# Thin whitetopping overlay over a deformed asphalt pavement of a highly trafficked urban intersection

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**Abstract**

The construction of thin or ultra-thin whitetoppings is considered as an up-to-date rehabilitation technology for flexible pavement structures with repeatedly deformed pavement surface. The experiences on the first use of this technique in Hungary is presented briefly. A highly trafficked urban intersection with traffic signal was the site of the test section. The laboratory investigation of cored samples taken from the deformed pavement structure was followed by cement concrete mix design by KTI-institute. Four previous trials were carried out in May-July 2007. The experience gained in these trials was utilised in the actual execution of the experimental section in October 2007. The deteriorated asphalt layers were milled in 120 mm depth. A 85 m-long whitetopping in 120 mm thickness was placed using manual paving technique. 1.75x1.75 m slabs were cut in the thin cement concrete layer without joint filler and dowels. The main quality parameters measured of the fresh cement concrete mixture were: slump, air bubble content, density, temperature, optimum time for curing plastic covers, strength. The density, compressive strength, splitting tensile strength, flexural strength, water permeability and surface texture depth were measured on the hardened concrete. After 6 months (severe winter), the section is in excellent condition, no damage can be seen. Several new thin whitetopping sections are planned in Hungary for 2008.

## Introduction

Since the development of the public highway networks has been more or less completed in the majority of the countries, the rehabilitation of these roads has come into prominence. Asphalt pavements can be considered as the most widespread type of road pavement all over the world. Even if they are properly designed and constructed and high quality basic materials are used, the pavement deformation (e.g. rutting) under high traffic load and in high temperature is almost inevitable. The traditional rehabilitation techniques using asphalt layers can usually provide just a short-term solution, consequently the pavement deterioration is repeated in some years. In several countries, thin (101-200 mm) or ultra-thin (51-100 mm) white-toppings were successfully used for the repair of deteriorated asphalt pavements.

The experiences on the first use of this pavement rehabilitation technique in Hungary will be presented subsequently.

## Some foreign whitetopping experience

It is evident that the highway engineers all over the world search for cost effective road pavement construction, maintenance and rehabilitation techniques. In the past,

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this theory often resulted in asphalt concrete being the only alternative overlay procedure vs the total reconstruction of a portland cement concrete pavement (Cable et.al, 2001). In response to these needs, engineers developed the bonded and unbounded overlay with portland cement concrete and whitetopping of asphalt concrete road surfaces.

The oldest type of concrete overlays over an existing asphalt pavement is termed white- topping. They are placed directly on the existing asphalt pavement, and no special measures are taken to either achieve or prevent bond between the new concrete and the old asphalt layer (Delatte, 2008). Ultra thin whitetopping (UTW) overlays are suited to asphalt pavements on local roads and intersections with severe rutting, shoving, and pothole problems. Their use began in the early 1990s and has included parking lots, residential streets, low-volume roads, general avation airports and intersections. UTW is 50-100 mm thick with joint spacing of 0.6-1.8 m. Very severely distressed or stripped asphalt pavements are poor candidates for UTW. The thickness design of UTW is based on the concrete pavement strength, thickness of asphalt remaining after surface preparation, the k-value of the layers under the asphalt, and the traffic volume.

Thin whitetopping overlays fill the gap between UTW and conventional whitetopping, and are 100-200 mm thick, with 1.8-3.7 m joint spacing. The performance of thin whitetopping relies on bond with the underlying asphalt pavement. Its thickness design is similar to that of the conventional cement concrete pavement with a relatively high k-value assigned to the existing asphalt.

Some examples of successful application and/or research results in the field:

- in 1998, eight UTW test lanes were constructed over existing hot-mix asphalt pavement; various combinations of thickness, joint spacing, fiber reinforcement, and asphalt base type were used; pavement profiles were obtained periodically during the Accelerated Loading Facility loading history; ride statistics (RN and IRI) were calculated, these latter parameters depended on load position and HMA base type (Rasmussen et.al, 2001),
- in 1994, 41 UTW sections of pavement including three overlay depths, four joint patterns, three surface preparations, and fiber usage were constructed; deflection testing, visual surveys, coring, and direct shear testing continued over seven years; ways were identified to estimate accurately the overlay performance in terms of bond strength retained (Delatte, 2008),
- in 1999, two UTW sections were built at bus stop in a city over a thin (45 mm) asphalt layer, thermal gradient, and curling deformation induced by these gradients were measured; after 19 months of heavy traffic no defects were found even over the 45 mm thick asphalt layer (Balbo et.al, 2001),
- in 1995, two cement concrete overlays were placed on CRCP pavements and one on a rutted asphalt pavement; the variables in the study were concrete mix design, overlay thickness, and base material; overlays of 51 and 102 mm thickness worked well on hydraulic cement concrete pavements, while the 76 and 102 mm ones on asphalt concrete pavements (Spinkel et.al,2001).

## Selection of the site for TW trial section

In Hungary, a ministerial decision was made on making a trial with a thin concrete overlay for the rehabilitation of a repeatedly rutted asphalt concrete pavement. In county Csongrád, ten possible sites were scrutinized so that the most suitable could be chosen as a trial section. They were ranked based on the actual deformation of asphalt layers, the quality parameters of cored asphalt layers, the pavement bearing capacity, the eventual public transportation (tram, trolleybus etc.) and the availability of pavement surface public utility fittings (e.g. manhole cover). The following site was selected for the trial: Szeged, main road no. 5, km 165+145 – 165+230, in an intersection with traffic signal.

The 85 m-long section of 7 m width to be rehabilitated has a high lorry traffic (number of daily trucks: 2743; AADT: 13 785 vehicle/day). In spring 2007, 150 mm deep ruts were measured in the right traffic lane.

It was decided that cement concrete mixture composition variants developed using the laboratory test results of KTI (Institute for Transport Sciences) Cement Concrete Laboratory should be produced in a mixing plant, and laid in a previous small-scale trial in order to select the optimum mix design, and the most appropriate laying technology.

## Preliminary laboratory test results

After various modifications, the cement concrete mix design in Table 1 could meet the requirements of both fresh and hardened concretes. The quality parameters achieved are presented in Table 2.

Table 1 TW cement concrete mixture composition selected for the trial in laboratory

| Component | Type or fraction | Mass ($kg/m^3$) | Volume ($dm^3/m^3$) |
|---|---|---|---|
| Aggregate | sand 0/1 | 181 | 68 |
| | sand | 542 | 205 |
| | chippings KZ 2/4 | 480 | 175 |
| | crushed stone NZ 4/11 | 629 | 229 |
| | Subtotal | 1832 | 677 |
| Cement | CEM I 42.5 N | 420 | 135 |
| Water | $m_w/m_c$=39.5 % | 168 | 168 |
| Plastificator | Glenium C 323 MIX = 1.50 % | 6.3 | 6.3 |
| Air-training agent | Micro Air 107 = 0.05 % | 0.2 | 0.21 |
| Plastic fibers | Fortatech fiber HG 190 | 1 | 1 |
| Air | | - | 15 |
| Total | | 2428 | 1000 |

Table 2 Main quality parameters of the TW cement concrete mix design

| Quality parameter type | | Parameter value |
|---|---|---|
| Air content, % | | 4.9 |
| Slump, mm | | 480 |
| Compressive strength, N/mm$^2$ | 1 day | 27.15 |
| | 2 days | 39.32 |
| | 28 days | 73.05 |
| Split tensile strength at 28 days, N/mm$^2$ | | 4.97 |
| Water penetration depth, mm | | 6 |
| Frost resistance test, 50 cycles | Loss of mass, % | 0.11 |
| | Loss of compressive strength, % | 3.60 |
| Shrinkage at 75 days, ‰ | | 0.342 |

**The construction of the trial section**

As it was already mentioned, previous small-scale trials were performed in order to test the laying conditions, and to check the concrete quality parameters achieved [6]. Four previous trials were carried out between 23rd May and 17th July 2007. The reason of the need of several trials was that the laboratory test of cores taken from the laid concrete layer during the first trials resulted in too high porosity, too low strength and not suitable surface texture. (The air temperatures during these trials reached or sometimes considerably surpassed 30 $^{o}$C every case). It was decided that the actual trial laying must not be carried out at a so high temperature. That is why, relatively late, on 11th October 2007 (at a temperature range of 6-10 $^{o}$C) started the trial work by the traffic diversion from the section, as well as the demolition of the pavement of failed right traffic lane. Since the weather abruptly turned to cold, another cement type was used. No fiber was added to the mixture to reach appropriate pavement surface texture.

The failed pavement was demolished, and new asphalt base layer constructed. (This widened part of the pavement had different layers with poorer bearing capacity). The new pavement structure built here, right before the intersection:

- 2x60 mm asphalt concrete type AB-16/F,
- 500 mm mechanical stabilisation type M50,
- 200 m sandy gravel sub base,
- geotextile.

The next step was the milling of old asphalt pavement in 120 mm. (The thickness of remained asphalt layers amounted to 100-120 mm). The milled asphalt pavement surface was cleaned by compressed air to enhance the future bonding. The white- topping was placed in 120 mm on 15th and 16th October 2008 using manual laying technique (the only 85 m long trial section did not make it possible to use concrete finisher). Needle vibrator and vibration beam were used for the compaction of the cement concrete layer.

In three days after the laying of this whitetopping, cores were taken for further laboratory tests. After having built the new shoulder, the trial section was opened to traffic on 24$^{th}$ October 2007. (1.75x1.75 m slabs were cut in the whitetopping without joint filler and dowels).

**Quality control**

The final cement concrete mix design actually used for the trial work slightly differed from the one developed in the KTI-laboratory, and presented in Table 1 (Table 3).

Table 3. Concrete mix design actually applied in the whitetopping trial

| Material | Quantity (kg/m$^3$) |
|---|---|
| CEM I. 42.5 N | 420 |
| Sand type OH 0/1 | 168 |
| Sand type OH 0/4 | 503 |
| Chippings KZ 2/4 | 445 |
| Crushed stone 4/11 | 582 |
| (Tap) water | 180 |
| Plastificator type Sky 581 1.0 % | 4.2 |
| Air-training agent type Micro Air 107-5 | 0.29 |

As quality requirements, 390-450mm slump (MSZ EN 1235-5) and 5.0-6.5 Vol% air bubble content (MSZ 12350-7) of the fresh concrete were identified. The following parameters were tested: density, temperature, optimum time for curing plastic covers, strength values.

During the construction, 30 concrete cubes of 150x150x150mm were made for compression strength, permeability and frost resistance test, while 5 concrete beams of 150x150x600mm for flexural strength test, and 5 concrete cylinders ϕ150x300mm for splitting strength test. The test results obtained are summarized in Tables 4 and 5 (Technological, 2007).

Table 4 Early strength test results

| Age (day) when testing | Density (kg/m$^3$) | Compressive strength (N/mm$^2$) | Splitting tensile strength (N/mm$^2$) |
|---|---|---|---|
| 1.5 | 2280-2345 | 17.9-23.3 | 1.69 |
| 2.5 | 2309-2354 | 24.8-30.5 | 2.26 |
| 3.5 | 2282-2364 | 29.0-39.3 | 2.74 |
| 5.5 | 2270-2370 | 30.8-47.4 | 2.69 |
| 14 | 2310-2400 | 43.2-58.6 | |

Note: the lowest strength values were obtained on samples cured together with the pavement

Table 5 Strength test results at the age of 28 days

| Sample form and size | Cube (150x150x150 mm) | Beam (150x150x600 mm) | Cylinder ($\phi$150x300mm) |
|---|---|---|---|
| Mechanical parameter tested | Compressive strength (N/mm$^2$) | Flexural strength (N/mm$^2$) | Splitting tensile strength (N/mm$^2$) |
| Measured values | 52.3<br>55.4<br>60.1<br>67.0<br>60.9<br>67.9 | 6.3<br>7.1<br>7.7<br>6.6<br>5.3 | 3.17<br>2.89<br>3.74<br>3.46<br>3.66 |
| Mean value | 60.6 | 6.6 | 3.38 |

The results of permeability test on 150x150x150mm concrete cubes at the age of 28 days were between 14 and 16mm water penetration. The strength results of the 18 cores of 100 mm diameter cored of the pavement are presented on Table 6.

Three core cylinders were taken of the cement concrete layer together with the underlying asphalt course. The shear tests performed at the interface of layers resulted in the following values: 0.92; 0.90 and 0.91 N/mm$^2$.
Table 7 shows the texture depth results of the completed cement concrete pavement surface.

Table 6 Strength test results of $\phi$100mm cored cylinders

| Test type | Compressive strength (N/mm$^2$) | Density (kg/m$^3$) | Splitting tensile strength (N/mm$^2$) | Density (kg/m$^3$) |
|---|---|---|---|---|
| 1<br>2<br>3 | 42,1<br>31,4<br>33,2 | 2330<br>2277<br>2252 | 4.35<br>4.85<br>4.50 | 2380<br>2450<br>2320 |
| Mean value | 35,5 | 2290 | 4.50 | 2380 |

Table 7 Texture depth on the TW surface

| Location of the measurement | Texture depth (mm) | | | | | | | | Mean value (mm) |
|---|---|---|---|---|---|---|---|---|---|
| Slab close to the shoulder | 0.8 | 1.0 | 0.58 | 0.72 | 0.51 | 1.50 | 0.8 | 0.9 | 0.82 |
| Third slab from the shoulder | 0.6 | 0.85 | 0.45 | 0.60 | 0.85 | 1.10 | 0.9 | 0.9 | 0.80 |

Photo 1 illustrates the deformed asphalt pavement surface beside the experimental thin concrete section, while Photo 2 presents the surface of whitetopping with joints.

Photo 1  Deformed asphalt pavement surface along the experimental section

Photo 2   Whitetopping surface with joints (April 2008)

**Conclusions**

Based on the experience and test results of the thin whitetopping trials, the following conclusions can be drawn:

- the preliminary laboratory test series performed – after various repeated efforts – in KTI-laboratory resulted in a cement concrete mix design meeting the main specified quality requirements (air content 5.0-6.5 Vol%; compressive strength at the age of 1 day ≥ 27 N/mm$^2$; compressive strength at the age of 28 days ≥70 N/mm$^2$),
- the use of fiber, plastificator and air-training agent help in meeting the predetermined requirements of the mixture,
- the high (420 kg/m$^2$) share of cement in the mixture, and the low (0.395) water-cement factor could successfully increase the early strength of the mixture allowing to reopen the trial section to traffic relatively soon,
- the consistency of the mixture samples taken from mixer truck had a higher standard deviation than expected, however, this value became acceptable after the homogenisation during transport (slump = 410-460 mm),
- some 90 % of the air content test results of fresh concrete met the specified 5.0-6.5 Vol% range,
- the water-cement factor of fresh concrete was in the range of 0.42±0.02,
- the early compressive strength values of concrete cubes proved that the trial TW section could have been opened to traffic already on the third day after the laying of the course (actually two more days were waited for before the opening due to the extremely high share of lorry traffic),
- the 28-day compressive strength values of the concrete samples tested happened to be in the range of 52-68 N/mm$^2$, the lowest value was given in the case of a sample with relatively high (6.4 Vol%) air void content and low density (2295 kg/m$^3$),
- the mean value of the flexural strength of the samples reached 6.6 N/mm$^2$, some 10 % above the planned 6 N/mm$^2$,
- the average splitting tensile strength was 338 N/mm$^2$ with acceptable standard deviation,
- the average 28-day compressive strength of cored samples happened to be lower by nearly 20 N/mm$^2$ than that of the samples cured in laboratory during the whole period,
- the actual shear strength at the interface between concrete and asphalt cored layers was lower than that obtained in laboratory using samples produced in laboratory,
- the texture depth values of the completed TW surface exceeded the specified 0.5 mm value, the too high standard deviation came from the manual methods used for surface roughening,
- the slab size of 1.75x1.75m has seemed to be suitable so far,
- the condition of the TW surface in April 2008, after 6 months of heavy traffic and a cold winter is excellent, no damage can be observed,
- based on the success of the trial, several new TW projects are planned for 2008.

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