DYNAMIC MASTER CURVES OF POLYMER MODIFIED ASPHALT FROM THREE DIFFERENT GEOMETRIES

GIOVANNI POLACCO*, OTAKAR JOSEF VACIN[1], DARIO BIONDI, JIRI STASTNA[1] AND
LUDOVIT ZANZOTTO[1]

Department of Chemical Engineering, University of Pisa, via Diotisalvi 2, 56126, Pisa, Italy
[1]Department of Civil Engineering, The University of Calgary, 2500 University Drive, T2N 1N4,
Calgary, Canada

*Email: g.polacco@ing.unipi.it
Fax: x39.0505.11266

Received: 15.9.2002, Final version: 8.4.2003

ABSTRACT:
Polymer modified asphalt is an highly temperature sensitive material. To obtain the master curves of dynamic material functions, for this material, it is necessary to perform the testing over the temperature interval from -30°C to at least 90°C. Since in this temperature range the polymer modified asphalt undergoes the transition from a glass-like to a Newtonian-like material, the benefit of using three testing geometries is studied here. The geometries used were: torsion bar (for the low temperatures), plate-plate (for the mid range temperatures) and bob and cup (for the high temperatures). The advantage of the combination of these three geometries is discussed. Stress and strain controlled rheometers were used to conduct all dynamic experiments. Master curves obtained by these geometries cover up to 20 decades of the reduced frequency.

ZUSAMMENFASSUNG:
Polymer-modifizierter Asphalt ist ein temperaturempfindliches Material. Um die Meisterkurven der dynamischen Materialfunktion zu erlangen, muss ein Temperaturintervall von -30°C bis mindestens 90°C getestet werden. Weil polymer-modifizierter Asphalt in diesem Temperaturbereich eine Transition von glasähnlichem zu Newton-gleichem Material durch macht, werden hier die Vorteile der drei Testgeometrien untersucht. Die benutzten Geometrien sind: Platte-Platte (für Temperaturen in mittleren Bereich); Torsion balken (für niedrige Temperaturen) und "bob and cup" (hohe Temperaturen). Die Vorteile der Kombination dieses drei Geometrien wird diskutiert. "Stress and strain" - kontrollierte Rheometer wurden benutzt um alle dynamischen Experimente zu kontrollieren. Meisterkurven dieser Geometrien decken bis zu 20 Dekaden der reduzierten Frequenz ab.

RÉSUMÉ:
Le bitume modifié par des polymères est un matériel caracterizé par une grande susceptibilité thermique. Au fin d'obtenir les courbes maîtresses pour ce matériel, on doit réaliser l'essai dans l'intervalle de température entre -30°C et 90°C. Puisque le bitume modifié par polymères subit, dans cet intervalle de témperature, la transition vitreuse et celle à l'état Newtonien, nous avons étudié ici l'avantage possible d'employer les trois geometries d'essai. Les geometries utilisés étaient: plat-plat (pour les températures moyennes de gamme); barre de torsion (pour les basses températures) et le plomb-tasse (pour les températures élevées). L'avantage de combiner les trois geometries est discuté. Toutes les mesures dynamiques ont eté effectuées avec les rhéomètres à contrôle d'effort ou de contrainte. Les courbes maîtresses obtenues par ces geometries couvrent jusqu'à 20 décades de la fréquence réduite.

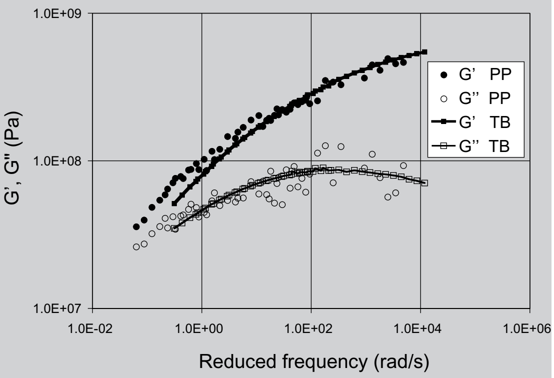
KEY WORDS: Polymer modified asphalt, dynamic material functions, time temperature superposition, different geometries

1 INTRODUCTION

Asphalt is a material with complex chemical structure, which varies with its origin and the method of production. Rheologically, it is possible to characterize asphalt as a viscoelastic material having high temperature sensitivity. It is generally believed that asphalt is also a rheologically simple material, i.e. the time-temperature superposition principle (TTS) applies to asphalt [1, 2]. In order to focus the topic it is useful to mention seminal works dealing with these problems. In 1943 Leaderman [3] was the first to recognize the similarity among creep curves measured at closely separated temperatures. It is nowadays known that the similarity between viscoelastic parameters, when measured at closely spaced temperatures, is quite common and not restricted to a few

© Appl. Rheol. 13 (2003) 118-124

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org



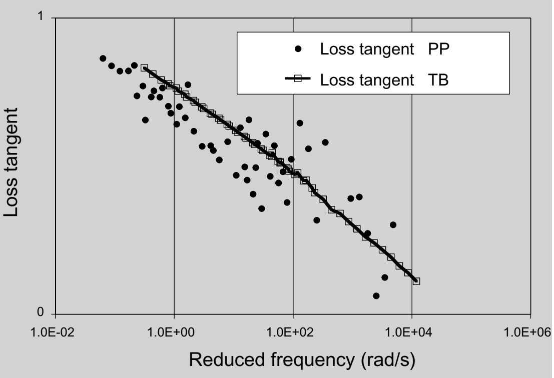


Figure 8 (left): Sample A, dynamic moduli, T_r = 22°C comparison of the PP and TB geometry.

Figure 9 (right): Sample A, loss tangent, T_r = 22°C comparison of the PP and TB geometry.

uli and the loss tangent are shown. The values obtained with TB and PP are similar, but those from PP are scattered around the TB data. This is a consequence of the definition of the complex viscosity ($|\eta^*| = |G^*|/\omega$) for which the division by frequency "smooth" the graph for high frequencies where there is a bigger denominator and enlarges the scattering for frequencies less than 1. When using PP geometry the lower (higher) is the temperature (frequency), the worse is the accuracy of the measurement due to slipping and breaking of the asphalt sample. This can be seen in Figs. 8 and 9, where the scattering increases from left to right. That problem is hidden in the complex viscosity graph thanks to the frequency at denominator and this is an interesting example of how it is always prudent to check the behavior of all dynamic functions when constructing the master curves of the storage and loss moduli. Sometimes, one can encounter a dubious practice when only the master curve for one viscoelastic function is presented, without checking master curves for other dynamic functions. For the discussion of problems generated by such a "shortcut" see e.g. [23, 24].

4 CONCLUSIONS

As already mentioned, the good master curves (for both samples) can be composed from the dynamic data obtained in all three geometries. Especially by adding the TB and BC geometries to the commonly used PP geometry the domain of the reduced frequencies is so wide that both principal relaxations are captured. Therefore, dynamic testing of highly temperature sensitive materials, e.g. asphalts, may require the use of three different fixtures: PP, TB and BC. Each of the three geometries has advantages and disadvantages depending on the operating temperature (linear viscoelastic behavior of the tested material is assumed). Therefore, in order to obtain good data in the whole temperature range where material changes from a brittle solid to a fluid, it is favorable to use all the fixtures. The shift from one fixture to another must be done at a temperature which depends on the viscoelastic properties of the material. In the case of asphalt, it is theoretically possible to measure the rheological properties using PP in a wide range of temperatures. However, when close to glass transition the slipping and breaking can occur, leading to very scattered and noisy data. Such problems are almost eliminated with TB. On the other hand, close to the room temperature, asphalt starts to become soft and it is not able to support its own weight and keep the shape of the torsion bar. Slipping and breaking cause no more a problem for PP geometry which starts to give better data. PP (and cone-plate) geometry remains the best one until the material approaches the liquid state. In this case the tendency to flow out from the space between the plates and the low torque values (due to the limited PP surface) appears. Both problems can be solved with a BC fixture giving more reliable data than PP in this case. In conclusion, this note gives examples of isotherms obtained with three different geometries and two rheometers. For both studied polymer modified asphalts, the data can be successfully shifted into the master curves of dynamic material functions. The importance of the requirement that the same values of the horizontal shifting factors must superpose all the viscoelastic functions is also stressed.

5 REFERENCES

[1] Christensen Jr DW, Anderson DA: Interpretation of Dynamic Mechanical Test Data for Paving Grade Asphalt Cements, Proc. of AAPT 61 (1992) 67-99.

[2] Stastna J, Zanzotto L, Vacin O: Thermomechanical Properties of Several Modified Asphalts, Applied Rheology 10 (2000) 185-191.

[3] Leaderman H: Elastic and Creep Properties of Filamentous Materials and Other High Polymers, The Textile Foundation, Washington (1943).

[4] McCrum NG, Read BE, Williams G: Anelastic and Dielectric Effects in Polymeric Solids, Wiley, London (1967).

[5] Ferry JD: Viscoelastic Properties of Polymers, Wiley, New York (1980).

[6] Brodnyan JG., Gaskin FH, Philippoff W, Lendart EG: The Rheology of Asphalt I, Trans. Soc. Rheol. 2 (1958) 285-306.

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org

[7] Goodrich JL: Asphalt and Polymer Modified Asphalt Properties Related to the Performance of Asphalt Concrete Mixes, Proc. AAPT 57 (1988) 116-175.

[8] Lewandowski LH: Polymer Modification of Paving Asphalt Binders, Rubber Chemistry and Technology 67 (1994) 447-480.

[9] Bouldin MG, Collins JH: Rheology and Microstructure of Polymer/Asphalt Blends. Rubber Chemistry and Technology 64 (1991) 577-600.

[10] De Ferraris L, Gallino G, Italia P, Mancini G, Rebesco E: Rheological Characteristics of Polymer Modified Bitumens' in Proceeding of 5th Eurobitume Congress, Stockholm (1993) 133-137.

[11] Isacsson U, Lu X: Testing and Appraisal of Polymer Modified Road Bitumens State of the Art, Materials and Structures 28 (1995) 139-159.

[12] Ait-Kadi A, Brahimi B, Bousmina M: Polymer Blends for Enhanced Asphalt Binders, Polym. Eng. Sci. 36 (1996) 1724-1733.

[13] Lu X, Isacsson U: Rheological Characterization of Styrene-Butadiene-Styrene Copolymer Modified Bitumens, Construction and Building Materials 11 (1997) 23-32.

[14] Sybilski D: Relationship Between Absolute Viscosity of Polymer-Modified Bitumens and Rutting Resistance of Pavement, Materials and Structures 27 (1994) 110-120.

[15] Shenoy A: Developing Unified Rheological Curves for Polymer Modified Asphalt, Part I, Theoretical Analysis, Materials and Structures 33 (2000) 425-429.

[16] Stastna J, Zanzotto L, Ho K: Fractional complex modulus manifested in asphalts, Rheol. Acta 33 (1999) 344-354.

[17] Lesueur D, Gerrard JF: Polymer Modified Asphalts as Viscoelastic Emulsions. J. Rheol. 42 (1998) 1059-1074.

[18] Stastna J, Zanzotto L, Vacin OJ: Viscosity Function in Polymer-Modified Asphalts, Colloid and Interface Sci. 259 (2003) 200-207.

[19] Tayebali AA, Goodrich JL, Sousa JB, Monismith CL: Influence of the Rheological Properties of Modified Asphalt Binders on the Load Deformation Characteristics of the Binder-Aggregate Mixtures, Polymer Modified Asphalt Binders, Wardlaw/Shuler Eds. (1992) 77-96.

[20] Collins JH, Bouldin MG, Gelles R, Berker A: Improved Performance of Paving Asphalts by Polymer Modification, Proc. of AAPT 60 (1991) 43-77.

[21] ARES Instrument Manual 902-30004 Rev. C (1997).

[22] Stastna J, Vacin OJ,, Zanzotto L, Dynamic and Relaxation Properties of Neat Asphalt Binder, Asphalt Mastic and Paving mix, JAABT 1 (2002) 21-35.

[23] Plazek DJ: What's Wrong With the Moduli Charley Brown? Or Get the H out and go to L, J. Rheol. 36 (1992) 1671-1690.

[24] Plazek DJ, Echeverria I: Don't cry for me Charlie Brown, or with Compliance Comes Comprehension, J. Rheol. 44 (2000) 831-841.

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org