EVALUATION OF VALIDITY OF CONVENTIONAL TEST METHODS IN CASE OF POLYMER-BITUMENS

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INTRODUCTION

When testing polymer-bitumens, non-linear behavior of material is observed in test conditions at behavior of conventional, plain bitumens is linear. Polymer-bitumen systems show non-Newtonian behavior in a wider range of temperature and shear than plain bitumens. Paper presents results of testing of polymer-bitumens with discussion of validity of conventional test methods when applied for polymer-bitumen systems. Several polymer-bitumen systems were tested including bitumens modified with SBS elastomers (elastomer-bitumens) and polyolephinic plastomer PO (plastomer-bitumens). Test program contained: penetration at 5, 10, 15, 25, 40, 50°C and at 25°C under load 50, 100, 200g, Softening Point R&B, Fraass Breaking Point, viscosity at 60°C, ductility at 5, 15, 25°C. Viscosity was measured in rotational viscometer at various shear rates. Zero-shear viscosity was calculated from viscosity-shear rate relationship according to simplified Cross Equation [1]:

$$\eta = \frac{\eta_0}{1 + (K \cdot d\gamma / dt)^m}$$

where: η - apparent viscosity, mPas, η_0 - zero-shear viscosity, mPas, $d\gamma/dt$ - shear rate, 1/s, K - constant, s, m - constant.

Wheel-tracking test was conducted on asphalt concrete with polymer-bitumens and plain bitumens in LCPC apparatus at 45°C, load 0.5 kN, contact pressure 0.6 MPa. Rutting resistance was expressed as a number of wheel passes to rut depth 10mm, N_{10}, calculated according to Equation:

$$h = a \cdot \ln^b N$$

where: h - rut depth, mm, N - number of wheel passes, a,b - constants. N_{10} was related to binder properties.

PENETRATION

Elastomer-bitumens show non-linear relationship of log(penetration) vs temperature above 25°C (Fig. 1). Penetration is lower than expected. Bitumen and plastomer-bitumen show linear relationship in temperature range from 5 to 50°C. The same conclusion comes out from penetration test under various load (Fig. 2). In case of elastomer-bitumens relationship of penetration vs load deviates from linear when increasing load. This is not observed in case of bitumen or plastomer-bitumen. Penetration tests showed that elastomer-bitumens are less temperature and load susceptible than bitumen or plastomer-bitumen.

Zero-shear viscosity at 60°C shows a very weak relationship with penetration at 25°C (Fig. 3). Two separate group of polymer-bitumens may be easily recognized depending on consistency of base bitumen used for modification. A great variety in viscosity is observed among polymer-bitumens of equal penetration. In a group of binders of penetration at 25°C from 40 to 70x0.1mm, viscosity at 60°C varies from 4×10^5 mPas to 1.5×10^7 mPas, i.e. the highest value is 38 times of the lowest!

SOFTENING POINT

There is a doubtful relationship between R&B Softening Point and Penetration at 25°C (Fig. 4). The same Softening Point may be obtained by elastomer-bitumens of significantly different penetration. Soft base bitumen highly modified with elastomer (i.e. 6-7% by mass) results in a binder of very high Softening Point, above 70°C, comparative with that obtained by harder base bitumen low modified (i.e. 3-4%).

Relationship of Plasticity Range and Penetration Index in case of some elastomer-bitumens deviates significantly from linear observed in case of plain bitumens and plastomer-bitumens (Fig. 5) as a result of devation of Softening Point and Fraass Breaking Point as well as Penetration from relationships found for bitumens by Heukelom [2].

When relating Softening Point to Zero-shear viscosity at 60°C an interesting shape of relationship was found as linear but with a break point at 68.2°C (with respective Zero-shear viscosity 7380000 mPas) - Fig. 6. The relationship is much stronger than for penetration. A sharp change in slope is observed at this point which means that below this point increase in Softening Point reflects increase in viscosity of binder while above this point increase in Softening Point does not bring increase in viscosity. This observation may explain doubts in significance of Softening Point in case of some soft highly modified elastomer-bitumens. For a polymer-bitumen of Softening Point 60°C its zero-shear viscosity at this temperature would be 2164000 mPas which is much above 1300000 mPas as determined by Heukelom for plain bitumens.

LOW-TEMPERATURE PROPERTIES

Vonk et al. [3] analysed validity of Fraass Breaking Point for evaluation of low-temperature behavior of elastomer-bitumens. Fraass Breaking Point temperature was compared with accoustic emmision test results, showing that the first did not reflect low-temperature behavior in some cases. Fraass Breaking Point reflects a certain stiffness of binder not its ability to combat tensile strain. Fig. 7 presents results of tests of ductility at various temperatures related to penetration measured at the same temperature. A group of results obtained for penetration below 20x0.1mm has been chosen which represent hard binders tested at 15 or 25°C or soft binders tested at 5°C. Significant difference may be noted when comparing materials of the same penetration from two groups. Plain bitumens and plastomer-bitumens are grouped in the first while elastomer-bitumens in the second. At the same penetration elastomer-bitumen shows higher ductility than plain bitumen or plastomer-bitumen. In average, at penetration of 10x0.1mm bitumen or plastomer-bitumen shows ductility of 5.0cm while elastomer-bitumen of 28.2cm. When considering that ductility test was conducted on hard bitumen, these results may be regarded as reflecting low temperature behavior of binders. No relationship of ductility at low temperature and Fraass Breaking Point was found. Conclusion is similar to that which came out from SHRP: low-temperature properties of bituminous binder shall be characterized by stiffness but also tensile strain.

RUTTING RESISTANCE OF ASPHALT CONCRETE VS BINDER PROPERTIES

Comparison of rutting resistance of asphalt concrete with Softening Point of bituminous binder showed a weak relationship (Fig. 8). Much higher regression coefficient was achieved in case of zero-shear viscosity at 60°C (Fig. 9). However in both cases the same phenomenon may be noted: elastomer-bitumens from soft base bitumen highly modified may be overestimated in terms of rutting resistance when evaluating on base of Softening Point or zero-shear viscosity. In case of the latter the potential reason lies in equipement possibilities which do not allow to approach sufficiently low shear rates [1]. In case of Softening Point a break point may be noted at a point of about 70°C which is the value of break point of realtionship of Softening Point and zero-shear viscosity at 60°C. The best rutting resistance was obtained with harder grade elastomer-bitumen with a lower modification or with highly modified plastomer-bitumen based on hard bitumen.

CONCLUSIONS

Non-linear non-Newtonian behavior of polymer-bitumens may be found in conventional tests depending on temperature and load conditions. All conventional test methods as penetration, R&B Softening Point, Fraass Breaking Point have validity limited to relatively low modified polymer-systems, esecially in case of elastomer-bitumens. In case of Softening Point, the limiting value was found as 68.2°C. Zero-shear viscosity calculated from viscosity-shear rate relationship reflects susceptibility of binder to permanent deformation. The test method is limited with equipement potentials to aproach zero shear conditions in case of highly modified polymer-bitumen systems.

REFERENCES

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3. **Vonk W.C., Robertus C., Jongeneel D.J., Korenstra J.**: *Accoustic emmision: a new tool for assessing the relative performance of binders and asphlats at low temperatures.* The East-West European Road Conference, Warsaw, 22-24 Sept. 1993

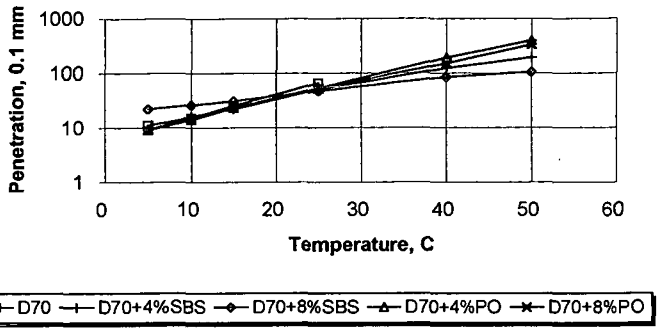

Fig. 1. Penetration vs Temperature of plain bitumen and polymer-bitumens

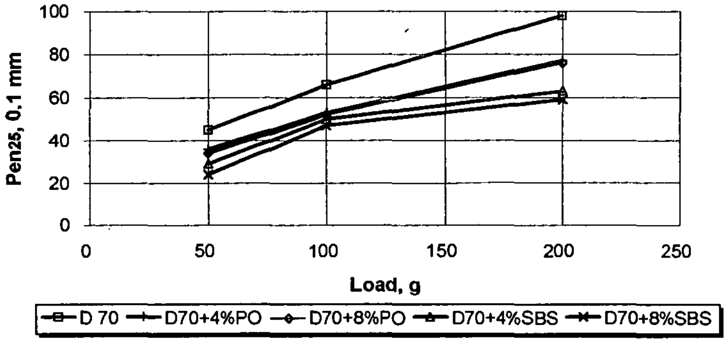

Fig. 2. Penetration vs Load of plain bitumen and polymer-bitumens

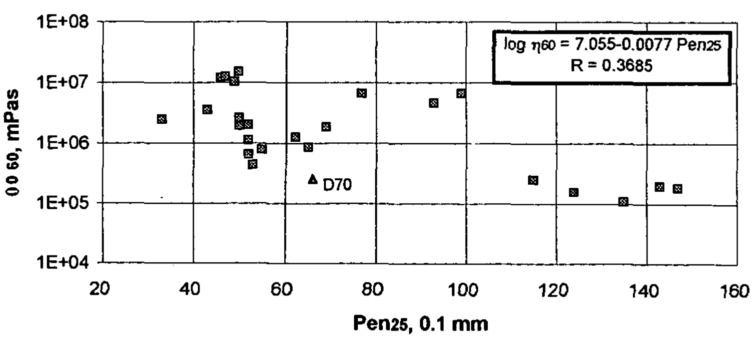

Fig. 3. Zero-shear viscosity at 60°C vs Penetration at 25°C

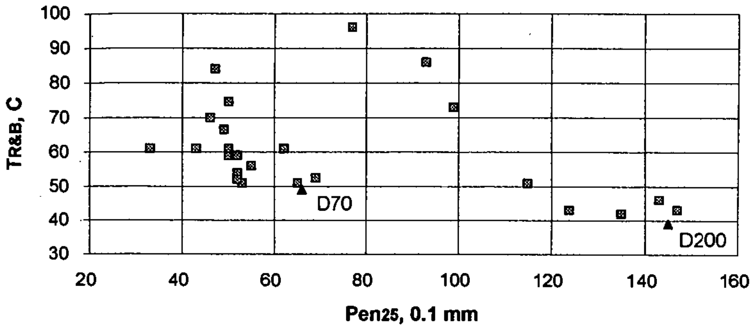

Fig. 4. R&B Softening Point vs Penetration at 25°C

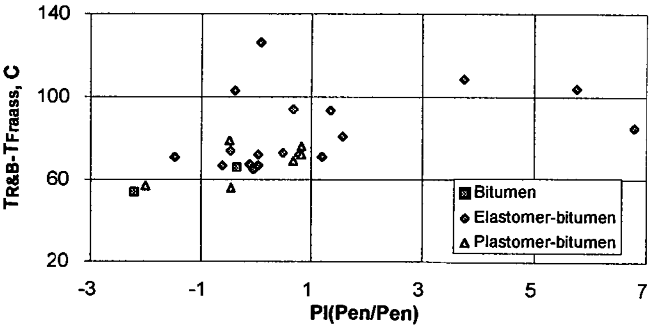

Fig. 5. Plasticity Range ($T_{R\&B}$-T_{Fraass}) vs Penetration Index

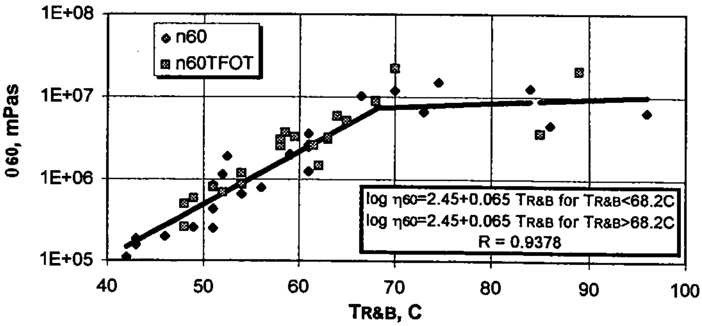

Fig. 6. Zero-shear viscosity at 60°C vs R&B Softening Point

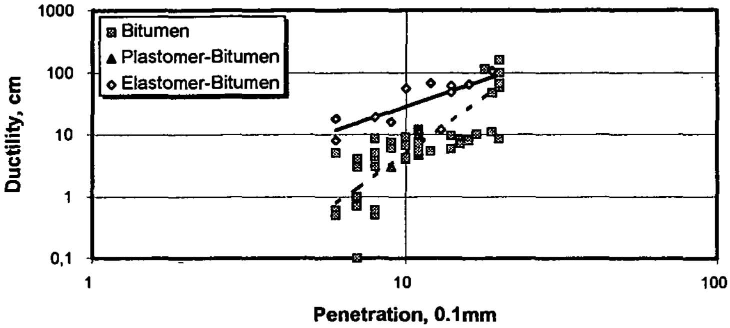

Fig. 7. Ductility vs Penetration at the same temperature (Penetration below 20x0.1mm)

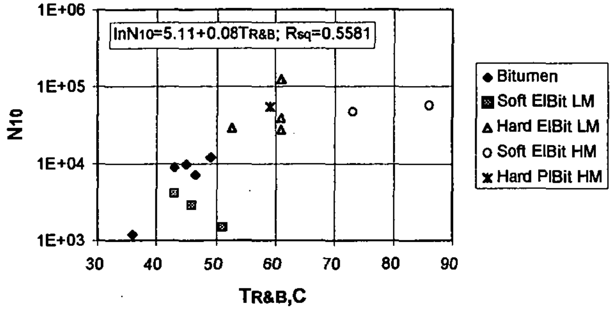

Fig. 8. Rutting Resistance of Asphalt Concrete vs R&B Softening Point of Binder

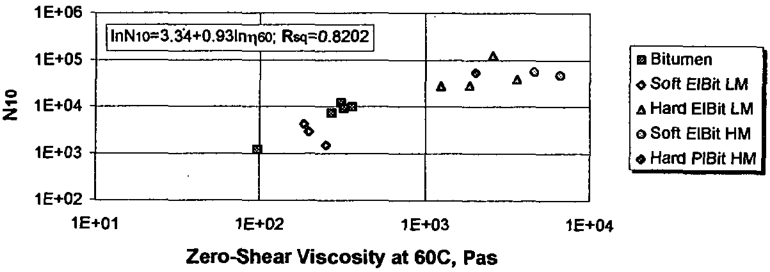

Fig. 9. Rutting Resistance of Asphalt Concrete vs Zero-Shear Viscosity at 60°C of Binder