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MTE TECHNICAL COMMUNICATION DOCUMENT

MnROAD DATA EVALUATION USING THE HIRSCH MODEL

BACKGROUND

Using the Hirsch model to predict mixture stiffness

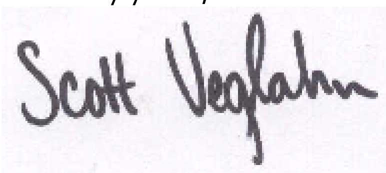
Tim Clyne,

Estimating the stiffness, or dynamic modulus, of an asphalt mixture using the Hirsch model has limitations as you approach softer binder stiffnesses. The Hirsch model formula has a lower asymptote around 30,200 psi which will inhibit the model from accurately predicting low frequency mixture stiffness values. Since the measured mixture stiffness for cells 20b and 21b have higher modulus values at the lower frequencies, but still below the lower limit, they have a better opportunity to predict a more accurate value. Cells 16b and 22b have lower low frequency modulus data that cannot be predicted using the Hirsch model causing a greater separation between the predicted data and the measured data. I have generated master curves from the Elvaloy and PPA modified binder AMPT data and then compared it against the predicted mixture stiffness values generated from the Hirsch model. At a 20°C reference temperature the predicted stiffness is a little higher, but trends closely to the measured data. When I evaluated the sample at a 40°C reference temperature though, the predicted stiffness drifts further from the measured stiffness at the lower frequencies. This drift is due to the lower limit of the Hirsch model. See **Figure 1** and **Figure 2** for the graphs comparing the master curves at the two reference temperatures. The 20°C binder data was tested using the recovered binder before PAV with the 8mm parallel plates, whereas the 40°C binder data was tested using the recovered binder before PAV with the 25mm parallel plates. In a better attempt to visualize the lower limits associated with the Hirsch model, I broke it down into individual parts as seen in
Figure 3. You will notice that the first half of the equation approaches ~30,200 psi and the second half of the equation approaches 0 psi as the binder modulus values decrease. It is because of this lower limit that predicting binder stiffness values from original mixture values below 30,200 psi (or 210,000 kPa) is not applicable.

As for the approach of using predicted data versus measured data to generate an assumption about the amount of binder blending within the sample, I think incorporates too many variables. Recovery of the binder should age the binder beyond that of the mix and would in turn raise the predicted stiffness values. Also, the lower limit of the Hirsch model forces low frequency values to have a minimum predicted mixture stiffness, further separating the predicted values from the measured values.

If you have any questions feel free to let me know and I will do my best to help answer them.

Sincerely yours,



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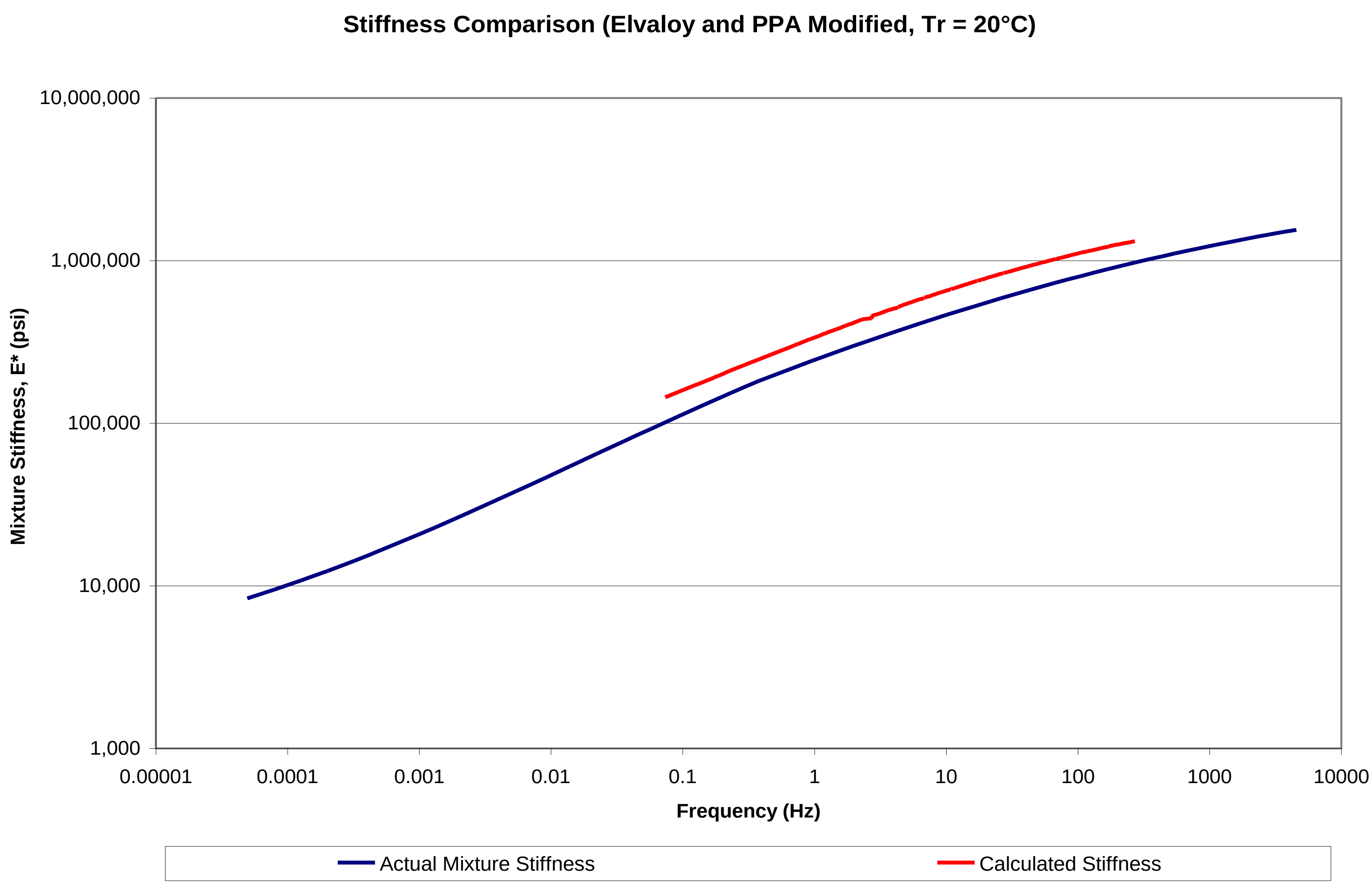

Figure 1: Measured and Predicted Stiffness Comparison (T_r = 20°C)

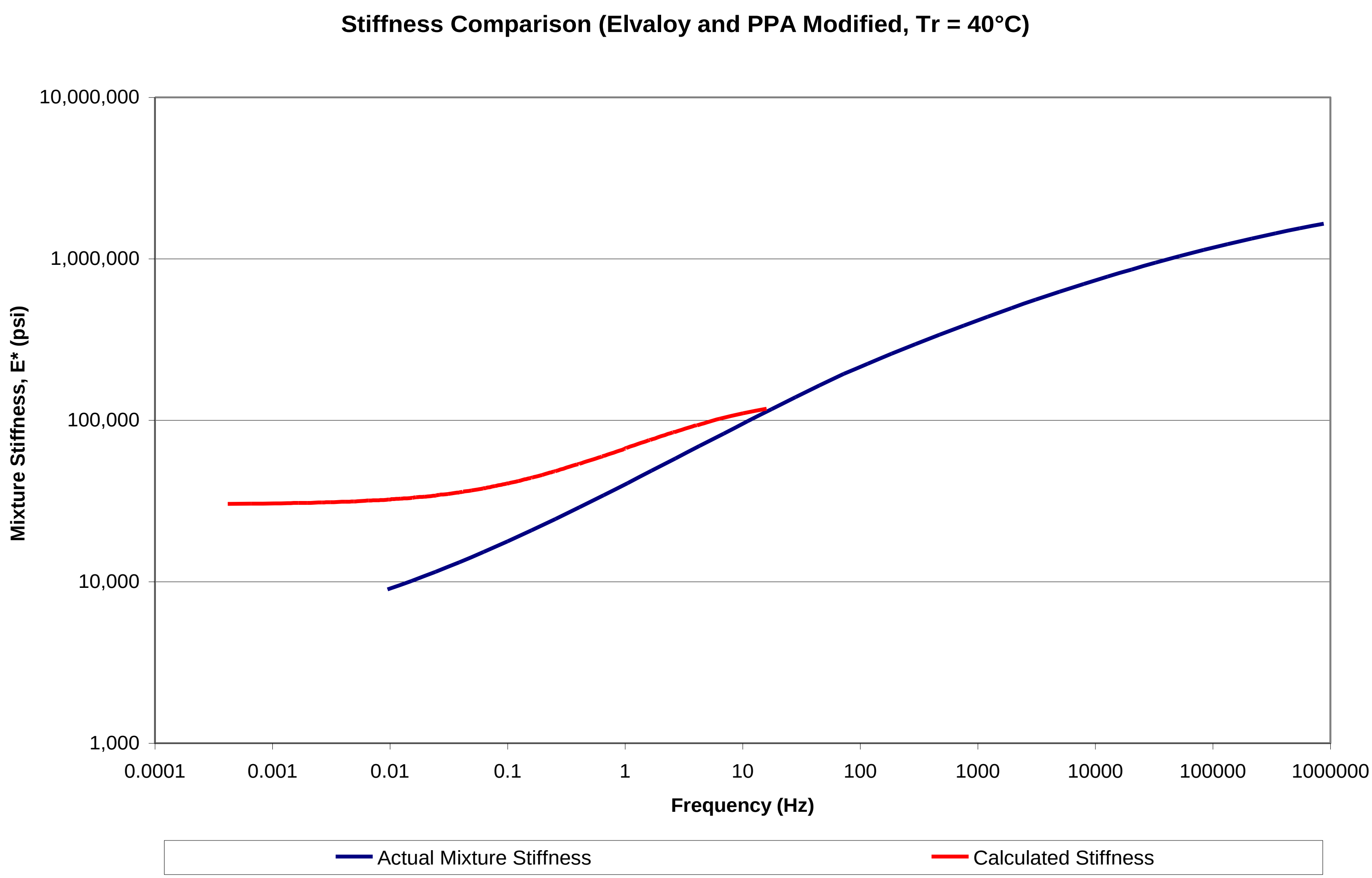

Figure 2: Measured and Predicted Stiffness Comparison (T_r = 40°C)

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VMA	17.89
VFA	63.67
1-VMA/100	0.82
VMA*VFA/10000	0.11

$$E^*_m = Pc\left[4{,}200{,}00\left(1-\frac{VMA}{100}\right)+3G^*_b\left(\frac{VFA\times VMA}{10{,}000}\right)\right]+(1-Pc)\left[\frac{1-\frac{VMA}{100}}{4{,}200{,}000}+\frac{VMA}{3\times VFA\times G^*_b}\right]^{-1}$$

(A) (B) (C)

$$Pc=\frac{\left(20+\frac{VFA\times 3G^*_b}{VMA}\right)^{0.58}}{650+\left(\frac{VFA\times 3G^*_b}{VMA}\right)^{0.58}}$$

G^*_b	Pc	A*(1-VMA/100)	B*(VFA*VMA/10000)	First half
10000	0.5594	3448635	3.42E+03	1931086
1000	0.2506	3448635	3.42E+02	864219
100	0.0816	3448635	3.42E+01	281414
10	0.0249	3448635	3.42E+00	86011
1	0.0111	3448635	3.42E-01	38411
0.1	0.0090	3448635	3.42E-02	31027
0.01	0.0088	3448635	3.42E-03	30234
0.001	0.0087	3448635	3.42E-04	30159
0.0001	0.0087	3448635	3.42E-05	30153
0.00001	0.0087	3448635	3.42E-06	30153

G^*_b	(1-Pc)	(1-VMA/100)/C	VMA/(3*VFA*G_b)	Second half	E^*_{mix}
10000	0.4406	1.96E-07	9.37E-06	46078.54	1977164
1000	0.7494	1.96E-07	9.37E-05	7984.58	872203
100	0.9184	1.96E-07	9.37E-04	980.32	282394
10	0.9751	1.96E-07	9.37E-03	104.10	86116
1	0.9889	1.96E-07	9.37E-02	10.56	38421
0.1	0.9910	1.96E-07	9.37E-01	1.06	31028
0.01	0.9912	1.96E-07	9.37E+00	0.11	30234
0.001	0.9913	1.96E-07	9.37E+01	0.01	30159
0.0001	0.9913	1.96E-07	9.37E+02	0.00	30153
0.00001	0.9913	1.96E-07	9.37E+03	0.00	30153

Figure 3: Breakdown of the Hirsch Model Calculation using Various Binder Stiffnesses