Evaluation of a newly developed asphalt binder selection system for mix design

B. O. Lerfald & J. Aurstad
SINTEF, Dep of Road and Railway Engineering, Trondheim, Norway

L. J. Bakløkk
Norwegian Public Roads Administration, Centre for Road and Traffic Technology, Trondheim, Norway

E. O. Andersen
A/S Norske Shell, Trondheim, Norway

ABSTRACT: A Norwegian research project (PROKAS) has been conducted in the period 1998 – 2004. One objective was to develop performance-based specifications for Norwegian asphalt mixtures. As a part of this project a new binder selection system was sketched (Andersen, 2000). This system was based on results from the Norwegian research project *New Asphalt technology*, a project aiming at adaption of the Superpave binder system to Norwegian conditions. An attempt to verify this binder selection system in the laboratory has been made. Deformation properties of asphalt mixtures with different binder stiffnesses have been measured (Lerfald, 2004). The same aggregates and material gradings were used in all samples. The new asphalt binder selection system shows relatively good correlation with results from the deformation tests. However, further testing with other mixtures and higher temperatures will be required to fine-tune and fully verify the system.

KEY WORDS: Asphalt binder, mix design, deformation.

1 BACKGROUND

Rutting of asphalt pavements in Norway is caused by wear from studded tires and deformation of the asphalt mix. A lot of research has been carried out to develop pavements more resistant to studded tire wear. Less emphasis has been put on the deformation part.

The main objective with the PROKAS project has been to develop a mix design system based on functional properties. As part of the project a new asphalt binder selection system was developed (Andersen, 2000). To evaluate this system a specific study was conducted on how different binder properties influence on the deformations and stiffness properties of the asphalt mix. A test method, not previously used in Norway, has been used to measure the deformation properties; Indentation Repeated Load Axial Test (INDENT) on the Nottingham Asphalt Tester (NAT).

2 A NEW BINDER SELECTION SYSTEM

In the PROKAS project a new asphalt binder selection system has been developed. This system is based on the Superpave binder classification system, but adjusted for Norwegian conditions. The system is based on traffic volume, traffic speed and temperature conditions, and it is suitable for unmodified binders. For modified binders other procedures have to be used. The system is shown in Figure 1.

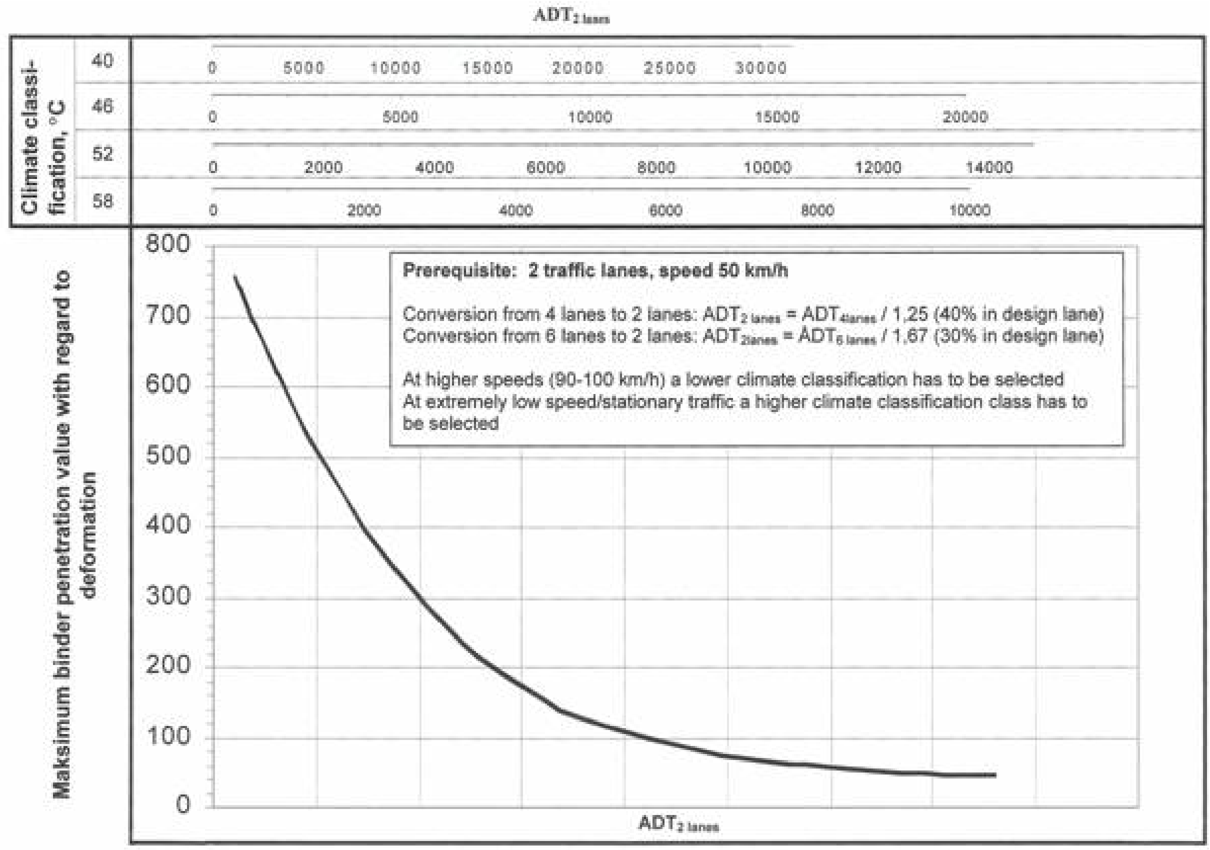


Figure 1: A new Norwegian binder selection system (penetration values at 25 ºC)

Norway has a practice of using soft binders for low volume roads, often refered to as V(iscosity)-grades. Penetration values of 300 and above in Figure 1 should be regarded as theoretical and represent a transition zone between conventional penetration grade bitumens and the V-grade bitumens. Actual penetration values in this range are normally measured at 15 ºC. For corresponding values at 15 ºC, see EN 12591, table 2.

The binder selection procedure is as follow:

I) Prediction of highest pavement temperature, climate classification

The highest critical pavement temperature is calculated using the following formula:

$$T_{max20} = (T_{airmax} - 0.0055\varphi^2 + 0.15\varphi + 36) \cdot 0.9545 - 0.8$$

here:

- T_{airmax} is highest average air temperature in the hottest 7 days period. (^oC)

- φ is degree of latitude in ^{o}
- T_{max20} is the pavement temperature in 20 mm depth (^{o}C)

The calculated pavement temperature is the highest expected temperature with regard to deformation properties. This temperature is used for selecting the climate classification class (upper left in Figure 1). The class above the calculated T_{max20} is to be chosen. (Example: if T_{max20} is calculated to 44 ºC, climate classification 46 is selected.)

II) Selection of penetration value on the basis of climate classification and traffic volume

In Figure 1 the selection of maximum penetration value is done by means of climate classification class and traffic volume. From the actual ADT line, a vertical line is drawn down to the point of intersection with the curve and then horizontally to the y-axis. There the actual penetration value with regard to deformation properties can be read. Figure 1 has the following assumptions:

- traffic speed 50 km/h
- 2 traffic lanes

For other conditions, see comments in Figure 1.

III) Control of low temperature properties

Next step is to control if the selected bitumen satisfy the low temperature criteria. The critical low temperature in the pavement, T_{min}, is calculated:

$$T_{min} = 0.859 \cdot T_{airmin} + 1.7$$

here:

- T_{airmin} is dimensioning low air temperature (^{o}C)

In the Norwegian bitumen specifications the low temperature criteria is based on the Fraass breaking point. The critical low temperature is converted to the Fraass breaking point value using the following equation:

$$\text{Fraass} = 0.7 \cdot T_{min} + 6.8$$

This value is controlled according to the values in the specifications.

3 PROCEDURE FOR EVALUATION OF THE NEW ASPHALT BINDER SELECTION SYSTEM

To evaluate the new binder selection system deformation tests of asphalt mixes have been performed by the Indentation Repeated Load Axial Test (INDENT) on the Nottingham Asphalt Tester (NAT). A testing programme was carried out on an AC 11 mix. The same aggregates and grading curves were used for all samples, while the bitumen grades were varied (35/50, 50/70, 70/100, 160/220, 330/430 and V12000). The deformation tests were performed at one temperature (in this case 40 ºC).

These deformation tests give a set of results where deformation is a function of the number of load cycles. A chosen level of deformation and the corresponding number of cycles founds the basis for verifying the curve in Figure 1, as principally shown in Figure 2.

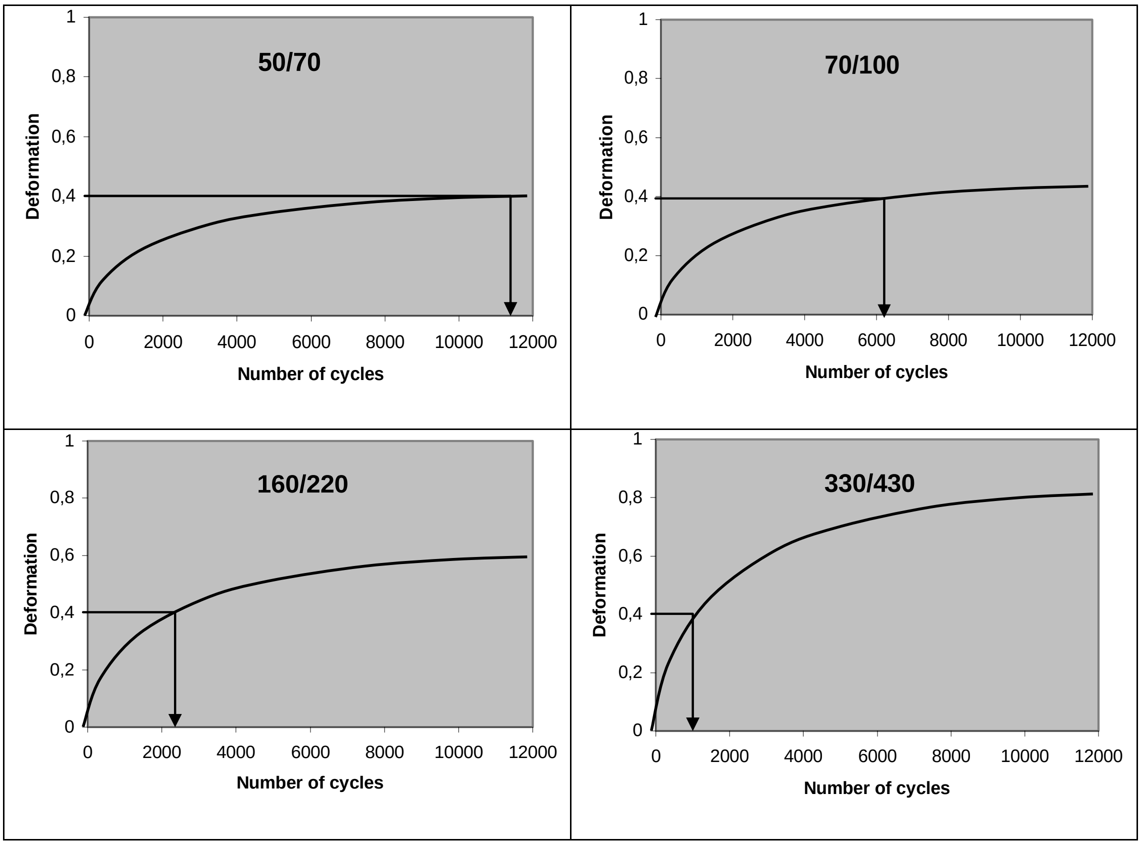


Figure 2: Principal procedure for verification of the new Norwegian binder selection system

To verify all classes of climate classification, similar tests should have been performed at all temperatures 40, 46, 52 and 58 ºC (climate classification classes in Figure 1).

4 TEST METHODS AND STANDARDS

4.1 Preparing of samples in gyratory compactor

Laboratory mixing of the asphalt was done according to method 14.5532 in Handbook 014 (Norwegian Public Roads Administration, 2004). Compaction of samples in the gyratory compactor was done according to method 14.5533 in Handbook 014. Type of gyratory compactor used was an ICT 150.

4.2 Deformation properties

The deformation properties were measured using the Indentation Test (INDENT) in the NAT. The following standard was used: Pr EN 12697, Bituminous mixtures – Test methods for hot mix asphalt – Part 25: “Cyclic compression test”, Test method A: “Uniaxial cyclic compression test with confinement” (August 2003). The test is carried out with a frequency of 0.5 Hz and a stress level of 100 kPa. Totally 3600 pulses is applied (total time for the test is about 2 h).

5 MATERIALS

5.1 Aggregates

The aggregates used in this investigation were the same as used when producing an asphalt concrete pavement (AC 11) at Trondheim airport, Værnes, in 2003. In Table 1 the mixture formulation and the compact density is shown.

Table 1: The mixture formulation and compact density of aggregates (AC 11)

Aggregates	**Mixture formulation (%)**	**Compact density (g/cm^3)**
Fossberga 8-11 mm	35	2.703
Fossberga 0-8 mm	40	2.688
Forness 0-10 mm	19	2.856
Franzefoss filler	6	2.740
Binder content	5.6	

5.2 Bitumen

The characteristics of the bitumens used in the investigation are given in Table 2.

Table 2: Binder characteristics

Binder grade	**Penetration (0.1 mm)**	**Viscosity, 60 °C (mm^2/s)**	**Softening point (°C)**
35/50	35		53
50/70	57		49
70/100	85		45
160/220	185		39
330/430	341		33
V12000		11800	27

6 PREPARATION OF SAMPLES

The test samples were produced using the gyratory compactor. The samples for measuring deformation properties should have a diameter of 148 ± 5 mm and a height of 60 ± 2 mm. According to Norwegian specifications (method 14.5533 in Handbook 014) the deformation samples are produced with a diameter of 150 mm and a height of 100 mm. After compaction 20 mm are cut off from each side. Thus, the middle 60 mm of the sample is tested.

7 RESULTS

7.1 Sample data

The samples data are given in Table 3. Three different void contents are given; the voids calculated in the gyratory computer program, voids measured on 100 mm thick surface dried samples and on sawn 60 mm thick samples.

Table 3: Samples for deformation tests (d = 150 mm), AC 11

Series	Type of binder	Sample	Void content (%)		
			In gyrator	100 mm thickness	Sawn to 60 mm thickness
A1	35/50	A11	4.0	2.9	2.2
		A12	4.0	2.6	1.8
		A13	4.0	2.3	1.6
		A14	4.0	2.8	2.1
		A15	4.0	2.5	2.0
A2	50/70	A21	4.0	2.3	1.4
		A22	4.0	2.3	1.7
		A23	4.0	1.5	0.9
		A24	4.0	2.8	1.9
		A25	4.0	2.7	2.0
A3	70/100	A31	4.0	2.6	1.9
		A32	4.0	1.5	0.8
		A33	4.0	2.5	1.5
		A34	4.0	2.2	1.4
		A35	4.0	2.6	1.8
A4	160/220	A41	4.0	1.1	0.6
		A42	4.0	2.7	1.6
		A43	4.0	3.3	2.0
		A44	4.0	2.2	1.5
		A45	4.0	2.9	2.6
A5	330/430	A51	4.0	2.7	2.5
		A52	4.0	2.3	1.7
		A53	4.0	2.9	1.9
		A54	4.0	2.8	1.9
		A55	4.0	2.6	1.9
A6	V12000	A61	4.0	2.7	2.4
		A62	4.0	2.6	1.9
		A63	4.0	2.5	1.9
		A64	4.0	2.9	2.5
		A65	4.0	2.7	2.1

7.2 Deformation properties

The deformation properties were measured at 40 ºC. In Table 4 and Figure 3 the results are shown for all series.

Table 4: Deformation after 3600 cycles at 40 ºC (µstrain), AC 11

Series	A1	A2	A3	A4	A5	A6
Mean value	3175	4318	5084	7884	9649	13043
Standard deviation	503	577	709	1721	629	2148

In Figure 3 the mean deformation curves are shown for all series.

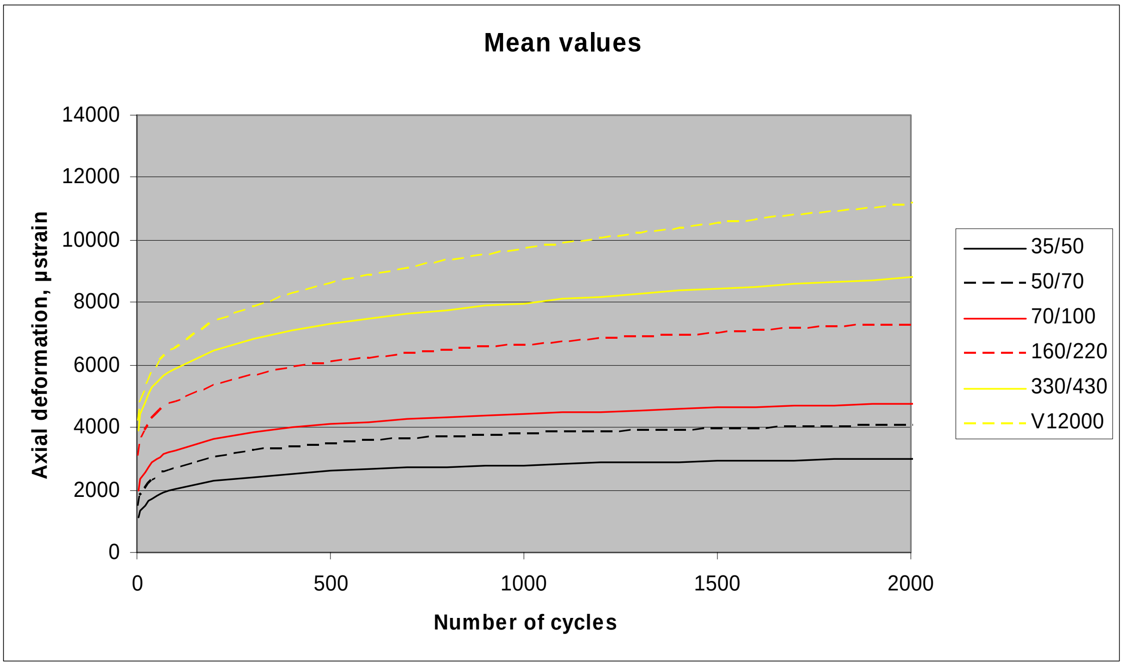


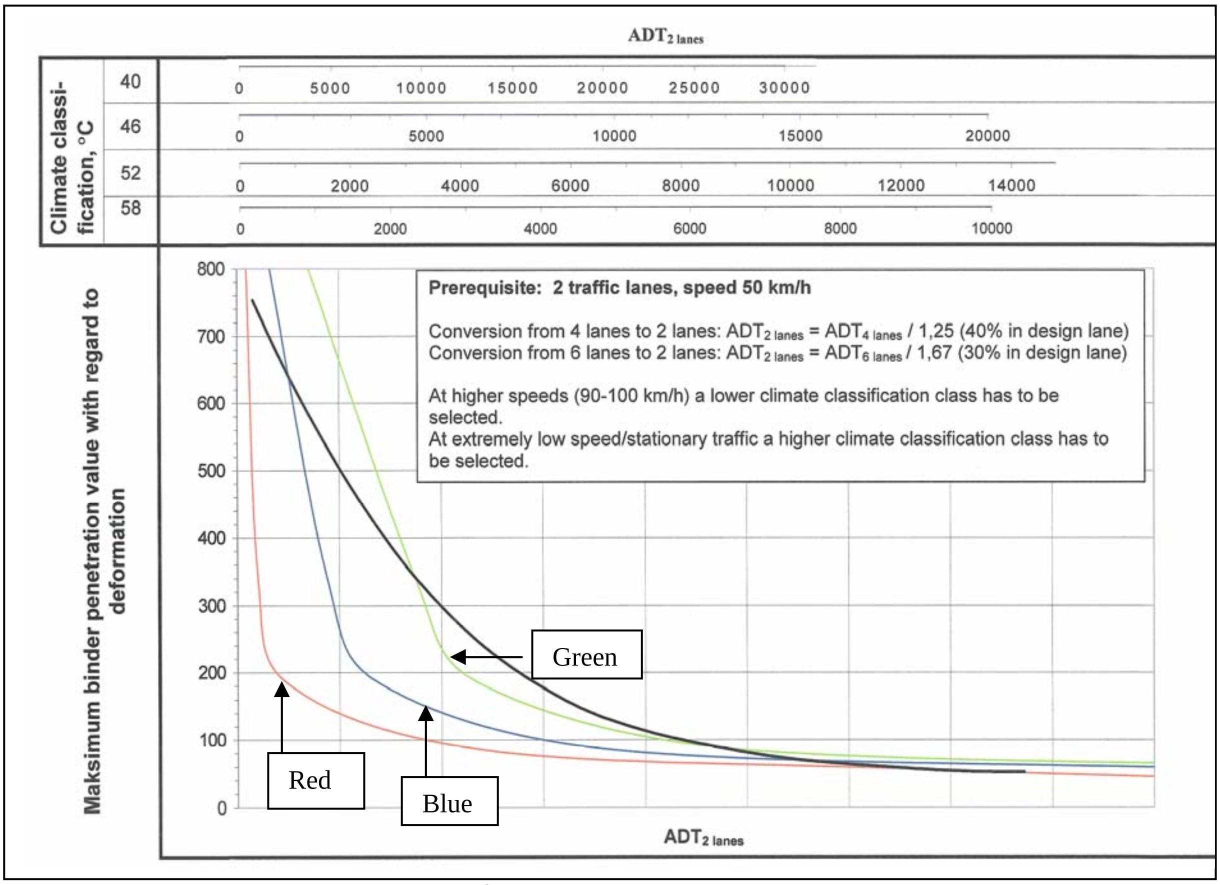
Figure 3: Deformation properties – mean values (AC 11 with different binder stiffnesses)

7.3 Evaluation of a new asphalt binder selection system

The binder selection system is checked by deformation tests in the laboratory. A given deformation is chosen and for different asphalt mixes with different binder grades the number of cycles required to give this deformation, is detected.

The first evaluation of the binder selection system (Figure 1) was based on the following presumptions:

- Indentation test on NAT performed at 40 ºC, that is checking the "upper" climatic class in Figure 1 and Figure 4 (corresponding to PG 40 in the SUPERPAVE system).
- The numbers of test cycles are equal to ADT (Average Daily Traffic).
- Penetration values from Table 2 are plotted against ADT (= number of cycles).
- Numbers of cycles are detected from Figure 3 for deformation levels 8000, 10000 and 12000 µstrain. These values are plotted in Figure 4 with red, blue and green colour respectively.
- Due to relatively small deformations at 40 ºC it was necessary to extrapolate some of the curves.



Red curve is based on axial deformation 8000 µstrain.
Blue curve is based on axial deformation 10000 µstrain.
Green curve is based on axial deformation 12000 µstrain.
ADT = Average Daily Traffic.

Figure 4: Results from deformation tests on laboratory produced AC-samples, plotted in a new asphalt binder selection system (Figure 1)

As can be seen in Figure 4 the shapes of the coloured curves are somewhat different from the original binder curve, but it seems like they are better corresponding with increasing level of deformation.

8 CONCLUSIONS

The aim of the investigation was to evaluate a proposal for a new Norwegian binder selection system developed in the project PROKAS. The influence of varying binder stiffness on deformation properties of a standard asphalt mixture (AC 11) was examined as a part of this evaluation.

Main conclusions from the investigations are:

- The Indentation test on NAT seems to rank asphalt mixes with the same aggregate and varying binder stiffness in a reliable way.
- Results from deformation measurements of asphalt mixes with different binder grades seems to correlate relatively well with the new proposed system for binder selection based on local climate and traffic loadings.
- Further analyses of other mixes and other levels of temperature will have to be carried out for fine-tuning and final verification of the system.

REFERENCES

Andersen, E. O., 2000. *PROKAS A new asphalt binder selection system for mix design.* 15.6.2000 (in Norwegian).

Lerfald, B. O., 2004. *The importance of the binder with regard to deformations and stiffness properties – A laboratory investigation of an AC 11 mm mix on NAT*. PROKAS project report nr. 11. SINTEF report STF22 A04342 (in Norwegian).

Norwegian Public Roads Administration, 2004. *Handbook 014*, *Laboratory methods* (in Norwegian).