Functional testing of asphalt mixes on field samples

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ABSTRACT: The Norwegian research project PROKAS was conducted in 1998 – 2004. One objective was to develop performance-based specifications for Norwegian asphalt mixtures. As part of this project a number of samples were taken from different asphalt pavements in Norway. Material properties as stiffness and deformation resistance were examined using the indirect tensile modulus test and the indentation repeated load axial test. The tests were carried out on the Nottingham Asphalt Tester (NAT).

Results show that NAT seems to give reasonable E-modulus ranking of asphalt mixes, while there are great variations in the results from the deformation tests. Questions are raised if the used procedure for measuring deformation properties has to be adjusted/improved, or if another method can be more suitable.

These investigations have given useful experience regarding the material properties of different asphalt mixes in Norway. However, further laboratory testing on field samples has to be conducted before specifications are established.

KEY WORDS: Asphalt mixture, mix design, stiffness, 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 that are more resistant to studded tire wear. Traditionally, less emphasis has been put on the deformation part.

The main objective with the PROKAS project was to develop a mix design system based on functional properties. New test methods have been used to measure the stiffness modulus and the deformation properties; Indirect Tensile Stiffness Modulus (ITSM) and Indentation Repeated Load Axial Test (INDENT) on the Nottingham Asphalt Tester (NAT).

One part of the project has been to examine the deformation and stiffness properties of different asphalt mixes used in Norway (Lerfald 2004). Field samples were collected from different parts of the country, and elastic modulus and rutting resistance were measured on the cores. Based on these results, the objective was to establish functional requirements regarding stiffness modulus (E-modulus) and deformation properties.

2 TEST METHODS AND STANDARDS

2.1 Stiffness modulus

Stiffness was measured using the Indirect Tensile Stiffness Modulus (ITSM) test in the NAT. The following standard was used: Pr EN 12697, Bituminous mixtures – Test methods for hot mix asphalt – Part 26: "Stiffness", Annex C: "Indirect tension test on cylindrical specimens" (December 2003).

2.2 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).

3 SAMPLE PREPARATION

All core samples were taken from asphalt pavements laid in 2003. The cores had a diameter of 10 cm and 15 cm, for testing of stiffness modulus and deformation properties respectively. The preferred thickness should be at least 3.5 cm, due to the fact that the samples should be sawn on both sides before testing. The planned testing program is shown in Table 1.

Table 1: Testing program

Sample no. *)	Asphalt mixture	Pen. grade	Binder content (%)
1 – 20, A, B, C	AC 11	160/220	5.5
21 – 25 A, B, C	AC 16	70/100	5.1
26 – 30 A, B, C	SMA 11	70/100	5.8
31 – 35 A, B, C	SMA 16	70/100	5.9
36 – 40 A, B, C	AC 11	70/100	5.5
41 – 45 A, B, C	ACg**)11	160/220	5.7
46 – 50 A, B, C	Flexible AC 11***)		
56 – 60 A, B, C	ACg**) 11 with/RAP	160/220	5.8
61 – 65 A, B, C	AC 11 with /RAP	70/100	5.7
66 – 70 A, B, C	AC 16	70/100	5.7

*) Sample A is used for stiffness modulus and B and C for deformation properties.

**) ACg is AC with gravel.

***) Flexible AC is asphalt mixture with grading curves similar to AC with gravel and soft binder (viscosity at 60 ºC in the range of 350 – 12500 mm^2/s).

In Norway asphalt layers are laid rather thin, which (unfortunately) makes it difficult to take out field samples thick enough to cope with the test standards. Thus, it was not possible to test all samples in Table 1, as planned. An example on a thin and damaged sample is given in Figure 1.

Figure 1: Thin and damaged sample (diameter 10 cm), unsuitable for further testing

4 RESULTS AND DISCUSSION

4.1 Stiffness modulus

Data for the tested samples are given in Table 2.

Table 2: Data for elastic modulus samples

Sample no	Asphalt mixture	Pen. grade	Planned binder content (%)
1A – 20A	AC 11	160/220	5.5
21A – 25A	AC 16	70/100	5.1
26A – 30A	SMA 11	70/100	5.8
31A – 35A	SMA 16	70/100	5.9
36A – 40A	AC 11 L	70/100	5.5
41A – 45A	ACg[*)] 11	160/220	5.7
56A – 60A	ACg[*)] 11 with/RAP	160/220	5.8
61A – 65A	AC 11 with /RAP	70/100	5.7
66A – 70A	AC 16	70/100	5.7

[*)] ACg is AC with gravel.

The results from E-modulus testing at 10 and 20 ºC are given in Figure 2. Some statistical values for the tests performed at 10 ºC are given in Table 3.

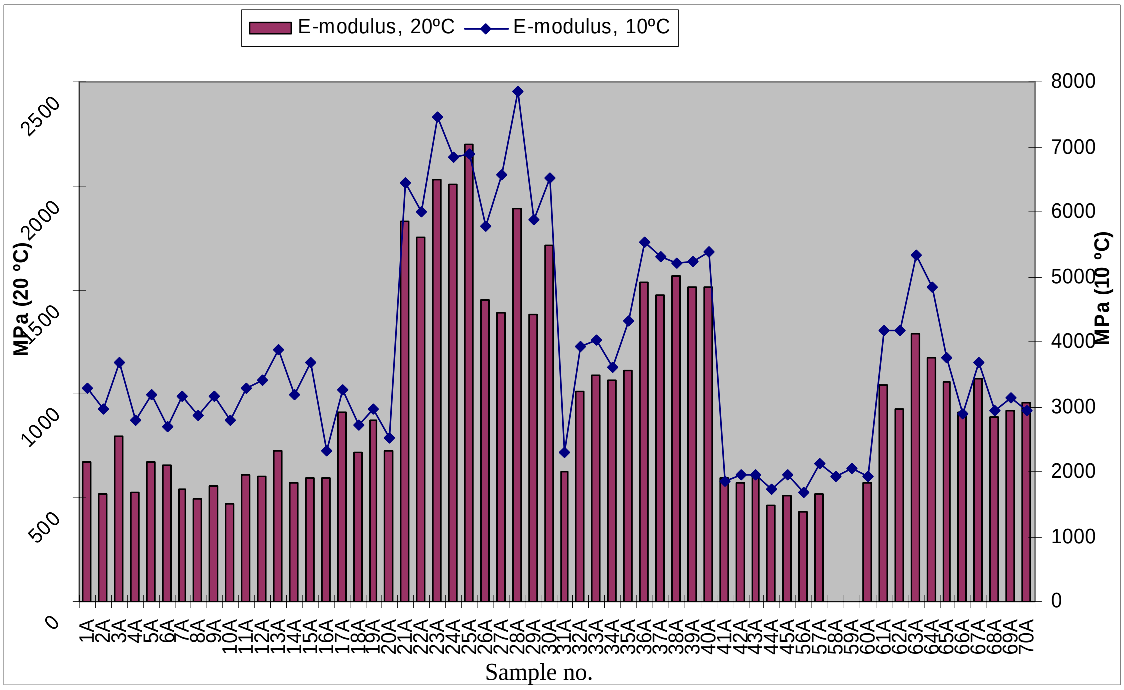

Figure 2: Stiffness modulus (E-modulus) at 10 and 20 ºC.

Table 3: Mean value and standard deviation for the stiffness modulus, MPa (10 ºC).

Sample no	1-20	21-25	26-30	31-35	36-40	41-45	56-60	61-65	66-70
Asphalt mix	AC 11	AC 16	SMA 11	SMA16	AC11	ACg*) 11	ACg*) 11 with/RAP	ACg*) 11 with/RAP	AC16
Mean value	3090	6726	6516	3639	5340	1881	1941	4454	3109
St.d. deviation	397	537	825	790	130	96	167	627	329

*) ACg is AC with gravel.

As could be seen from Figure 2 and Table 3, there are some variations in results between samples within the same asphalt mixture (same series).

4.2 Factors affecting the stiffness modulus

There are several sample characteristics that might influence on the stiffness results, such as:

- Asphalt layer thickness
- Void content
- Binder stiffness

All samples in the investigation were relatively thin. The results show no obvious connection between sample thickness and stiffness modulus level, but series with less varying thicknesses also reveal less varying results.

There is no clear connection between void content and stiffness modulus, but there is a tendency that lower void content gives higher stiffness modulus.

There is a clear connection between binder stiffness and stiffness modulus, as shown in Figure 3.

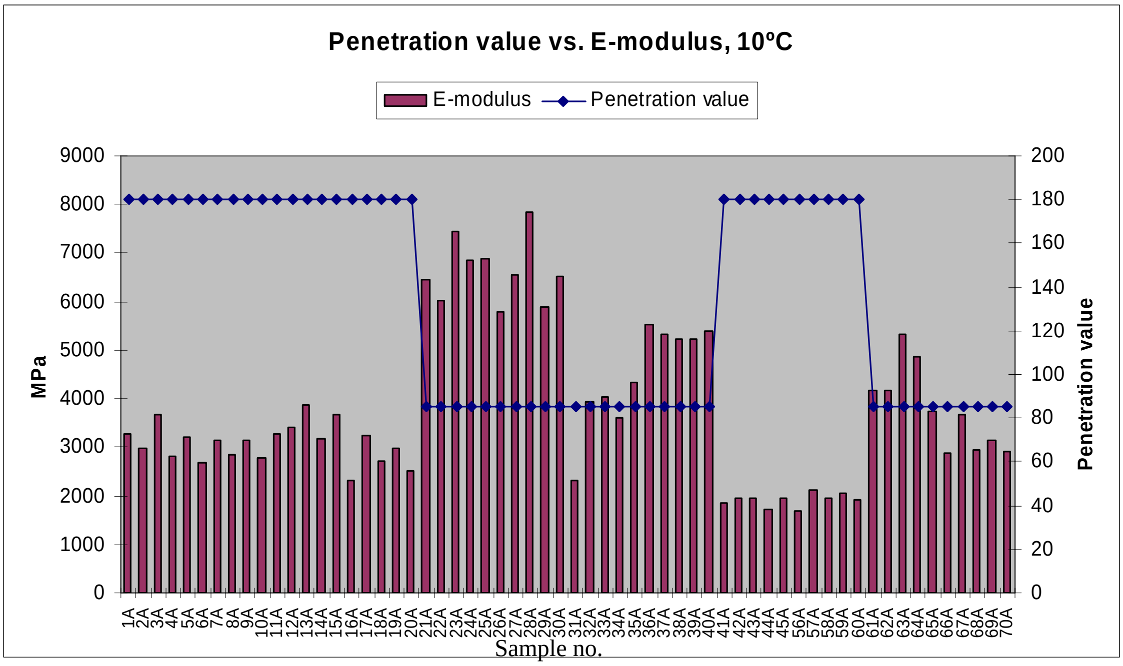

Figure 3: Binder stiffness and E- modulus for the field samples

4.3 Deformation properties

The deformation properties were measured at 40 ºC. Data for the tested samples are given in Table 4.

Table 4: Data for deformation properties samples

Sample no	Asphalt mixture	Pen. grade	Planned binder content (%)
1 – 20	AC 11	160/220	5.5
21 – 25	AC 16	70/100	5.1
31 – 35	SMA 16	70/100	5.9
66 – 69	AC 16	70/100	5.7

In Figure 4 and Figure 5 the results from samples 1-20 (AC 11 from Trondheim airport, Værnes) and 21-25 (AC 16 from E6 at Klemetsrud in Oslo) are given. As can be seen samples 1-20 show some variations, while the results from samples 21-25 are more even.

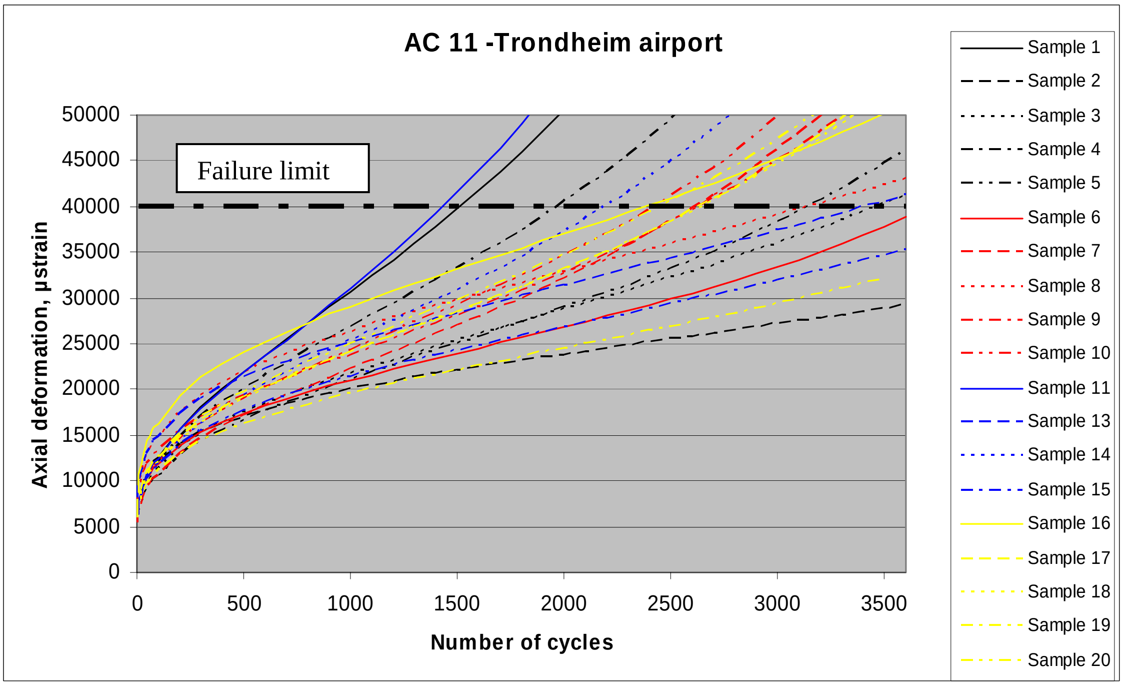

Figure 4: Deformation properties, AC 11 samples from Trondheim airport, Værnes

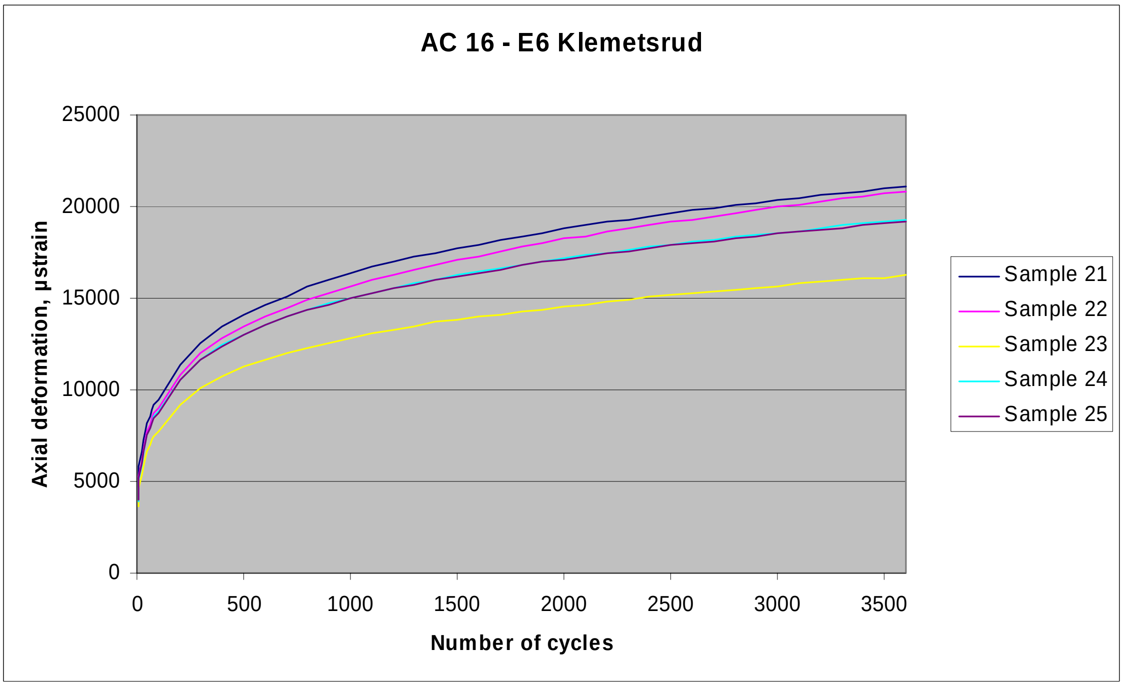

Figure 5: Deformation properties, AC 16 samples from E6 at Klemetsrud, Oslo

Mean values from all asphalt mixes are shown in Figure 6. As can be seen there are great differences in the deformation properties. The differences between the two AC 16-mixes may look surprising. The two mixes have same binder stiffness (70/100) but as shown in Table 4 different binder content (5.1 % vs. 5.7 %).

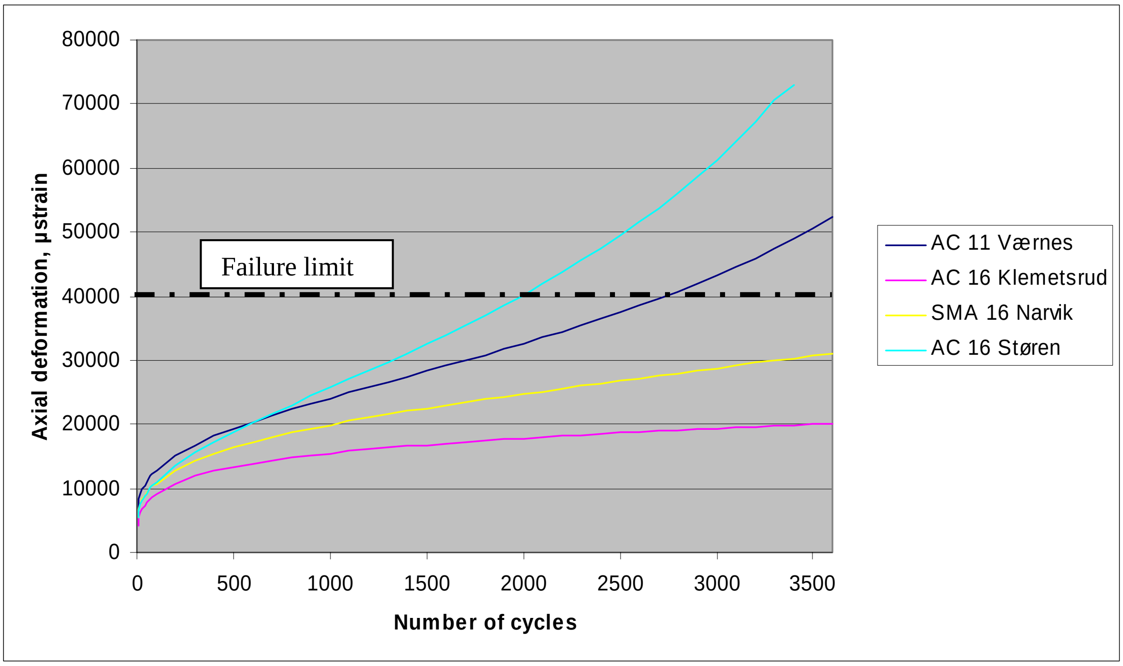

Figure 6: Mean values from measuring deformation properties

4.4 Factors affecting the deformation properties

Obviously, some asphalt sample parameters may also influence on the deformation properties. Extraction and recovery of binder were conducted on a selection of samples from each asphalt mixture. The deformation properties were then compared to the void content and the penetration value of recovered binder. The results from the extraction and testing of recovered binder are given in Table 5.

Table 5: Results from extraction and testing of recovered binder

Sample	**Asphalt mixture**	**Binder class**	**Recovered binder**		**Binder content (%)**	
			Pen. (1/10 mm)	**Softening Point (°C)**	**Planned**	**Measured**
2	AC 11	160/220	132	41	5.5	*)
6	AC 11	160/220	120	42	5.5	*)
11	AC 11	160/220	109	43	5.5	*)
13	AC 11	160/220	130	41	5.5	5.7
16	AC 11	160/220	112	43	5.5	5.5
21	AC 16	70/100	52	51	5.1	5.0
22	AC 16	70/100	49	51	5.1	4.7
31	SMA 16	70/100	67	48	5.9	6.5
32	SMA 16	70/100	61	48	5.9	6.3
34	SMA 16	70/100	61	49	5.9	6.2
67	AC 16	70/100	72	46	5.7	5.5
68	AC 16	70/100	89	45	5.7	5.6

*) The binder content is not calculated.

Void content vs. deformation properties for samples 1-20 (AC 11 from Trondheim airport, Værnes) are shown in Figure 7. There is a tendency towards increasing axial deformation with increasing void content.

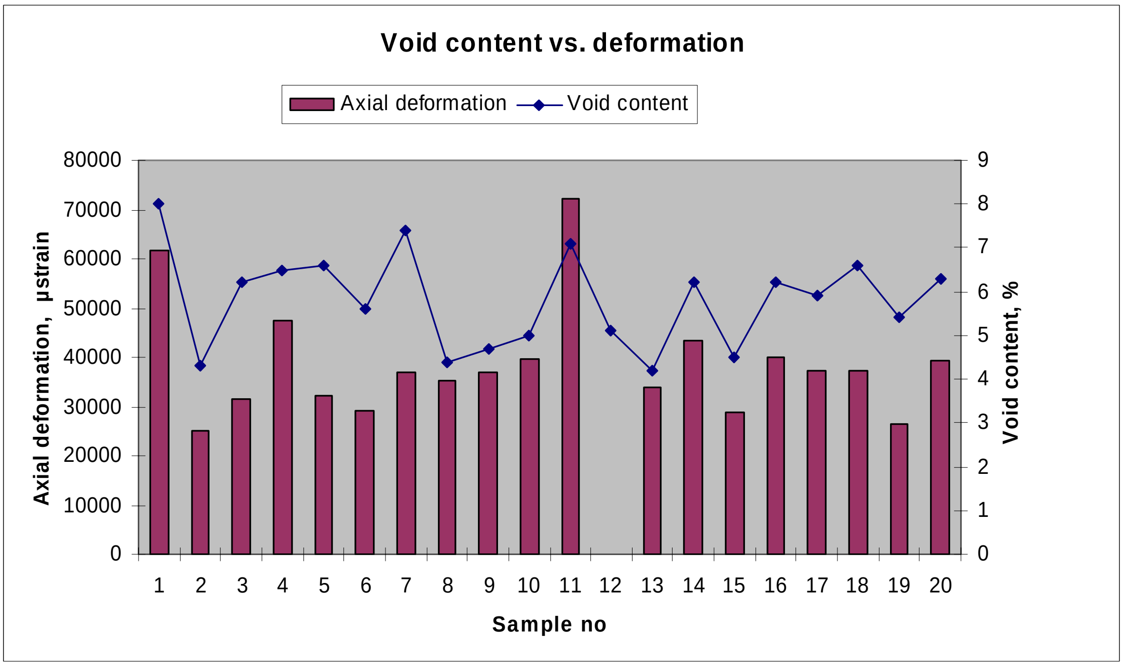

Figure 7: Axial deformation compared with void content (samples 1-20, AC 11 from Trondheim airport, Værnes)

In Figure 8 penetration values for recovered binders are compared with deformation properties. There is no obvious connection between penetration value and deformation properties. This is due to the fact that also other factors influence on both stiffness and deformation properties, for instance material grading and material shape (crushed vs. gravel material).

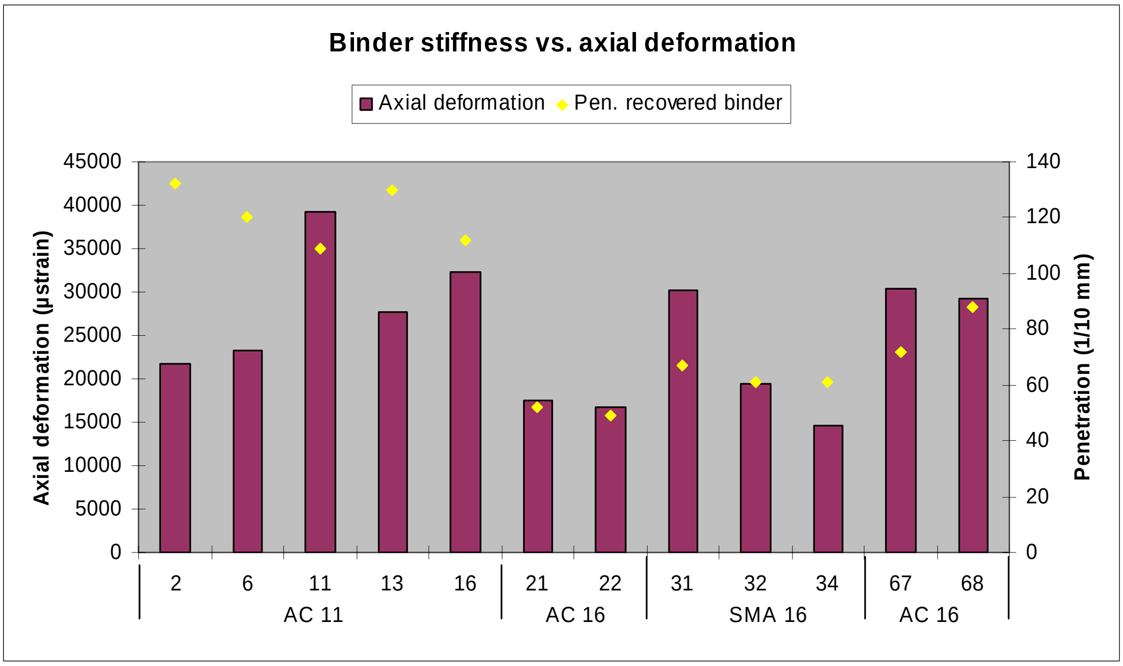

Figure 8: Axial deformation compared with penetration value for recovered binder

5 CONCLUSIONS

Core samples from different Norwegian asphalt pavements in field have been investigated regarding stiffness and deformation properties
Main conclusions from the investigations are:

- Careful and precise work is very important when taking test samples from field for scientific investigations, otherwise samples can easily be destroyed
- Asphalt pavements in Norway are often very thin. This makes it difficult to take samples from field that satisfy standardised geometrical requirements. Relevant adjustments could be:
    - Thicker pavement on a limited area for sampling purposes.
    - Testing of stacked samples (especially for measuring deformation properties).
    - Use of other test methods.
- The indirect tensile stiffness modulus test seems to give a reasonable ranking of the materials, and seems appropriate to be included in a performance based specification system. Some comments to the test:
    - The test is quickly run and easy to perform.
    - Variations between parallel samples in the same series are acceptable.
    - Increasing stiffness modulus when decreasing void content (tendency).
    - The connection between binder stiffness and stiffness modulus for the asphalt mixture is clearly revealed by this test.
- The indentation repeated load axial deformation test has more scattered results within the same series. Other comments to the test:
    - Same type of asphalt mixture taken from different locations show varying deformation properties. This verifies other investigations, common/simple laboratory equipment, without confinement, have problems with ranking asphalt mixtures with different aggregates (Nunn et al. 1999).

- Decreasing deformation properties when increasing void content (tendency).
- Question could be raised whether the test method has to be adjusted/improved or if another test method could be more suitable for measuring the deformation resistance.

The results from these investigations have given useful experience regarding the material properties of different asphalt mixes. The fact that different mixes of the same type obtain substantially different deformation properties indicates that there can be great potentials for improvements for many pavements in Norway. However, further laboratory testing on field samples has to be conducted before specifications based on these methods can be established.

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