Quality assessment of Norwegian field trials with Warm Mix Asphalt

T. Jørgensen
Norwegian Public Roads Administration, Oslo, Norway

R. Telle & R. Bragstad
Road Technology Institute, Høvik, Norway

ABSTRACT: Eleven test sections with Warm Mix Asphalt (WMA) were constructed in four Norwegian regions in 2011. WMA is produced and laid at lower temperature than traditional asphalt concrete due to a modified mix technique or use of a temperature reducing additive. The aim of the project was to document that WMA's are of same level of quality as ordinary hot mix asphalt.

The test roads sections were 1020 m in average. The trial WMA and the corresponding reference asphalt were laid in parallel lanes. Average daily traffic (ADT) of the test sections were 650 to 9000.

Six WMA techniques were applied and surveyed:

- WAM-foam
- LMK-foam
- Green asphalt (foaming and adding recycled asphalt)
- Rediset WMX (chemical additive)
- Cecabase RT (chemical additive)
- Sasobit (organic additive).

Same aggregates and gradation was used in the WMA and in the reference asphalt. The WMA-trial mixes were documented by binder testing, Marshall density, adhesion and wheel-track rutting.

In the field trials, temperature reductions of 20 to 39 °C were achieved with the WMA techniques. The WMA quality was assessed by measuring void content and wheel-tracking rutting on drilled cores from the newly laid pavement. The initial rutting and IRI-evenness of the test sections were measured with a mobile laser pavement profile scanner. The development of rutting and IRI-evenness will be measured annually. Due to differences between asphalt mixes, traffic volumes and local climates, emphasis was laid on the relative performance of the WMA and reference on each test section. There were no significant difference in quality between the new-laid WMA's and the reference asphalts. The long term performance of the test sections will be followed up.

KEY WORDS: Warm Mix Asphalt, field trials, rutting, IRI-evenness, asphalt quality, additive, foaming technique.

1 INTRODUCTION

In recent years developments in asphalt technology have made it possible to produce asphalt pavements at temperatures about 30 °C lower than traditional Hot Mix Asphalt (HMA) by the use of chemical additives or by the use of foamed bitumen in the asphalt plant. For some techniques even a greater temperature reduction can be achieved.

As a rule of thumb, a decrease in asphalt temperature of 10 °C reduces the asphalt fumes by 50 % (EAPA, 2005). A lowered asphalt production temperature will also give reduced consumption of fossil fuels and less CO_2-emissions. It is assumed that this temperature reduction is not leading to reduced asphalt quality.

To prove that this technology is ready to be used in large extent in Norway, FAV (Norwegian Asphalt and Road Contracting Association) started the project «LTA2011» with support from NHO (The Confederation of Norwegian Enterprises). Five asphalt contractors contributed with a total of eleven trial sections (Bragstad R., Telle R., 2012).

2 WMA TECHNIQUES

Warm Mix Asphalt may be produced using additives or by foaming the binder. In the LTA2011-project the following WMA-techniques were used (contractor company in brackets):

Additives

- <u>Cecabase RT (Nordasfalt and Lemminkäinen)</u>
  Surfactant which allows lowering of production temperature up to 40 °C.
  Cecabase RT is also a adhesion promoter. Dosage: 0,2 to 0,5 mass % of the binder.
- <u>Rediset WMX (Veidekke)</u>
  Allows lowering of the production temperature up to 40 °C
  Rediset contains wax and will improve the resistance to permanent deformation. Pellets are added to the bitumen tank. Stirring is necessary to ensure complete dissolution in the binder. Acts as an adhesion promoter. Dosage: 1 to 2 mass % of the binder.
- <u>Sasobit (Oslo Vei)</u>
  Fischer-Tropsch wax (synthesized) that allows lowering of production temperature up to 30 °C. Sasobit also improves the resistance to permanent deformation. In this trial a softer bitumen grade was used to attain the same deformation resistance as the reference bitumen. Dosage: 3 mass % of the binder. The bitumen and wax pellets were premixed before use. Anti-strip agent (amine) was used in WMA and reference asphalt.

Modified asphalt plant, use of foamed bitumen

- <u>WAM-foam (Veidekke)</u>
  Allows lowering production temperature up to 45 °C. The aggregate is mixed with a soft bitumen grade before a harder bitumen grade is foamed into the mix. The final binder grade of the mix is controlled by the relative content of soft and hard bitumen.
- <u>Green Asphalt (NCC)</u>
  Allows lowering of production temperature up to 40 °C. The binder is added to the aggregate without filler and mixed briefly before filler is added. Addition of RAP (asphalt granulate from reclaimed asphalt pavement) is used to lower the temperature of the mix. Amine is added to the bitumen.
- <u>LMK foam (Lemminkäinen)</u>
  Allows lowering of production temperature up to 40 °C. The binder is foamed into the mix, otherwise as conventional mixing. Amine is added to the bitumen.

3 2011 FIELD TRIALS

3.1 Basis for the quality assessment of WMA

The LTA2011 project provided that the WMA and the reference HMA pavements having identical composition with respect of aggregates, grading curve and binder content, will meet the same requirements and have the same life span when they are laid out in similar conditions and compacted to the same void content. It was assumed that the reference asphalt concrete is the right choice for the road.

In order to confirm the presuppositions, samples of the mix were taken for control of composition and cores from the pavement were taken for control of the void content.

Due to the lower production temperature of WMA, the binder will harden less than in the reference HMA. It was assumed that this may lead to higher initial rutting for WMA than for HMA. For this reason wheel-tracking testing were done on asphalt cores taken short time after paving. Initial rutting and initial evenness were also measured.

Lower production temperature and the presence of water from foaming are factors that may lead to poorer adhesion. Therefore adhesion testing were carried out on WMA and HMA mixes.

Asphalt concretes of different composition and property were tested in different laboratories. Some of the test methods have relatively poor reproducibility. Due to this, more emphasis was laid on the differences in the field trials between the corresponding WMA and reference HMA, than between the different WMA's.

3.2 Trial sites

Table 1 shows locations of the trial sections together with traffic and climate data.

Table 1: Overview of the trial sections

LTA-section	Reference mix[1] Bitumen	WMA-mix [2]	County / Council Road number	Length, m	Traffic, AADT [3]	Max. air temp., °C	Min. air temp., °C	Annual Precipitation mm
LTA 1-1	Ab11 70/100	Rediset WMX	Akershus /Ski KV7040	767	5700	30	-30	785
LTA 1-2	Ab11 70/100	WAM	Akershus /Ski KV7040	723	5700	30	-30	785
LTA 1-3	Agb11 160/220	WAM	S-Trøndelag / Hemne EV39	900	743	26	-22	878
LTA 2-1	Agb11 160/220, 8 % RAP	Green Asphalt 8 % RAP	Møre og Romsdal / Ålesund, FV658	851	1700	26	-12	1306
LTA 2-2	Ab16 70/100, 10 % RAP	Green Asphalt 30 % RAP	V-Agder / Kristiansand RV9	955	3482	28	-22	1294
LTA 3-1	Ab11 70/100	Cecabase RT	Vestfold / Horten FV310	935	8984	28	-22	881
LTA 3-2	Ab11 160/220	Cecabase RT	Vestfold / Horten FV310	863	9000	28	-22	881
LTA 3-3	Agb11 160/220	LMK foam	Telemark / Skien FV44	1247	650	30	-26	851
LTA 3-4	Agb11 160/220	LMK foam	Telemark / Skien FV44	1822	650	30	-26	851
LTA 4-1	Ab16 70/100	Cecabase RT	Nordland / Bodø RV80	861	3300	26	-20	1023
LTA 5-1	Ab11 70/100 preheated RAP	160/220 Sasobit preheated RAP	Akershus / Høland FV115	1035	4500	30	-28	644

[1] Ab11 and Agb11 corresponds to AC11

[2)] The binder is the same as in the reference mass unless otherwise stated
[3)] Traffic volume (annual average daily traffic, AADT)

4 RESULTS

4.1 Production and laying temperatures

Table 2 shows the average production temperature and the average paving temperature given by the contractors together with paving temperatures measured by the National Institute of Occupational Health (NIOH) in connection with environmental monitoring of the paving operation. The desired temperature reduction were achieved.

Table 2: Average asphalt production and paving temperatures given by the contractors

	Reference HMA	WMA	Difference (reduction)
Stated production temperature, °C	161	130	31
Stated paving temperature, °C	156	127	29
Paving temperature measured by NIOH, °C	154	126	28

Figure 1 shows the paving temperatures for the different WMA mixes together with temperature requirements from HB018, the Norwegian manual for road construction (Statens vegvesen, 2011). Green bars are values given by the contractor and blue markers respectively represent maximum, average and minimum temperature measured with an infrared thermometer during the paving operation. Black markers show requirements for the minimum production temperature and the minimum paving temperature according to HB018.

Six of the WMA pavements have average paving temperature over the minimum paving temperature requirement for HMA. Five WMA are in the range 1 to 8 °C below the HMA minimum paving temperature requirement.

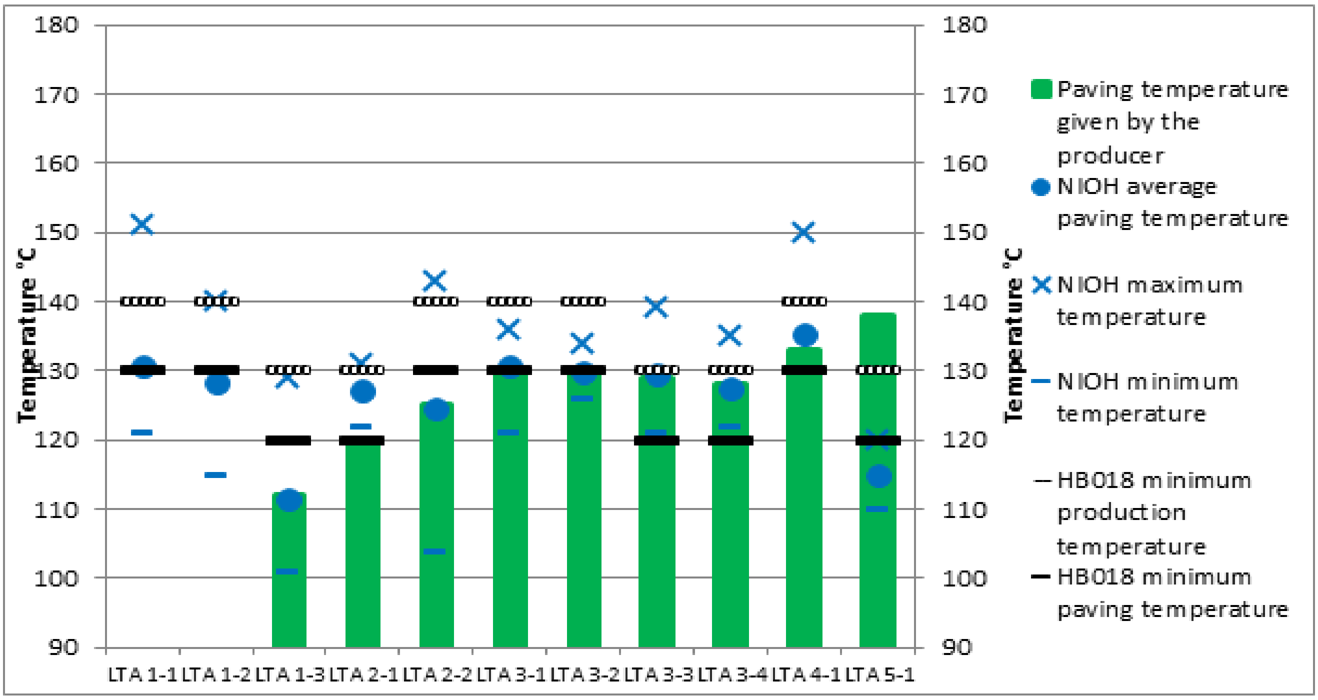

Figure 1: Paving temperatures and requirements for HMA and WMA mixes

4.2 Laboratory testing

Table 3 shows that the average void content the of the HMA reference mixes are higher than the corresponding WMA mixes, for both laboratory specimens and drilled pavement cores. For most of the corresponding pairs of WMA and HMA, the reference HMA mix has the highest void.

Figure 2 shows individual results for the pavement samples. Considering that LTA 3-3 and 3-4 are identical mixes, the results illustrates the daily variation. With the exception of trial LTA 5-1, no significant difference in void content between the reference and WMA pavements were found.

Table 3: Average void content and number of trial mixes where one type has higher void content than the other.

	Laboratory mixed samples		Cores from the road	
	Reference	WMA	Reference	WMA
Average void content, %	2.7	2.6	3.6	3.3
Mixes with higher voids	6	3	7	4

Figure 2 shows individual results for void contents in cores from the road.

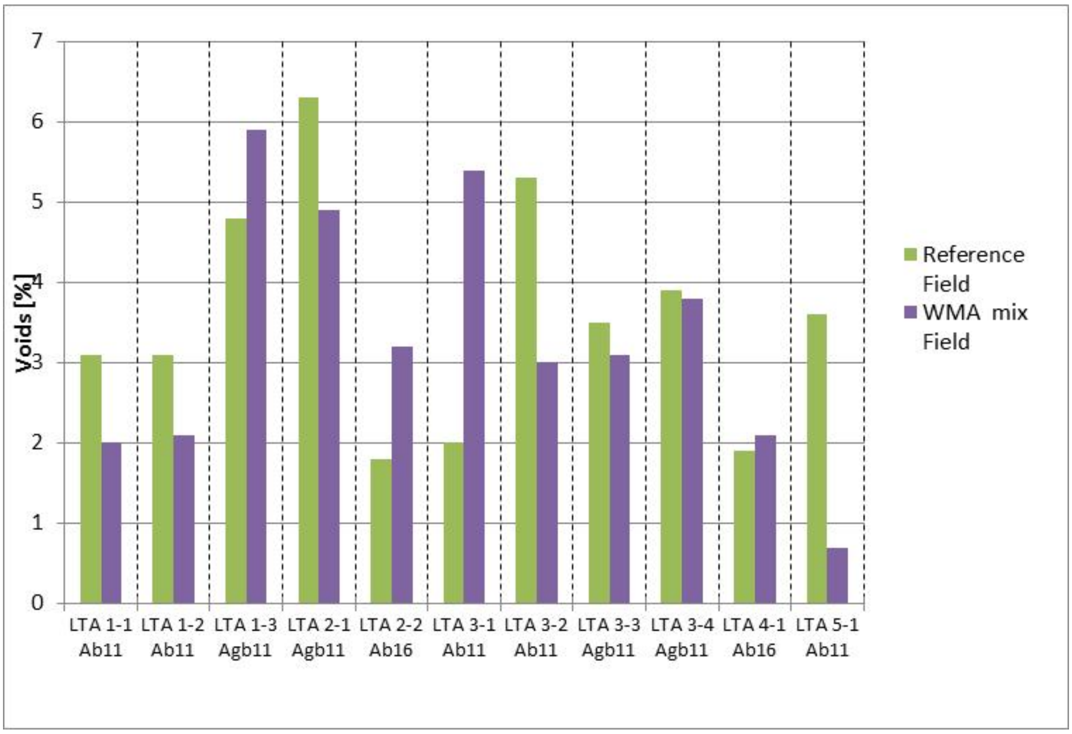

Figure 2: Void content in cores from the field trials

Figure 3 shows the results from the wheel-tracking test: % deformation relative to sample thickness after 10.000 cycles (NS-EN 12697-22). The red and blue series are results from samples prepared in the laboratory and the green and violet are cores with a diameter of 200 mm taken from the road. Sample 2-2 from the field was tested wet in Hamburg wheel-tracking test due to problems to build the samples into the wheel-tracking device for dry testing.

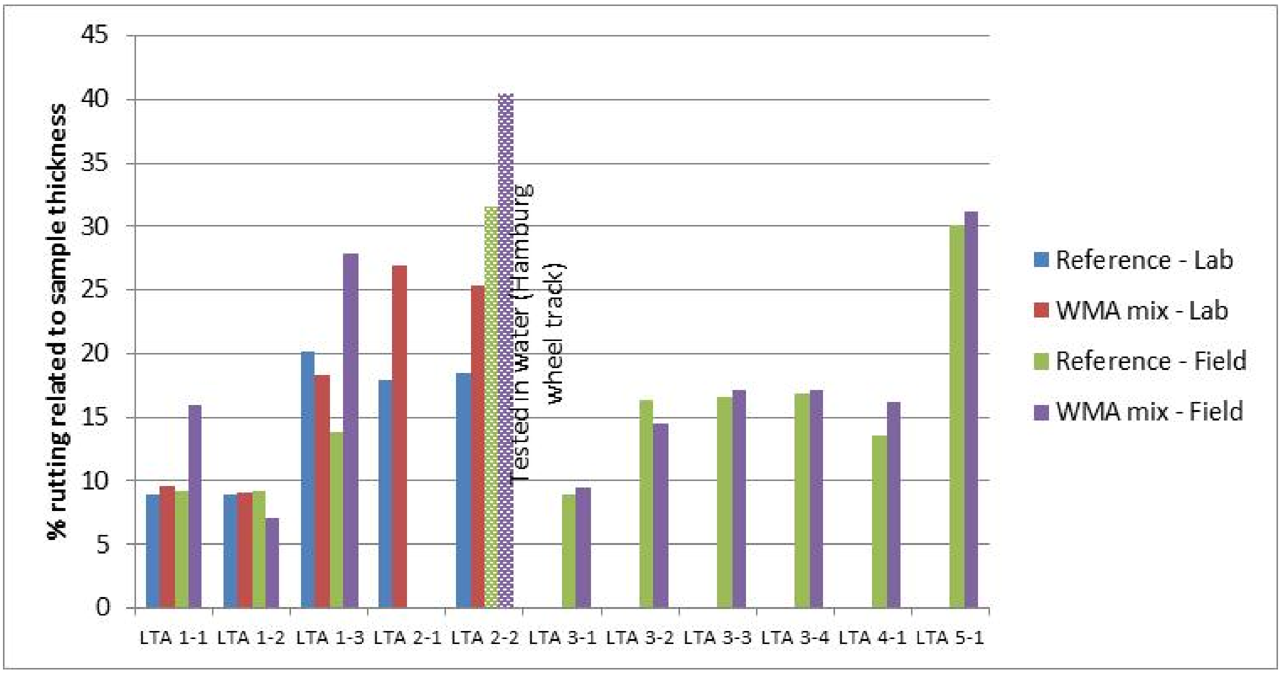

Figure 3: Wheel-tracking results of laboratory specimens and cores from field trials

Binder samples were taken from the asphalt plants and analyzed as indicated in Table 4. The applied amine and/or warm mix additive were added to the binder before testing. For foam WMA with two binder grades, binder testing was performed on recovered binder from the asphalt mix.

Table 4: Plan for binder testing

	Test metdod	Original	After RTFOT
Penetration 25 °C, 0,1 mm	NS-EN 1426	X	X
Softening point, R&B, °C	NS-EN 1427	X	X
Fraass breaking point, °C	NS-EN 12593	X	X
Change of mass ,%	NS-EN 12607-1	X	X
Flash point CoC, °C	NS-EN ISO 2592	X	X

Adhesion and water susceptibility was tested with the Rolling bottle test (NS-EN 12697-11) and Indirect tensile test, ITSR (NS-EN 12697-12).
Figure 4 shows the results from the Rolling bottle test (% coverage after 48 hours). There was no significant difference between the reference and WMA mixes.

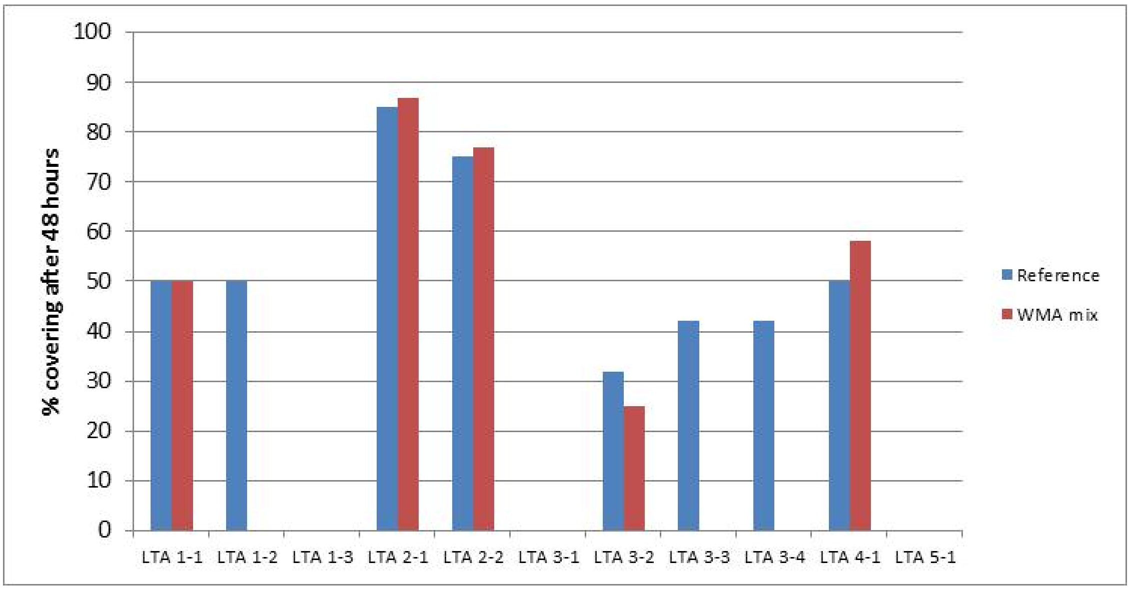

Figure 4: Results from rolling bottle test after 48 hours

Indirect tensile test (ITSR) was tested on dry and wet laboratory specimens respectively. Figure 5 shows the results. There were no significant difference in ITSR between WMA and HMA. All mixes fulfils the HB 018 minimum requirement of 0.70 on ITSR.

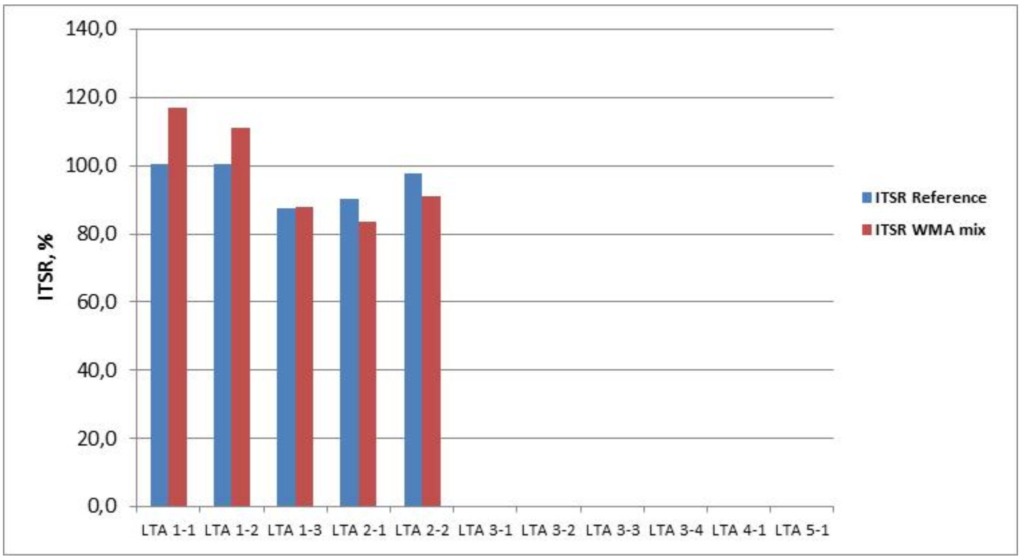

Figure 5: Adhesion test, indirect tensile strength ratio, ITSR

4.3 Initial rut depth and initial evenness (International Roughness Index, IRI)

Table 5 shows the average 90/10-values (90 percentile value) and mean values for initial rutting and evenness for WMA and reference HMA.

Figure 6 shows results for initial rutting (90/10-values). There were only minor difference in initial rutting between WMA and HMA. The difference between identical mixes, such as LTA 3-3 and 3-4 are of the same level. The results imply that there is no significant difference in initial rutting between HMA and WMA. The values were close to the maximum allowed rutting limit of 5 mm for 90/10-value. Three of the trial sections exceeded the limit.

No significant correlation between initial rutting and wheel-tracking results were found. This is likely, since wheel-tracking test measures characteristics of the mix under defined conditions, while initial rutting depends on factors associated with the paving operation and the time before traffic is put on.

Table 5: Initial rutting and initial evenness and number of trial sections with higher initial rutting either for WMA or referance HMA.

	Initial rutting [mm]				Initial evenness, IRI [mm/m]			
	90/10		Mean		90/10		Mean	
	HMA	WMA	HMA	WMA	HMA	WMA	HMA	WMA
Average value	4,1	4,1	3,3	3,5	1,9	1,9	1,2	1,2
Trial sections with higher initial rutting	5	6	4	6	5	5	2	5

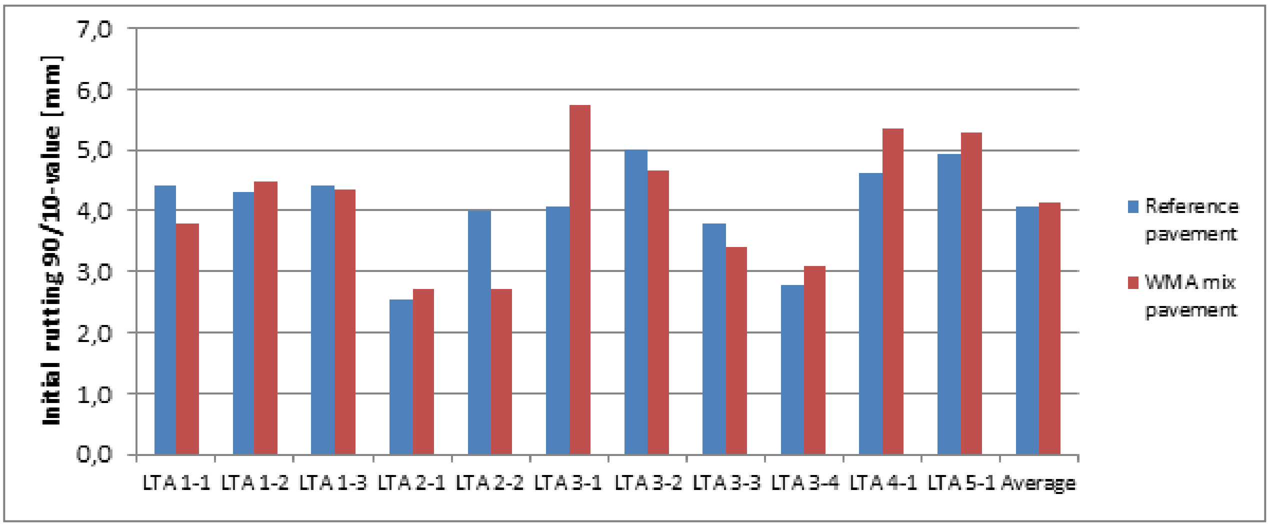

Figure 6: Initial rutting (rut depth), 90/10-values for the individual trial sections.

Figure 7 shows the results for initial evenness (90/10 IRI-values). LTA 1-1 and 1-2 values are rather high, but this is a municipal road with speed bumps, that cannot be completely filtered away from the data set.

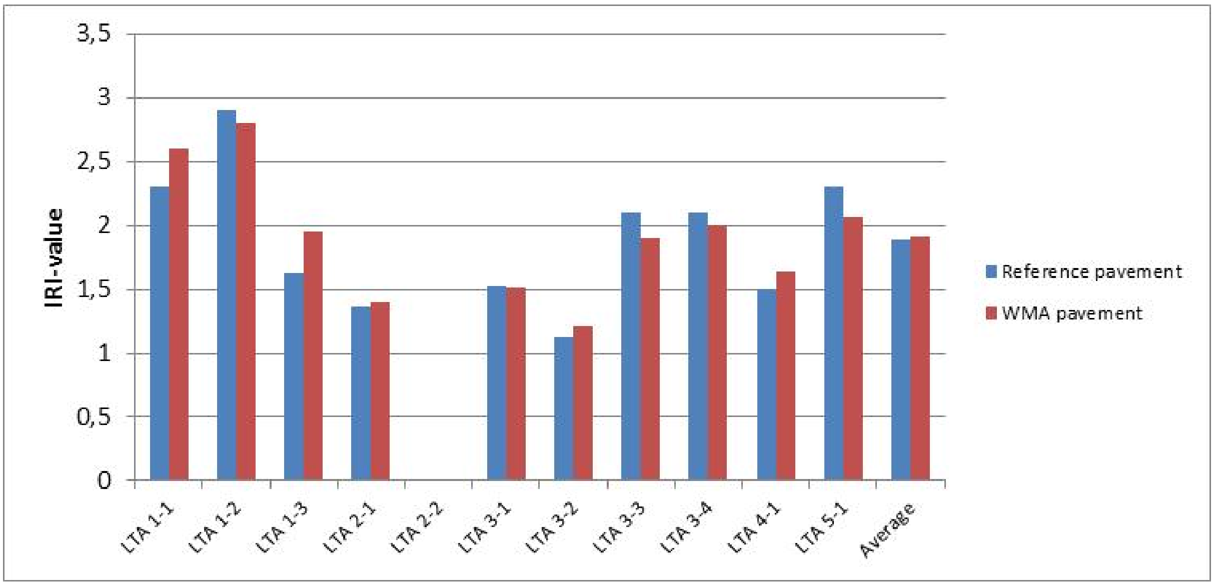

Figure 7: Initial evenness, IRI 90/10-value of the individual trial sections.

5 FOLLOW- UP OF TRIAL SECTIONS

5.1 Monitoring WMA and HMA pavements

The Norwegian national and county road net is monitored annually with a mobile laser profile scanner, which supplies data to the Pavement Management System of the Public Roads Administration. The IRI-eveness and rut depth are measured every 20 m of the road, and the values are stored in a central data base.

Figure 8 and Figure 9 show the development of rutting and IRI-eveness after one year. There are very small differences between WMA and HMA with regard to development of rutting and evenness.

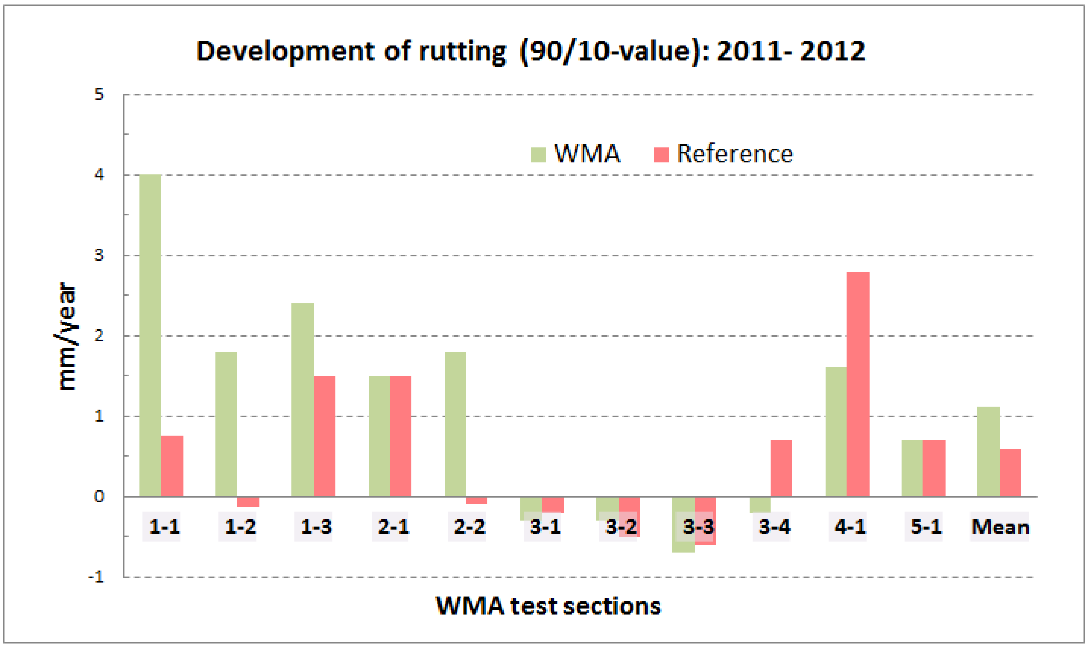

Figure 8: Development of rutting of trial sections after one year in service.

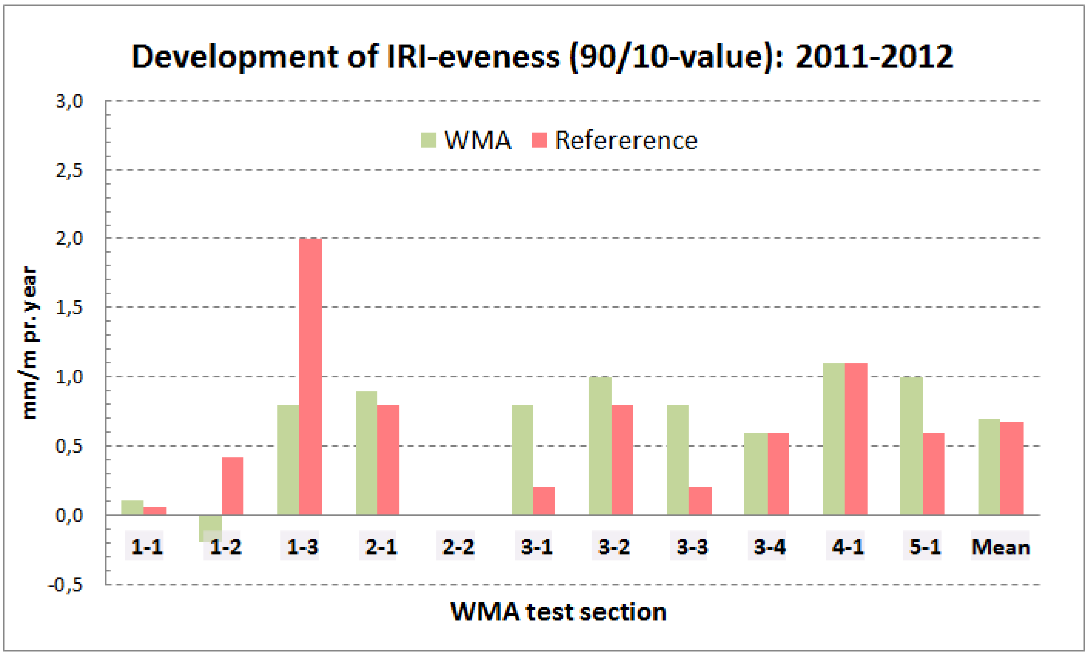

Figure 9: Development of IRI-eveness values of trial sections after one year in service.

6 CONCLUSIONS

In the field trials of the LTA2011 project, warm mix asphalt were produced and paved with a general temperature reduction of 30 °C compared to ordinary hot mix asphalt. The WMA had the same composition and void content as the reference HMA.

Resistance against deformation as measured by wheel-tracking device and by initial rutting, showed no significant difference between WMA and reference HMA asphalt. Some mixes showed higher wheel-tracking rates for WMA than for HMA, but initial rutting for the corresponding WMA-pavements were among the lowest.

Wheel-tracking rates and initial rutting showed no correlation. This seems likely since the wheel-tracking test measure characteristics of the mix under controlled conditions, while initial rutting is associated with the paving operation and the time before traffic is put on.

Initial IRI-evenness may be an indicator of the workability of the mix. The trials showed that WMA was similar to HMA in paving properties, and no problems with paving and compaction were reported.

None of the adhesion tests indicates that lower production temperature and eventual residual moisture have led to poorer adhesion of the WMA. Adhesion promotor (amine) was used in WMA and HMA .

After one year in service, the annual pavement registration showed almost the same development of rutting and IRI-evenness for WMA and HMA. The follow-up so far shows that the controlled lowering of temperature should not be an hindrance to achieve the same quality of WMA and HMA. The same service lifetime for WMA and HMA may be expected.

Norwegian Public Roads Administration will monitor the conditions of the trial sections over time through the research program "Durable roads" and also through the ordinary pavement registration program.

REFERENCES

EAPA, 2005. *Low Temperature Asphalt.* European Asphalt Pavement Association, Brussels, Belgium.

Bragstad R., Telle R., 2012. *Evaluation of the effects on asphalt quality when changing from hot mix asphalt to warm mix asphalt*. FAV-report V3.0, Oslo, Norway

Statens vegvesen, 2011. *Håndbok 018, Vegbygging.* Manual: Guidelines for road construction. Norwegian Public Roads Administration, Oslo, Norway

Jørgensen T., 2013. *LTA 2011- Oppfølging av forsøksdekker. Etatsprogrammet Varige veger.* Statens vegvesen report no. 197, Norwegian Public Roads Administration, Oslo, Norway.