UTW: TEST SECTION AT VILVOORDE ON THE R22 IN BELGIUM

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Abstract

UTW (Ultra Thin Whitetopping) is a very recent and innovative application to repair a degraded asphalt pavement. The repair technique tries to bond the two layers (overlay in concrete and lower lying asphalt pavement) to obtain a composite structure. The technique consists of milling off the rutted asphalt layer in a suitable thickness and covering it with a thin cement concrete layer (< 15 cm) that bonds perfectly with the underlying asphalt layer. UTW is characterised by a good bonding between concrete and asphalt and by the short distances between the joints (between 0.60 and 1.80 m).

For the first time in Flanders, a test section was carried out near the intersection of the Woluwelaan with the Houtemsesteenweg at Vilvoorde. A survey of the existing pavement, the project, the successive construction phases as well as the most important points of particular interest are described in this article.

1. Introduction

UTW (Ultra Thin Whitetopping) or ultra thin wearing course in cement concrete, with a thickness between 5 and 15 cm, is a very recent and innovative application to repair a degraded asphalt pavement. The technique first appeared in the United States in the early 1990s, and is currently undergoing rapid development in several countries. The repair technique tries to bond the two layers (overlay in concrete and lower lying asphalt pavement) to obtain a composite structure. By doing so, the concrete overlay can be kept significantly thinner for a similar load as compared to a non-bonding overlay.

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There are two reasons why the monolithic composite offers a long life span:

- because of the large material rigidity of concrete, the wheel loads are dispersed towards the underlying asphalt layer;
- the use of concrete ensures a thermal protection of the existing structure.

First, the general principles of a UTW pavement will be commented upon. Further attention will then go to the first test section in Flanders emphasising the points of particular interest during the construction.

2. The Principles Of UTW

2.1. Bonding Of Asphalt And Concrete.

Firstly, the bonding of the thin concrete overlay and the underlying asphalt layer is essential. In concrete road-surface cracks occur when the tensions in the concrete exceed the breaking resistance of the concrete. The tensions are brought about by wheel loads on the one hand and by environmental influences on the other.

Thanks to the bond between asphalt and concrete, the structure will perform as a whole (composite paving). The neutral axis of the tension diagram is shifted downwards, reducing pulling loads on the concrete slab as illustrated schematically in figure 1.

A hard-wearing bond between the asphalt and the concrete is obtained by carefully milling off the asphalt surface and by clearing it of dust. The bond is in other words a sort of mechanical joint between the layers.

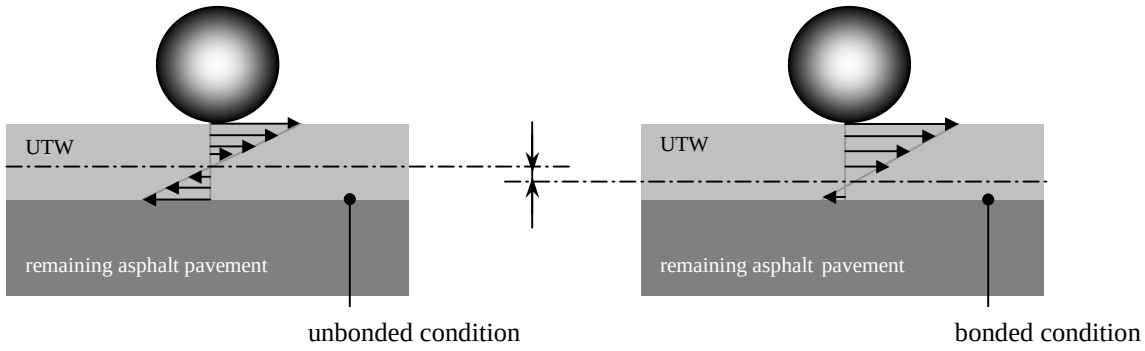

Figure 1: Influence of the bond between asphalt and concrete on the tension diagram in the concrete slab. The shifting downwards of the neutral axis reduces the pulling loads in the concrete.

2.2. Joint Distances

A second basic principle is that the joints are situated at short distances from each other: i.e. between 0.60 and 1.80 metres.

Traditional concrete pavements are designed to absorb the energy of the imposed loads by bending. Owing to this, the concrete pavement must be sufficiently thick to resist the tensions that occur through bending. Because of the limited thickness of UTW, it is necessary to reduce the distance between the joints considerably. In doing so, the energy of the wheel loads are transferred to the underlying asphalt layer by the lateral shifting movement, rather than by the bending, as shown schematically in figure 2.

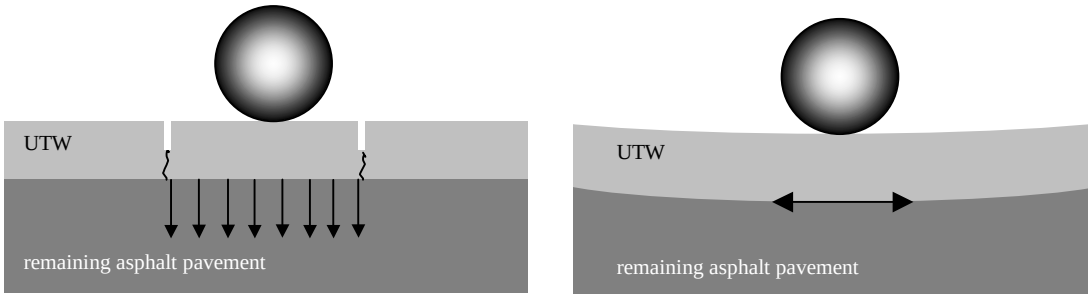

Figure 2: Influence of the distance between joints with UTW. A short distance between the joints considerably diminishes the pulling loads at the bottom of the concrete slab.

Besides tensions due to external load, changes in temperature and humidity over the thickness of the slab cause also internal tensions. The temperature gradient causes the curling up of the slab corners. The humidity gradient causes vaulting tensions in the slab. The short joint distances also reduce these tensions.

A mesh width of the joints along a square pattern with as its side 12 to 15 times the thickness of the slab is recommended. Characteristic values of the joints are approximately 3 mm wide with a depth of between 1/3 and 1/4 of the thickness of the slab.

2.3. Asphalt Thickness

The third basic principle is that the underlying asphalt pavement should remain sufficiently thick to form a good composite structure that can carry the loads. The thicker the asphalt layer is, the more the pulling loads are reduced in the concrete. This can again be explained by the lowering of the neutral axis in the concrete slab as shown in the figure.

Experience in American has shown that a minimum asphalt thickness of 35 mm will be sufficient to make a very good base of the UTW to bond. The quality of the asphalt is a good indicator of how well the UTW will perform. Depending on the quality of the underlying layers it can be advisable first to lay a new layer of asphalt to obtain an adequate structural underlay before proceeding with the UTW overlay.

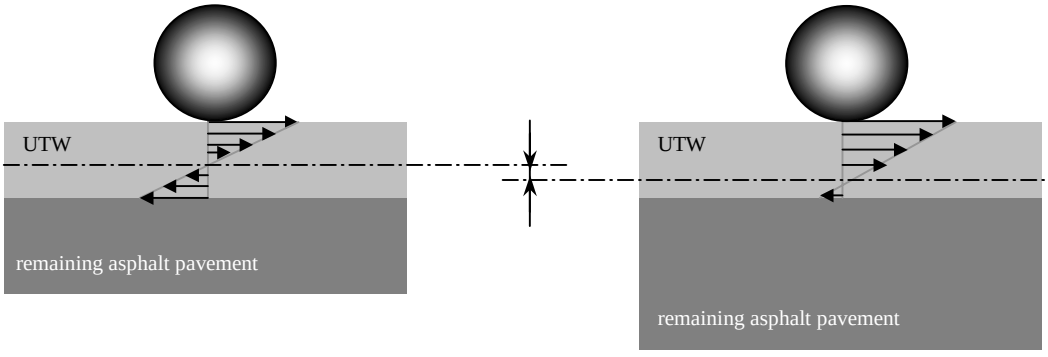

Figure 3: Influence of the thickness of the remaining asphalt layer (considering the same asphalt quality) on the tension diagram in the concrete slab. The thicker the asphalt layer, the more the neutral axis shifts downwards and the more the pulling loads in the concrete are reduced. The quality of the remaining asphalt layers however, is of greater importance than the thickness.

3. The UTW-Project On The R22 (Woluwelaan) In Vilvoorde (Belgium)

3.1. Location Of The Project

Vilvoorde is situated about 10 km (6.2 miles) from Brussels in the Flemish part of Belgium. The test section is situated on the R22 Woluwelaan near the intersection with the Houtemsesteenweg. This intersection is equipped with three-colour traffic lights and has 2 x 2 lanes of 7 m in width with a wide central reservation.



3.2. Structure of the pavement

The structure of the pavement is composed as follows:

- wearing course: 5 cm AB type II
- lower layers: 7 cm AB type III A
  7 cm AB type III A
  5 cm AB type III B
- road base: 25 cm stone chippings with continuous grading
- sub-base: 35 cm sub-base type I with drain

The road section was executed in 1991. On the right lane, there was occurrence of rutting, especially in front of the traffic lights.

3.3. Rutting

The Road Engineering Division carried out deflection measurements using. At the intersection, a transversal profile was drawn up in both directions and a number of cores were drilled straight across the road. These clearly show rutting.

The results of these measurements indicate that:
- the rutting is due to and can only be found in the wearing course
- there is no rutting in the lower layers or in the road base
- the road composition is adequate according to the traffic and the ground beneath

3.4. The Design Of The Test Section

Instead of the usual milling off and replacing of the uppermost layers by asphalt, the decision was taken to cast a thin layer of concrete.

3.4.1. Dimensions Of The Slabs

Because there is little or no experience in Belgium, the project was executed as a test section. In co-operation with the Road Engineering Division, the Research Center for Road Building and FEBELCEM, the decision was made to execute 3 experimental thicknesses (10, 12 and 15 cm) and 2 joint distances (1.16 and 1.75 m). This resulted in 5 different combinations:
- t = 10 cm; dimension 1.16m x 1.16m (test section 1: Mechelen -> Machelen + test section 2: Machelen -> Mechelen)
- t = 10 cm; dimension 1.75m x 1.75m (test section 2)
- t = 12 cm; dimension 1.16m x 1.16m (test section 1)
- t = 12 cm; dimension 1.75m x 1.75m (test section 2)
- t = 15 cm; dimension 1.75m x 1.75m (test section 1 + 2)

For the design of the joints of the UTW paving, the general design guidelines for joints in concrete slabs apply. This means for example that the joints in the pavement must be joined to the joints in the adjoining kerb or gutter. Several projects in the USA have proved a permanent load of the wheels on the joints to be very undesirable.

The transfer of the load between the slabs is ensured when applying UTW by the sliding resistance between granulates of the irregular torn surface under the sawed joint. This way of transferring is very effective because of the short joint distances. Moreover, the transfer of load is not as critical for UTW when compared with conventional pavements, because the load is transferred to the underlying asphalt pavement. The use of dowels is for this reason not necessary, and moreover not practicably feasible. The slabs are also not reinforced.

3.4.2. Composition Of The Concrete

The composition of the concrete of an UTW project is identical to traditional pavements apart from a number of specific adaptations:

- it is advised to use hard porphyry chipping from quarries;
- a continual granulate distribution with adequate 4/7 and a limited fraction of 7/14. Granulates up to 20 mm are also possible, but by using finer granulates, the concrete can more easily be processed;
- the composition is often decided by the demands to re-open the road to traffic, which means that fast drying concrete is often used, in other words 425 to 450 kg cement per m^3.

The concrete composition used is as follows:

- a low water-cement factor, which increases the durability of the concrete;
- addition of plasticizers to improve the compression;
- river sand 0/4 ± 700 kg
- porphyry chippings 4/7 ± 460 kg
- porphyry chippings 7/14 ± 555 kg
- cement CEM III 42,5 LA 450 kg
- plasticizer ± 1 l
- super plasticizer 3 to 4 l
- water ± 185 l

3.5. Points Of Attention During The Execution

3.5.1. Preparation Of The Asphalt Surface

During the execution of the works special attention should be given to the roughness of the surface of the asphalt (see Figure 4), and the borders should be intact and straight. By milling, a sufficiently rough surface is formed, which promotes the bonding between the concrete and the asphalt. The milling should be done according to the granulates of the asphalt.



Figure 4: Flat milled asphalt surface

Where the milled surface is situated immediately between 2 layers of asphalt, deeper milling is necessary.

Before the casting of the concrete, the milled surface should be cleaned thoroughly, preferably with water and pressurised air (see Figure 5).



Figure 5: Pressurised cleaning of the milled surface

The transition between 2 different layers of thickness in the test section was executed progressively over the length of 1 slab.

It is necessary to incorporate an extra thickness between the UTW pavement and the asphalt pavement in order to built up the tension gradually. This transition is necessary everywhere in the direction of traffic flow. (see Figure 6).

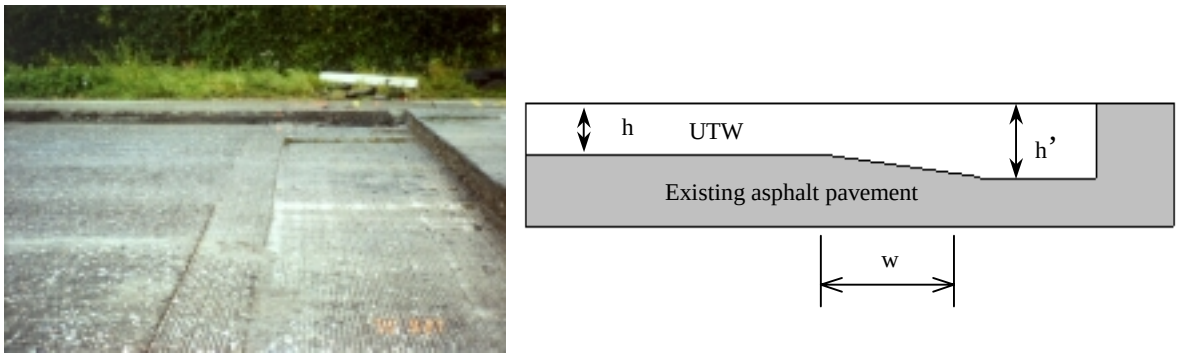

Figure 6: Transition from UTW to the adjacent asphalt pavement
w = ± 2 m; h' = h + 75 mm and min. 150 mm

3.5.2. Casting Concrete

The casting of UTW pavements does not differ from other concrete pavements. Before casting the concrete, it is recommended that the surface of the asphalt be moistened (see Figure 7), in order to prevent water absorption from the concrete.



Figure 7: Moistening the asphalt surface immediately before casting the concrete.

Depending on the size of the repair the concrete is cast with sliding formwork or with a vibrating beam. In Vilvoorde the test-section is cast with sliding formwork (see Figure 8).



Figure 8: Casting with sliding formwork.

3.5.3. Aftercare

Regarding aftercare, all traditional surface treatments can be applied to a UTW pavement. On the test section, transversal brooming was applied. To protect the newly cast concrete, the amount of curing compound must be doubled compared with normal directions for use.



Figure 9: Aftercare of the newly cast concrete with curing compound.

3.5.4. Joints

Transversal and longitudinal joints must be sawed as fast as possible to prevent initial tensions. Long delays can cause uncontrolled edge cracks. Early sawing can cause crumbling at the location of the joints.

It is recommended to start the sawing as soon as it is possible to walk normally on the concrete, and to use several sawing machines simultaneously. It is a good idea to make one or more test cuts to check how the edges of the saw cut behave. According to the literature, it is not necessary to fill the joints.



Figure 10: View of the UTW pavement

3.6. Execution

Contractor NV Verhaeren & Co did the execution of the test section in September 2000.

3.6.1. Section Mechelen -> Machelen: length 177m (test section 1)

While milling the first 10-cm section, it was established that the partition between the lower layers lay at a depth of 11 cm. To prevent the danger of this last centimetre coming loose, the decision was made to execute this section at 12 cm.

The test section was executed on September 19, 2000. The weather was sunny with a temperature of around 25°C and strong winds.

Due to supply problems the finishing machine repeatedly stood idle. In the course of the afternoon a number of diagonal windshakes were detected.

The decision was made to first saw 1 in 5 joints to absorb the first shrinkage (this approximately 8 hours after the casting of the concrete). The following morning, the intermediate joints were sawed.

Since the first sawed joints absorb most of the shrinkage, these are larger than the intermediate joints. For this reason, these joints were filled. The intermediate joints were not filled. The joints between asphalt and concrete were also filled with cast joint filler to prevent water penetration as far as possible.

Apart from the above mentioned windshakes, no cracks were detected. The section was opened to traffic after 3 days.

3.6.2. Section Machelen -> Mechelen: length 177m (section 2)

This section was executed on September 27, 2000. Because the weather conditions did not differ considerably from those at the execution of the first test section the decision was made to reduce the concrete proportion to 425 kg/m³ and to add an air bubble former at the rate of 4%.
There were no problems in the concrete supply. The joints were executed in the same way. The section was opened to traffic after 4 days.

One month after the opening of the section to traffic, six cracks were detected. All cracks but one are located in the first or the first and the second strip next to the water channel. All these cracks originate in a transversal joint or crack in this water channel (see figure 11). As the UTW pavement is directly cast against the water channel, both structures behave as a whole. The expansion and shrinkage movements of the concrete water channel have caused a crack in the UTW pavement near the joints of the water channel. In the future, it would be desirable to provide a sound joint over the total thickness between the water channel or side strip to be retained and the UTW pavement.



Figure 11: Sympathetic cracks in the UTW pavement due to the joints of the water channel.

Due to the better weather conditions, the addition of an air-entraining agent and the lower cement content, no cracks appeared in this section after construction. The average compression strength measured on the cylinders with section S = 100 cm² after 28 days was 66,6 N/mm² compared to 72 N/mm² in the first section. After 5 days however, a average compression of 39,6 N/mm² had already developed.

4. Initial Conclusions And Recommendations

As the test section was only recently constructed (September 2000), conclusions are principally based upon the execution mode and the observations made during and after the first winter period.

Experience from the USA, Sweden, France and other countries shows that the UTW pavement usually behaves well generally, even with heavy traffic, and exhibits long durability.

A sound pre-investigation of the existing road structure and the careful execution of the following basic principles are an absolute necessity.

- The bonding between the concrete overlay and the underlying asphalt is one of the most critical elements for reducing tensions and ensuring durability. To this end, it is necessary to start from a clean, but rough surface obtained by milling and cleaning with compressed air. Moreover, the use of a plasticizer and a good compression of the concrete (through using sliding form work) can have a positive impact on the bonding.
- A second basic principle is the short joint distances, between 12 and 15 times the thickness of the pavement. They reduce the bending tensions in the slab and the sliding tensions between the overlay and the asphalt pavement.
- It is necessary for the remaining asphalt pavement to be structurally adequate (principally the quality of the asphalt layer), because the asphalt pavement is in fact the supporting structure.

In the design, the composition of the concrete and the placing of the joints must in particular be studied profoundly. A wheel load occurring mainly at the joints proved in the USA to be very undesirable. It should also be examined whether there are no differences in the foundations of the section to be repaired.

During the execution of the works, special attention should furthermore be given to the following:

- moistening the surface of the asphalt immediately before casting the concrete;
- when using fixed formwork, the sides should be well compressed using a vibrating needle; priority should be given to sliding formwork;
- protection of the newly cast concrete against drying out misting with an adequate amount of curing compound (min 200 g/m²);
- sawing of the joints as early as possible, as from the moment when it is possible to tread on the concrete normally;
- joints must be sawed to a depth of 1/3 of the concrete overlay and the joint width should be no more than 3 mm. Because of the large number of joints, adequate sawing material should be present at the construction site. It is a good idea to start with one or more test cuts to check how the edges of the saw cut behave;
- the concrete composition has to be carefully studied

The UTW behaved well after a severe winter period. The only appearing cracks are the wind cracks in the first section due to the wind and a too high cement content. In the second section, the only cracks are the sympathetic cracks due to the movements of the joints of the adjacent

water channel. It is desirable to provide a sound joint over the whole thickness between the water channel or side strip to be retained and the UTW pavement.

References

1. Le Béton de Ciment Mince Collé (BCMC)
   Cimbéton
   J. Adbo

2. Dunne overlagen van cementbeton
   RR OCCN 53-n-1990
   ir. Karel Verhoeven

3. Nieuwe toepassingen van cement en beton
   Bouwkroniek
   ir. L. Hendrikx

4. Recouvrements minces adhérents en béton de ciment sur revêtements bitumineux - thin bonded overlays of asfalt pavement
   Routes - Roads no. 302 - April 1999 (p. 40-52)
   Lawrence W. Cole

5. Le recours au béton de ciment mince collé (BCMC) pour remédier à l'orniérage - The use of thin bonded Portland cement concrete (TBPCC) to remedy rutting
   RGRA no. 768 - December 1998 (p. 57-60)
   G. Bonnet, J.P. Christory, J.F. Duchaillut, D. Grob, J. Abdo, A. Sainton

6. Ultra Thin Whitetopping: Ontario experience
   Canadian Portland Cement Association
   Harry Sturm & David Morris

7. Whitetoppings - Long term performance and recommendations
   Royal Institute of Technology (KTH), Stockholm, Sweden
   Prof. Johan Silfwerbrand, ph. D., Dept. Of Structural Engineering

8. Béton de ciment et béton de cement mince collé, L'expérience americaine
   Lawrence W. Cole

9. Designing Whitetopped Parking Lots to Last
   Concrete construction – April 1994 Volume 39 Number 4
   Larry Cole

10. Whittetopping – State of the practice
    American Concrete Pavement Association