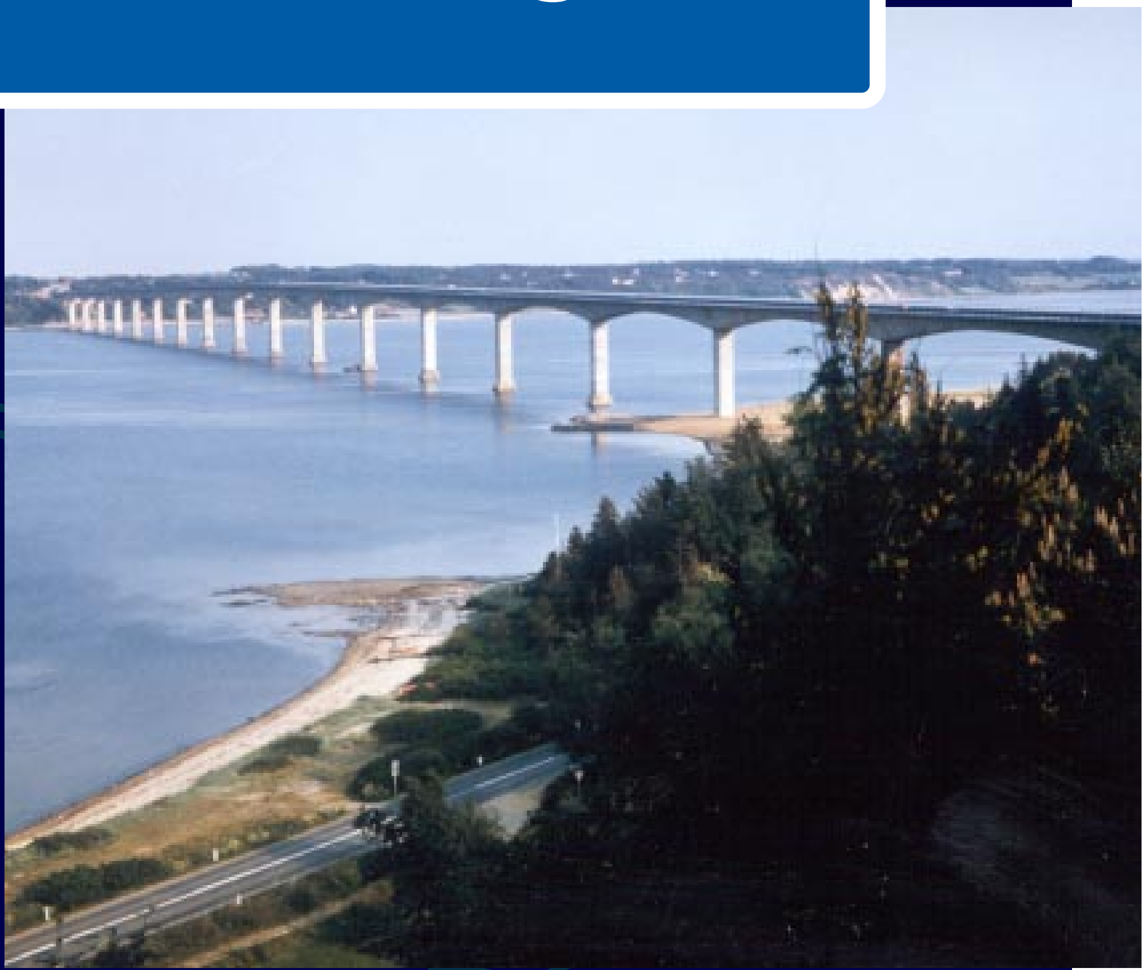
Surfacing of concrete bridges



Danish Road Institute
Report 106
2000

Road Directorate
Ministry of Transport - Denmark

Road Directorate
Danish Road Institute
Elisagaardsvej 5
P.O. Box 235
DK-4000 Roskilde
Denmark
Telephone: +45 46 30 70 00
Telefax: +45 46 30 71 05
vd@vd.dk
www.vd.dk

Title: Surfacing of concrete bridges
Author: Vibeke Wegan
Photos: Vibeke Wegan, Peter Randløv, Annette Neidel
Dated: December 2000
Copyright: Road Directorate, All rights reserved
Published by: Road Directorate, Danish Road Institute
ISBN: 87-90145-71-2
ISSN: 0909-1386

Surfacing of concrete bridges

Vibeke Wegan

Danish Road Institute
Report 106
2000

Contents

Abstract

The estimated life for concrete bridges in Denmark is 100 years. One condition to ensure this long lifetime is waterproofing of the bridge deck together with a high quality asphalt pavement.

The surfacing of the concrete bridge deck is important because the concrete should be protected against water and de-icing salts. These factors can lead to reduction of the durability of the concrete by washing out the concrete and risk of frost damage. Penetration of water will also increase the risk of alkali silica reactions, and chlorides from de-icing salts may reach the steel reinforcement in the concrete and initiate corrosion.

The first layer in the surfacing of the concrete bridge is the waterproofing. The traditional way to waterproof concrete bridge decks is two layers of fully torch-welded polymer modified bitumen sheets on a primer system. The sheets consist of an impregnated non-woven polyester reinforcement covered by polymer modified bitumen on both sides.

On top of the waterproofing sheets, a draining layer is laid. The draining layer consists of 15 mm very open-graded asphalt concrete with an air void content of 20 percent by volume. The purpose of this layer is to permit drainage of water from the surface of the waterproofing to drain channels, which lead the water to drip-pipes or drains at the abutment and thus relieve the waterproofing from water pressure.

The drain channels are placed in deep lines parallel to the edge beams and directly above the waterproofing sheets. The drain channels are normally made of very open-graded epoxy concrete with a thickness of more than 25 mm and with a width between 100 and 150 mm. The drip-pipes are placed under the drain channels. Each pipe normally drains about 100 m^2 bridge deck.

Above the draining layer, the protecting and wearing course are laid with a thickness of 80 to 100 mm in total. The protecting course is normally asphalt concrete with a high content of aggregate larger than 4 mm and with low air void content (less than 4 percent by volume). The protecting course is a binder layer, which also protects the waterproofing from mechanical damage, and minimises leak of water to the draining layer.

On smaller bridges, the wearing course is often the same as that used on the adjacent road. On larger bridges Stone Mastic Asphalt (SMA) is normally used as wearing course.

Introduction

The estimated life for concrete bridges in Denmark is about 100 years. One condition to ensure this long lifetime is waterproofing of the bridge deck together with high quality asphalt pavement. When the performance of the waterproofing and the asphalt pavement is as specified in the Danish Road Standards [1, 2, 3], the lifetime for the wearing course on the bridge is approximately 25 years and 50 years for the protecting course and the waterproofing. Hence, during the lifetime for a concrete bridge, the wearing course has to be replaced three times, while the protecting course and waterproofing have to be replaced once.

The surfacing of the concrete bridge deck is important because the concrete should be protected against water and de-icing salts since these factors can lead to reduction of the durability of the concrete by washing out the concrete and risk of frost damage. Penetration of water will also increase the risk of alkali silica reactions, and chlorides from de-icing salts may reach the steel reinforcement in the concrete and initiate corrosion.

The first layer on the concrete bridge is the waterproofing. The traditional Danish way to waterproof concrete bridge decks is two layers of fully torch-welded polymer modified bitumen sheets on a primer system. On the waterproofing sheets a draining layer is laid. The purpose of this layer is to permit drainage of water from the surface of the waterproofing to drain channels. Above the draining layer, the protecting and wearing course are laid with a thickness of 80 to 100 mm in total. Construction of the surfacing for a concrete bridge is illustrated in figure 1.

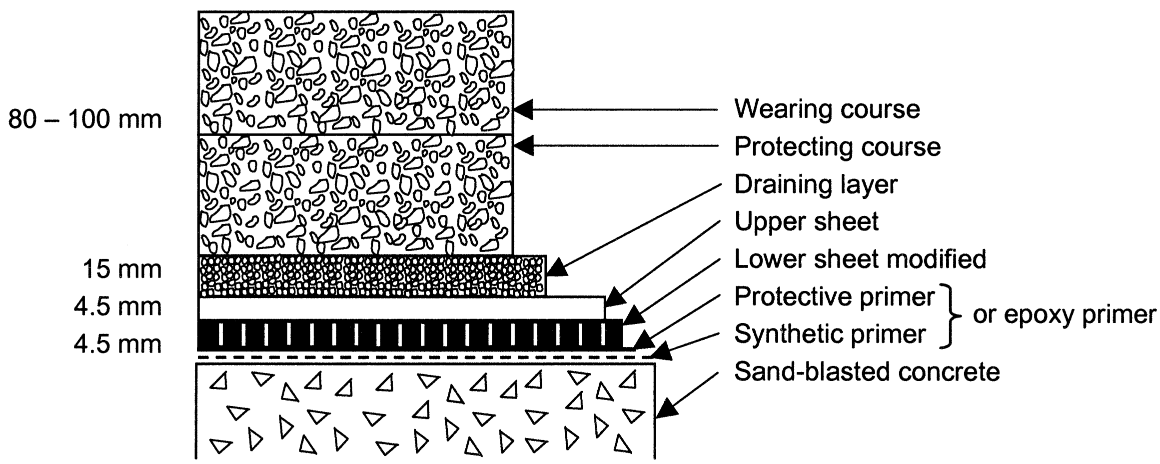


Figure 1. Construction of the surfacing for a concrete bridge with an estimated lifetime of 100 years. During this lifetime, the wearing course has to be replaced three times, while the protecting course and waterproofing have to be replaced once.

The main functional requirements for the waterproofing and asphalt pavement are the following:

- The waterproofing must be watertight under all conditions.
- Waterproofing and asphalt pavement must have mechanical stability and strength to resist traffic loads including compression and shear forces in curves and during braking and acceleration.
- Waterproofing and asphalt pavement must be resistant to cracking and stratification during influence from temperature variations and traffic loads.
- Waterproofing and asphalt pavement must maintain mechanical and chemical resistance during normal loads, and from weathering and de-icing chemicals.

Waterproofing sheets

The concrete surface, where the waterproofing should be applied, should have a gradient of more than 10 per thousand in the longitudinal direction to ensure that drainage can occur in the drainage layer built in and on the surface of the asphalt pavement. This is very important since the lack of this gradient has shown several damages on concrete bridges due to water penetration.

When the concrete has cured to a sufficient strength (during summer season this strength can be obtained after only 3 days) the concrete surface is shot or sandblasted in order to remove excess cement laitance and to create a surface texture that will ensure good bonding when the waterproofing is carried out. As soon as possible after the shot or sandblasting, a primer is applied on the clean concrete which must be surface-dry. The purpose of the primer is to establish a good bond to the waterproofing sheets and to close the voids in the concrete, thus minimising the risk of formation of blisters or bulges between the concrete and the waterproofing sheets. Sealing of the concrete surface with two layers of sand dusted epoxy primer is used when total assurance against blister formation is wanted.

It is only allowed to use a primer type approved in Denmark [4]. Today, three primers are type approved. Two are based on synthetic materials in a solvent and one is a solvent free epoxy primer dusted with sand. The two synthetic primers containing solvent cannot withstand direct torch-welding, when the waterproofing membranes are applied and hence they are protected by a second primer that consists of 50% solution of polymer modified bitumen.

When the primer or primers have been applied, the texture of the concrete surface must be between 0.4 and 1.3 mm measured by the sand patch method [5] all over the bridge deck.

After priming of the concrete bridge deck, normally two polymer modified bitumen sheets are fully torch-welded on the surface. For bridges with low daily traffic (ADT < 2000), without considerable importance for local and regional traffic, without heavy traffic or without braking or turning traffic, only one polymer modified bitumen sheet is specified (upper sheet).

The polymer modified sheets consist of an impregnated non-woven polyester reinforcement covered by polymer modified bitumen on both sides. The thickness of each sheet is 4.5 mm. The lower sheet has 1 mm polymer modified bitumen on top of the reinforcement and 2.5 mm on the under side. In the upper sheet the reinforcement is placed at the top of the sheet, with only 0.1 - 0.2 mm polymer modified bitumen above the reinforcement and 3.3 - 3.4 mm under the reinforcement. It is important to have a minimum of polymer bitumen on top of the upper sheet, since a draining layer is laid on top of the upper sheet, and hence too much bitumen on top may risk blocking the drainage. The sheets are normally 1 m wide and 10 m long.

The sheets are normally torch-welded by a gas burner battery with 6 to 10 flames. The joining of the bitumen sheets must have an overlap of at least 100 mm in the longitudinal direction (which is also the longitudinal direction of the bridge) and at least 150 mm in the transverse direction. Overlaps are placed in accordance with the direction of the slope in such a manner that the sheet in the upper position overlaps the sheet in the lower position. The second layer of polymer modified bitumen sheets is applied in such a manner that the overlaps are displaced by at least the width of one overlap in relations to the first layer.

It is recommended that the waterproofing should be applied in the summer months (from April to September). After application, the waterproofing sheets should be covered with a light cover such as tarpaulins to protect the sheets against sunlight and development of blisters between the sheets and concrete. Further, it is recommended to apply the asphalt layers as soon as possible.

Figure 2. Polymer modified waterproofing sheets are torch welded to the surface of the primed concrete.

Flashing at the edge beam

The edge beam is a very important part of the waterproofing since experience has shown that many problems with the waterproofing start at this point. For that reason, particular care is taken at the edge beams where water often is “gathered” due to the transversal gradient of the bridge. Further, movements due to temperature and shrinkage between the pavement and the concrete with the applied waterproofing sheets have to be taken into account.

At the edge beams, the waterproofing sheets are applied approximately 10 cm upwards against the edge beam. On the top of the polymer modified bitumen sheets, an elastic synthetic sheet is placed without gluing. On the three sheets, a stainless steel profile is bolted to the concrete. Tightening the bolts at least twice with a torque spanner before the asphalt layer is applied regulates the pressure, from the steel profile against the sheets.

Under the steel profile, no overlap of the polymer modified bitumen sheets or the synthetic sheet must take place, and only butt-joining is allowed. An example of the construction at the edge beam is illustrated in figure 3.

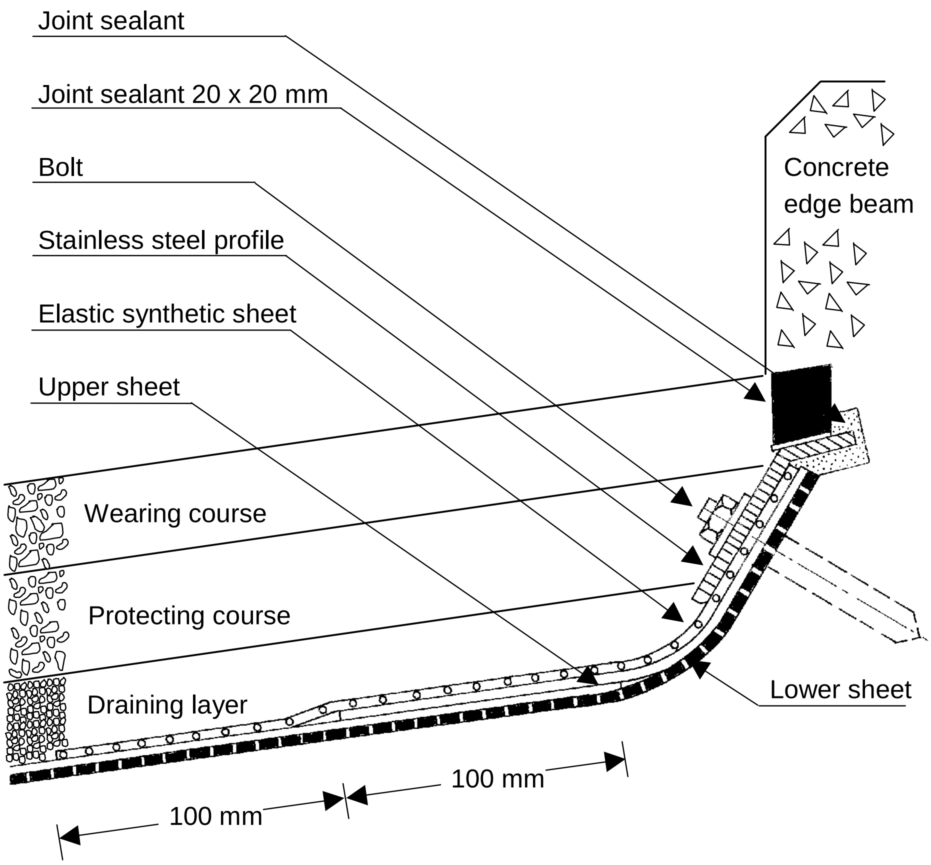


Figure 3. Special care is taken at the edge beam where the sheets are fastened with a stainless steel profile to the concrete.

Draining

It is important to relieve the waterproofing from any water-pressure. To ensure this, the upper side of the waterproofing is drained to drip-pipes or to direct outlets. Thus, the slope of the upper side of the waterproofing is directed towards such outlets.

A drainage layer provides the drainage of the waterproofing. An open-graded asphalt concrete is laid on the surface of the waterproofing sheets in a thickness of 15-20 mm. The purpose of this layer is to permit sub-surface drainage of any seepage water through the above-lying pavement through drain channels to drip-pipes or drains.

The open-graded asphalt concrete must retain a large content of air voids, approximately 20 vol-%, when compacted and post-compacted by the traffic. Further, the stability of the layer must be sufficient for its function as a base layer for the pavement.

The open-graded asphalt concrete normally consists of crushed granite and standard bitumen in 4-5% by weight. The percentage passing the 8 mm sieve shall be 100% and the percentage passing the 2 mm sieve less than 25% by weight. After the drainage layer is laid, it must be rolled immediately.

Drain channels are placed in deep lines parallel to the edge beams and directly above the waterproofing sheets. They are always placed outside the trafficked area. The drain channels are normally made of very open-graded epoxy concrete in a thickness of more than 25 mm and with a width between 100 and 150 mm. Further, drain channels are also laid parallel with the joints, at the upstream side of the joint.

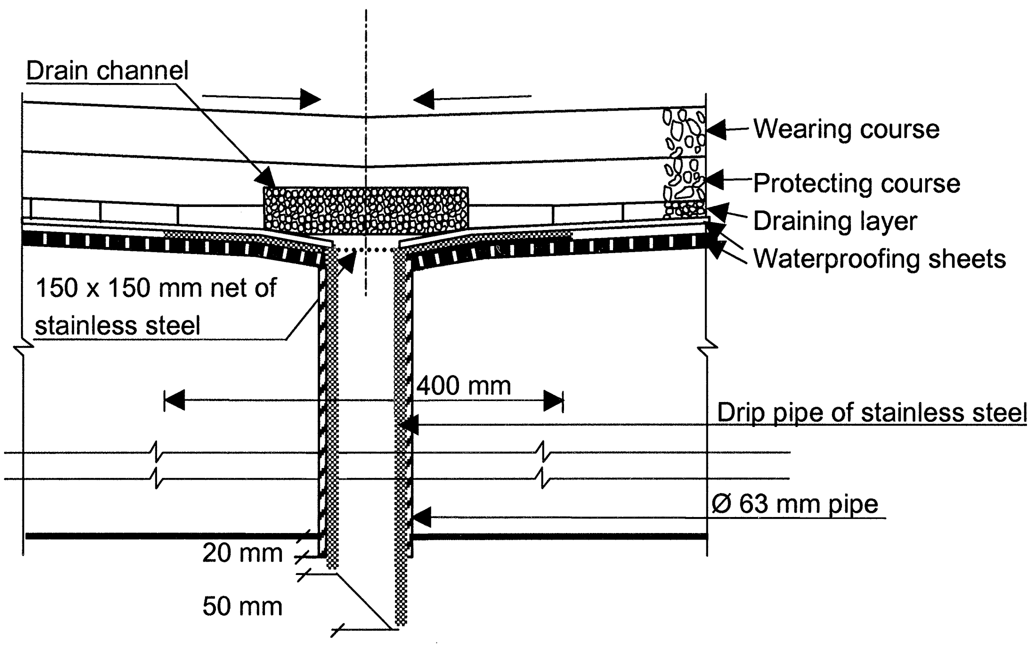


Figure 4. Drip-pipe placed lower than the surface of the waterproofing under a drain channel.

Drip-pipes are placed under the drain channels. They must be corrosion resistant and sufficiently wide to avoid closing. Each pipe normally drains about 100 m^2 bridge deck.

Due to the risk of ice building during winter times, drip-pipes ought to be placed away from trafficked areas under the bridge.

The drip-pipes are placed lower than the surface of the waterproofing. To establish this, a funnel-shaped recess is made in the concrete surface with a depth of 10-20 mm. The inner diameter of the drip-pipes is no less than 50 mm to avoid that a layer of lime plugs them.

Protecting and wearing course

Above the draining layer the asphalt pavement is laid with a thickness of 80 to 100 mm. It normally consists of a protecting and a wearing course.

The protecting course is in most cases asphalt concrete (ABM), modified compared to traditional asphalt concrete, with a high content of aggregate larger than 4 mm and with low air void content (lower than 4 percent by volume). ABM is made with a hard bitumen grade (penetration, 100g, 5 seconds, 25°C, is between 50 and 70 1/10 mm) and is rich in binder content.

The protecting course is a stable and dense binder layer, which also protects the waterproofing from mechanical damage and prevents penetration of surface water. Due to the stability of the pavement and for the sake of the heat influence on the waterproofing sheets lying below, the protecting course should not be thicker than 50 mm.

On smaller bridges, the wearing course is often the same as that used on the adjacent road. On larger bridges, Stone Mastic Asphalt (SMA) is normally used as wearing course. The wearing course should also be made with a hard grade or polymer modified bitumen.

The specifications for asphalt pavements on bridges are based on the specifications for pavements for roads but are made more rigorous in their requirements, a stronger material and performance control is demanded together with a more comprehensive inspection during the execution of the work. The control is primary sharpened in the intensity of which cores are taken from the pavement for material control in the laboratory. In addition, cores must be taken 20 mm from joints in the asphalt layer in order to measure the air void content.

Joint sealing

In the longitudinal direction of the bridge, a joint is made between the wearing course and the edge beam with the purpose of absorption of movements between the concrete edge beams and the asphalt pavement due to traffic and temperature. This joint is filled with a hot poured joint sealant or a cold applied joint sealant after priming of the sides in the joint. Before applying the primer and sealant, the joint must be cleaned, which normally is done by sandblasting. The joints are filled up to the edge. Where the vertical joint side continues above the joint level, the joint sealant is moved upwards in a small groove. Only a type approved joint sealant and matching primer may be used.

Expansion joints may be necessary between the adjacent road and the bridge or between bridge elements on longer bridges. These expansions joins can be made mechanically or by use of a bituminous joint sealant filled with stone aggregate (asphaltic plug joint).

To obtain large movements (a real dilatation joint) an asphaltic plug joint is made in both the protecting course and the wearing course. (The width of the joint is approximately 200 mm wider in the wearing course than in the protecting course below). Hot stones are placed in the joint and immediately compacted. Immediately after compaction, hot bituminous sealant is poured on the stones in such a way that the binder fills all the voids and just covers the stones. This procedure is performed at least twice or until the asphaltic plug joint is level with the wearing course.

Final remarks

The concept described for surfacing of concrete bridge decks has been used many years in Denmark with a very good result. At the Great Belt Link, the concept has recently been used for the 6.6 km long concrete bridge. On this bridge, the surfacing consists of two layers of epoxy primer to get assurance against blistering, 15 mm open graded asphalt concrete, 40 mm protective course (ABM) and 40 mm SMA as wearing course. The bridge surfacing was completed in 1995 and the lifetime of the wearing course is expected to be at least 25 years after heavy traffic.

Figure 5. The 6.6 km West bridge on the Great Belt Link has two layers of epoxy primer to get assurance against blistering, 15 mm open graded asphalt concrete, 40 mm asphalt concrete (ABM) as protective course and 40 mm Stone Mastic Asphalt (SMA) as wearing course.

References

[1] "Guidelines for Design of Bituminous Waterproofing and Bridge Pavement" (in Danish only), 8.50.05, Road Directorate, May 1992.

[2] "General Work Conditions, Waterproofing" (in Danish only)", Road Standard, May 1992.

[3] "General Work Conditions, Bridge Pavements" (in Danish only), Road Standard, December 1994.

[4] Vibeke Wegan (1994): " Guidelines for Type Approval of Waterproofing Materials for Concrete Bridges", Danish Road Institute, Report 73.

[5] Sand patch method (in Danish only), Danish Road Institute, Test Procedure 90.1, June 1997.

Rapporter/Reports

Nr./No
År/Year

82/97 Friction Test
Comparative testing with 3 different equipments carried out during the summer 1996
(Bent Lund)

83/97 Eighth International Conference on Asphalt Pavements. Seattle USA, August 10-14, 1997. Papers.
(H.J. Ertman Larsen, Per Ullidtz, Susanne Baltzer, Lynne H. Irwin.)

84/97 TRB Annual Meeting 1997
DRI Paper Presentation at Session 13
Pavement Instrumentation, Part 1.
(Robin A. Macdonald, Wei Zhang)

85/97 Subgrade Performance Study
Part I: Materials, Construction and Instrumentation
(Robin Macdonald, Susanne Baltzer)

86/97 Fifth International Conference on the Bearing Capacity of Roads and Airfields
Trondheim, July 6 - 8, 1998, Papers
(Robin Macdonald, Wei Zhang, Susanne Baltzer, Per Ullidtz, Jesper L. Lund)

87/98 Pavements Subgrade Performance Study
Part II: Modeling Pavement Response and Predicting Pavement Performance
(Wei Zhang, Per Ullidtz, Robin Macdonald)

88/98 Road Unevenness
Paper presented at the 1998 FISITA World Automobile Congress, Paris
(Bjarne Schmidt)

89/99 Development of improved mechanistic deterioration models for flexible pavements
(Hans Ertman Larsen, Per Ullidtz)
(Electronic edition)

90/99 Friktionsmålinger
Sammenlignende målinger mellem ROAR og Stradograf
(Bjarne Schmidt)

91/99 Grundere til broisolering
- typegodkendelse
- materialevalg
(Jeanne Rosenberg)

92/99 The Structure of Polymer Modified Binders and Corresponding Asphalt Mixtures
(Vibeke Wegan, Bernard Brûlé)

93/99 PIARC World Road Association
International Experiment to Harmonise Longitudinal and Transverse Profile Measurement and Reporting Procedures, Draft Report
(Bjarne Schmidt, Jim Wambold, Akira Kawamura, Guy Descornet)
(Electronic edition)

94/99 Evolution and Harmonization of Evenness Evaluation Techniques
(Bjarne Schmidt)
(Electronic edition)

95/99 Investigation of Gyratory Compaction used for Asphalt Mix Design
(Jørn Raaberg)
(Electronic edition)

96/99 Development of Models for Economic Evaluation of Pavement Maintenance: the PAV-ECO Project Providing an Efficient and Socially Acceptable Road Transport Network
(Gregers Hildebrand, Philippe Lepert)
(Electronic edition)

97/99 Development of a Laser-Based High Speed Deflectograph
(Gregers Hildebrand, Søren Rasmussen, Raúl Andrés)
(Electronic edition)

98/99 Accelerated Pavement Testing
1999 International Conference
October 18-20, Reno, Nevada
(Carsten Bredahl Nielsen, Per Ullidtz, Wei Zhang, Susanne Baltzer, Robin A. Macdonald)
(Electronic edition)

99/00 Stabilitet og holdbarhed af danske asfaltbelægninger
(Jeanne Rosenberg, Jørn Raberg)
(Electronic edition)

100/00 Response and Performance of a Test Pavement to two Freeze - Thaw Cycles, Danish Road Testing Machine RTM2: 1998
(Wei Zhang, Robin Macdonald)
(Electronic edition)

101/00 Responses and Performance of a Rehabilitated Test Pavement to Accelerated Load Testing
Danish Road Testing Machine RTM3: 1999
(Wei Zhang, Robin Macdonald)
(Electronic edition)

102/00 Responses and Performance of a Rehabilitated Test Pavement to one Freeze - Thaw Cycle
Danish Road Testing Machine RTM3: 2000
(Wei Zhang, Robin Macdonald)
(Electronic edition)

103/00 PIARC World Road Association
International Experiment to Harmonise Longitudial and Transverse Profile Measurement and Reporting Procedures, Final Report
(Bjarne Schmidt, Jim Wambold, Akira Kawamura, Guy Descornet)
(Electronic edition)

104/00 Examination of pollution in soil and water along roads caused by traffic and the road pavement
(Knud A. Pihl, Jørn Raaberg)
(Electronic edition)

105/00 Thin pavements with synthetic binder used in Denmark
(Jeanne Rosenberg)
(Electronic edition)

106/00 Surfacing of concrete bridges
(Vibeke Wegan)
(Electronic edition)

Road Directorate
Niels Juels Gade 13
P. O. Box 1569
DK-1020 Copenhagen K
Denmark
Telephone: +45 33 93 33 38
Telefax: +45 33 15 63 35

Road Directorate
Elisagaardsvej 5
P. O. Box 235
DK- 4000 Roskilde
Denmark
Telephone: +45 46 30 70 00
Telefax: +45 46 30 71 05

Road Directorate
Thomas Helsteds Vej 11
P.O. Box 529
DK - 8660 Skanderborg
Denmark
Telephone: +45 89 93 22 00
Telefax: +45 86 52 20 13