# Rollpave, a prefabricated asphalt wearing course

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ABSTRACT: Increasing traffic puts higher demands on construction and maintenance of pavements. To minimize hindrance for the road-user, a high quality durable pavement must be realized in short available time. The Dutch Ministry of Transport, Public Works and Water Management is working on smart and efficient use of infrastructure. Their pilot project Modular Road Surface aimed at a prefabricated road with a high noise reduction that could be constructed and replaced quickly. To address this topic a prefabricated asphalt wearing course was developed by a consortium of Dura Vermeer and Intron. This Rollpave concept consists of a prefabricated thin asphalt layer that can be unrolled like a carpet. This layer can be bonded very quickly by an innovative bonding system based on electromagnetic waves. Rollpave has been realized on three test sections on motorways A35 and A37 with an average length of 450 metres and width of 12 metres. Typical dimension of one asphaltmat is 50 metres by 3.75 metres. An extensive testing program has been carried out on all three test sections. It has been shown that it is possible to create a safe prefab road for motorways. The speed of construction needs to be improved. The concept is rather independent of the weather conditions; one test section has even been constructed while freezing. The noise reduction of Rollpave is better than single-layer porous asphalt and approaches the performance of two-layer porous asphalt. The paper will focus on the Rollpave concept and the results of the three test sections.

KEY WORDS: Prefabricated, asphaltmat, noise reduction, reversible bonding, porous asphalt.

## 1 INTRODUCTION

Increasing traffic puts higher demands on construction and maintenance of pavements. To minimize hindrance for the road-user, a high quality durable pavement must be realized in short available time.

The Dutch Ministry of Transport, Public Works and Water Management some years ago started their innovation program ‘Roads to the Future’. In co-operation with commercial companies solutions were sought in order to find a smart and efficient use of infrastructure in the Netherlands. Within the theme Road Surface of the Future the pilot project Modular Road Surface was started. The purpose of the pilot project was to develop a prefabricated road with a high noise reduction that could be laid and replaced quickly so that the hindrance for road users is minimized. Furthermore, the social costs are reduced due to less waste of time in traffic congestion caused by the construction and maintenance activities. To address this topic a prefabricated asphalt road was developed by a consortium of Dura Vermeer Infrastructure (Road-Contractor) and INTRON (Consultancy in material engineering).

This Rollpave concept consists of a prefabricated thin noise reducing asphalt layer that can be unrolled like a carpet. This layer can be bonded and unbonded to the existing underlying layer very quickly and easily by an innovative bonding-system. This reversible bonding-system is based on selective and wireless heating of a bond-layer with electromagnetic waves. The properties and dimensions of the asphaltmat can be tailored to provide specific performance, such as noise reduction, skid resistance and durability. Because the product is prefabricated in an indoor hall, the asphaltmat can always be produced under the same optimal conditions. Another advantage is that the quality control has already been carried out on production site. As a result, no failures and surprises should show up at the final destination i.e. on the job site. This paper describes the product, the test sections and the results of the monitoring program.

## 2 ROLLPAVE

### 2.1 Asphaltmat

The main purpose of the project was to develop a prefabricated road with a high noise reduction that could be constructed and replaced quickly so that the hindrance to the road user is minimized. A noise reduction of 5 dB(A) at 100 km/h relative to a dense asphalt concrete (AC 16 surf) was required. In order to accomplish to the requirements a highly flexible open noise reducing asphalt layer was developed.

The asphalt is laid on a metal reinforced bituminous membrane with a thickness of approximately 3 mm developed by Smid & Hollander (producer of bituminous products). The bituminous membrane is modified with a SBS polymer and has a dual function. Firstly it carries the asphalt layer which is crucial in the process of rolling up and -off, secondly it functions as a bituminous bond-layer. Figure 1 shows a schematic overview of the asphaltmat.

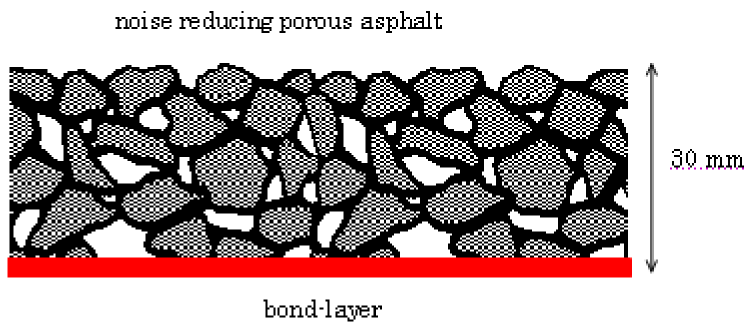


Figure 1: Composition of the asphaltmat.

During the development of the asphalt mix an optimization was made between the acoustical and civil technical properties. From several measurements and studies it has been shown that the tyre/road noise is dominant at traffic speeds above 40 km/h. This means that for the reduction of traffic noise at higher speeds primarily the tyre/road noise should be reduced. This can be achieved by adding the following characteristics to the road surface:

- low macro texture in order to minimize the vibration of the tyre;

- high micro texture in order to reduce the air pumping effect;
- a low flow resistance is realized by a certain amount of accessible voids and layer thickness.

The mix was designed by means of volumetric calculations. To determine the optimum texture, the thickness and the volume of air voids, absorption and texture measurements were conducted in the laboratory on various designed mixes. In order to create an optimum texture a high quality stone with a maximum grain size of 6 mm was chosen. Furthermore, from acoustical point of view a thickness of 30 mm was chosen.

Apart from the acoustical properties the mix also should comply with civil technical properties such as skid resistance, resistance to raveling and resistance to permanent deformation. The skid resistance was determined by means of Skid Resistance Test (SRT) measurements in the laboratory. An indication of the resistance to raveling, which is the most common damage on porous asphalt, was determined by means of Cantabro tests. Because of the high polymer-modified bitumen (PMB) and a high quality stone the resistance to raveling was sufficient. Due to the use of an optimized stone matrix (stone-to-stone contact) and PMB a high resistance to permanent deformation was obtained.

## 2.2 Bonding

A pavement structure is normally constructed with various layers of asphalt. Bonding between asphalt layers is very important for the bearing capacity of the entire pavement structure. A tack coat, mostly bitumen emulsion in The Netherlands, takes care of the bonding between asphalt layers. After the 'breaking' process of the bitumen emulsion the hot mix asphalt is laid on the tack coat. Due to the heat of the asphalt the water disappears and the bitumen is melted and the asphalt layers are bonded irreversibly.

One of the main objectives of the project was the quick laying and replacement of the concept. To address this topic the bonding of Rollpave is realized by means of an innovative switch on/off system. This reversible bonding-system is based on selective and wireless heating of a bond-layer by electromagnetic waves. An induction machine activates an electromagnetic field which is caught by a special metal grid in the bond-layer, see figure 2. The asphalt layer doesn't notice this electromagnetic field and is not affected at all. The grid absorbs the energy, heats up and transfers the heat to the bitumen in which it is embedded. The bitumen melts and acts as a ordinary tack coat. The main advantage of the system is that the layer can be quickly and easily bonded during construction phase and unbonded when the asphalt must be replaced or removed for any reason.

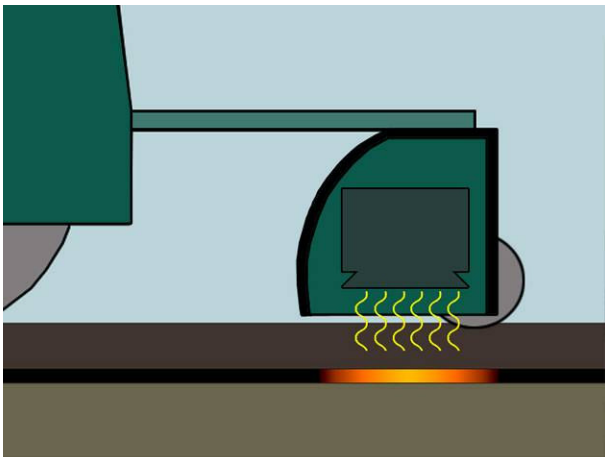

Figure 2: Principle of selective heating of only the bond-layer by means of induction.

The bonding strength of the Rollpave concept was determined by means of shear tests (Leutner) in the laboratory. From these tests it was concluded that the strength complies with the requirements. However, it was also concluded that the thickness of the bond-layer has a great influence on the shear strength. It's important to tune the thickness of the bituminous bond-layer properly with the condition of the underlying surface (fine or rough).

## 2.3 Laying process

For the first applications the asphaltmats were produced outside. Later on the production was moved to a large indoor hall with controlled climatic conditions. After the asphaltmat is produced, it will be rolled up on a reel by a large forklift truck, see figure 3. For that purpose a frame has been developed to control the movement of the reel with the asphaltmat. The forklift truck only carries the reel and moves forwards and backwards. An operator standing near the asphaltmat controls the speed of unrolling of the asphaltmat independent of the movement of the forklift truck. The operator can shift the reel in all directions: upwards, downwards, to the left and to the right. The reel can also be rotated in the vertical and horizontal plane. The forklift truck itself can put the reel with the asphaltmat on a truck, see figure 4. After transportation to the construction site the asphaltmat is rolled off on the underlying binder course, see figure 5. Finally it is bonded by means of the induction machine. No rollers are now needed for compaction because Rollpave is already compacted in the hall. A construction time of 300 m per hour is estimated in the future if all the equipment is suitable for the Rollpave concept.

As the bonding system is reversible, the asphaltmat can also be removed quickly and easily in case of damage or at completing its function of temporary pavement by simply detaching it from the binder course. The bond-layer is again activated by the induction machine. It weakens and can be rolled on the reel again.


Figure 3: After production the asphaltmat is rolled on the reel.

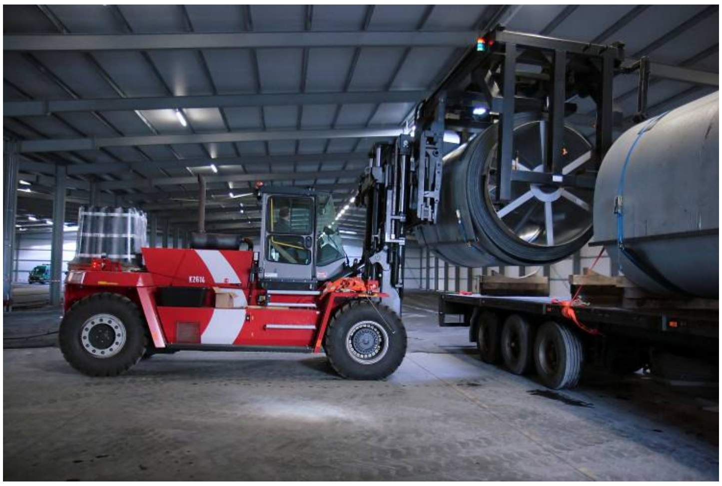

Figure 4: The asphaltmats ready for transport.

Figure 5: The operator controls the movement of the asphaltmat and places it very precisely.

2.4 Benefits and applications

Due to the prefab production process the quality of the asphaltmat is guaranteed and independent of weather conditions as it is produced at controlled climatic conditions. Furthermore, the construction becomes rather independent of the weather conditions and can be laid during almost the entire year. Only during rainfall laying is not possible. The Rollpave concept can be constructed quickly and traffic can be allowed immediately after construction because Rollpave doesn't have to cool down. Furthermore, the asphaltmat can be repaired and replaced very quickly. A construction time of 300 m road surface in an hour is possible. All these aspects lead to minimal hindrance for the road user and also the social costs due to traffic jams are minimized. Due to the prefab production process, it is possible to address other functions easily to the asphaltmat like data transfer and dynamic road marking. Because the product is prefabricated, the quality control has already been carried out on production site in the hall.

Due to the increasing traffic the hindrance to the road user must be minimized, as the hindrance leads to traffic congestion which consequently leads to an increase of social costs. Rollpave is suitable as a wearing course for motorways, urban roads, bridge decks and parking decks. It is ideal for temporary road constructions, for example on building sites thanks to is ease and speed of laying and removal. It can also be used on places where damage has occurred unexpectedly and quick maintenance is required. Also if road sections with frost damage have to be maintained in a period with temperatures under the freezing-point, when laying of hot mix asphalt is not possible, Rollpave can be a solution.

## 3 TEST SECTIONS

The first application of Rollpave has been successfully realized on a trafficked test section of 100 m by 5 m near the motorway A50 in November 2001. Four asphaltmats of 50 m length, 2½ m width were rolled up on wooden reels with an inner diameter of 2½ m. A conventional hose reel cart was used. In poor weather conditions (0 - 5°C) the asphaltmats were unrolled and bonded to the binder course.

The second application was in September 2002 at the Delft University of Technology. A test section with a length of 20 m and a width of 5 m was constructed. The test section was intensively loaded by the Lintrack, an Accelerated Pavement Tester. The results of this test were very positive (Houben et al. 2004).

These two applications were part of the pilot project Modular Road Surface. Because of the positive results the Ministry of Transport, Public Works and Water Management decided to further explore the potentials of the Rollpave concept. Dura Vermeer and Intron were given the opportunity to further develop the concept. Three test sections on motorways were provided. In this stage the frame to be used in the forklift truck was designed and two of those frames were built. Steel drums with an inner diameter of 2 m were produced, width is 4 metres. Typical length and width of the asphaltmat for the test sections on the motorways is 50 metres by 3.75 metres.

This first application on a motorway was on the A35 nearby Hengelo end of June 2006. The goal was to investigate the possibilities of Rollpave on a large scale. This was the first test site with real intensive traffic loading. The laying speed was no issue, it was meant to gather some experiences for the other two planned Rollpave test sections. Rollpave was laid carriageway wide (12.5 m including the fast, slow and emergency lane) with a length of 480 m.

The second application on a motorway was on the A37 nearby Nieuw-Amsterdam in January 2007. The goal was to investigate if Rollpave could be laid under winter conditions. During the laying process the temperatures of the pavement varied between -3 to +3°C, while the air temperature varied between -5 to +4 °C. Rollpave was laid carriageway wide (11.5 m) with a length of 430 m.

The third application on a motorway was on the A37 nearby Nieuw-Amsterdam in October 2007. Here the emphasis was on the process of laying. The goal was to investigate if Rollpave could be laid in a weak curve (radius 1050 m). Rollpave was laid carriageway wide (11.5 m) with a length of 350 m.

In between two other road sections were constructed. One in a recreational area nearby Deventer. Here the advantage of a prefabricated product was fully exploited; conventional asphalt paving equipment was not able to reach this location. Another road section was made in Groningen, this was to test an improvement in noise and skid resistance characteristics. In table 1 an overview of all test sections of Rollpave is presented.

Table 1: Rollpave test sections.

| Date | Location | Length [m] × width [m] |
|---|---|---|
| 2001, November | A50 Apeldoorn, petrol station | 100×5 |
| 2002, August | Delft University of Technology, Lintrack | 20×5 |
| 2006, June | A35 Hengelo, motorway | 480×12.5 |
| 2006, November | Deventer, recreational area | 30×3 |
| 2007, January | A37 Nieuw-Amsterdam, motorway | 430×11.5 |
| 2007, June | Groningen, industrial area | 130×3.5 |
| 2007, October | A37 Nieuw-Amsterdam, motorway | 350×11.5 |

## 4 RESULTS OF MONITORING

### 4.1 Tests

To monitor the behaviour of Rollpave on the three motorway test sections the following items were addressed:

- The construction time to complete the whole Rollpave test section is compared to the expected construction time of a section with single- and two-layer Porous Asphalt (PA). PA is the standard wearing course for Dutch motorways, in 2009 80% of the wearing courses was PA. Also the laying speed of single asphaltmats is measured.
- The noise reduction is measured with SPB (in conformity with ISO 11819-1) and with CPX (in conformity with ISO 11819-2). The noise reduction is expressed as the difference in noise between the Rollpave level measured at IPG mix and the level of the reference mixture dense asphalt concrete 16 (AC 16 surf) measured at IPG mix. The IPG mix consists of a traffic composition of 85% light vehicles with a speed of 115 km/h and 15% heavy vehicles with a speed of 85 km/h. The IPG mix noise level result is calculated from these measurements. To get an idea of the noise levels, the IPG mix SPB values in dB(A) are given of respectively old PA, new PA, new TLPA and the reference AC 16 surf: 82.2, 77.2, 75.3 and 81.3 dB(A).
- The skid resistance is measured in conformity with test 150 of the Dutch national contract regulations (CROW, 2005). This test is carried out under wet conditions at a speed of 50 km/h with 86% wheel slip.
- The brake deceleration is determined according the DVS method. The brake deceleration is calculated from the length of the brake distance of a car fully braking without ABS.
- The longitudinal evenness was for the first two motorway test sections based on rolling straight edge measurements according to the Dutch national contract regulations (CROW, 2005). For the third test section the requirement was based on IRI values measured with the Automatic Road ANalyser (ARAN).
- The water drainability is measured in conformity with EN-12697-40 in situ drainability.
- The visual inspections were conducted according to CROW publication 146 (2005, December).
- The bonding between Rollpave and the binder layer was determined in the laboratory with the Leutner test and in situ with torque tests.
  *Laboratory bonding test.* Instead of specimen with a diameter of 150 mm according to the German test description (FGSV, 1999), drilled cores with a diameter of 100 mm were tested at a temperature of 20ºC. The maximum shear stress at failure is determined.
  *In situ bonding test.* To get a separate surface the Rollpave pavement is drilled with a 100 mm hollow core up to a depth of 40 mm. In the upper surface of this core two little holes

are drilled. In these holes two steel pins are pushed which can be fixed to a torque wrench. After carrying out the torque test, it was also observed in which layer the unbonding took place.

4.2 Test results

In table 2 the most important results including the requirements are presented. Keep in mind that Rollpave was developed and tested as a maintenance technique for existing road sections.

Table 2: Test results including requirements for the three motorway test sections.

| Test | Requirement | A35 | A37 - 1 | A37 - 2 |
|---|---|---|---|---|
| Construction time | 70% of single-layer PA and 50% of two-layer PA | Not measured | Longer | Longer |
| Noise reduction<br>- SPB@100 km/h<br>- CPX@80 km/h | <br>Aim: 7±1 dB(A)<br>- | <br>4.4 dB(A)<br>95.0 dB(A) | <br>3.1 dB(A<br>95.8 dB(A) | <br>5.2 dB(A)<br>94.1 dB(A) |
| Skid resistance | ≥ 0.45 | 0.50 | 0.42 | 0.73 |
| Braking deceleration | ≥ 5.2 m/s$^2$ | 6.1 | 5.4 | 6.7 |
| Longitudinal evenness<br>- Rolling straight edge<br>- ARAN (IRI) | <br>Maximum deviation 3 mm<br>- | <br>2 of 5 100m sections>3 mm<br>1.4 | <br>All 5 100 m sections>3 mm<br>1.7 | |
| Water drainability (Becker) | - | 119 seconds | 32 seconds | - |
| Visual inspections<br>- after laying<br>- after 2 years | No cracks, raveling or open longitudinal joints | <br>No damage<br>Some potholes | <br>No damage<br>Some potholes | <br>No damage<br>Some potholes |

4.3 Discussion of results

With regard to the addressed items the following conclusions can be taken:

- The construction time needed to complete the whole test section with Rollpave is longer in comparison with single- and two-layer PA. Firstly this is caused by the fact that Rollpave needs a very even binder layer. Because of the constant thin prefabricated layer Rollpave can’t fill out the roughness and unevenness of the milled binder layer and it was necessary to lay a totally new even binder layer. This situation can be avoided when Rollpave is laid in new construction on a new binder layer or on flat concrete structures like bridges and tunnels. This can also be avoided when replacing a Rollpave mat by a new one. Secondly this is caused by the logistics of the whole process of laying. Two forklift trucks with two frames were available, if one is unrolling one mat the other is getting a new one. But still, starting unrolling a new mat takes a long time because of the necessary accurate positioning of the beginning of the mat. In future it is worthwhile to develop a faster laying process. The laying speed of one single mat is rather fast; on average it takes 6 to 10 minutes to unroll a mat with a length of 50 to 60 metres. Also the speed of bonding with electromagnetic waves has to be improved or another fast bonding system has to be developed.

- During production extra attention was paid to noise reduction, but unfortunately Rollpave couldn't meet the aim of 7±1 dB(A). Although this goal wasn't achieved, Rollpave has a very good noise reduction. It acts better than the single-layer PA, which is the standard wearing course on motorways in the Netherlands. It can be concluded that Rollpave is almost as silent as two-layer PA with a PA 8 top-layer.
- The skid resistance on the A35 did meet the contract requirements, but the next test section on the A37 did not. Because the result was not below the intervention level of 0.38 this caused no safety problems. However, for the next test section the skid resistance had to be improved strongly. This was done by applying Neorough, a fine broken slag material, on top of the hot asphalt during production of the mats. The skid resistance was improved enormously. The same remarks as for the skid resistance are valid for the brake deceleration.
- Rollpave didn't meet the requirements for the longitudinal evenness because of the slight difference in layer thickness of the prefab Rollpave mats. During production much attention has been paid to create mats with same thicknesses. But the limits of the paving equipment restricted the results.
- Because of the fine divided voids in the asphalt mixture (with grading 2/6) the water draining capacity of Rollpave is less than that of new PA. The results are at the same level as clogged PA. If the water drainability of PA is between 30 and 50 seconds, it means it is clogged.
- Visual inspections showed no damage after laying. But after two years some potholes were observed in the wheel paths. Research on those spots learned that debonding of the bond-layer was the cause of these potholes. On some spots no metal was found in the prefab bonding-layer. With progress of time the potholes also damaged the binder layer. For the future a better, more secure, bonding system has to be developed.
- The bonding between Rollpave and the binder layer was determined in the laboratory and in situ.

  *Laboratory bonding test.* The average maximum shear stress of the Leutner test of Rollpave was 0.22 MPa. This is very low in comparison with conventional wearing courses (0.79 to 1.42 MPa). But in the interface between Rollpave and the binder layer no cracks were observed, only elastic deformation. After a rest period the Rollpave moved again in its original shape and could be tested again in the Leutner test. Because this second test resulted in approximately the same result, it was concluded that in this case no shear stress was measured and that the Leutner test was not suitable to test the bonding between Rollpave and the binder layer.

  *In situ bonding test.* The in situ torque tests were carried out at high temperatures. The maximum Rollpave surface was up to 52ºC. In 8 of the 10 tests the failure was caused by the binder layer. In the other 2 tests failure was observed in the bonding layer. The bonding strength was strongly influenced by the temperature. From these tests it can be concluded that with the induction technique sufficient bonding can be achieved.

## 5 CONCLUSIONS AND RECOMMENDATIONS

The Rollpave concept consists of a prefabricated asphaltmat rolled up on a reel, which can be bonded and unbonded to an underlying binder course very quickly and easily by an innovative bonding-system. This reversible bonding-system is based on selective and wireless heating of a bond-layer with electromagnetic waves. The properties and dimensions of the asphaltmat can be tailored to provide specific performance, such as noise reduction, skid resistance and durability. The concept is rather independent of the weather conditions; construction and maintenance can be performed at any time, except during rainfall. Rollpave is suitable as a wearing course for motorways, urban roads, bridge decks and parking decks. It is ideal for temporary road constructions, for example on building sites or at temporary events, thanks to its ease and speed of laying and removal. It can also be used on places where damage has occurred unexpectedly and quick maintenance is required. Also if road sections with frost damage have to be maintained in a period with temperatures under the freezing-point, when laying of hot mix asphalt is not possible, Rollpave can be a solution.

The three test sections on the motorways have shown the potency and restrictions of the Rollpave concept:

- It is possible to create a safe, comfortable and good road with a prefabricated wearing course on a large scale.
- An asphaltmat consisting of a thin noise reducing wearing course can be produced throughout the whole year in an indoor hall.
- In winter a thin noise reducing wearing course can be laid on a motorway while freezing.
- A prefabricated asphaltmat can be laid in a typical weak curve on a motorway.
- The noise reduction of the prefabricated asphaltmat is better than the noise reduction of porous asphalt and almost as good as that of two layer porous asphalt.
- The laying speed with the available equipment is lower than the laying speed of porous asphalt.
- Insufficient bonding between the prefabricated asphaltmat and the underlying binder course can soon result in damage.

Further development of the Rollpave concept should focus on the laying speed and the bonding to the underlying layer.

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