Journal of Thermal Analysis, Vol. 32 (1987) 1797–1800

DEPENDENCES BETWEEN THERMAL METHODS FOR DETERMINATION OF PROPERTIES OF POLYMER–ASPHALT COMPOSITES

J. Zieliński and *A. Bukowski*

INSTITUTE OF CHEMISTRY, THE TECHNICAL UNIVERSITY OF WARSAW,
BRANCH AT PŁOCK, 09–400 PŁOCK ŁUKASIEWICZA 17,
POLAND

Attempts were made to determine correlations between the different thermal methods used for estimating the properties of polymer–asphalt compositions. The compositions containing asphalt, polypropylene and PVC were prepared by mixing the melted components. A number of methods were found usable for estimation of the thermal properties of the compositions, and the possibility of describing the obtained results in terms of mathematical relationships was demonstrated.

The bituminous materials widely applied in the building industry and highway engineering require, among others, improvement of their thermal resistance and mechanical strength. Modification of heavy oil residues by means of polymers is one of the methods of improving these properties. Polymer–asphalt compositions can be applied in many branches of the economy, such as civil and sanitary engineering, the building industry and highway engineering. These compositions have very complex physico-chemical structures. The available literature deals mainly with giving recipes and methods for the preparation of polymer–asphalt compositions [1, 2].

The aim of the present investigations was the determination of correlations between some chosen methods for investigating polymer–asphalt compositions, and the improvement of their themal resistance.

The investigations were carried out with the following compositions:

— the residue from Rhomaskino crude oil, obtained after distillation at reduced pressure, and

— (in order to draw comparisons) polymers having different chain structures and properties (atactic polypropylene (aPP) with molecular mass = 26,000, isotactic polypropylene (iPP) with molecular mass = 240,000, and emulsion polyvinyl chloride (PVC) with molecular mass = 80,000).

The compositions were prepared by mixing the melted components for 2.5 h at $T = 453$ K for aPP and iPP, and at $T = 403$ K for PVC.

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Akadémiai Kiadó, Budapest

As there is no particular methodology for determining the properties of polymer–asphalt compositions, we have adopted the methods commonly applied for investigating asphalts and plastics:

— softening point (T_M) (Ring and Ball),

— dropping point (T_K) (Ubbelohd),

— fragility point (T_L) (Fraas),

— fragility point by a method of bending on a mandrel (our own elaboration) (T_{LT}),

— hardness (Schopper and Höppler's consistometer).

It was hoped to utilize the results of the investigations applied in our work to determine correlations between the investigative methods, and to establish the dependences in the form of functions for physico-chemical quantities determined by means of particular methods on such parameters, among others, as temperature or the polymer content in the composition.

To accomplish these objectives, we used a program of multiple linear regression with application of a programmable Tektronix 31 minicomputer.

On the basis of the results obtained [3, 4], we established dependences in the form of mathematical equations for quantities determined by means of particular investigative methods:

For compositions containing up to 9 wt.% aPP:

$T_K = T_M + 8.6 \qquad T_{LF} = T_{LT} - 2.4$

$T_{LF} = 3.907 \cdot 10^{-2} T_M^2 - 25.427\, T_M + 4391.9$

$T_M = -0.664 \cdot 10^{-2} X^2 + 0.859\, X + 313.3$

$T_K = -2.503 \cdot 10^{-2} X^2 + 0.729\, X + 322.7$

For compositions containing above 20 wt.% aPP:

$T_K = T_M + 6.3 \qquad T_{LF} = T_{LT} - 1.7$

$T_{LF} = -2.324 \cdot 10^{-2} T_M^2 + 19.327\, T_M - 3761.3$

$T_M = -2.390 \cdot 10^{-4} X^2 + 0.099\, X + 418.9$

$T_K = -9.24 \cdot 10^{-4} X^2 + 0.186\, X + 422.8$

Moreover, for compositions containing iPP and PVC the following dependences were obtained:

$T_K = T_M + 1.8 \qquad T_{LF} = T_{LT} - 4.2 \;$ (≥ 6 wt.% iPP)

$$\left.\begin{array}{l} T_K = T_M + 11.7 \\ T_M = -3.686 \cdot 10^{-3} X^2 + 0.273\, X + 313.4 \\ T_K = 4.713 \cdot 10^{-3} X^2 + 1.128 \cdot 10^{-2} X + 326.3 \end{array}\right\} \text{0–30 wt.\% PVC}$$

$T_{LF} = T_{LT} - 5.6 \;$ ($\leq$ 9 wt.% PVC)

$T_{LF} = T_{LT} - 1.9 \;$ ($\leq$20 wt.% PVC), where

X = polymer content in vacuum residue.

Mechanical properties were investigated by means of a number of methods, but dependences which could be expressed by a mathematical equation were obtained only for the Schopper method and with Höppler's consistometer determining hardness. As model compositions, we investigated those which contained aPP. It was shown that the values of hardness determined with the Schopper (H) and Höppler (F_K) methods could be described by means of one equation:

$$F_K^{393} = (4.339\,X - 121.65 + H) \cdot 10^{-4} \;\; (\mathrm{N/m^2})$$

where $X = 40, \ldots, 70$ wt.% aPP

$$F_K^{393} = (7.08\,X - 232.66 + H) \cdot 10^{-4} \;\; (\mathrm{N/m^2}),$$

where $X = 80, \ldots, 100$ wt.% aPP.

Conclusions

The results of our investigations show that the following methods are useful in the evaluation of the thermal and mechanical properties of polymer–asphalt compositions:

— determining softening and dropping points for compositions containing up to 95 wt.% aPP, up to 9 wt.% iPP and up to 50 wt.% PVC;

— determining fragility points, particularly foor compositions containing up to 9 wt.% aPP and iPP, and for the whole range of PVC concentrations;

— determining hardness with the Schopper and Höppler methods for compositions containing $\geqslant 40$ wt.% aPP.

It was observed that the produced compositions had greater thermal resistance and strength against operating loads. It was found that it was possible to describe the obtained results in terms of simple mathematical relationships.

These dependences are conditioned by the nature and content of the polymer in the system and by the measurement parameters.

References

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Zusammenfassung — Es wurde versucht, Übereinstimmungen zwischen den verschiedenen Methoden zur Abschätzung der Eigenschaften von Polymer–Asphalt-Gemischen festzustellen. Die Gemische von Asphalt, Polypropylen und PVC wurden durch Mischung der geschmolzenen Komponenten erhalten. Es konnte einerseits eine Anzahl von brauchbaren Methoden zur Abschätzung der thermischen Eigenschaften der Gemische gefunden werden und andererseits eine Möglichkeit zur Fassung der erhaltenen Resultate in mathematische Beziehungen dargestellt werden.

Резюме — Предприняты попытки нахождения корреляций между различными термическими методами, используемыми для определения свойств составов полимер–асфальт. Составы, содержащие асфальт, полипропилен и поливинилхлорид, получали смешиванием расплавов отдельных компонент. Был найден ряд методов, пригодных для определения термических свойств таких составов и показана возможность описания полученных результатов на основе различных математических соотношений.