CONCEPTUAL PHENOMENOLOGICAL MODEL FOR INTERACTION OF ASPHALT BINDERS WITH MINERAL FILLERS

By:

Ahmed F. Faheem,

Hussain U Bahia

University of Wisconsin- Madison

THE UNIVERSITY of WISCONSIN MADISON

Outline

- Background
- Introduction
- Conceptual Model
- Test for Free Asphalt Volume
- Experimental Plan
- Summary of Results
- Factors Affecting Filler Stiffening
- Summary of Findings and Conclusions

Background

- Einstein Model for Diluted Composites (1911)

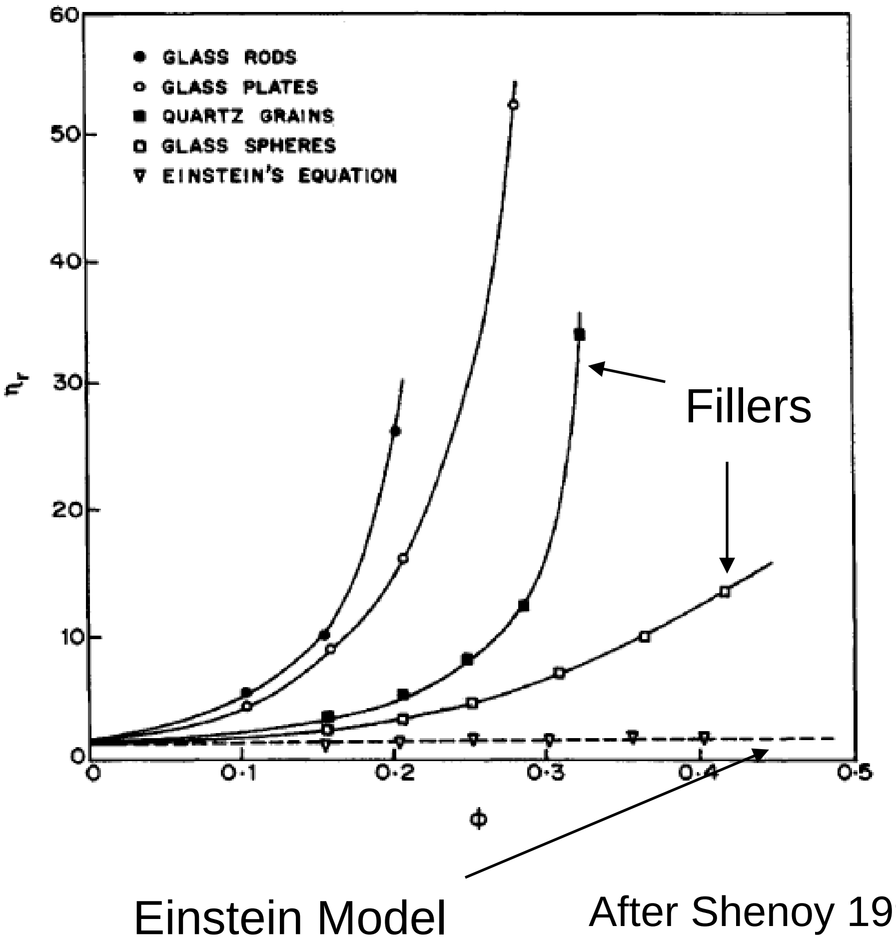
$$\eta_r = 1 + K_E \text{Ø}$$

η_r= Viscosity of composite/ viscosity of matrix

K_E= Einstein Constant =2.5

Ø: Filler volume fraction

- Many modification to this equation have followed.



After Shenoy 1999

Background

- **The Marion–Pierce model**

$$G^*_{mastic} = G^*_{binder}\left(1 - \frac{\phi}{\phi_m}\right)^{-2}$$

- **Nelsen Model**

$$\frac{G_c}{G_m} = \frac{1 + ABV_P}{1 - B\psi V_P}$$

Where A= KE-1, and

$$B = \frac{\left(G_P / G_m\right) - 1}{\left(G_P / G_m\right) + A}$$

$$\psi = 1 + \frac{1 - \phi_m}{\phi_m^2} V_P$$

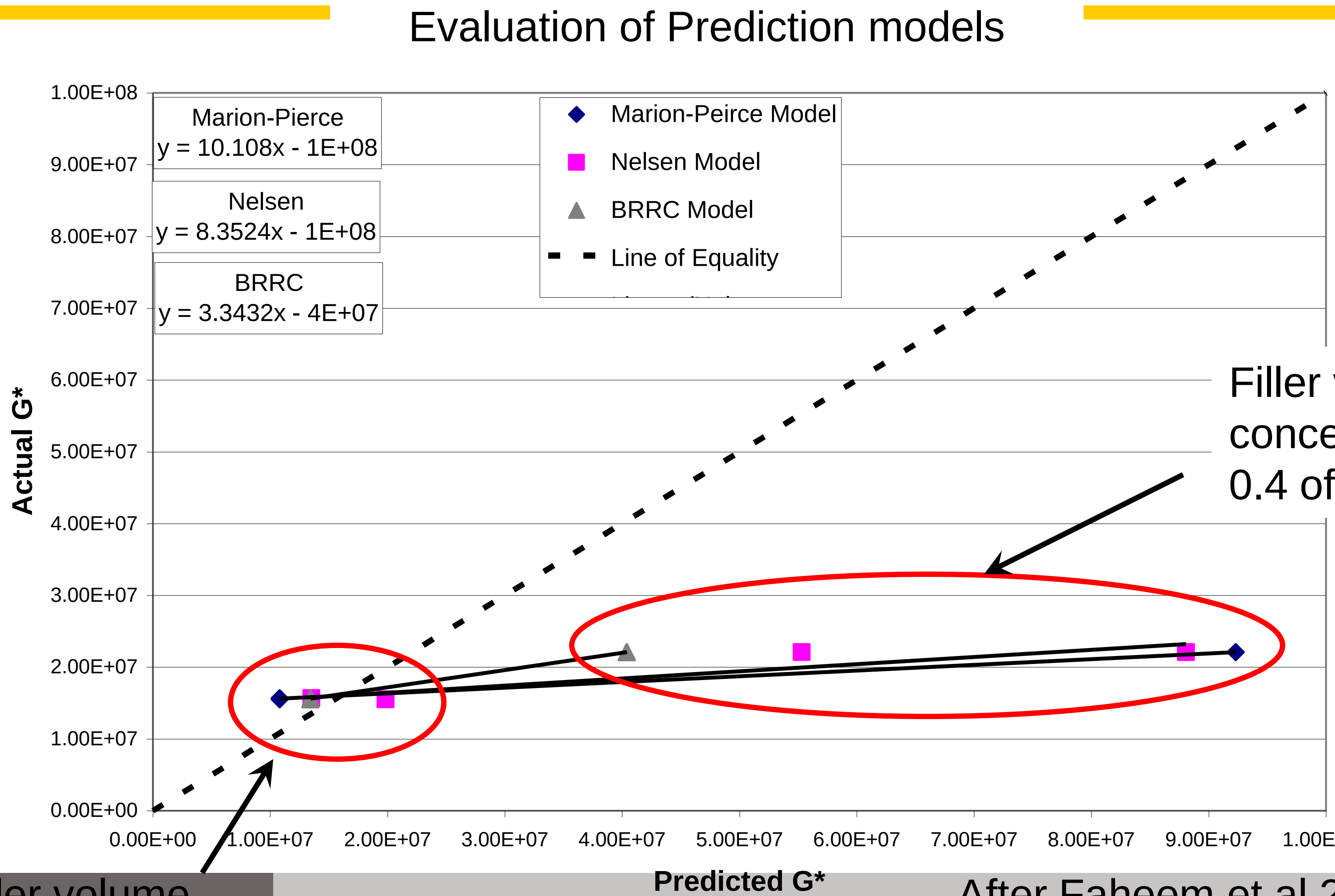
Filler Maximum Packing Fraction.

- **BRRC Model**

$$\Delta R \,\&\, B = \frac{1021.2 * K}{(100 - V_F(1 + K))}$$

K = f/b, f = filler volume fraction (%), b = bitumen volume fraction (%) and Vf = % voids (Rigden)

Evaluation of Models



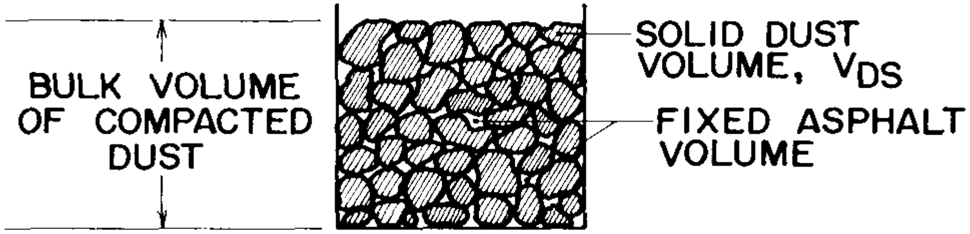
Filler volume concentration of 0.4 of total mix

Filler volume concentration of 0.2 of total mix

After Faheem et al 2008

Problem Statement

- Currently the filler influence on asphalt mastic is estimated using the Fractional voids method.

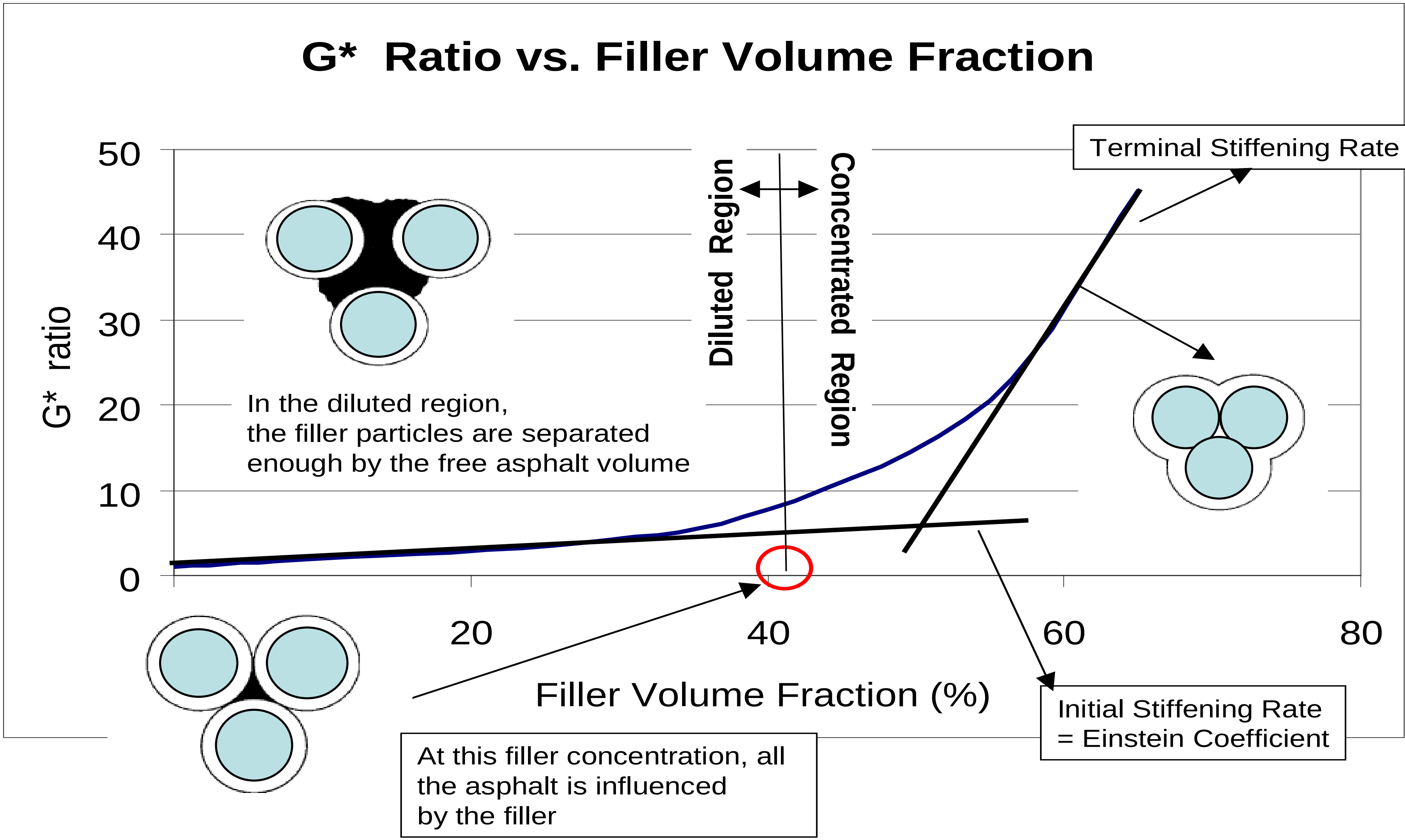


  - Measures filler volume fraction at maximum mastic stiffness.
  - Does not elaborate the trend of increase in stiffness as the filler concentration increases.
  - Does not help identify the mechanism by which filler particles interact with the asphalt matrix.

Hypothesis

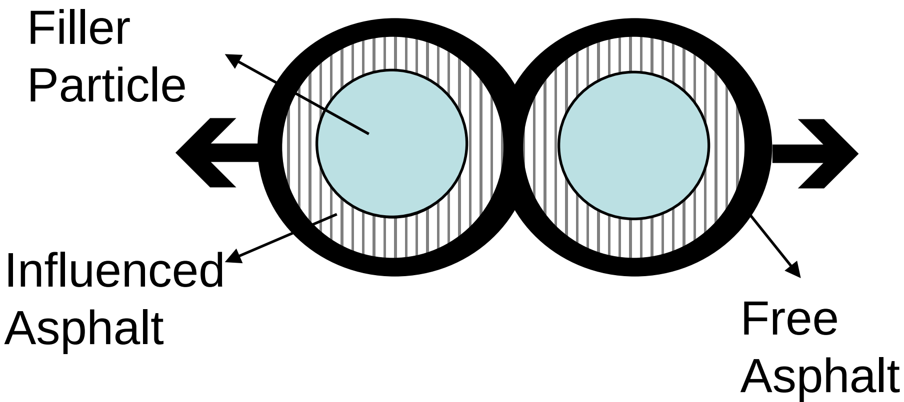
- The filler influence in the mastic follows two regions:
  a. **DILUTED**, where the increase in the stiffness takes a linear trend as a function of volume of filler, where the rate of increase is named: "**Initial Stiffening Rate**"
  b. **CONCENTRATED**, where the increase in stiffness transitions to a higher rate of stiffness called: "**Terminal Stiffening Rate**".

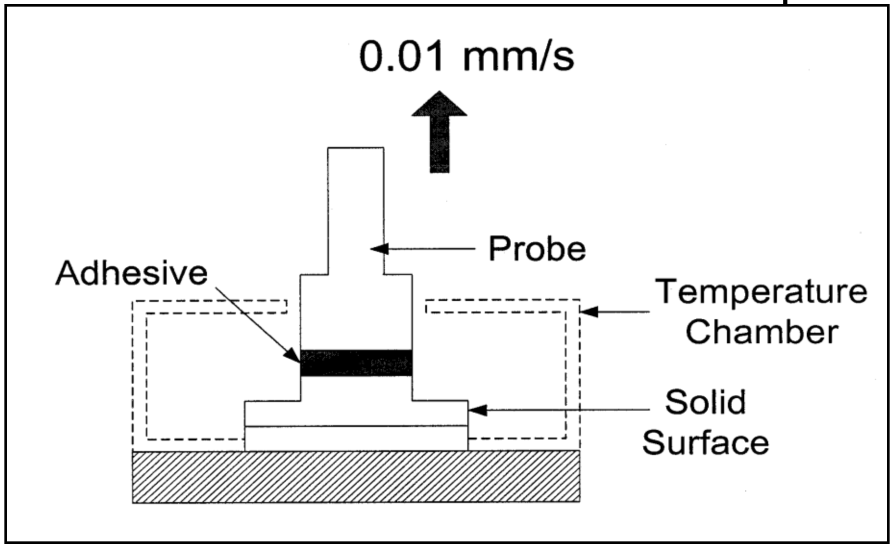
Conceptual Model



Test for the Presence of Free Asphalt

- Asphalt in the mastic is divided into 2 fractions
  - Free Asphalt
  - Influenced Asphalt
- The free asphalt is holding the mastic system together





(After Kanitpong 2004)

Experimental Variables

	Filler Properties	Binder Properties	Mastic Properties
Controlled Variable	1- Filler source - *Limestone* - *Dolomite* - *Granite* - *Fly Ash* - *Carbon Black*	1- PG grad - *PG64-22*	1- Filler Volume Fraction - *5 concentrations*
Dependent Variables	1- Fractional Voids 2- Size distribution	1- Complex Shear Modulus 2- Tack Factor	1- Relative Complex Shear Modulus 2- Tack Factor

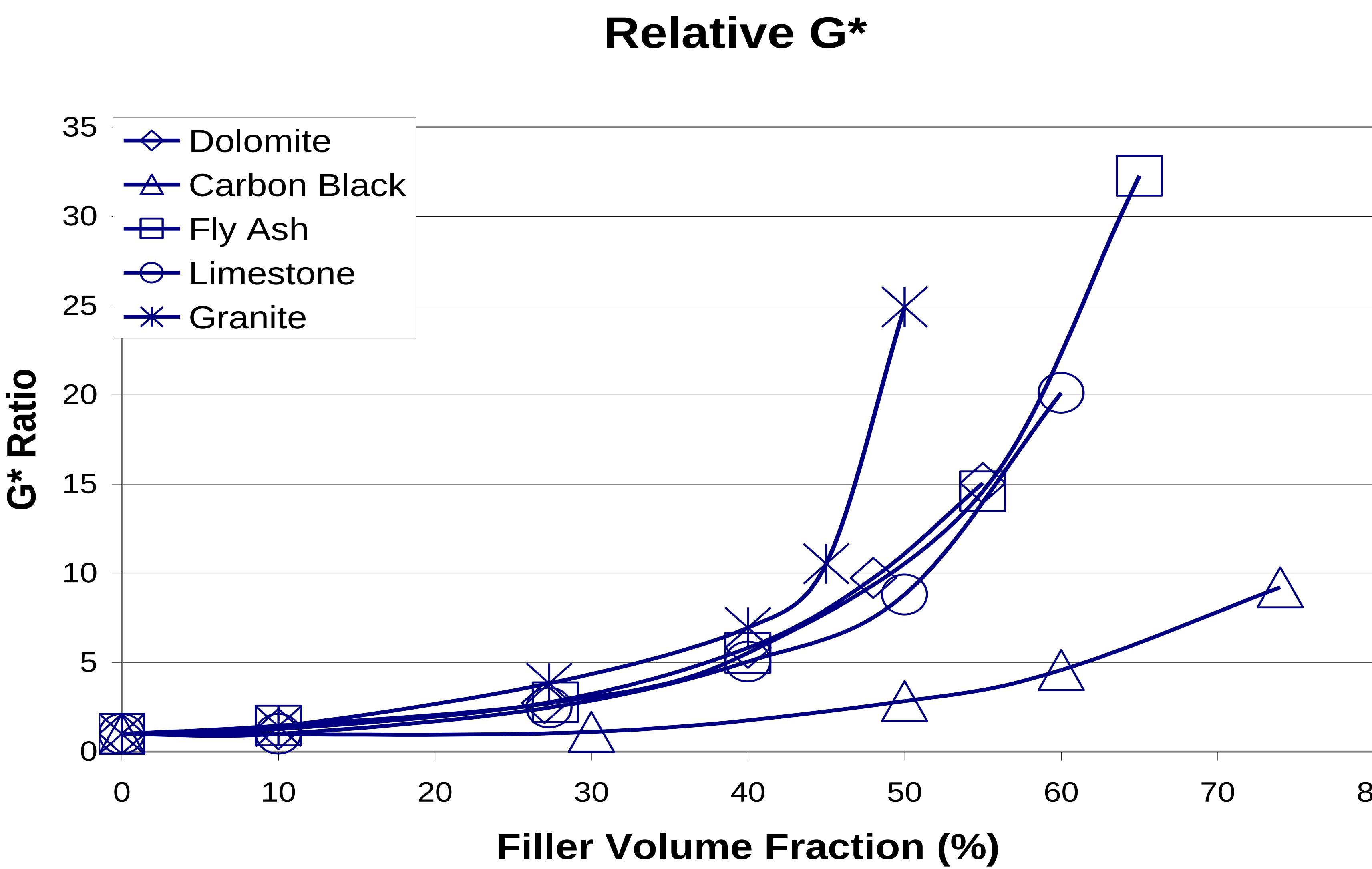
THE UNIVERSITY of WISCONSIN MADISON

Summary of Results

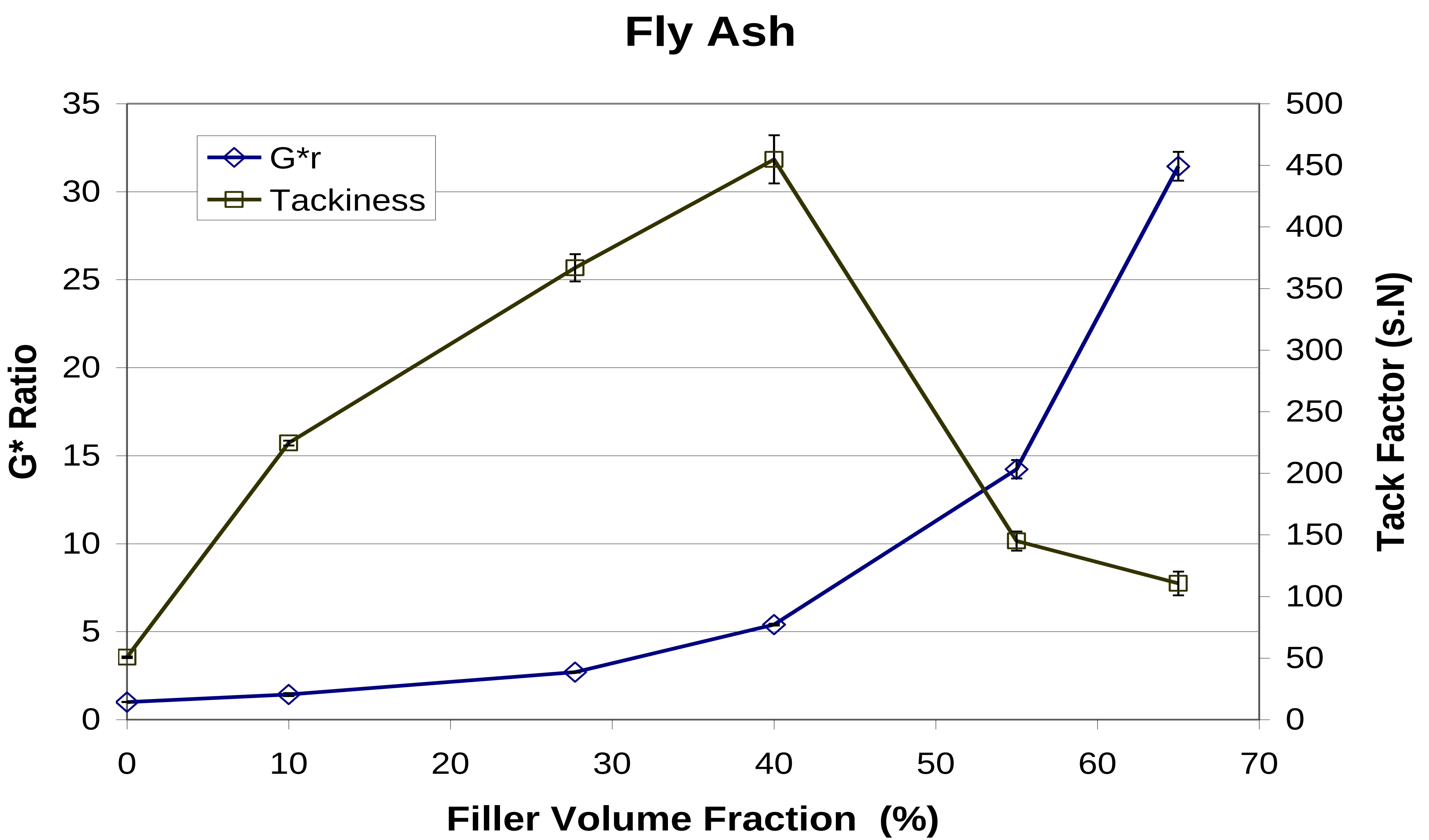
Physical Properties of Fillers

Filler Type	Rigden Voids (%)	D10 (μm)	D50 (μm)	D90 (μm)	SG
Granite	38%	2.07	17.97	149.15	2.62
Type C Fly Ash	26%	0.97	9.77	49.22	2.53
Dolomite	43%	4.03	31.44	81.62	2.59
Limestone	35%	2.54	26.37	67.21	2.65
Carbon Black	11%	0.08	0.08	0.08	0.23

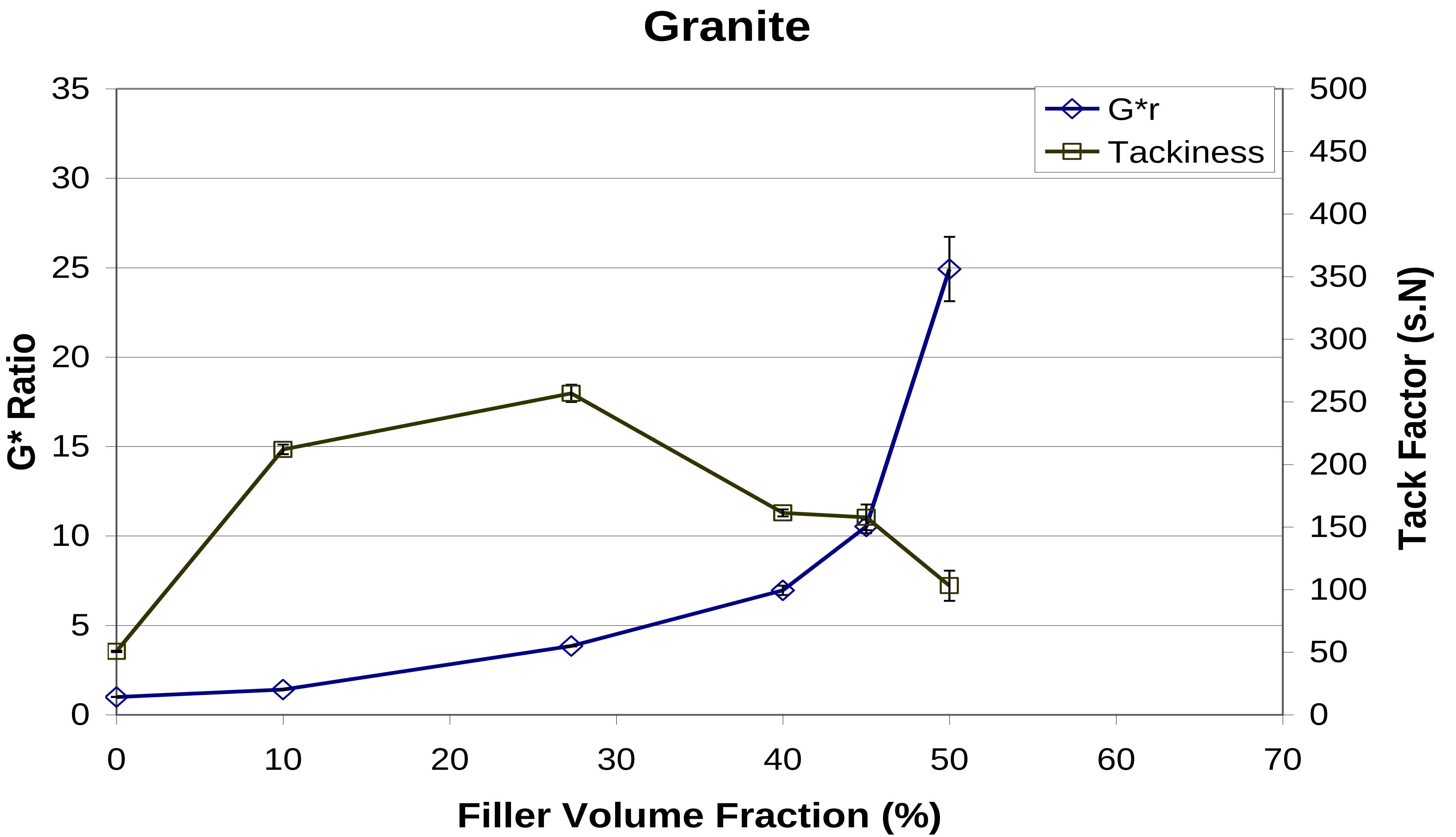
Effect of Filler on Mastic Stiffness



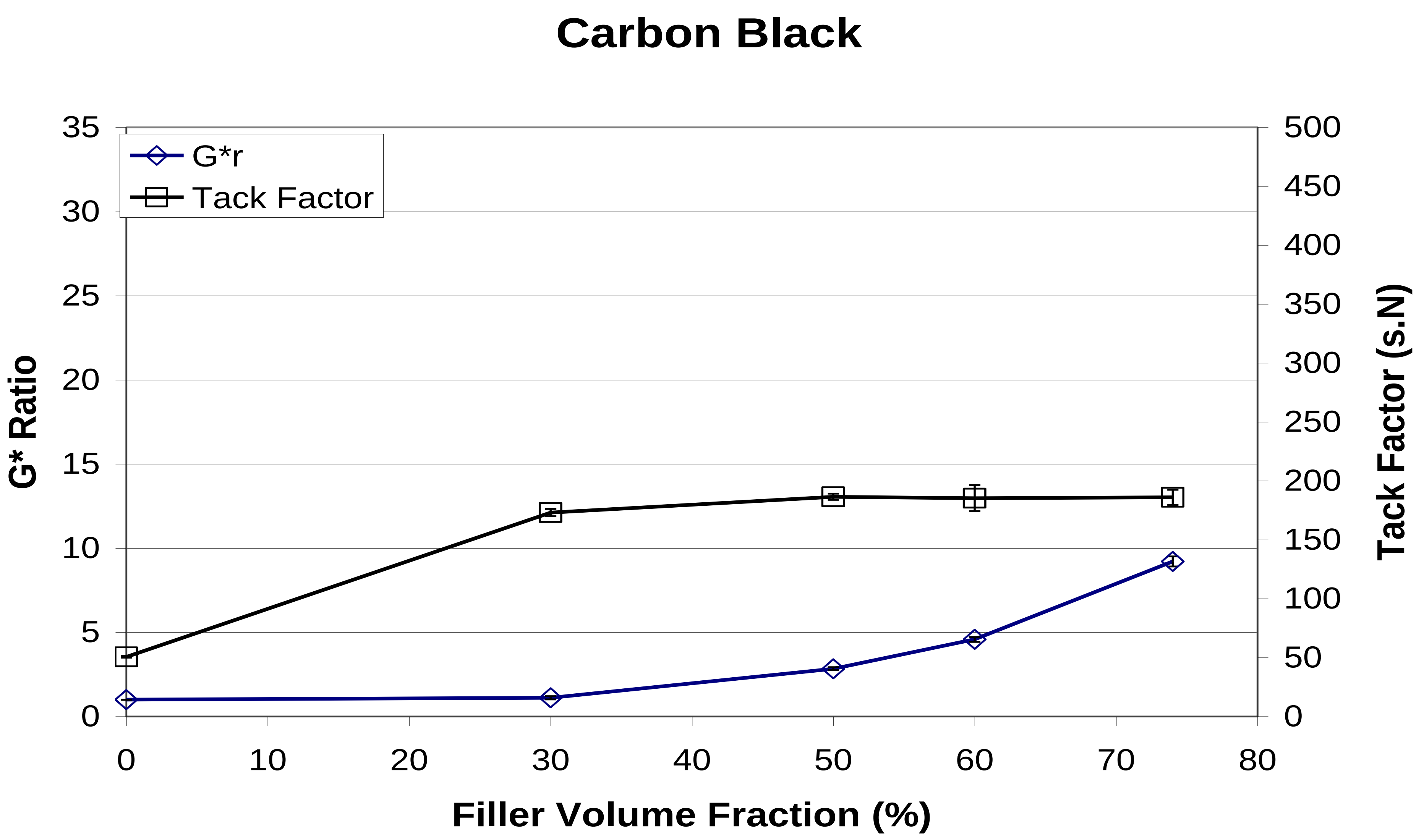
Mastic Stiffness and Tackiness



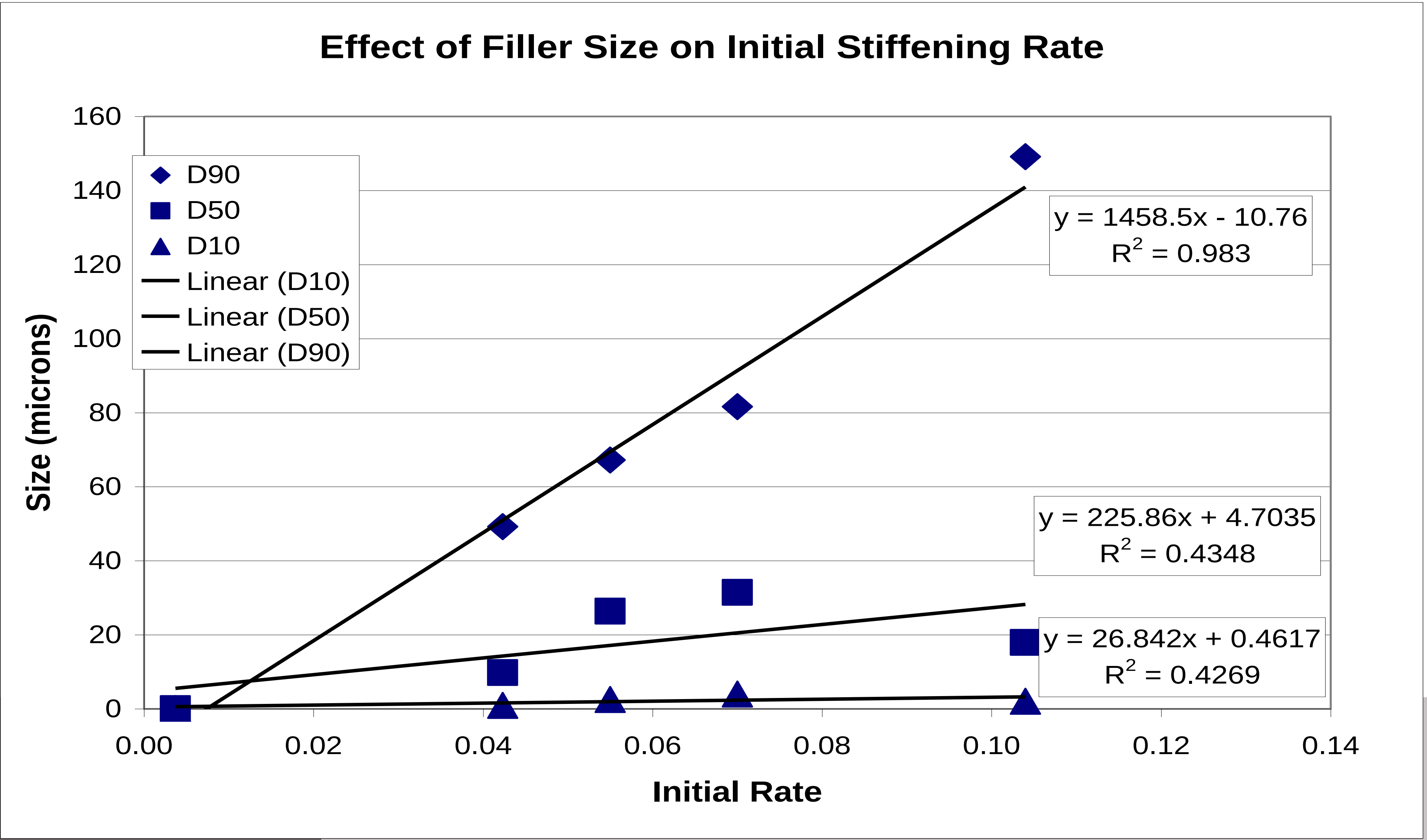
Mastic Stiffness and Tackiness



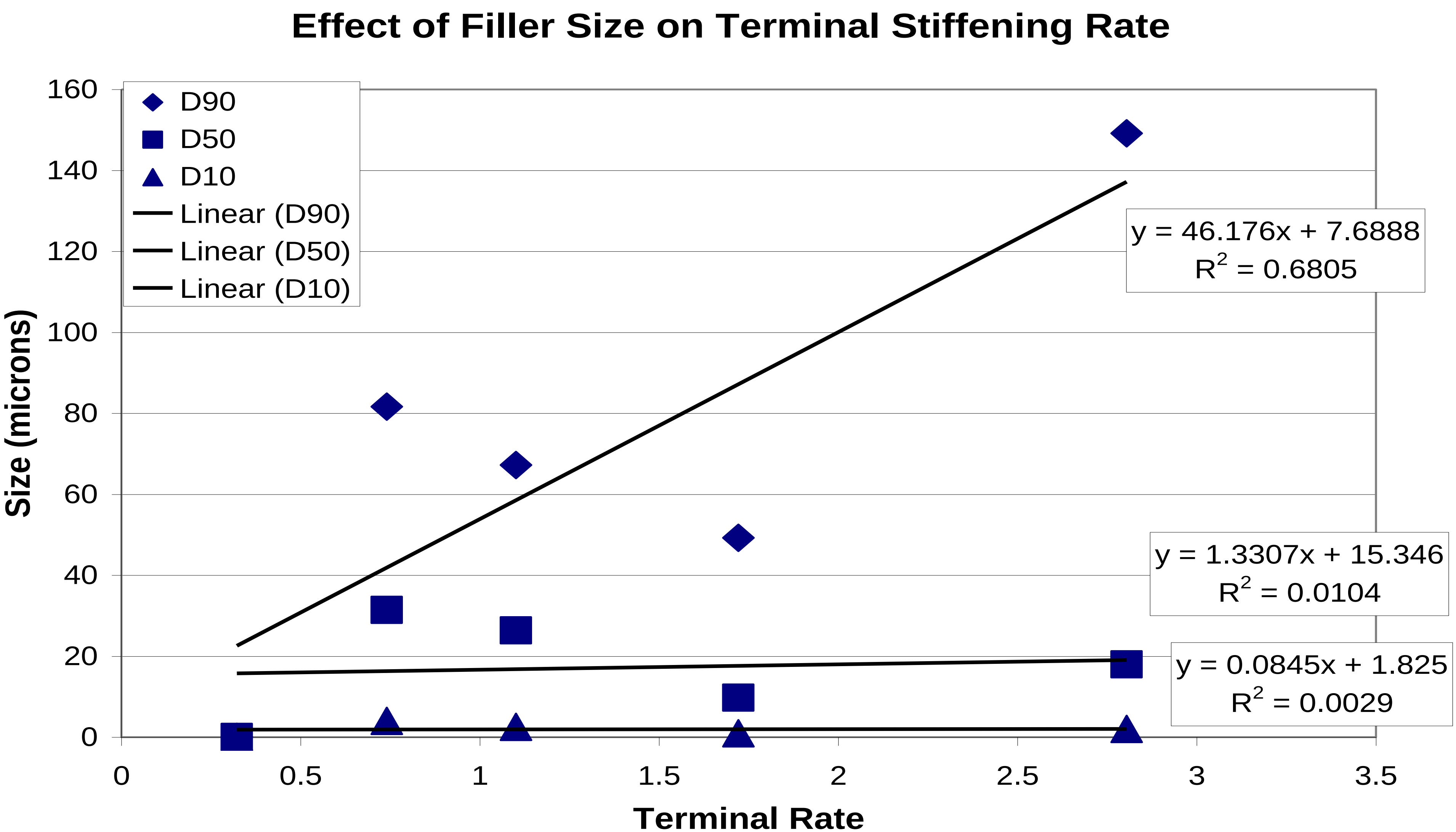
Mastic Stiffness and Tackiness



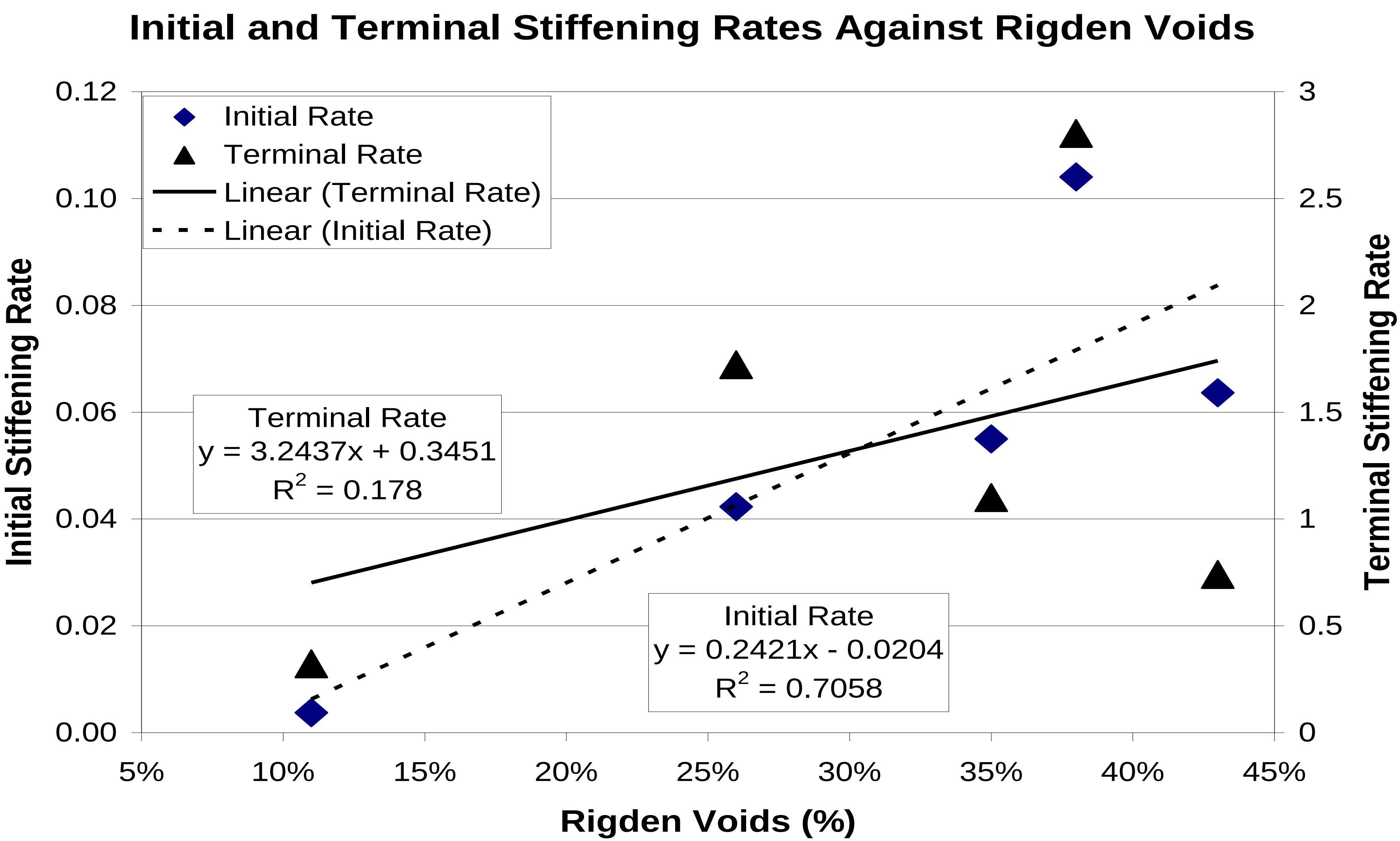
Factors Affecting Initial and Terminal Stiffening Rates



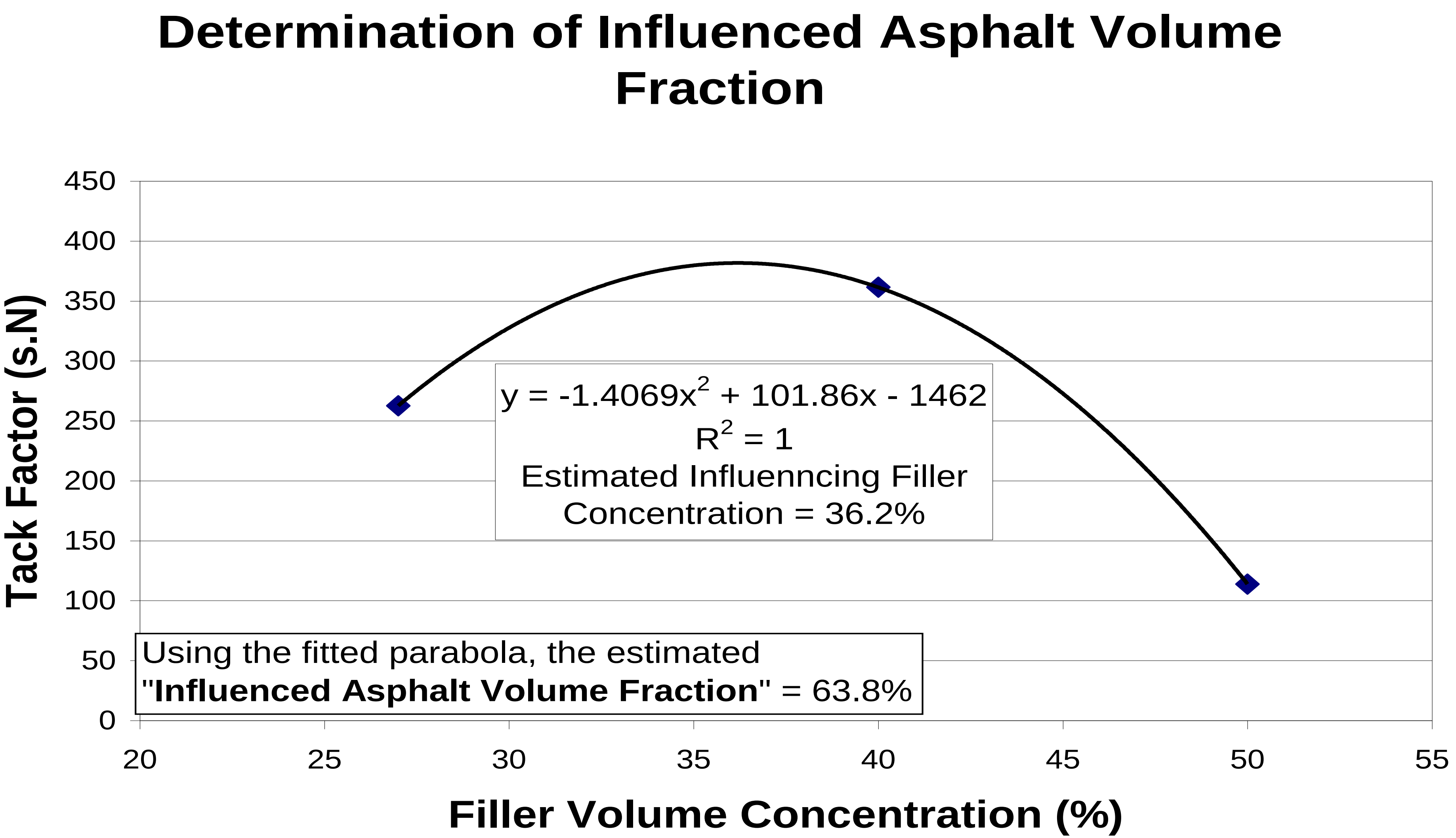
Factors Affecting Initial and Terminal Stiffening Rates (Cont'd)



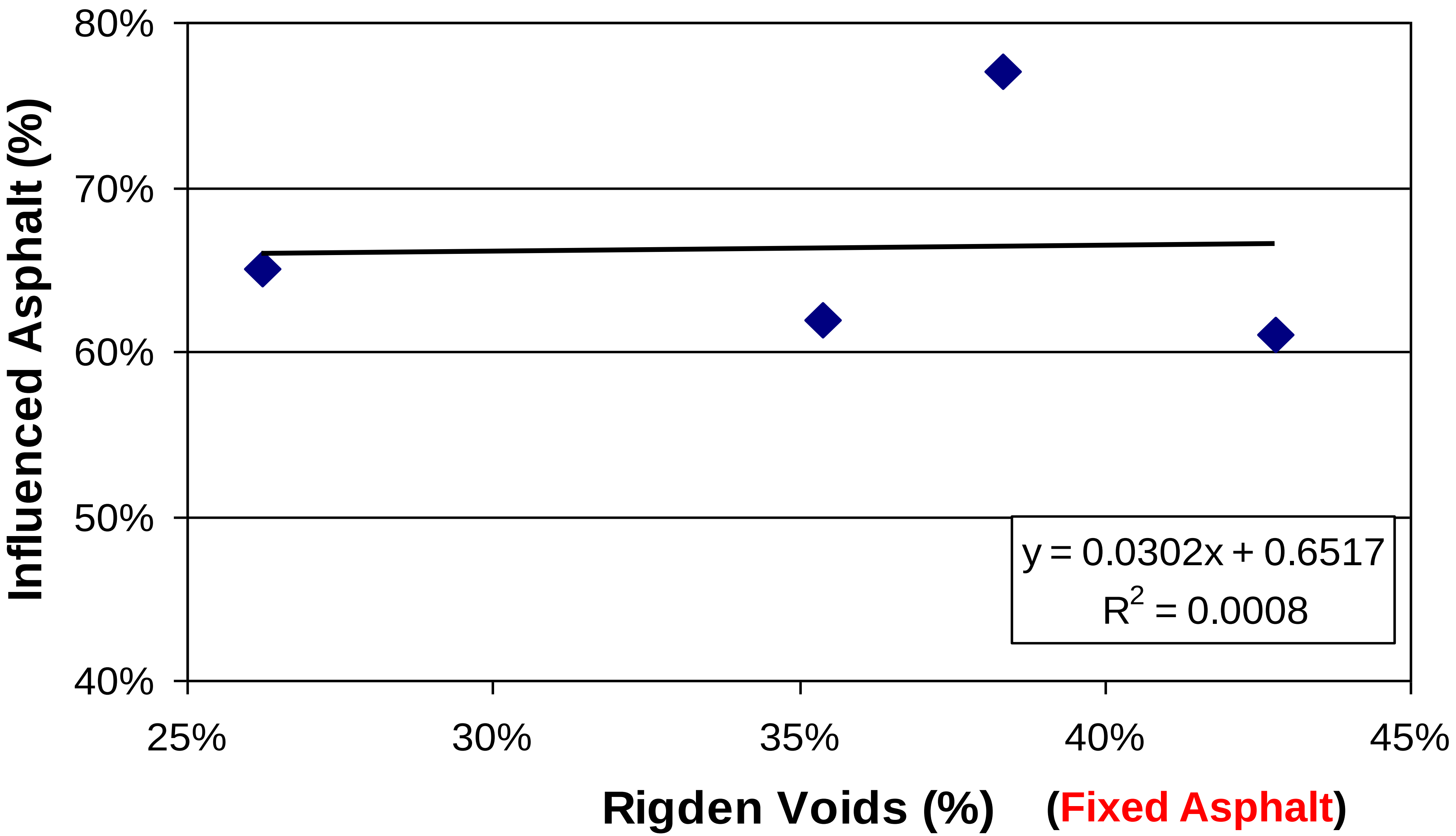
Factors Affecting Initial and Terminal Stiffening Rates (Cont'd)



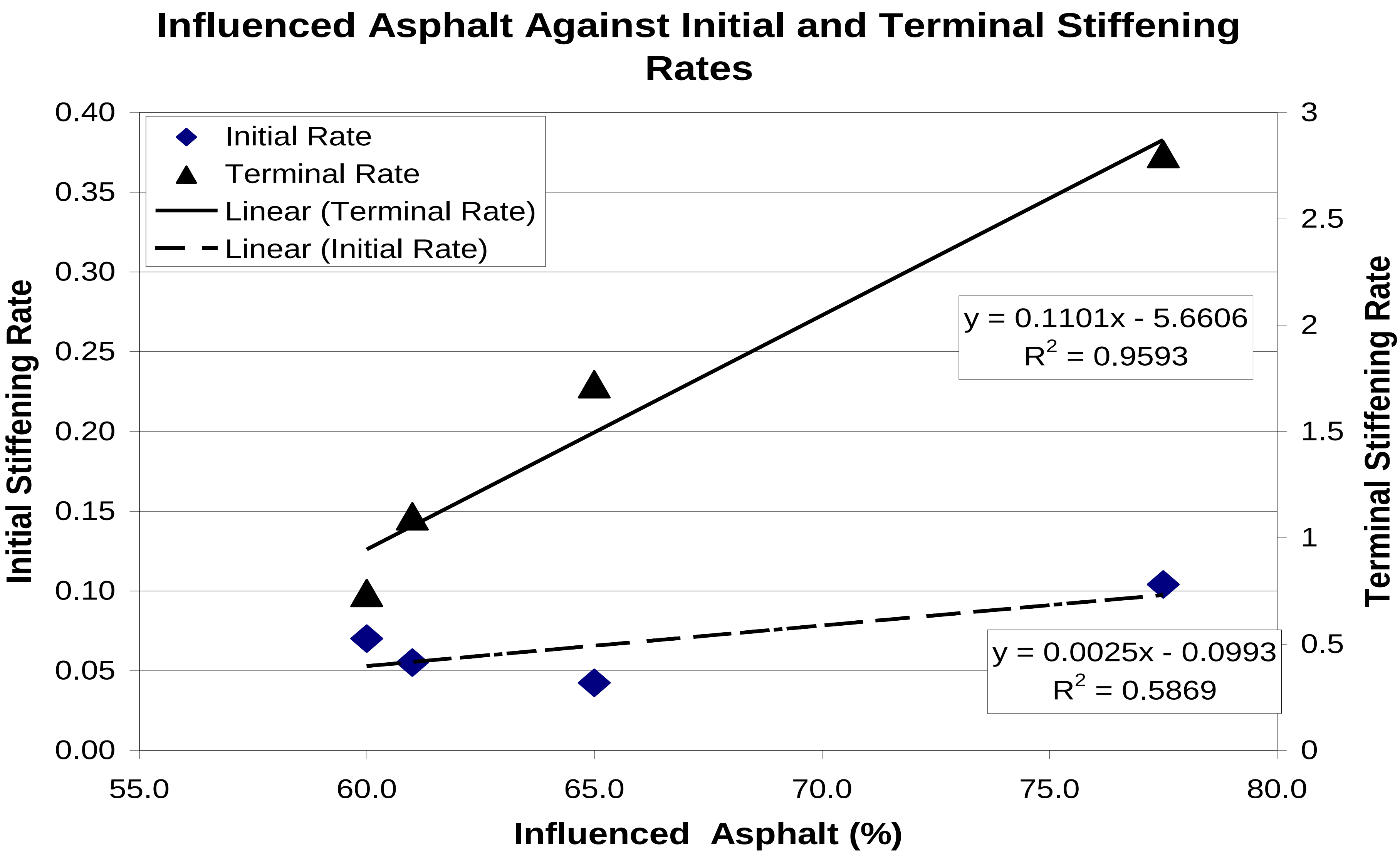
How to Measure the Influenced Asphalt Volume Fraction



Fractional Voids vs. Influenced Asphalt Volume



Factors Affecting Initial and Terminal Stiffening Rates (Cont'd)



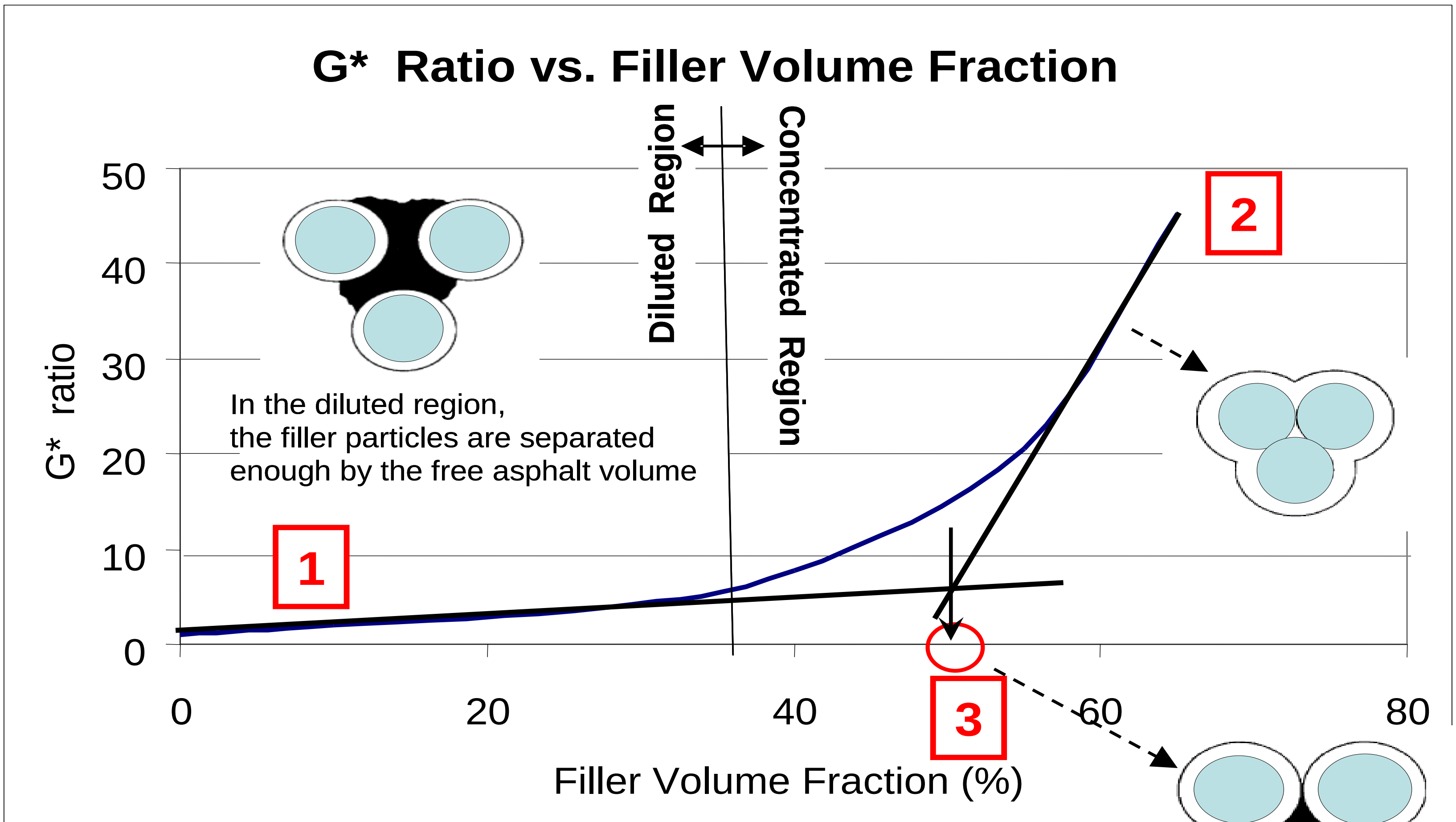
Summary of Findings

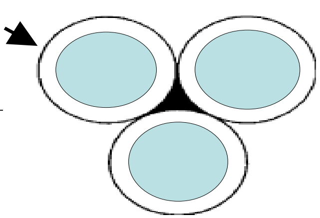
- The tackiness test allows calculating the volume of the "**influenced asphalt**" directly
- The tackiness test helped validate the **Two-Regions** hypothesis of this study
- The stiffening rate within the ***Diluted Region*** is highly dependent on the ***Rigden voids*** of the filler and the ***Nominal Maximum Particle Size***.
- The stiffening rate within the ***Concentrated Region***, which is assumed to be an indication of filler-bitumen interaction, is highly dependent on the ***Influenced Asphalt Volume*** fraction.

Update and Acknowledgment

- Update on Recent Testing
  - Recent testing matched the results of this study.
  - New testing included measuring physical and chemical properties of filler.
- Thanks to MTE for their help in filler procurment and testing.

Conceptual Model Parameters





1. **Initial Stiffening Rate**
2. **Terminal Stiffening Rate**
3. **Critical Filler Concentration**

At this concentration the transition is due to the consumption of "Free Asphalt"

Thank You!