Light Coloured Asphalt

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ABSTRACT

In the Netherlands many roads are illuminated in the evening and at night. Both inside and outside urban areas and from bicycle paths to motorways. This public lighting consumes a tremendous amount of energy, which also means considerable CO2-emissions. Dura Vermeer has developed Luminumpave, a light coloured asphalt to reduce public lighting. The maximum effect is obtained by using a light coloured stone, an almost colourless synthetic binder (clear binder) and white pigment. The lighter colour also has an effect on road safety and on the thermal properties of the asphalt pavement

As part of an innovation cooperation with Rijkswaterstaat in September 2011 on motorway A35 a test section is laid. A reference section with the top layer of standard two-layer porous asphalt (PA 8) and three variants Luminumpave were realised (PA 8 with black bitumen, and PA 8 and SMA 11 with clear binder) with a total length of 625 meters. The purpose of this test section was to investigate the suitability as a wearing course on motorways and the quantification of the effect on the public lighting. The studies and measurements have focused on:

- *the civil engineering properties to assess the applicability;*
- *the light reflection properties in order to determine the reduction in public lighting.*

From the civil engineering research it can be concluded that Luminumpave is suitable for use on motorways. The reflection of sunlight causes lower temperatures in the asphalt pavement and as a result less rutting is expected. The lighting research has shown that a reduction of the public lighting of more than 40% is possible. This means huge energy savings and associated reduction in CO2-emissions. Also on unlit roads a light coloured surface seems to be very interesting. The visibility of a light coloured road surface is much better than that of a standard (dark coloured) road surface.

Keywords: Energy saving, Green procurement, Light Reflection, Porous asphalt, Safety

1. INTRODUCTION

Light coloured asphalt has been used for many years for many reasons. It has an effect on:

- The public lighting
  Because of its lighter colour and optimized surface texture a better visibility of the road surface is obtained. As a result, public lighting can be dimmed. A reduction in light means a reduction in energy consumption and thus an emission reduction (such as CO_2). Furthermore the 'horizon pollution' is reduced for humans and animals;
- Road safety
  Better visibility of the road surface under all circumstances is likely to result in a reduction in the number of traffic accidents. At the entry and exit of a tunnel road safety may be improved by a less abrupt transition from daylight to artificial light. The reflection of light can also mean a more pleasant living environment (social security);
- The thermal properties of an asphalt pavement
  Due to the reflection of sunlight, the temperature of a light coloured asphalt pavement and the underlying asphalt layers is likely to be lower than in a standard dark coloured asphalt pavement. This can maybe lead to a longer life (less rutting).

Light coloured asphalt can be realized with light coloured mineral aggregates, white pigment, and (optionally) a clear (colourless) binder. It can be produced in many variations:

- Light coloured asphalt can be produced with a (standard) black bitumen or a clear binder. With a clear binder the lighter colour is visible immediately after construction. With a black bitumen the lighter colour of the stones will only appear after the bitumen skin at the surface has been removed by traffic and climate. This will happen sooner in the wheel track than between the wheel tracks, this can result in a visually weird (zebra) pattern. If the black bitumen skin is removed immediately after construction (e.g. by shot blasting or planing), the lighter colour is immediately visible and a visually homogeneous image results;
- Depending on the traffic intensity a polymer modified clear binder can be applied;
- The light coloured stone chips can be used for 100% in the asphalt mixture, but a blend with other types of crushed stone is also possible;
- In addition to the light colour, the surface texture is also important with regard to scattering of the light and the retro-reflection of the light from the headlights. Light coloured asphalt can be used in standard wearing courses but the effect is stronger as Porous Asphalt and SMA.

Dura Vermeer has developed their own light coloured asphalt named Luminumpave. On a Dutch innovation event in 2009 it has won the award for 'Best innovation of tomorrow'. It was decided to make a proposal for the Innovation Test Centre (ITC) of Rijkswaterstaat. This publication describes the construction of the test section followed by an overview of the tests including some results.

Figure 1: Light coloured asphalt

2. TEST SECTION

Light coloured asphalt is already applied for several decades, especially in (urban) tunnels for improved visibility. The use of light coloured Porous Asphalt and SMA on motorways in The Netherlands is new. Because of the limited experience as top layer of two-layer Porous Asphalt and SMA it was necessary to carry out a series of studies and measurements in order to demonstrate and give confidence that it can function as wearing course on a motorway. Lighting research (light reflection properties) should be conducted in order to quantify the extent to which the public lighting can be reduced. A test section is necessary in order to carry out these studies and measurements. The cost per square meter light coloured asphalt are dependent on aforementioned considerations, a range between two and seven Euro can be used. Energy savings on public lighting represents direct savings for the road authority, longer life as well. Fewer accidents mean indirect cost savings. A concrete and realistic business case is difficult and is not part of this study.

The aim of the study is:
Investigate the suitability of light coloured asphalt as wearing course on a motorway and quantify the effect on the public lighting.

During the development of the product many laboratory tests had already been carried out. Because of the application on a motorway a polymer modified clear binder has been selected. A blend of white and standard stone chippings results in an optimal price / performance ratio. The studies and measurements carried out in the context of the ITC-cooperation consist of determining the civil engineering properties and light reflection properties. A test section is necessary to assess these properties. A location is selected on motorway A35 between Delden and Hengelo-South (west carriageway between km 59.1 and km 59.6). The A35 motorway is located from Wierden to Enschede and is especially important for both regional traffic and through traffic towards and from Germany.

The construction of the test area has taken place in 2011 during the week of Monday, September 26th to Saturday, October 1st. In addition to a reference section (section A), three different variants of light coloured asphalt (sections B, C and D) are constructed:

A. 30 mm standard top layer PA 8 (grading 4/8) with greywacke and black polymer modified bitumen as a reference mixture;
B. 30 mm light coloured PA 8 (grading 4/8) with a blend of ‘white’ aggregate and greywacke and black polymer modified bitumen;
C. 30 mm light coloured PA 8 (grading 4/8) with a blend of ‘white’ aggregate and greywacke and clear polymer modified binder;
D. 30 mm light coloured SMA 8 with a blend of ‘white’ aggregate and greywacke and clear polymer modified binder.

The length of the first three sections is approximately 175 m per section. The fourth section is located on a bridge deck having a length of approximately 100 m. Samples of the four mixtures were taken during production to make gyratory specimen and slabs in the laboratory. After construction cores were drilled. In order to get a visual indication of the end result the bitumen skin on a few square meters of the emergency lane has been removed by planing. The first civil engineering measurements and the first lighting research took place on Thursday night and Friday night (September 29th and 30th 2011) just before opening of the test section for traffic.

Figure 2: The first metres with clear binder (section C) on A35

Figure 3: Visibility of standard (left) and light coloured asphalt

Figure 4: Paving of light coloured asphalt

Figure 5: Transition between sections B and C

Figure 6: Planed small section for indication of end result

3. RESEARCH

This chapter presents an overview of the tests and measurements in the context of the ITC cooperation agreement. Investigations into a possible improved road safety are not included in this this agreement.
The tests and measurements carried out comprise the determination of:
- the civil engineering properties to assess the applicability;
- the light reflection properties in order to quantify the reduction in lighting.

This paper only presents a short view at some specific properties. The full study and results are described in the (non public) ITC Luminumpave final report (LUP.13.R1.def, July 26, 2013).

Civil engineering properties
In order to demonstrate the suitability of asphalt as a light coloured wearing course on a motorway, it is necessary to carry out a study of the civil engineering properties. The following properties were addressed:
- initial skid resistance and brake deceleration test
- skid resistance after one year
- surface texture and longitudinal evenness
- friction with SRT pendulum method
- water permeability with Becker
- visual inspection initially and after one year
- warming- and cooling properties over one year by means of thermocouples in wearing course and temperature sensors along the motorway
- adhesion to the marking (direct tensile tests)
- water sensitivity on gyratory specimen
- resistance to ravelling with ARTe on slabs
- skid resistance on drilled cores with Wehner/Schulze
- bonding to the underlying layer on drilled cores with Leutner shear

The required brake deceleration of the reference section A was not directly met, the second measurement few months later did. All other civil engineering properties met the expectations and requirements. This paper addresses the skid resistance and the resistance to ravelling because these are possibly affected by the different special constituents. It also describes the warming- and cooling properties because that is the only 'non-standard' research.

Figure 7: Brake deceleration test

Skid resistance
Before opening of the test section the initial skid resistance (86% slip @ 70 km/h), the brake deceleration (with equipped personal car without ABS) and friction with SRT pendulum method were determined. After one year the skid resistance was measured again. On drilled cores with a diameter of 225 mm from sections A, B and C the skid resistance is tested with the Wehner/Schulze testing machine. The average values are shown in the table.

Table 1: Skid resistance results

		Skid resistance (≥0.43)		Friction SRT	Deceler. (≥5.2)	Wehner/Schulze	
Section	Asphalt mixture	Sep 2011	Sep 2012	Sep 2011	Sep 2011	Initial	End
A	Reference PA 4/8 with black PMB	0.52	0.56	79	5.0	0.44	0.44
B	Light coloured PA 4/8 with black PMB	0.56	0.55	76	5.2	0.49	0.37
C	Light coloured PA 4/8 with clear PMB	0.64	0.58	74	5.3	0.48	0.41
D	Light coloured SMA 8 with clear PMB	0.57	0.53	71	5.5	-	-

Initially section A with the reference mixture did not meet the requirement of 5.2 m/s^2 at the brake deceleration test. A few months later at the second measurement with 5.5 m/s^2 it reached the requirement. It appears that the initial skid resistance of reference section A with 100% Greywacke is lower than that of the sections B , C and D with blend of 'white' aggregate and Greywacke. But after one year, the skid resistance of section A has increased while that of sections B, C and D slightly decreased. After one year, all four of the sections are about the same level. More or less the same trend can be observed at the Wehner/Schulze test.

Resistance to raveling
The ravelling resistance has been tested on slabs which were made in the laboratory from asphalt mixture produced in the asphalt mixing plant. The slabs were tested at RWTH Aachen (Germany) with the *Aachener Rafelings Tester* (ARTe).

Table 2: Resistance to raveling results

		Resistance to raveling ARTe	
Section	Asphalt mixture	Loss of mass [%]	Visual assessment
A	Reference PA 4/8 with black PMB	0.3	minimal raveling
B	Light coloured PA 4/8 with black PMB	0.2	no raveling
C	Light coloured PA 4/8 with clear PMB	0.4	no raveling
D	Light coloured SMA 8 with clear PMB	0.1	no raveling

It appears that material from section C shows the highest average mass loss but that only slabs with the reference mixture show some signs of raveling. This appears to correspond to the practical behaviour outside on section A on the A35 where also some raveling can be observed.

Warming- and cooling properties
Due to the reflection of sunlight the temperature of a light coloured asphalt surface and the underlying asphalt layers on a sunny day are likely to be lower than in a standard dark coloured asphalt pavement. This can lead to a longer life (less rutting). During cold days, other cooling properties might have an effect on the slipperiness. To examine these potential effects over the year temperature is measured. This has been done by thermocouples inside the wearing course and by temperature sensors for the outside temperature alongside the motorway. Two data loggers at the roadside continuously (every ten minutes) recorded the measured values of the thermocouples and temperature sensors.
Section D is a bridge deck, experience shows that the temperature profile of a pavement on a bridge deck has a different temperature behaviour than before and behind the bridge. Especially on cold days with temperatures around zero degrees this is important for road users. On warm days there may also be a difference, but that is much less relevant for road users. From the results it can be concluded that there is no difference on cold days in temperature of the surface of the different sections. This is also the experience of the road users and the road authority. Based on this information the winter maintenance operations do not require any adaptation. The same amount of salt can be sprayed at the same time on light coloured roads as on the other roads. But on hot summer days a difference of the surface temperature is seen. The dark coloured reference section A always appears to be the warmest, followed by sections B, C and D. Due to its location on the bridge deck the lowest temperature for section D is explicable. The light coloured section C is always significantly lower in temperature than the dark coloured section A, this difference can go up to eight degrees Celsius. Section B is in between, the light colour of the stones starts a bit to be visible. It should be noted that this is only one thermocouple per section and the exact depth location in the wearing course can differ a little (basically they are one cm below surface).

Light reflection properties
A light coloured wearing course can have a positive effect on the visibility of the road surface for the road user. Possibly the public lighting can be reduced while the visibility remains the same. In case of an unlit road the visibility of the road surface may be significantly improved. To support these possible effects a lighting research was conducted. This analysis of the photometric optical reflection properties of asphalt comprises the determination of :

- day-night visibility at sky light (Qd)
- night visibility at headlights (Rl)
- night visibility at public lighting (average luminance coefficient Q0 -S1 -S2)

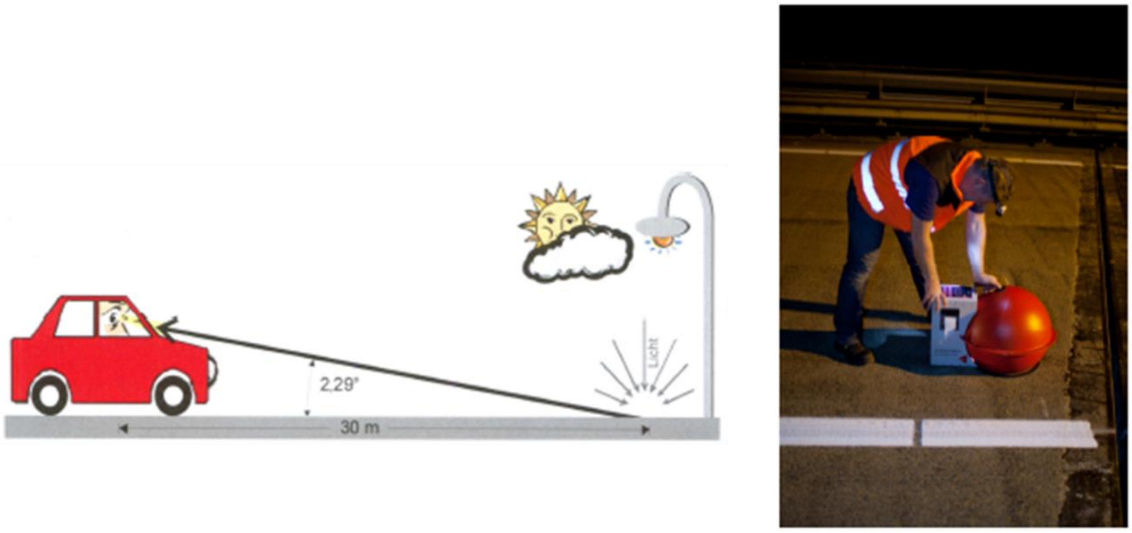

Figure 8: Day-night visibility at sky light (Qd), source: Zehntner

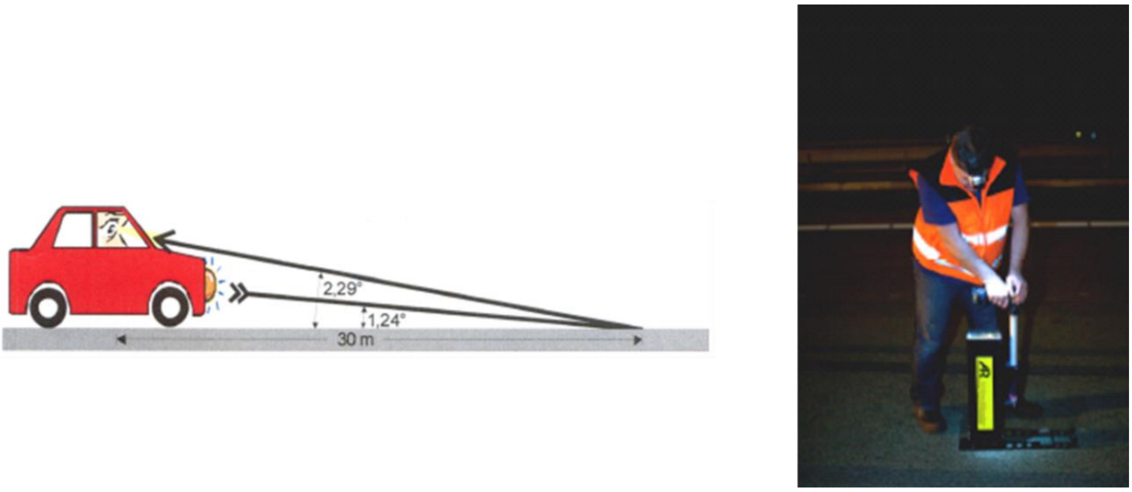

Figure 9: Night visibility at headlights (Rl), source: Zehntner

Figure 10: Night visibility at public lighting (average luminance coefficient Q0-S1-S2)

Immediately after construction of the test section, a first lighting research has been conducted (September 2011). There is no public lighting on this part of the A35. For the part of the lighting research in which the standard light fixtures are compared with LED lighting, temporarily light poles were placed twice. The most recent lighting research has been conducted in November 2015. The average values of the light reflection properties are shown in the table.

Table 3: Light reflection properties

		Q0			S1			Rl			Qd		
Section	Asphalt mixture	Sep11	Sep12	Nov15	Sep11	Sep12	Nov15	Sep11	Sep12	Nov15	Sep11	Sep12	Nov15
A	Reference PA 4/8 with black PMB	0.040	0.034	-	1.035	1.152	-	3	6	-	37	39	-
B	Light coloured PA 4/8 with black PMB	0.041	0.040	-	1.049	1.132	-	3	7	-	36	47	-
C	Light coloured PA 4/8 with clear PMB	0.083	0.066	0.054	0.597	0.401	0.363	17	12	16	81	68	63
D	Light coloured SMA 8 with clear PMB	0.080	0.070	0.056	0.647	0.629	0.363	15	10	15	72	60	63

The main findings of the lighting research are:

- Based on the first results light coloured asphalt is able to achieve an energy label B for public lighting (electrical consumption of approximately 3,600 watts/km) compared to a traditional dark coloured comparable two-layer Porous Asphalt with energy label E (electrical consumption approximately 7800 watts/km). By applying light coloured asphalt the energy label shifts on to a more energy efficient label. This is interesting for governments with regard to green public procurement. The 2015 results showed less possible reduction of public lighting, this may be caused by a slightly wet surface.
- Light coloured asphalt with the clear binder (sections C and D) reflects up to about twice as much light towards a driver of his own headlights compared to a traditional dark coloured comparable two-layer Porous Asphalt (section A). Further research must clarify the effect of this increased visibility in practical terms concerning safety.
- The measurements of the day visibility Qd show the same proportions as the average luminance coefficient Qo (public lighting). This means that with light coloured asphalt in lunar and sky light a higher luminance of the asphalt in the direction of a motorist is obtained. As a result, the road course of the road-alignment is further visible (better view on longer distance). This is certainly important for roads without public lighting.

4. EXPERIENCES

In 2011 Rijkswaterstaat together with Dura Vermeer decided to build a test section with light coloured asphalt on motorway A35 because of:

- an expected reduction in energy costs of public lighting;
- an expected longer lifetime compared to standard dark coloured Porous Asphalt (due to reflection of sunlight the entire asphalt structure will have a lower temperature);
- a more comfortable and tranquil view on the road because of a lighter surrounding.

In last winter seasons the test section has been treated as a standard two-layer Porous Asphalt wearing course (14 grams of salt per square m). The light coloured asphalt test sections behaved as standard two-layer Porous Asphalt. In 2012 the average workday intensity was about 35,000 vehicles. In February 2013 between 2 and 5 mm rutting in the right lane was measured. Light coloured asphalt is a special mixture and can not just be obtained at any asphalt mixing plant at any time. Local emergency repairs will have to be done with traditional mixtures.

Points of interest are the erosion of the black bitumen at the surface in the wheel tracks of section B. The wheel track has therefore become significantly lighter in colour (see photos below). Section C (with clear binder) was immediately after construction lighter in colour than three years later. By pollution from rubber tires and / or erosion of the clear binder (see photos below) the surface looks less reflective than before. The surface however remains significantly lighter in colour than a traditional wearing course.
The contrast between a light coloured wearing course and white thermoplastic marking needs special attention, there are no standards available. Especially the central marking seems to become less visible on the long distance and at darkness. The fact that the road is ascending towards the bridge over the Twente canal maybe affects this assumption. But immediately after construction Rijkswaterstaat has received much positive response from road users. Motorists with a mild form of night blindness report that they experience the test section as very pleasant and comfortable.

Figure 11: Transition between section B and C, February 2014

Figure 12: Detail transition between section B and C, February 2014

5. CONCLUSIONS AND DISCUSSION

Conclusions

Prior to the ITC cooperation agreement laboratory research was conducted on light coloured asphalt. From this research it could be concluded that this light coloured asphalt met the Dutch requirements for the top layer of two-layer Porous Asphalt and SMA.

After construction of the test sections the braking deceleration of the reference section A did not directly meet the requirement, at the second measurement a few months later it did. All other civil engineering properties met the requirements and expectations. From monitoring the heating and cooling properties it can be concluded that the surface temperature on cold winter days did not differ among the four variants. But during the hot summer days the light coloured road sections C and D (both with clear binder) showed significantly lower surface temperatures (up to eight degrees difference).
→ From the civil engineering studies and measurements it can be concluded that light coloured asphalt is suitable for application on motorways (in The Netherlands).

The lighting research has shown that a reduction of the public lighting of more than 40% is possible. This means huge energy savings and associated reductions in CO_2 emissions. Light coloured crushed stone chippings, white pigment and polymer modified clear binder however make it a precious asphalt mixture. A business case should determine whether light coloured asphalt is cost effective. Due to cost considerations, it is useful to keep the layer thickness as thin as possible. In tunnels with 24-hour lighting it can be rather interesting.
Due to the disappearance of the bitumen skin at the surface, the sections may becoming lighter in colour in time. It was therefore recommended to carry out the lighting study later again. This took place end of 2015 on test sections C and D with the clear binder, four years after construction. Visually these sections still look really bright but the measurements showed less obtrusive results. The deposition of pollution and rubber at the surface is maybe the cause of this. Also the slightly wet surface has maybe influenced the test results.
On unlit roads a light coloured wearing course seems to be very interesting. The visibility is much better than on a standard road surface. This is due to the higher retro reflection of the headlights. And with moon and sky light the road course at longer distance is better visible. However the contrast between a light coloured surface and white thermoplastic marking needs attention, there are no standards and no requirements. The safety at dangerous locations on motorways may be improved with light coloured asphalt. Traffic safety has not been addressed in this study. Additional research should give a final verdict on this aspect.
→ From the lighting research it can be concluded that light coloured asphalt can lead to significant savings on public lighting, this means lower energy costs and lower CO_2 emissions. On unlit roads light coloured asphalt improves the visibility of the road surface.

Discussion

Application of a light coloured wearing course on unlit roads improves traffic safety and should therefore be used as standard practice.

On roads with public lighting the extra costs of light coloured asphalt is unlikely to outweigh the savings in energy costs. However because of the better visibility (also a form of comfort) and CO_2 reduction this should not prevent the use of light coloured wearing courses.

Many tests can be used for determination of light reflection properties. A uniform method of measuring and characterising the light reflection properties of asphalt pavements is desirable for achieving consistency in tenders and propositions.