Use of Polymer Modified Binders to develop more Lasting Pavements for Nordic Conditions

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ABSTRACT: Rutting is a major problem on asphalt pavements in Norway. This is partly because of wear from studded winter tires and partly because of deformations from growing traffic with increasing tire pressures and heavy axle loads. This development in traffic together with more severe Nordic climatic influences now calls for innovative pavement solutions. To meet these growing traffic and climatic challenges, we have to obtain pavements with both improved cracking and deformation resistance (flexibility and stability). Therefore there is now more focus on polymer modified binders (PMB).
A number of Norwegian asphalt pavements with PMB from the last years are now closely monitored to evaluate the long term field performance. On some of these sections, extensive laboratory investigations have been conducted related to both wear resistance (Prall testing) and deformation properties (Dynamic creep test/Nottingham Asphalt Tester (NAT) and Wheel Track). The paper presents the recent results from these studies, comparing field and laboratory data. The main objective is to learn in what way PMBs can be a practical and economical tool for obtaining longer lasting pavements in Norway.

KEY WORDS: Asphalt pavement, pavement wear, deformation, polymer modified binders.

1 INTRODUCTION

In Norway rutting of asphalt pavements is a major problem. The air temperature can vary between -40 °C in winter to +35 °C in summer. The summer pavement temperature can be at the level of 50 – 60 °C. At winter time the major part of the vehicles are using studded tires. The rutting in the asphalt pavements is partly due to wear from these studded winter tires and partly deformations from heavy axle loads. To meet these growing traffic and climatic challenges, we have to obtain pavements with both improved cracking and deformation resistance.

The Norwegian Public Roads Administration (NPRA) is focusing on the use of polymer modified binders (PMB) to obtain long lasting pavements with regard to wear and deformation. A number of Norwegian asphalt pavements with PMB from the last years are now closely monitored to evaluate the long term field performance. The program will continue in the years to come, with different test sections and types of mixes. One goal with this investigation is to develop performance-based specifications according to the new European standards. This means that the deformation properties have to be documented using the wheel-track and the wear resistance has to be documented using the Prall apparatus. Basic work on this field was carried out in the Norwegian research project PROKAS, in the period 1998 – 2004 (Lerfald et al. 2004). In 2007 a test section was established at the main road E18. Four asphalt mixes, two with PMB and two with unmodified bitumen pen 70/100, will be tried out at this site. In 2008 six test sections were established, three at the main road E18 and three at Rv 282. In these sections one asphalt mixture was produced with unmodified bitumen pen 70/100, while the rest was produced with PMB. All sections are located in the southern part of Norway.

2 MATERIALS AND TESTING

2.1 Asphalt mixes

In test section established in 2007, four different asphalt mixes have been analyzed. The mixes were Asphalt Concrete (AC) and Stone Mastic Asphalt (SMA), both with maximum aggregate size of 11 mm. Both types of mixes were produced with PMB and B 70/100, as shown in table 1.

Table 1: Information of asphalt mixes on test sections established in 2007.

Asphalt mixture	*Type of binder*	*Binder content, (%)*
SMA 11	B 70/100	5,80
SMA 11	PMB	5,80
AC 11	B 70/100	5,70
AC 11	PMB	5,70

The test sections established in 2008 consist of three pavements at Rv 282 and three pavements at E18, all with Asphalt Concrete (AC). In the test sections at Rv 282 the same type of aggregate is used, all with maximum aggregate size of 11 mm, and the type of binders used are 70/100 and two types of PMB. The test sections at E18 consist of two mixes with maximum aggregate size of 16 mm and one with maximum aggregate size of 11 mm, all with PMB. Information of test sections established in 2008 is given in table 2.

Table 2: Information of asphalt mixes on test sections established in 2008.

Asphalt mixture	*Location (Road-section number)*	*Type of binder*	*Binder content, (%)*
AC 11	Rv 282-1	B 70/100	5,70
AC 11	Rv 282-2	PMB	5,70
AC 11	Rv 282-3	PMB	5,70
AC 11	E 18-1	PMB	5,60
AC 16	E 18-2	PMB	5,30
AC 16	E 18-3	PMB	5,50

Both cored samples from field and laboratory produced samples from each mix have been tested. The laboratory samples were produced from asphalt mixes taken from the truck just before laying.

2.2 Test methods

The specimens were tested in the Prall apparatus with regard to resistance to studded tire wear. The Prall test is described by EN 12697-16, “Bituminous mixtures - Test methods for hot mix asphalt - Part 16: Abrasion by studded tyres”.

The Prall value is expressed as:

$$S = (m_1 - m_2) / \gamma \qquad (1)$$

where:

S = Prall value (wear), cm^3
m_1 = weight of sample before testing, g
m_2 = weight of sample after testing, g
γ = bulk density of sample, g/cm^3

The principle of the test method is that a cylindrical specimen, having a diameter of 100 mm and a height of 30 mm, is worn by abrasive action during 15 min by 40 steel spheres. The test temperature is 5 °C. A sketch of the Prall apparatus is shown in figure 1.

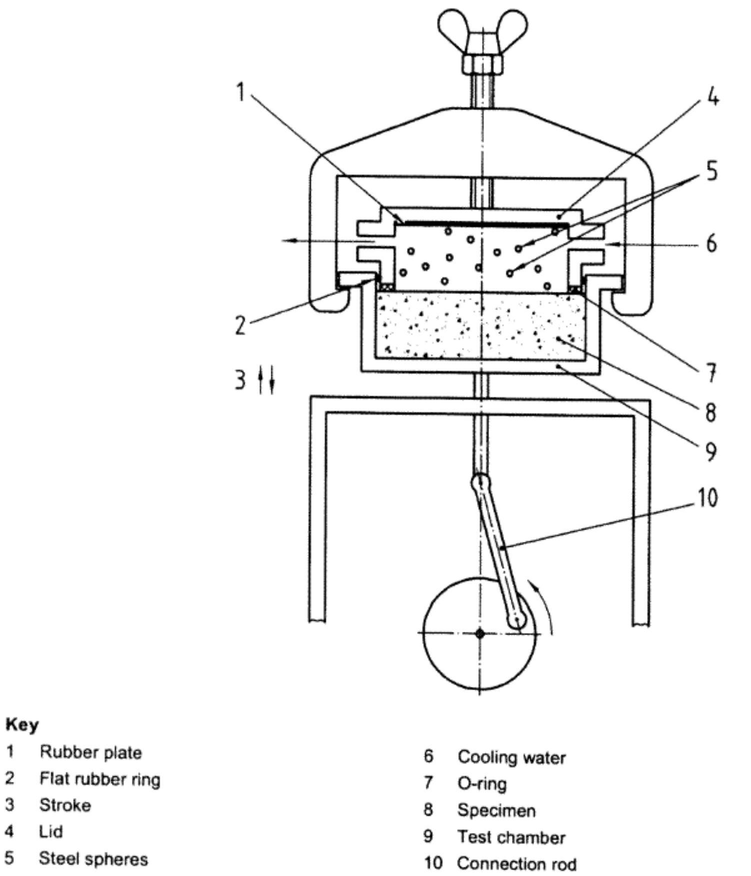

Figure 1: Prall apparatus, principal sketch/cross section (EN 12697-16)

The deformation properties were tested using the wheel-track apparatus and the Nottingham Asphalt Tester (NAT). The NAT is relevant for use in production control, and it is therefore of interest to evaluate the correlation between the NAT and the wheel-track.

The NAT test is described by EN 12697-25, “Bituminous mixtures - Test methods for hot mix asphalt - Part 25: Cyclic compression test, Test method A – Uniaxial cyclic compression test with confinement". The wheel track is described by EN 12697-22, "Bituminous mixtures - Test methods for hot mix asphalt - Part 25: Wheel tracking". In this study small size device, procedure B, is used. The specimens are tested in air at 40 °C and 50 °C.

The Proportional Rut Depth, PRD is calculated as:

$$PRD_{AIR} = (d_N/specimen\ thickness\ (mm)) * 100 \tag{2}$$

where:

PRD_{AIR} is the proportional rut depth at N cycles

d_N is the rut depth after N cycles (N is in this project 10 000)

The laboratory produced wheel track samples are produced using roller compactor according to EN 12697-33, "Bituminous mixtures - Test methods for hot mix asphalt - Part 33: Specimen prepared by roller compactor". The laboratory produced samples tested in NAT and Prall are produced according to method 14.5533 in handbook 014 Laboratory Tests (Norwegian Public Roads Administration Manual, 2005).

3 RESULTS AND DISCUSSION

This section presents the main results from the laboratory testing of the asphalt mixes.

3.1 Results from testing of deformation properties in Wheel-track.

The results from testing field samples at 50 ºC are shown in figure 2 and figure 3 for test sections established in 2007 and 2008 respectively, while figure 4 and figure 5 shows the results from testing laboratory compacted samples at 50 ºC.

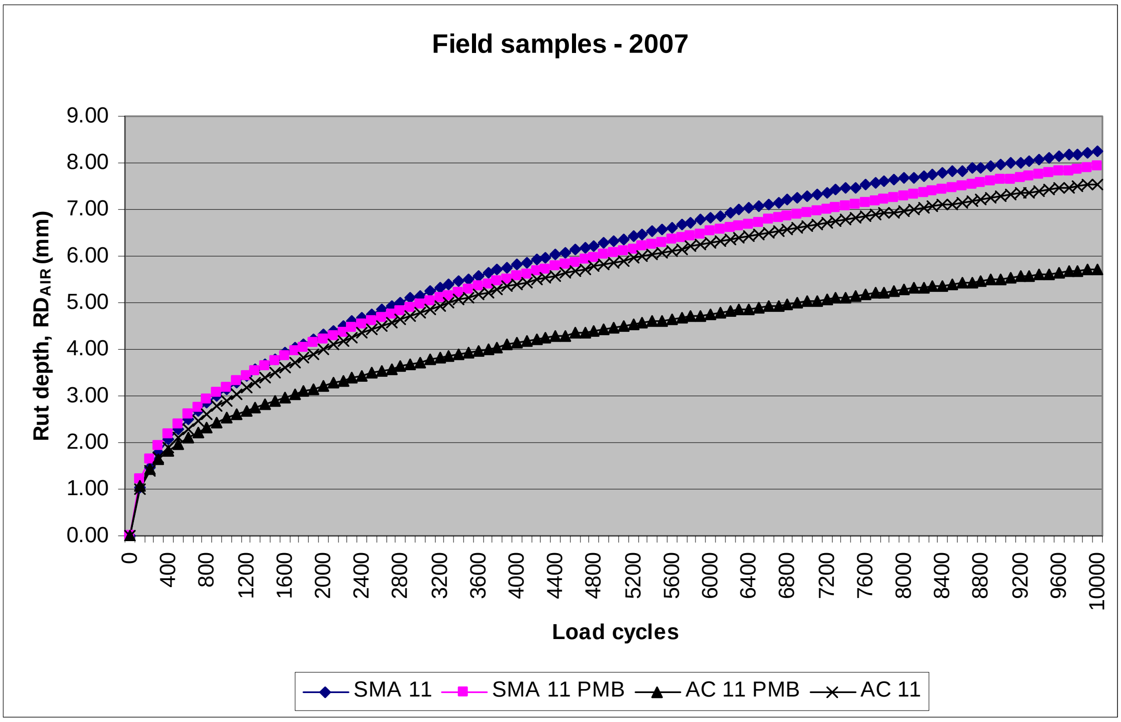

Figure 2: Deformation of field samples in wheel track from test section established in 2007 (Test temperature 50 ºC).

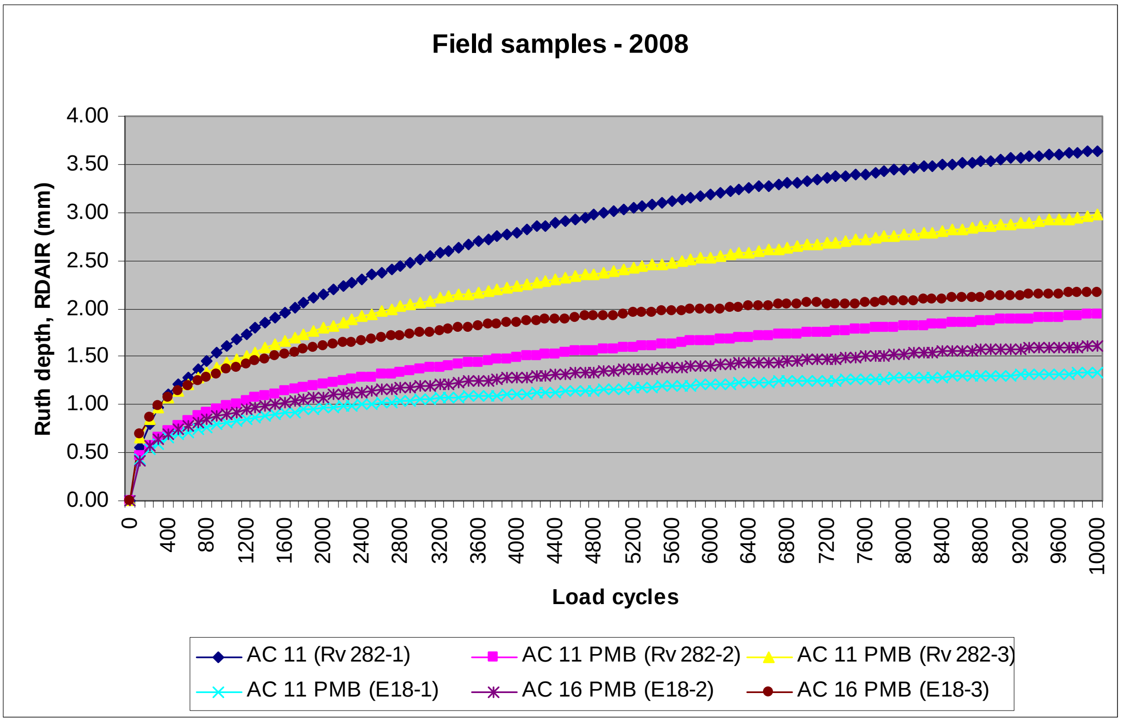

Figure 3: Deformation of field samples in wheel track from test sections established in 2008 (Test temperature 50 ºC).

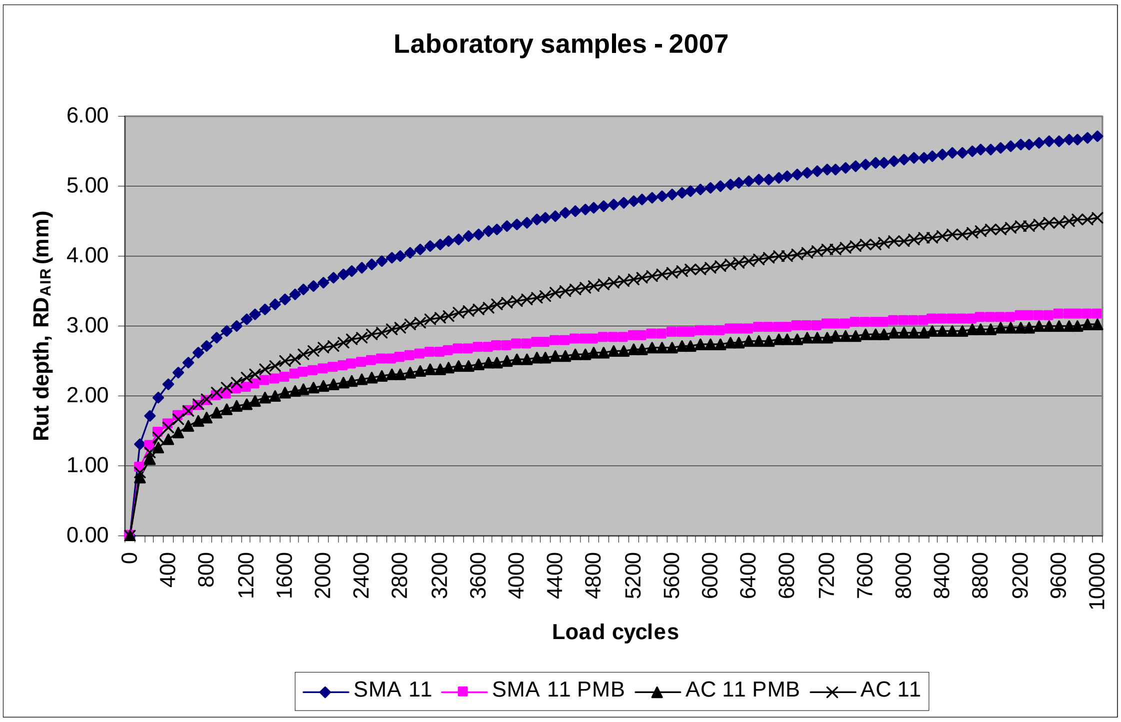

Figure 4: Deformation of laboratory samples from test section established in 2007 (Test temperature 50 ºC).

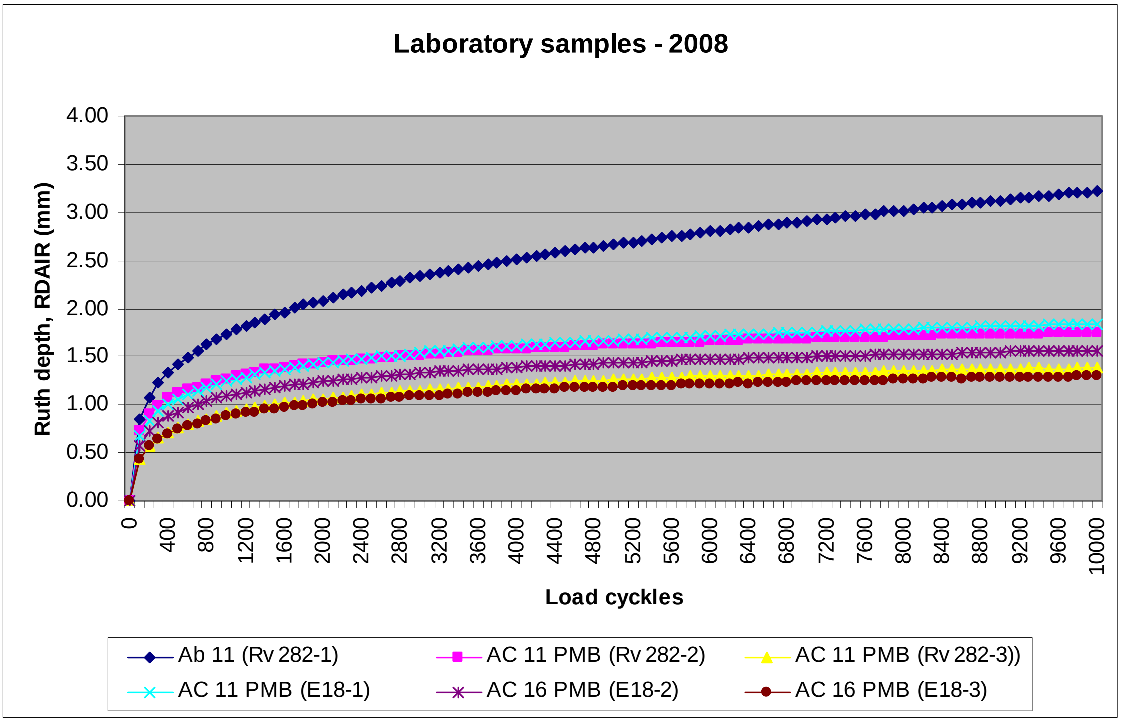

Figure 5: Deformation of laboratory samples from test sections established in 2008 (Test temperature 50 ºC)..

The results presented in figures 2-5 show that the deformation properties are improved when using polymer modified binders. The deformation properties for laboratory compacted samples are better than the deformation properties of the core samples from field. Figure 6 shows a comparison between asphalt mixes with B 70/100 and asphalt mixes containing PMB, expressed as deformation ratio for asphalt mixes from test sections established in 2007.

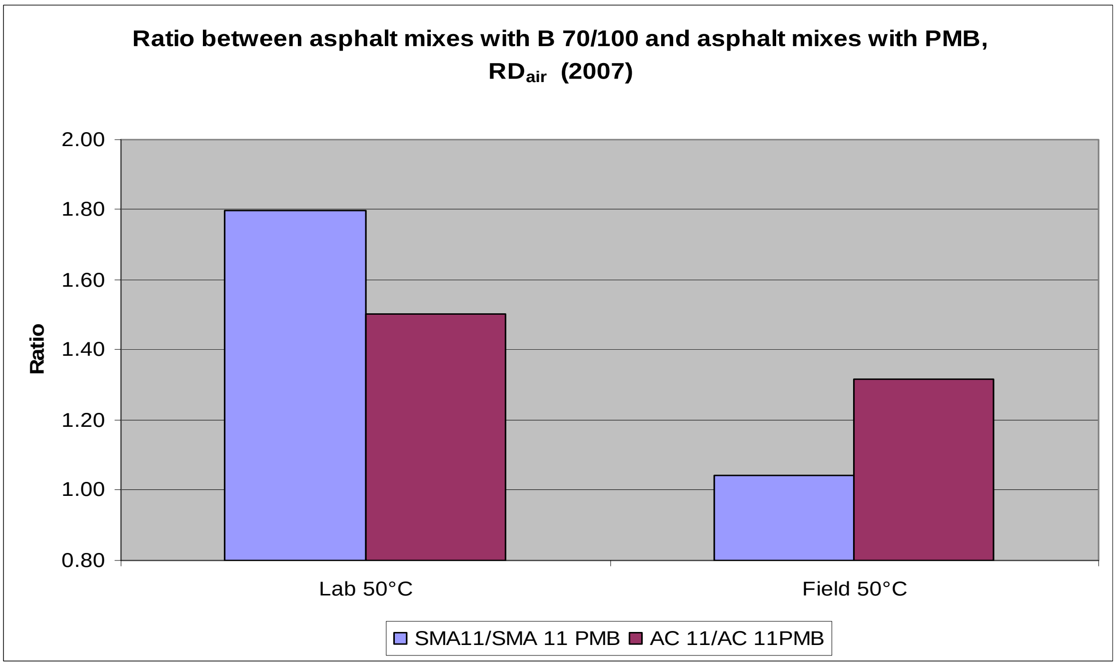

Figure 6: The ratio between asphalt mixes with B 70/100 compared with asphalt mixes with PMB with regard to deformation properties - test section established in 2007.

3.2 Results from testing of deformation properties in NAT

There are tested both laboratory compacted samples and core samples from field. The results from testing field samples in NAT are shown in figure 7 and figure 8, for samples from test sections established in 2007 and 2008 respectively.

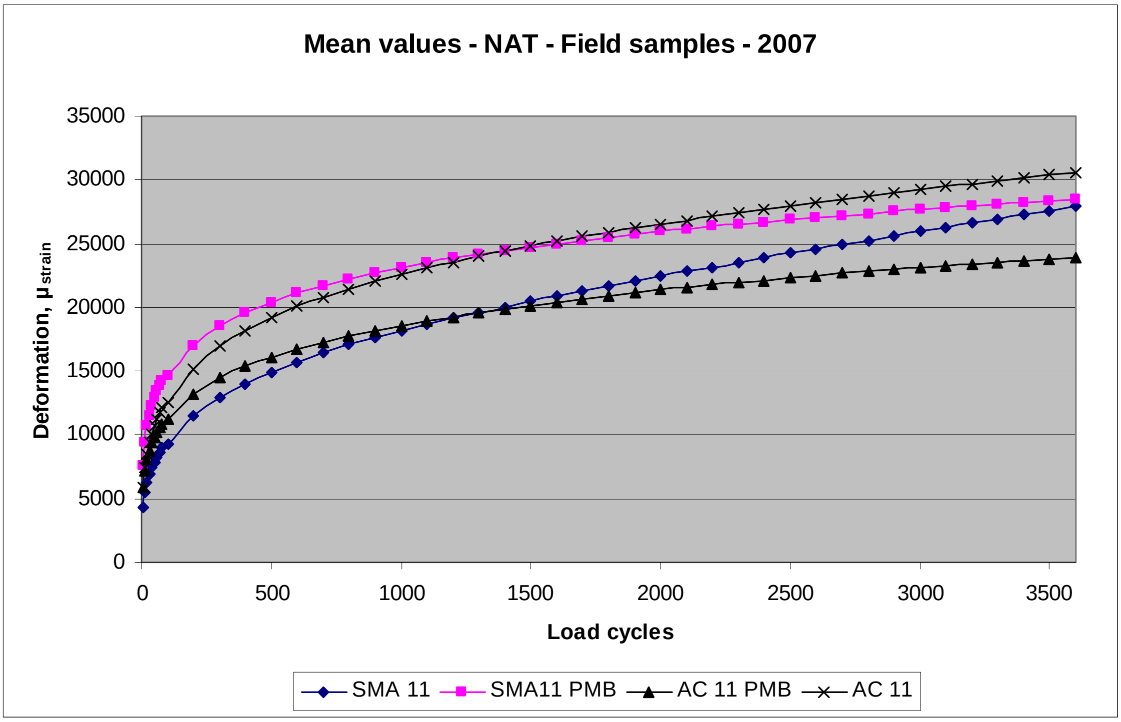

Figure 7: Mean values – NAT – Field samples – test sections established in 2007.

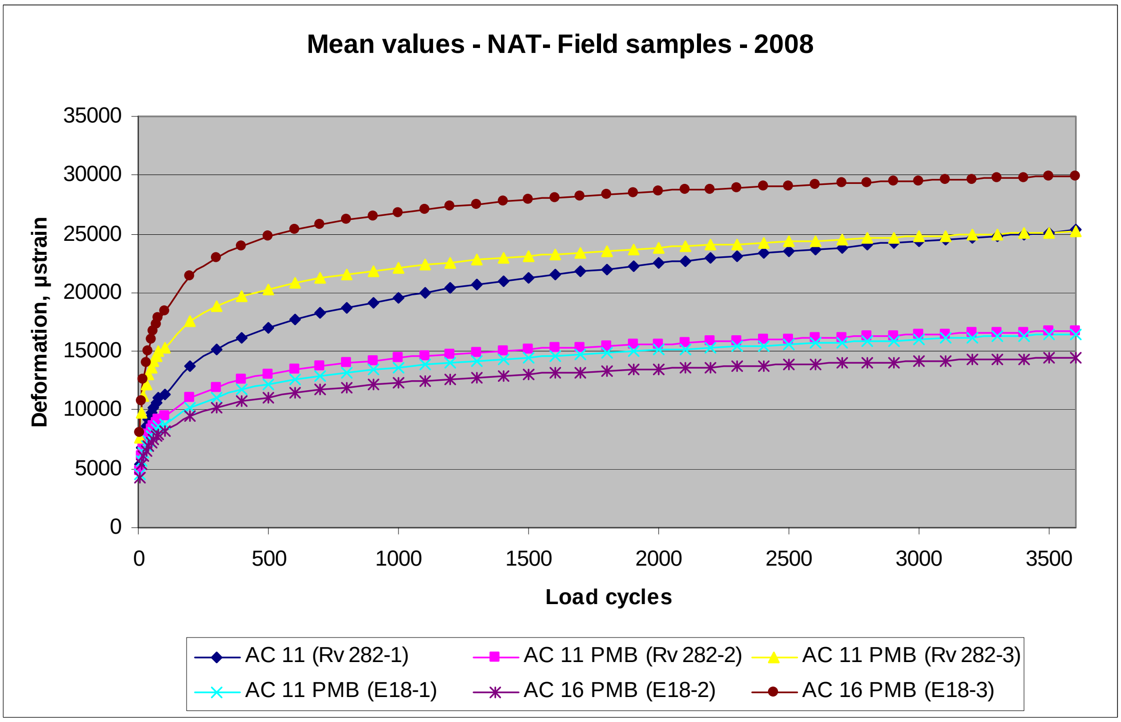

Figure 8: Mean values – NAT – Field samples – test sections established in 2008.

It is expected that the asphalt mixtures with PMB have better deformation properties than the asphalt mixtures with conventional binder. The results shown in figure 7 indicate that there are only minor effects of the modification for the SMA. The results in figure 8 are as expected. When considering use of different types of asphalt mixes it is important to have test methods where analyzing laboratory samples correlate with testing of the same mix on core samples from field. In figure 9 the correlation between laboratory and field samples are shown for all samples from the test sections established in 2007 and 2008. As could be seen in Figure 9 the ratio vary between 2.5 and 5.5.

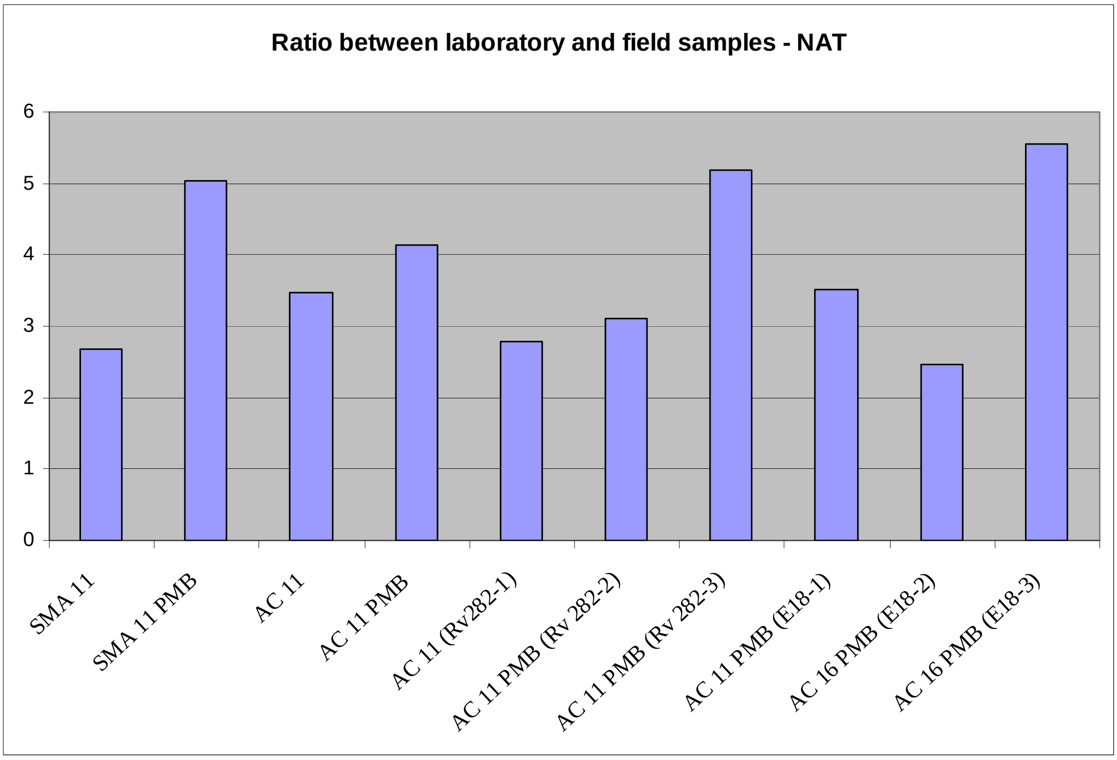

Figure 9: NAT – The ratio between the NAT results on laboratory and field samples.

3.3 Results from testing of wear resistance properties in Prall

The results after testing laboratory and field samples with regard to wear resistance are shown in figure 10. Figure 10 shows that the wear resistance is improved for asphalt mixes containing PMB compared with asphalt mixes containing B 70/100 (result from asphalt mixes from test sections established in 2007). Laboratory samples have better wear resistance properties than the field samples for all mixes.

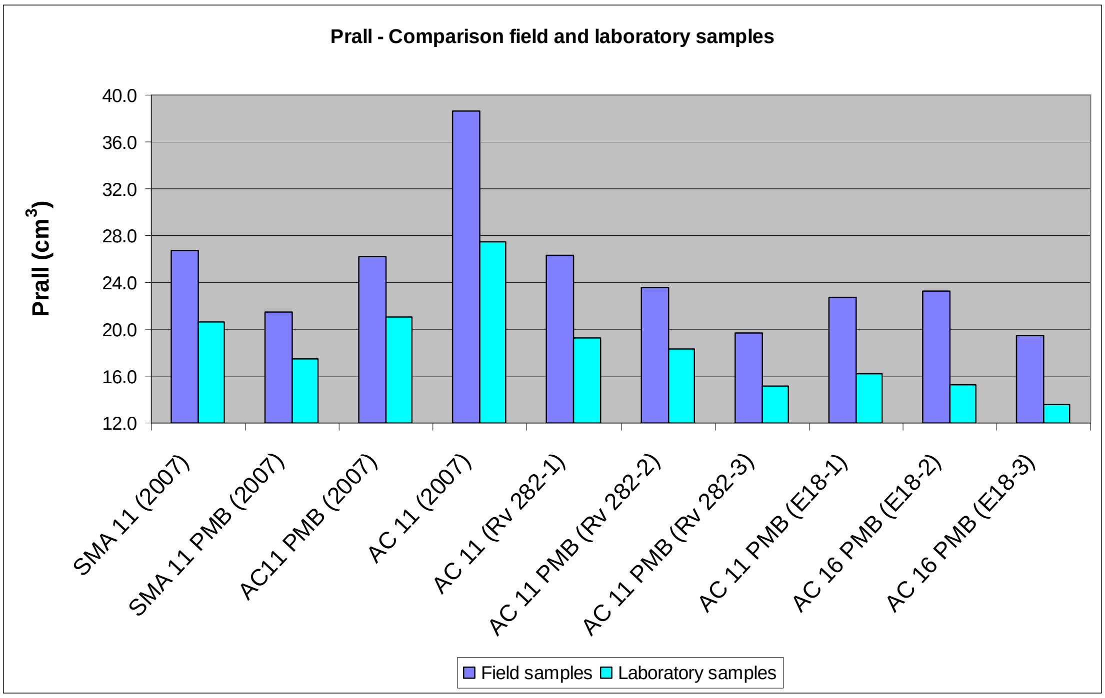

Figure 10: Prall values – comparison of laboratory compacted samples and field samples.

3.4 Comparison of results from wheel-track and NAT

The results obtained from wheel-track and NAT-testings of asphalt mixes from test sections established in 2007 have been compared. This is due to the fact that requirements for deformation properties of the asphalt mixtures will be based on the European standards. There wheel-track is the chosen test for declaration, while NAT is a possible test for production control. In figure 11 the correlation between the two methods is shown for laboratory compacted samples. The correlation for field samples is shown in figure 12.

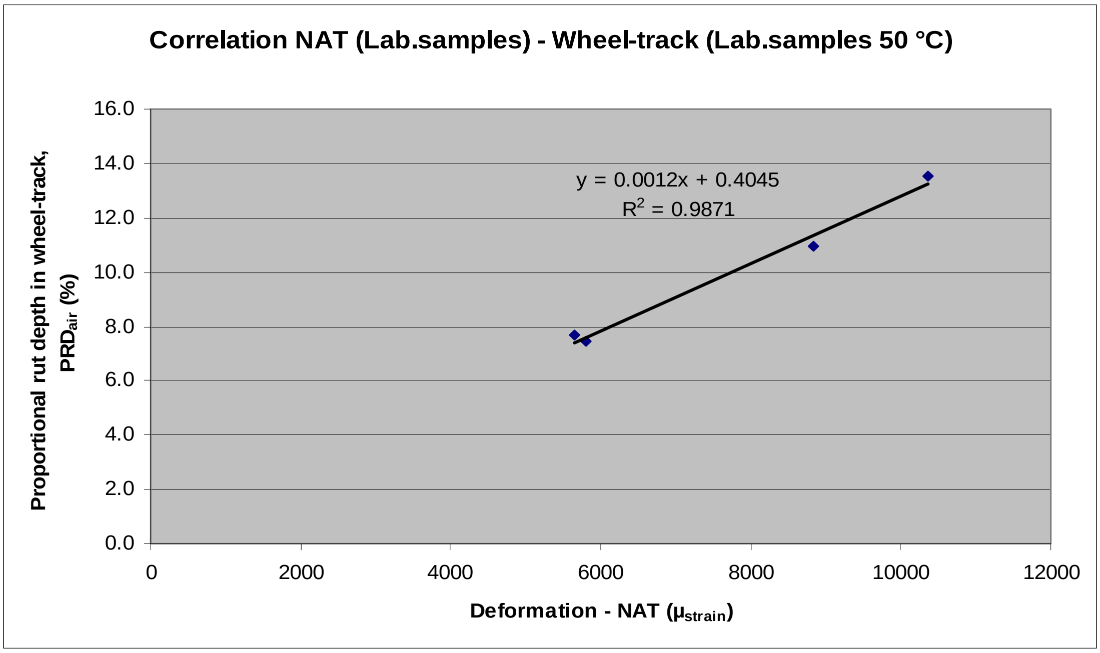

Figure 11: Correlation between results from wheel track and NAT results.

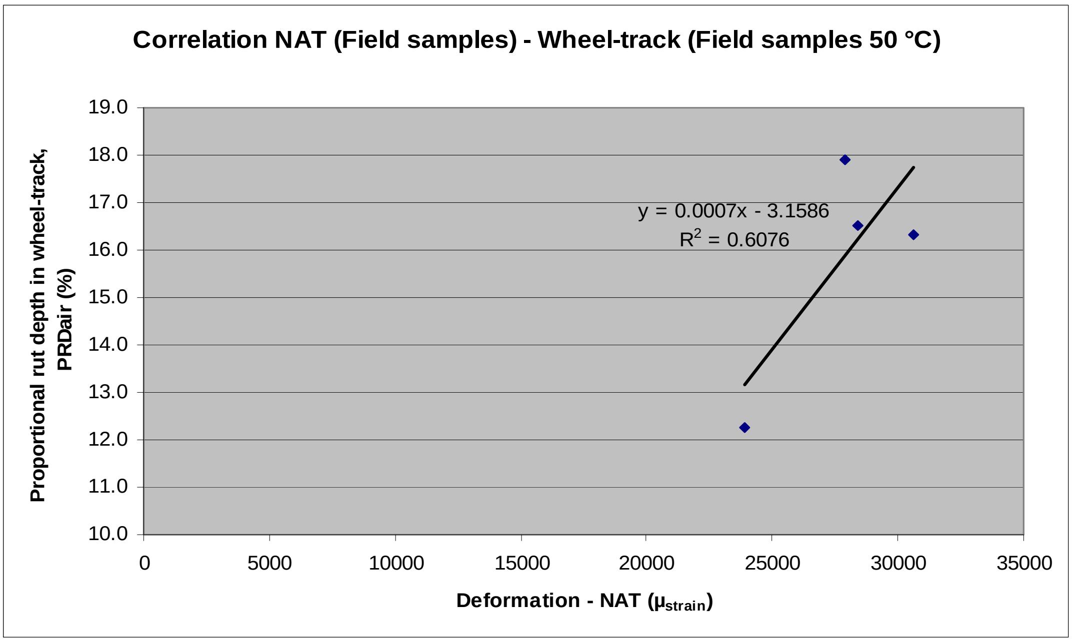

Figure 12: Correlation between results from wheel track and NAT results (field samples).

As can be seen from figure 11, there is good correlation between NAT and wheel track for laboratory samples, while the correlation for field samples is considerably poorer, as shown in figure 12.

4 CONCLUSIONS

In this project the deformation properties and wear resistance properties of 10 asphalt mixes have been measured using wheel track, Nottingham Asphalt Tester (NAT) and Prall-apparatus. The findings can be summarized as follows:

- The results indicate that use of polymer modified binders improves both the deformation resistance and the wear resistances of asphalt mixes, compared with asphalt mixes containing ordinary bitumen.
- Generally, laboratory compacted samples have better deformation and wear resistance compared with cored samples from field.
- The results shows good correlation between wheel track and NAT for laboratory compacted samples.
- The results show poor correlation between wheel-track and NAT for core samples from field.

The results presented in this paper is based on a limited investigation, and further test sections and types of mixes will be followed up in the years to come. Especially it will be studied the type of PMB and also how the filler-bitumen mix affect the deformation and wear resistance properties of an asphalt mixture.

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