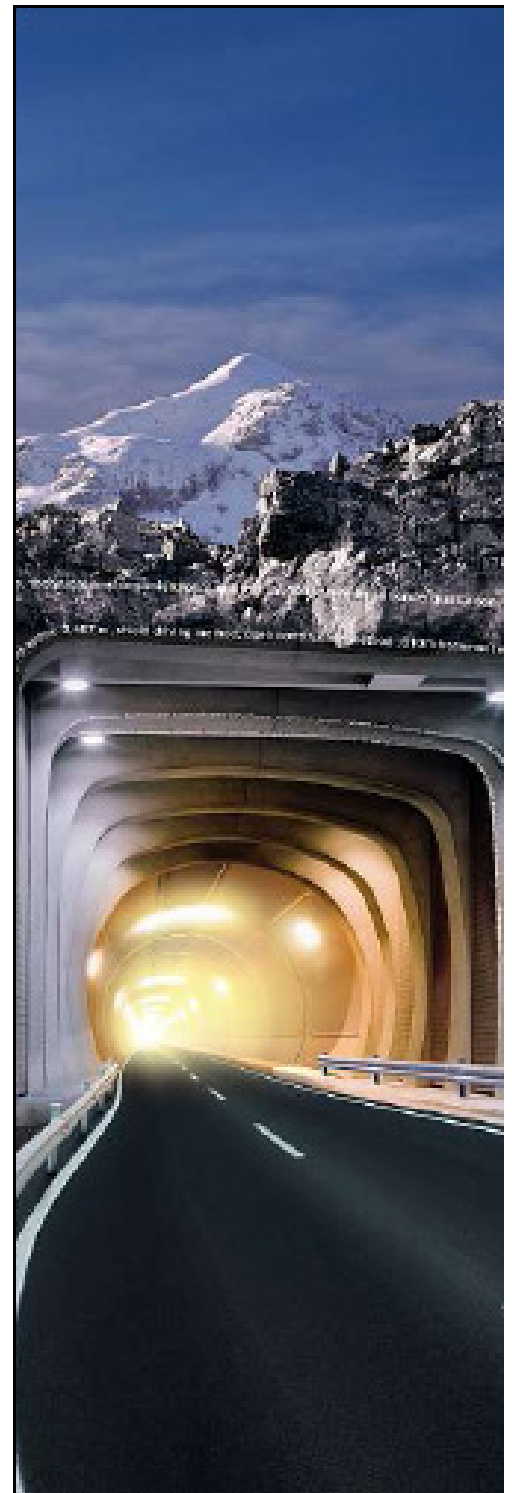


Asphalt pavements in tunnels

EAPA - Position Paper



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Asphalt in Tunnels

EAPA

CONTENT

1	General.....	4
2	Asphalt.....	4
3	Pavement Design	4
4	Fire Resistance of tunnels	5
5	Application of asphalt in tunnels	7
5.1	Skid resistance (safety).....	8
5.2	Safe in use and during accidents (safety)	8
5.3	Visibility (safety / energy)	9
5.4	Longitudinal and transverse evenness (comfort)	9
5.5	Noise reduction capacity (comfort).....	9
5.6	Road construction - maintenance (cost efficiency).....	10
6	Sustainability of Asphalt.....	10
7	Experiences / Typical Examples.....	11
8	Conclusion.....	11
9	Literature	12
10	Appendix: Examples of tunnels with an asphalt pavement.....	14
10.1	Czech Republic, Prague	14
10.2	The Netherlands	14
10.3	Tunnels in Denmark.....	16
10.4	Spain	16
10.5	Germany	17
10.6	France.....	18
10.7	Norway.....	19
10.8	Slovenia.....	20
10.9	Poland.....	20
10.10	United Kingdom	21

1 General

Most of the world's paved roads are surfaced with asphalt, which gives good performance and durability under the most heavily trafficked conditions. Asphalt materials are therefore eminently suitable for use in the construction and surfacing of roads in tunnels.

Asphalts give good performance and durability under the wide range of climatic and traffic conditions. More and more often asphalts are used for industrial areas or for specific applications, such as in buildings, at airports and as base courses for railway tracks and are also widely used in tunnels.

The use of asphalt in road tunnels is a topic which is currently discussed by many engineers in the construction industry. The background for these discussions is mostly related with safety in tunnels and the reaction to fire of asphalt. This document will describe the possibilities of the use of asphalt in tunnels. It will address the construction issues of paving asphalt in tunnels, noise reduction, skid resistance, maintenance and lightness in tunnels as well as the safety aspects with regard to paving activities and the reaction to fires in tunnels.

2 Asphalt

Asphalt is basically a mixture of natural raw materials: coarse and fine (sand), aggregates, filler and bitumen. In addition to these "standard" materials from natural sources, some additives may be incorporated to influence the performance of the product. Examples are adhesion agents, modifiers and fibers. Hot mix asphalt is a mixture of approximately 95% of well graded aggregates, together with filler and sometimes additives. Bitumen makes up the remaining 5% of the mixture.

Bitumen is the black, 'sticky' component (binder) that "glues" the aggregate together. Polymer modified bitumens are increasingly used to modify the performance of the asphalt mixtures in special applications. Bitumen is refined from crude oil, but not all crude oils are suitable for the production of bitumen. Bitumen crude oils are usually so-called "heavy, naphthenic base to mixed base" crude oils. These crude oils produce a large amount of residue during distillation, which have a low level of macrocrystalline paraffin and a sufficient level of high-molecular bitumen. Filler is used in asphalt to fill the smallest voids and to stabilize the binder.

From the outset a clear distinction must be drawn between bitumen and tar. Bitumen is derived as a residual product from the refining of crude oil. Tar is derived from the pyrolysis of coal. Because of known health and safety concerns regarding tar, its usage as a primary material was terminated in most countries many years ago [1].

3 Pavement Design

The design of the asphalt pavement (layers) and the thicknesses needed for the individual pavement layers depend on several issues such as:

- Type of tunnel (immersed /precast or drilled/bored tunnel –where the bearing capacity of the subgrade may need to be considered)
- The design life of the pavement
- The expected amount of traffic expressed on equivalent standard axle loads
- The materials available locally
- The temperature in the tunnel, etc.

In some countries they have specific standards for the pavement design, for example in Austria, standard RVS 09.01.23 [2] regulates the layer thickness of pavements in tunnels. Depending on the traffic along the road tunnel different thicknesses of the bituminous bound layers (from 14 cm to 21 cm) can be selected from a catalogue.

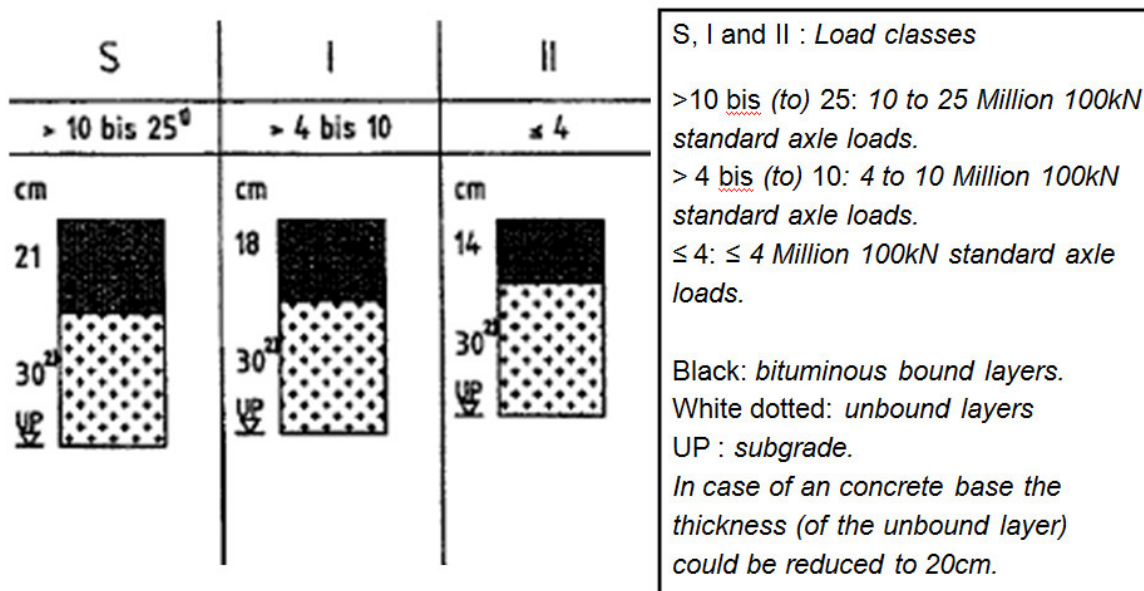


Figure 1: Asphalt layer thicknesses in Tunnels (RVS [2])

The base of the asphalt wearing and base course is an unbound layer of 30cm thickness.

4 Fire Resistance of tunnels

Requirements

Directive 2004/54/EC of the European Parliament and of the Council of 29 April 2004 describes the minimum safety requirements for tunnels in the trans-European road network.

Safety in tunnels requires a number of measures relating, amongst other things, to the geometry of the tunnel and its design.

In addition, one of the essential requirements mentioned in the Construction Products Directive is “Safety in case of fire”. Safety in case of fire according to the CPD means that the construction works must be designed and built in such a way that in the event of an outbreak of fire the construction complies with requirements regarding to the following considerations:

- the load-bearing capacity of the construction can be assumed for a specific period of time,
- the generation and spread of fire and smoke within the works are limited.
- the spread of the fire to neighbouring construction works is limited,
- occupants can leave the works or be rescued by other means
- the safety of rescue teams is taken into consideration.

Asphalt pavements in tunnels are also subject to these considerations.

Regarding the load-bearing capacity, this means that the main structure of all tunnels where a local collapse of the structure could have catastrophic consequences, e.g. immersed tunnels or tunnels which can cause the collapse of important neighbouring structures; shall ensure a sufficient level of fire resistance. This aspect is not directly related to the fire resistance of the pavement, although indirectly the generation and spread of fire from the pavement also has an influence on the total fire resistance of the construction.

Tests and categories

The above mentioned aspects are translated into European standard EN 13501-1, prepared by the Technical Committee CEN/TC 127 “Fire safety in buildings” [3].

Committees that prepare technical specifications relating to the essential requirements in the CPD, which contain performance requirements against reaction to fire, should make reference to the classifications given in this European Standard. The aim of the EU Standard 13501-1 is to define a harmonized procedure for the classification on reaction to fire of construction products.

The European Standards for Bituminous Mixtures (EN 13108 series) also refer to this European standard EN 13501-1. In the paragraph on Reaction to fire in the European Standard for Bituminous Mixtures it is written that in the case when the manufacturer declares a Euroclass for reaction to fire the asphalt it shall be tested and classified in accordance with EN 13501-1.

The Euroclasses in the EN 13501-1 differentiate between floorings and other construction products.

The EN 13501-1 describes “floorings” as “upper layers of a floor, comprising any surface finish with or without an attached backing and with any accompanying underlay, interlayer and adhesive.”

From this definition it can be concluded that an asphalt pavement is subject to the categories for floorings [4]. The Standard EN 13501-1 describes the tests that have to be carried out to classify a construction product.

Results

Recently tests have been carried out on various bituminous mixtures in different countries using the procedures from EN 13501-1 [5 and 6]

All these tests result in the following conclusions:

The Standard EN 13501-1 “Fire Classification of construction products and building elements – Part 1: Classification using test data from reaction to fire tests” supplies a set of tools to classify asphalt pavements according to the Euro Classes.

Depending on the specific composition of the asphalt mix the product can be classified as Bfl or better (A2fl, A1fl). This means that an asphalt pavement does not lead to fire flashover and has a non- (or very limited) contribution to the fire. Besides this, all tests showed no measurable quantity of smoke evolving from the test specimens during the tests.

Classification and test results according to EN 13501-1 support all studies carried out so far that lead to the conclusion that asphalt as a pavement does not easily ignite and does not contribute to the fire size. The contribution to the rate of heat release and total fire load is insignificant especially in the case of a car fire.

This means that bituminous mixtures can be applied with no restriction in tunnels, with the only exception for the use of porous asphalt. Due to its open and permeable character it is advised not to use porous asphalt. In the case of an accident involving dangerous and/or flammable fluids it is possible that these could flow over a greater area with the potential for spread of a fire.

5 Application of asphalt in tunnels

The requirements for roads in tunnels are comparable with the requirements for a road surface in general. The road (surface) should be:

- Safe
- Comfortable
- Sustainable (in relation to energy use and durability)
- Cost efficient

These requirements can be translated into functional requirements for the road (surface) in relation to the following issues:

- Skid resistance (safety)
- Safe in use and during accidents (safety)
- Visibility / Colour / Light reflection (safety / energy)
- Longitudinal and transverse evenness (comfort)
- Noise reduction capacity (comfort)
- Road construction - maintenance (cost efficient)
- Durable (Sustainability)

These items will be discussed in the next paragraphs.

5.1 Skid resistance (safety)

Skid resistance is a major topic for road safety. Especially in tunnels a safe and consistent traffic flow should be guaranteed and the best available technique should be chosen. The deterioration of skid resistance from asphalt as well as concrete surfaces occurs more rapidly - especially in long tunnels - than on roads outside. The reason for this phenomenon is that outside of a road tunnel tire abrasion or dust gets blown away from wind or washed away by rain. Inside of a tunnel this material gets stuck on walls or pavements.

With the help of special equipment walls get washed periodically to remove this detritus, but in the case of pavements it is not so easy to wash away. Different methods are known to clean surfaces, but these will help road operators only for short periods.

The advantage of asphalt pavements is the ease with which maintenance works like milling or laying thin layers on top of the surface for long lasting repairs can be applied.

5.2 Safe in use and during accidents (safety)

The significant fires that occurred in long Alpine tunnels between 1999 and 2005 did lead to several studies, reports and articles addressing fire safety in tunnels.

At the same time, discussions started regarding the use of concrete pavement versus asphalt pavements. This item was studied by PIARC Committee C5 "Road Tunnels Committee". The conclusions of this committee are formulated in [7], stating "It is clear from all the studies and research efforts documented above, that asphalt, as a pavement material, does not add significantly to the fire size (both heat release rate and total fire load) in the case of a road tunnel fire. This is primarily true in the initial phase when (self-) evacuation must take place.

The position of PIARC in its report of 1999 (ref. 1) still remains fully valid: standard (dense) asphalt pavements do not have any significant adverse impact on safety during a fire and can be used in road tunnels".

Concrete itself does not contribute to a fire; however spalling can occur during a tunnel fire [8]:

"Spalling results in the rapid loss of the surface layers of the concrete during a fire. It exposes the core concrete to fire temperatures, thereby increasing the rate of transmission of heat to the core concrete and the reinforcement. Since the spalling occurs in the initial stages of a fire, it may pose a risk to evacuating occupants and fire-fighters [8]"

Recent disasters with tunnel fires and other structures have shown that spalling of concrete is a major threat for structural safety in general and for the safety level of its users in particular. This spalling can take place gradually but also in the form of explosions [9].

5.3 Visibility (safety / energy)

Visibility is important for road users to identify the position where they are and where they want to go to. For roads in general, the reduction of splash and spray, light reflection and contrast are important.

Because it (normally) does not rain in tunnels the reduction of splash and spray is not relevant if there is no standing water on the pavement.

The other two remaining issues are light reflection (lumination) and contrast.

The lamination (the amount of light that is reflected by a surface) is important in tunnels. The road user needs to be able to detect objects and to determine whether they are other road-users or non-moving objects. For this reason certain objects have predefined reflectors.

Also 'detection' is important. Detection is the contrast between observed objects and it is the difference in lamination. So for being able to see the driving lane in the tunnel, the visibility of road-markings is important.

White (or yellow) road-marking on black asphalt gives a good contrast and it is easy to detect the road alignment.

To reduce the lighting costs in tunnels bright coloured asphalt could be used, or a white-coloured aggregate could be used in the asphalt mixture, which could be combined with 'blanc' bitumen (either bitumen with very low asphaltenes or a synthetic resin binder).

5.4 Longitudinal and transverse evenness (comfort)

Asphalt is used to obtain a very good longitudinal and transverse evenness in comparison to the well known problems with concrete slabs. The use of asphalt pavements therefore results in a decreased vehicle vibration and an increase in driving comfort.

5.5 Noise reduction capacity (comfort)

Traffic noise in tunnels is an important topic, especially at tunnel portals which influences the local environment. In the FEHRL report called SILVIA – Sustainable Road Surfaces for Traffic Noise Control, published in the year 2006 [10] - a guidance manual for the implementation of low-noise road surfaces was developed.

Asphalt in general is considered to be particularly effective in reducing noise in tunnels to enhance the acoustic environment of road users and at tunnel portals to reduce the noise impact on local communities. There are several types of asphalt surface layers having a good noise reduction, such as SMA, thin surfacings, BBTM, etc. that can be used in tunnels to reduce the noise. More details can be found in [11].

Because of its sound absorptive qualities, asphalt is also effective in reducing noise in confined road spaces where buildings on both sides of the road form a deep narrow “canyon”. The effect is further enhanced if there is a cover, or partial cover, over the road (FEHRL report [10]).

5.6 Road construction - maintenance (cost efficiency)

Pavement maintenance is an important factor for European road networks and their operators, and because of the growing amount of traffic and the resulting damages or fatigue characteristics maintenance operations get a huge topic in financing. Long road and lane closures are worst case scenarios for road operators

This topic demonstrates a big advantage for flexible constructions because maintenance work on asphalt pavements is a much less complicated process than for rigid concrete constructions. It can be completed quickly and economically. As a result, asphalt pavements minimize the often overlooked user delay costs associated with traffic delays, detours and road closures, which can be astronomical. For a busy motorway, traffic delays from a single construction project can easily cost a local economy a huge amount of money.

Maintenance works are additionally minimized through the positive effect of a constant temperature inside of a tunnel. Asphalt mixes and their ingredients (especially the bitumen type) can be specially designed and optimized to those local conditions.

Through the use of Warm Asphalt Technology (a technology that allows a reduction in the temperatures at which asphalt mixes are produced and placed [22]) the fumes generated by the construction equipment are less than the exhaust gases of the traffic and the normal ventilation system of the tunnel should be able to cope with this issue.

Equally, with the use of Hot Mix Asphalt, the ventilation system should be capable to cope with any fumes arising.

6 Sustainability of Asphalt

Studies show that asphalt pavements minimize impacts on the environment from the production of the paving material, to the placement of the pavement on the road, to rehabilitation, and through recycling [12]. Also, low energy consumption for production & application, low emission of greenhouse gases and conservation of natural resources contribute to minimising the impact on the environment [12].

Cleaner air, improving water quality, being long lasting, as well as energy savings through recycling are characteristics which mark asphalt as the environmentally sustainable pavement. By minimizing its impact on the environment and maximising

its positive value asphalt pavement technology is clearly positioned to provide the public with sustainable roads in and outside of tunnels for the future [12].

7 Experiences / Typical Examples

In the appendix several examples of the use of asphalt pavements are shown.

8 Conclusion

The results of the current report show that the use of asphalt as road construction material in tunnels has several advantages.

Tunnel pavements made of asphalt are safe in case of fire, last long and are easy to maintain in case of damage.

In many other important topics like skid resistance, maintenance or noise reduction asphalt seems to be the ideal material for tunnel constructions.

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10 Appendix: Examples of tunnels with an asphalt pavement

10.1 Czech Republic, Prague

New road tunnel in Mrazovka

The Mrazovka tunnel [13] with two separate tubes is part of the internal ring road of Prague and has a length of 1200 m. Because of different advantages such as quicker realisation, lower cost, no joints needed and the possibility of quick reparation - if necessary - an asphalt pavement was constructed.

Important requirements for the pavement were reached through a special mix design. The 20 cm thick asphalt construction was designed with bright aggregate and different asphalt and geotextile layers. The surface course was paved with 35 mm thick stone mastic asphalt.

By using asphalt nearly 200 joints that would have been necessary in a concrete pavement were eliminated. The skid resistance of the surface course is better than on a concrete pavement. Besides all of this, the asphalt pavement was cheaper than a concrete construction.

The tunnel was opened to traffic in 2004.

10.2 The Netherlands

There a lot of tunnels in The Netherlands. Most of them have an asphalt pavement. There are also some tunnels with a concrete pavement, but these are smaller community tunnels. All the tunnels in the primary network of highways have an asphalt pavement.

Table 2 shows a list of the main tunnels in The Netherlands.

With regard to pavement design in tunnels, in the past one layer of asphalt has been applied to provide a smooth, safe and comfortable surface. If the existing concrete was very uneven and if the available height was sufficient, a regulating layer was first applied.

Nowadays a first layer of Porous Asphalt is applied, 30 mm thick of 0/11 or 50 mm thick of 0/16 depending on available height in the tunnel. To improve the water sensitivity a polymer binder is advised. The second layer is a dense asphalt concrete with a maximum void content of 4% acting as a waterproof (impermeable) layer. Porous asphalt is not allowed as surface layer (to prevent any possible spread of any flammable liquids in the PA layer, which would also collect at the lowest point).

Table 2: Main tunnels in The Netherlands

Tunnels with Asphalt Pavements in The Netherlands			
Tunnel	Road	Location	Length [m]
Beneluxtunnel	RW A4	Rijnmond	710
Botlektunnel	RW A15	Rijnmond	1180
Coentunnel	RW A10	Amsterdam	1280
Drechtunnel	RW A16	Zuid-Hollandse Waarden	820
Heineoordtunnel	RW A29	Rijnmond	1060
Kiltunnel	N217	Tunnel Dordtse Kil	900
Maastunnel	City	Rotterdam	1070
Noordtunnel	RW A15	Zuid-Hollandse Waarden	1270
Piet Heintunnel	City	Amsterdam	1500
Sijtwendetunnel	N14	Haaglanden	1880
Thomassentunnel	N15	Rijnmond	690
Velsertunnel	RW A22	Alkmaar	1660
Vlaketunnel	RW A58	Zeeland	770
Westerscheldetunnel	N62	Tunnel Westerscheldeweg	6600
Wijkertunnel	RW A9	Alkmaar	2000
IJtunnel	City	Amsterdam	1680
Zeeburgertunnel	RW A10	Amsterdam	950

The Westerschelde Tunnel with its 6,60 kilometres length, connecting Central Zeeland and Zeeuwsch-Vlaanderen, is an example of a project in which adjustments were made to the original design to increase the safety level [14].

Engineers working on the Westerschelde Tunnel took many steps to decrease the risk of fire or explosion to ensure safety. Two precautions taken to reduce this risk are described as follows: first, engineers used dense-graded non-porous asphalt concrete instead of open-graded because the open-graded increases the evaporation surface, thus increasing the risk of explosion if fuel leaks onto the road. Secondly, the road is slightly slanted so fuels drain into gutters which transport the fuels to explosion-safe storage tanks under the tunnel [14].

10.3 Tunnels in Denmark

In Denmark there are several tunnels with an asphalt pavement. Table 3 gives an overview of Danish tunnels with a length over 200 m (February 2008).

Table 3: Danish tunnels with a length over 200 m (February 2008)

Name	Length (m)	Lanes	Wearing course	Asphalt thickness (mm)	Last paved	Comments
Øresund Tunnel	3,510	2 x 2	SMA 16	30-35	2000	
Tårnby Tunnel	700	2 x 2	AC 11, open graded	30-35	1998	Very high void content (18 %). Sealed in 2004.
Frederikssundsvejs Tunnel	367	2 x 2	Mastic Asphalt		1969	
Guldborgsund Tunnel	460	2 x 2	HRA	38	1988	1 x 1 lane has first been taken into service in 2007.
Limfjords Tunnel	582	2 x 2	SMA	34	1992	

10.4 Spain

In [15] a Spanish view is presented including proposals for criteria and materials for the design and construction of pavement sections in tunnels due to the absence of National Specifications and recommendations. It gives a general review of relevant tunnel conditions for making the necessary decisions during the design period.

Criteria to evaluate the loads (traffic category) and pavement foundation are given. Two catalogues are provided, the first for different solutions to building the pavement foundations and the second to decide on materials and layer thicknesses for pavement sections, with alternative solutions based on bituminous materials and concrete. Finally, the article contains additional guidance on the factors that need to be considered before deciding on pavement type, and some recommendations on the construction processes for each material type.

Some conclusions and recommendations:

- Thinner pavement layers could be used when using the best quality materials;
- For the selection of the type of pavement it is necessary to take into account the quality of its execution, given the difficulties associated with traffic and the shortage of space to carry out repairs or of preventative maintenance.
- For the pavement type selection, one should not only evaluate the capital cost of the construction, but also keep in mind the technical criteria: structural and functional characteristics, construction process, maintenance needs and also the user delay costs due to the maintenance works.



Portada tunnel

10.5 Germany

A (short) selection of tunnels with asphalt pavements in Germany.

The tunnels shown in this overview have different purposes such as: crossing mountains, crossing rivers, noise-reduction downtown or traffic-reasons. They are sorted from north to south.

Elbetunnel

Autobahn A7 downtown in Hamburg; Crossing the river Elbe (3.543 m)

Weserquerung

Bundesstrasse B437 south of Bremen; Crossing the river Weser (1640 m)

Tunnel Rheinschlinge

Autobahn A44 in Meerbusch near Düsseldorf (1.682 m)

Universitätstunnel

Autobahn A44 downtown in Düsseldorf (1.177 m)

Rennsteigtunnel
Autobahn A71 near Suhl, Thuringia (7.900 m)

Engelbergtunnel
Autobahn A81 Heilbronn – Stuttgart in Leonberg near Stuttgart (2.530 m)

Tunnel Michaelsberg
Bundesstrasse B500 in Baden- Baden; Part of the ring-road around Baden-Baden, the B500 leads on into the Black Forest (1.214 m)

Grenztunnel
Autobahn A7 Füssen – Reutte; Border between Austria and Germany on the way from Stuttgart to Innsbruck (1.320 m)

Tunnel Nollinger Berg
Autobahn A861 in Rheinfelden (near Basel); Connecting A98/E54 (from Karlsruhe and Freiburg) in Germany with A3/E60 in Switzerland (1.264 m).

10.6 France

Examples from France are:

The Toulon Tunnel in the town of Toulon (link between motorway A 57 and A 50).
The length is 3.2 km and it is 7 m wide.

The wearing course is a 30 mm thick white thin asphalt concrete



Toulon Tunnel

An other example is the Fréjus tunnel from the A 43 motorway to Italy.
Its length is 12.870 m (1/2 in France and 1/2 in Italy) and it is 8 m wide.
The base course is a road base asphalt concrete and the surface course is a Thin asphalt concrete with modified bitumen.



A-86 tunnel from Rueil Malmaison to A 13 motorway

The A 86 tunnel from Rueil Malmaison to A 13 motorway has a length of 2 times 4.5 km (2 parallel tubes) with a width of 11 m. The surface course is a 30 mm thick white thin asphalt concrete.

10.7 Norway

In Norway there are thousands of tunnels and almost all have an asphalt surface.

The longest one is the Lærdalstunnellen, Rv 50, between Aurland and Lærdal in Sogn & Fjordane county. It has a length of 24.510 meters and was opened in November 2000. This tunnel is probably the longest tunnel in the world. The surface layer in the Lærdalstunnellen is AC.

The Rv 23 Oslofjordtunnellen, goes under the sea, as many other tunnels in Norway.

10.8 Slovenia



Ljubno tunnel

The Ljubno tunnel is located in the new highway between Ljubljana and Bled in the region of Gorenjska. It has a length of 260 m and has an asphalt pavement. The surface course is an SMA 11 PmB 45/80-65 with a thickness of 40 mm. The binder course is an AC 22 bin PmB 45/80-65 with a thickness of 80 mm. And the base course is an AC 32 base 50/70 with a thickness of 90 mm.

10.9 Poland

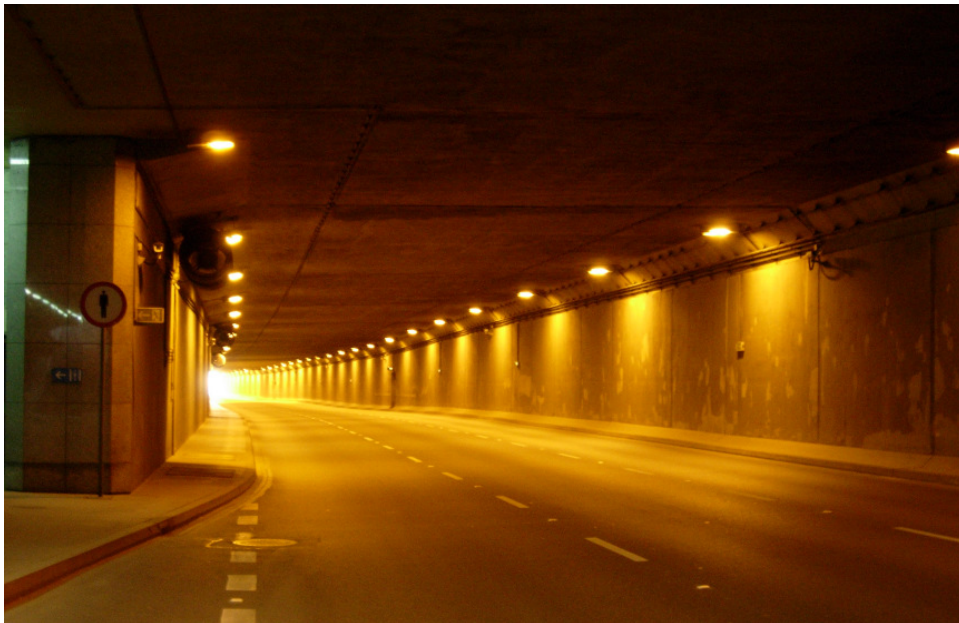
In Poland there are not many tunnels in road network. Existing tunnels are mainly located at big towns. An example of tunnel in municipal road network in Warsaw is Wislostrada Tunnel. In fact there is a double tunnel with three lanes in each direction. The total length is 700 m.

Pavement construction of the Wislostrada Tunnel:

- wearing course: 5 cm asphalt concrete AC 16 with low temperature binder PMB 25/55-63,
- binder course: 6 cm asphalt concrete AC 20 with low temperature binder PMB 25/55-63,
- insulation,
- cement concrete slab.



General view of northern in/out of the Wislostrada Tunnel



Wislostrada Tunnel inside

10.10 United Kingdom

The United Kingdom has a number of significant (and other smaller) road tunnels paved with asphalt. The following case studies illustrate two examples.

Site: Dartford Tunnel, east of London under River Thames, between the counties of Kent and Essex, roads M25 and A282, length approximately 1 mile.

As a result of the damage caused by intensive canalised heavy goods traffic in the Dartford West Tunnel, a contract for the replacement of the decks was let and work was started in April 2000. To ensure rutting resistance, stringent Wheel Tracking requirements were applied to both the binder course and surface course. The binder course was required to both withstand the stresses imposed by the heavy goods vehicles, and to provide a safe high texture surfacing until the final surface course could be laid, some time later to permit the continued use of the tunnel by traffic. Preparation works involved the laying of a waterproof membrane placed directly onto the concrete precast decking, followed by a Red Sand Carpet interlayer containing a modified binder

Materials : Thin Surfacing (a proprietary BBTM 10 type) laid at 20mm thick on top of a SMA 14 binder course laid at 35mm thick. Both materials utilised an SBS type PMB.

The final result is a durable, high texture low noise surfacing capable of withstanding one of the most onerous traffic environments in the UK.



Dartford Tunnel approach – toll plaza



Dartford Tunnel interior

Site: Tyne Tunnel, east of Newcastle-upon-Tyne under River Tyne, between the counties of North and South Tyneside, road A19, length 1550 m.

25,000 vehicles use the Tyne Tunnel, 24 hours a day, seven days a week, so to replace the road deck and surfacing a five-week schedule of weekend closure from 9pm on Friday to 6am on Monday was selected to minimize disruption to traffic. The old 40mm thick layer of Hot Rolled Asphalt was planed out, with a further 20mm excavated by hand to prevent damage to the concrete base.

Materials: Surfacing renewal employed a 20mm thick layer of Mastic Asphalt to provide a waterproofing layer, overlaid with a 40mm thick layer of a proprietary SMA 14 surface course.

The overall construction provides high levels of durability and rut resistance combined with excellent noise reducing characteristics which has made it more acceptable to customers during busy peak flow periods.



Tyne Tunnel approach



Tyne Tunnel interior