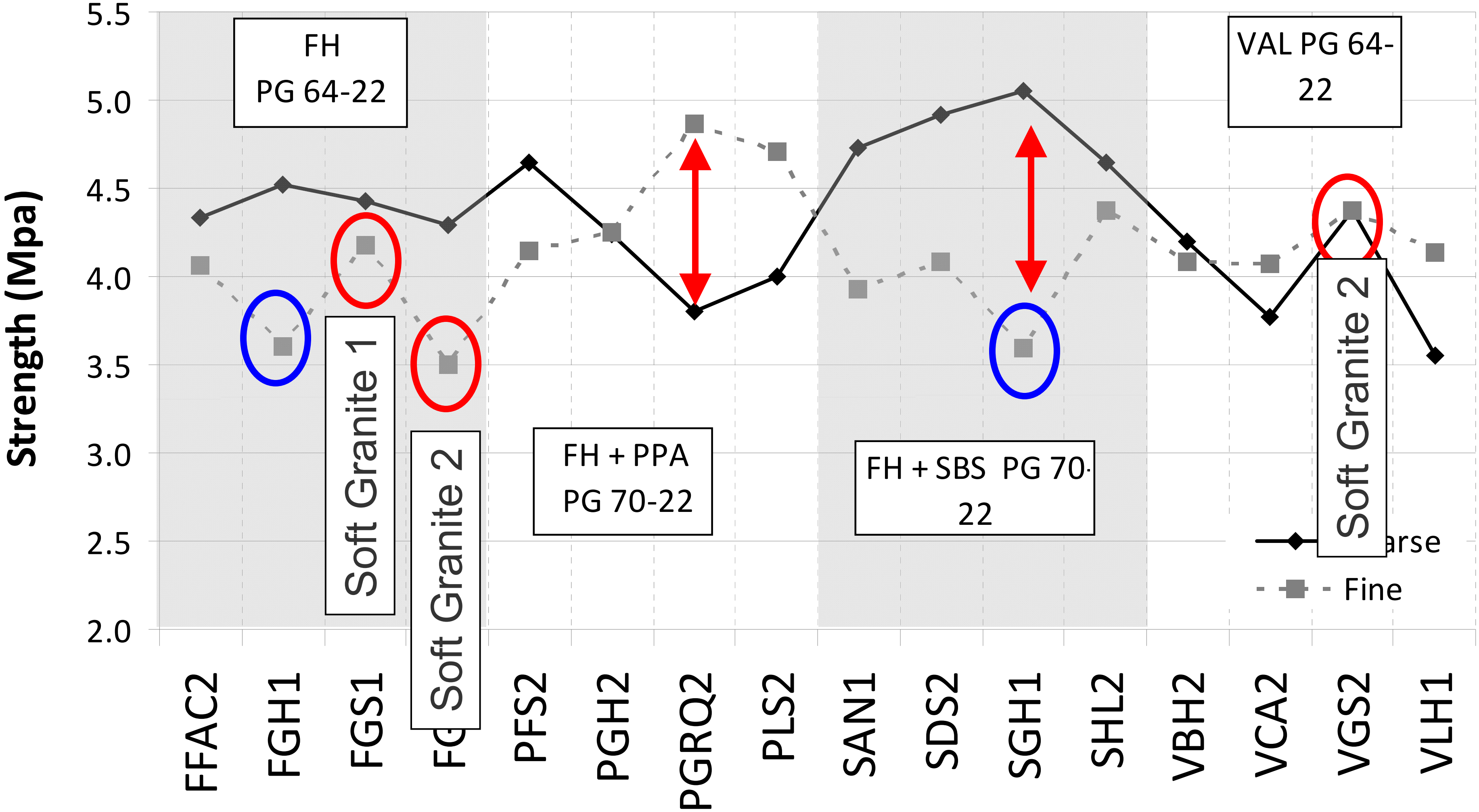
Distribution of Mixture Fatigue Life



>10K
> 50%

>7K
>50%

Distribution of Mixture Low Temperature Strength



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Summary of Other Mixture Properties

Mixture Fatigue Life

Variable	F-Value	P-Value
Gradation	37.73	0.000
Binder Source	2.99	0.090
Binder Modification	9.99	0.000
Filler Mineralogy	2.05	0.067

Mixture Low Temperature

Variable	F-Value	P-Value
Gradation	5.84	0.019
Binder Source	1.38	0.246
Binder Modification	5.08	0.010
Filler Mineralogy	1.96	0.065

Although filler mineralogy is significant, results could not quantify the filler/ mastic influence at this point.

Conclusions

- Fillers show influence on all mastic and mixture performance.
- The influence of some binder modification is highly dependent on fillers used ➔ Mix design.
- Mixture workability and permanent deformation could be predicted in terms of filler Rigden Voids and Volume Fraction.

Many Thanks !

- Project NCHRP 9-45 Panel.
- Dr. Ed Harrigan – Project Officer
- Suppliers of fillers and binders.

- *Contact:*
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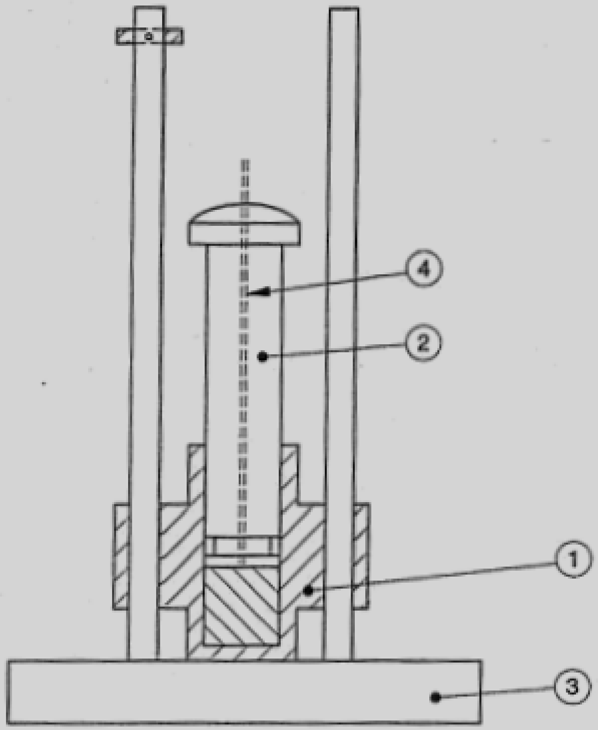
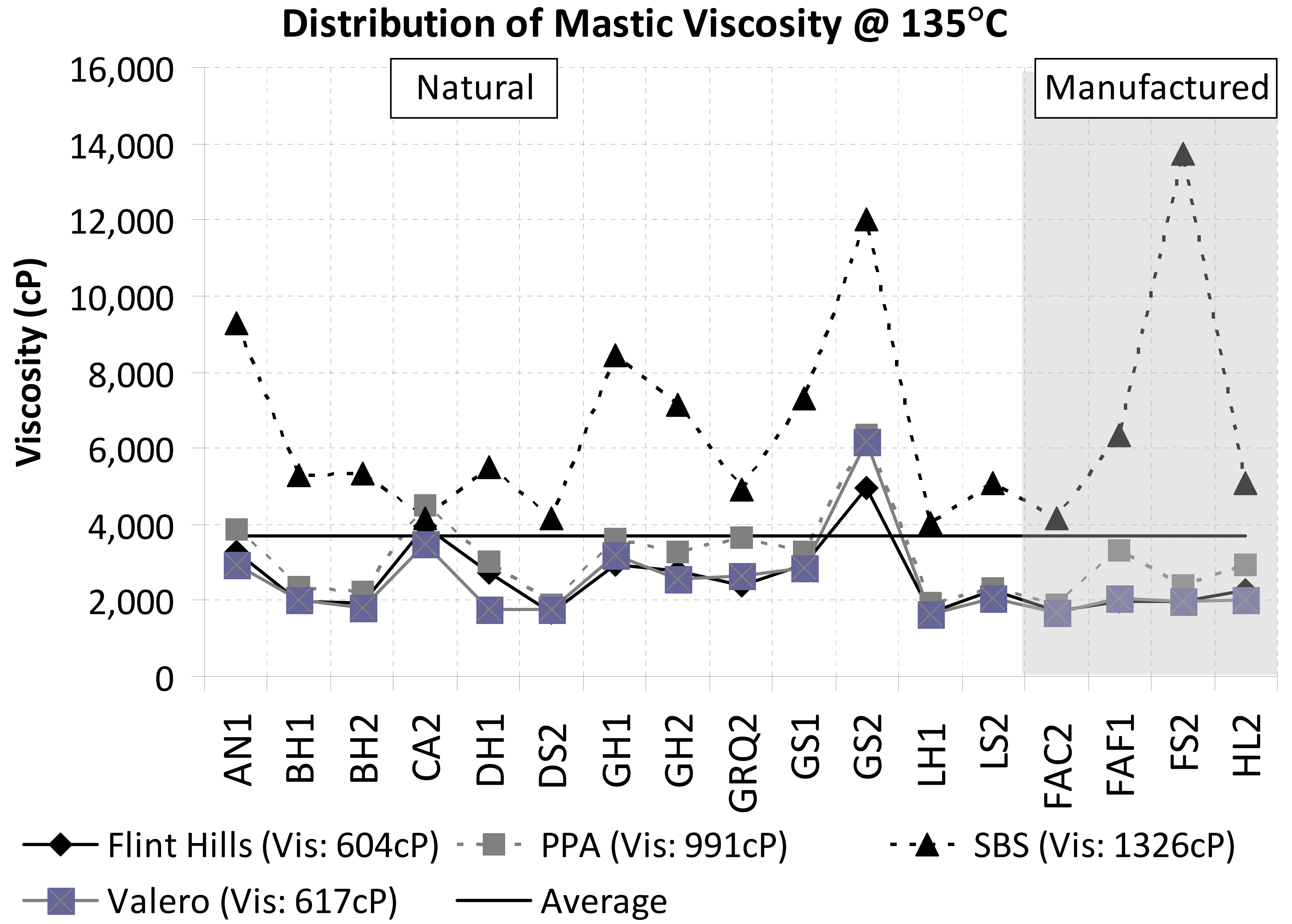
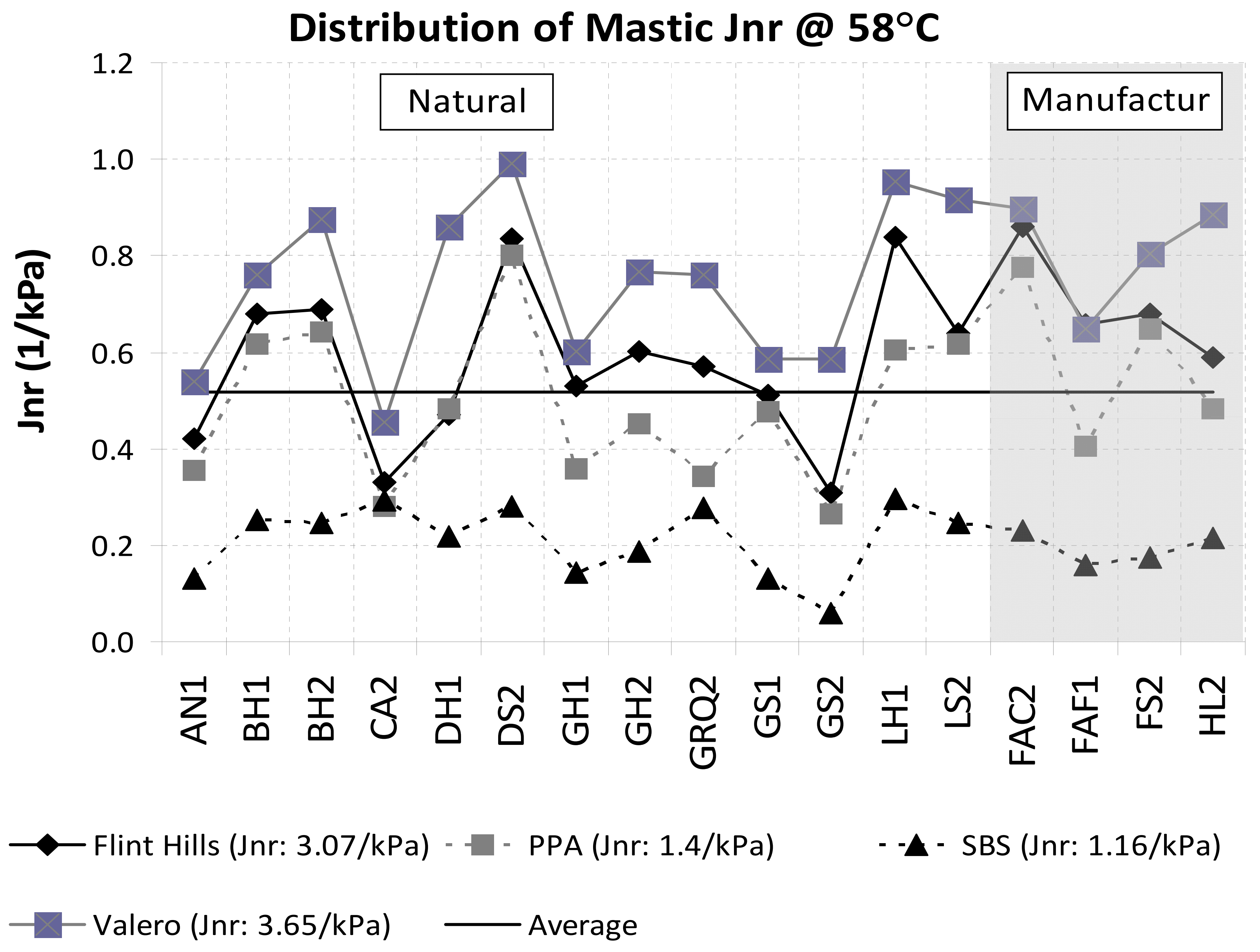
  - *afaheem@bloomcos.com*

RIGDEN VOIDS (BS 812, EN 1097-4)



1. Dropping block
2. Plunger
3. Base plate
4. Tare boring


Distribution of Mastic Viscosity @ 135°C
Viscosity (cP)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Natural
Manufactured
AN1
BH1
BH2
CA2
DH1
DS2
GH1
GH2
GRQ2
GS1
GS2
LH1
LS2
FAC2
FAF1
FS2
HL2
Flint Hills (Vis: 604cP)
PPA (Vis: 991cP)
SBS (Vis: 1326cP)
Valero (Vis: 617cP)
Average


Distribution of Mastic Jnr @ 58°C
Jnr (1/kPa)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Natural
Manufactur
AN1
BH1
BH2
CA2
DH1
DS2
GH1
GH2
GRQ2
GS1
GS2
LH1
LS2
FAC2
FAF1
FS2
HL2
Flint Hills (Jnr: 3.07/kPa)
PPA (Jnr: 1.4/kPa)
SBS (Jnr: 1.16/kPa)
Valero (Jnr: 3.65/kPa)
Average

Filler tests to be further investigated

Test	Cost	Sample Preparati	Running Test	Training require
Rigden Voids	Low ($3000)	Simple	Simple	Minimal
Laser Diffraction for size	High (~$ 35 K)	Moderate	Simple	Moderate
X-Ray Florescence for CaO Content	High ($50K- $150K)	Complicated	Simple	Moderate

Overall Testing Plan

PART 1

1. Collect **32 fillers**, 2 sources for each filler type.

2. Test the 32 fillers using *filler tests*.
Select 16 fillers to cover High and Low values for each of 8 filler characteristics (2)^4 .

Selected 17

PART 2

3. Mix the 16 selected fillers with **4 binders** and test the resulting **64 mastics** using *mastic tests*. Analyze results and select 16 mastics.

Tested 68 Mastics

PART 3

4. Mix 16 mastics with **two aggregate gradations** and test resulting HMA using *HMA tests* listed in Table 8.

5. Based on analysis of mastic and HMA testing, identify filler characteristics that have significant effect on HMA workability and performance.

Asphalt Binders for Producing Mastics

- PG 64-22 with low asphaltenes
  - (from a light crude source)
- PG 64-22 with high asphaltenes
  - (from a heavy crude source)
- Binder (a) modified with PPA to a PG 76-22
- Binder (a) modified with SBS to a PG 76-22

Effect of Filler vs. Effect of Binder on Mastics

Binder	Binder Viscosity		Relative Viscosity
FH (heavy)	603.575	Max	8.20
		Min	2.78
FH + PPA	991.200	Max	6.41
		Min	1.91
FH + SBS	1326.325	Max	9.05
		Min	3.05
Val (light)	616.500	Max	10.01
		Min	2.66

Narrowest range
(4.5)

Widest range
(7.35)

Effect of Filler vs. Effect of Binder on Mastics

Binder	Binder Jnr		Relative Jnr
FH (Heavy)	3.07	Max	0.28
		Min	0.10
FH + PPA	1.40	Max	0.57
		Min	0.19
FH + SBS	1.16	Max	0.26
		Min	0.05
Val (Light)	3.65	Max	0.27
		Min	0.12

- The relative values of the J_{nr} for the PPA indicate that the fillers may counter the effect of the acid modification
- Relative results are similar for the other binders

Effect of Filler vs. Effect of Binder on Mastics

- G*sinδ increased for all mastics
- Some fillers reduce fatigue life of the mastics
- PPA relative fatigue life is consistently < 1.0
- Could not quantify the influence of fillers in terms of measured properties

Binder	Mastics	Relative Fatigue Life	Relative $\lvert G^*\rvert \cdot \sin\delta$
FH	Max	1.33	3.31
	Min	0.10	1.41
FH + PPA	Max	0.41	3.44
	Min	0.23	2.15
FH + SBS	Max	2.10	4.22
	Min	0.85	2.88
Val	Max	1.06	2.89
	Min	0.09	1.64

Effect of Filler vs. Effect of Binder

- PPA relative m-value is hovering around 1.0
- The relative values for the other binders are very similar
- Fillers improved cracking temp. for all VAL mastics
- Could not quantify the influence of fillers in terms of measured properties

Binder	Range	Mastic Relative Stiffness	Mastic Relative m-Value	Δ Cracking Temp. (°C)
FH	Min	2.93	0.79	-6.95
	Max	4.74	0.90	4.25
FH + SBS	Min	4.16	0.79	-3.35
	Max	5.63	0.90	5.55
FH + PPA	Min	3.94	0.92	-10.55
	Max	5.61	1.06	5.15
VAL	Min	3.12	0.78	-7.15
	Max	5.18	0.98	-2.85

Effect of Filler vs. Effect of Binder

- All but one SBS mastics improved the MDR.
- Val Masics show less moisture damage resistance (except for Hydrated Lime mastic).
- Could not quantify the influence of fillers in terms of measured properties

Binder	Mastics	Δ Moisture Damage Ratio
FH (Heavy Neat)	Max	0.58
	Min	-0.31
FH + PPA	Max	0.14
	Min	-0.41
FH + SBS	Max	0.37
	Min	-0.02
Val (Light Neat)	Max	0.16
	Min	-0.64