EUROPEAN CONCRETE PAVING ASSOCIATION

UPGRADING EUROPE's ROAD FREIGHT NETWORK

CONCRETE INLAYS and ROAD WIDENING

CONTENTS

Inlay in CRCP on the motorway E40/A10 near Brussels (Ref. : AWV)

1. INTRODUCTION

Transport infrastructure is fundamental for the smooth operation of the internal market, for the mobility of persons and goods and for the economic, social and territorial cohesion of the European Union. This is why the European Commission has adopted the new EU infrastructure policy "The Trans-European Transport (TEN-T) Networks" which will put in place a powerful European transport network across the 28 Member States to promote growth and competitiveness. The new policy establishes a core transport network built on 9 major corridors. The core network will transform East-West connections, remove bottlenecks, upgrade infrastructure and streamline cross-border transport operations for passengers and businesses throughout the EU. [1]

The road is a vital link in transport infrastructure. Harmonisation in quality of the road and operation as well as the capacity of the infrastructure can provide continuous mobility on European corridors. The study "Economic Cost of Barriers to Road Transport" proved that the largest reported impediment for freight hauliers in the UK and Italy was congestion. [2]

The challenge is to improve the road network in order to ease traffic flow, reduce congestion, reduce journey time and enhance road safety. In addition, the selected method should contribute to the EU's climate change objectives.

This publication presents two **solutions for upgrading existing infrastructure**, and also provides useful examples of **tools to aid in decision-making** between different options.

The two solutions presented for upgrading existing infrastructure are:

- Concrete inlays: a rehabilitation technique consisting of replacing the surface of heavily trafficked lanes by a concrete pavement.

- Road widening: extending the pavement with an additional concrete lane, which is especially suited to heavy freight traffic.

The main objective of these two techniques is to benefit from the advantage of concrete pavements in terms of durability under heavy traffic.

Decision support tools are necessary in order to balance all factors, such as environmental and social considerations, and initial versus whole-life cost. In the examples presented, it is thanks to analyses based on such objective criteria that the benefits of concrete solutions are revealed. Such examples are intended to be useful to public authorities who may wish to adopt them for their own decision-making processes.

Considering the forecasts of increasing traffic volume, budget limitations and the current congestion levels, the solutions described in this publication aim at an additional reinforcement of the road infrastructure and offer a sustainable solution by extending the service life of the road and bringing the quality of the road network in line with the desired European targets for transport.

[1] http://ec.europa.eu/transport/themes/infrastructure/index_en.htm

[2] IRU Position Paper on "A road freight corridor in the Trans-European Networks (TENS)"

Rehabilitation of a highway by a concrete inlay (CRCP) – construction sequence

(Ref: P. De Winne, AWV)

Highway in bad condition

Partly milling off of the asphalt

Placing of a new asphalt sandwich layer

Positioning of steel reinforcement

Spreading and compaction of concrete

Placing and smoothing of concrete

Surface protection

New highway in CRCP

2. INLAYS: CREATING LANES FOR HEAVY TRAFFIC

Free-flowing road freight corridors would enable users to make the best use of existing infrastructure. Increased fluidity in the traffic flow increases efficiency for road users and saves fuel, which is often wasted in congestion.

Overlays and inlays are two important techniques for the renovation of major roads.

- With an overlay, the existing road, of whatever type, has a new concrete road surface added at a higher level. The old structure serves as base-structure.

- With an inlay, the concrete pavement is put in place after milling off the existing asphalt surface to a certain depth. On existing motorways, which are mostly in asphalt, an inlay can consist of strengthening the slow lane in order to adapt it to the heavy traffic load. Obviously, the "slow" lane, where most of the heavy trucks drive, will have a much shorter lifespan than the faster lanes, which are mainly used by light traffic. Therefore inlaying the slow lane with a concrete pavement is an ideal solution.

DESIGN AND CONSTRUCTION ASPECTS

Both JPCP (jointed plain concrete pavement) and CRCP (continuously reinforced concrete pavement) can be chosen for the construction of an inlay. When the aim is creating long-life pavements for heavy traffic, it is recommended to design with conventional thicknesses, i.e. with typical ranges of 23 to 28 cm for JPCP and 20 to 25 cm for CRCP.

Whatever type is chosen, attention must be paid in order that the remaining underlying structure has an adequate bearing capacity to ensure that the new pavement will last for the desired lifetime.

Basically, there are three possibilities:

- The existing asphalt layers are partly milled off. It should be checked that the remaining asphalt layers, which have suffered from fatigue due to the traffic load, are still in good condition and have a thickness of at least 80 mm.

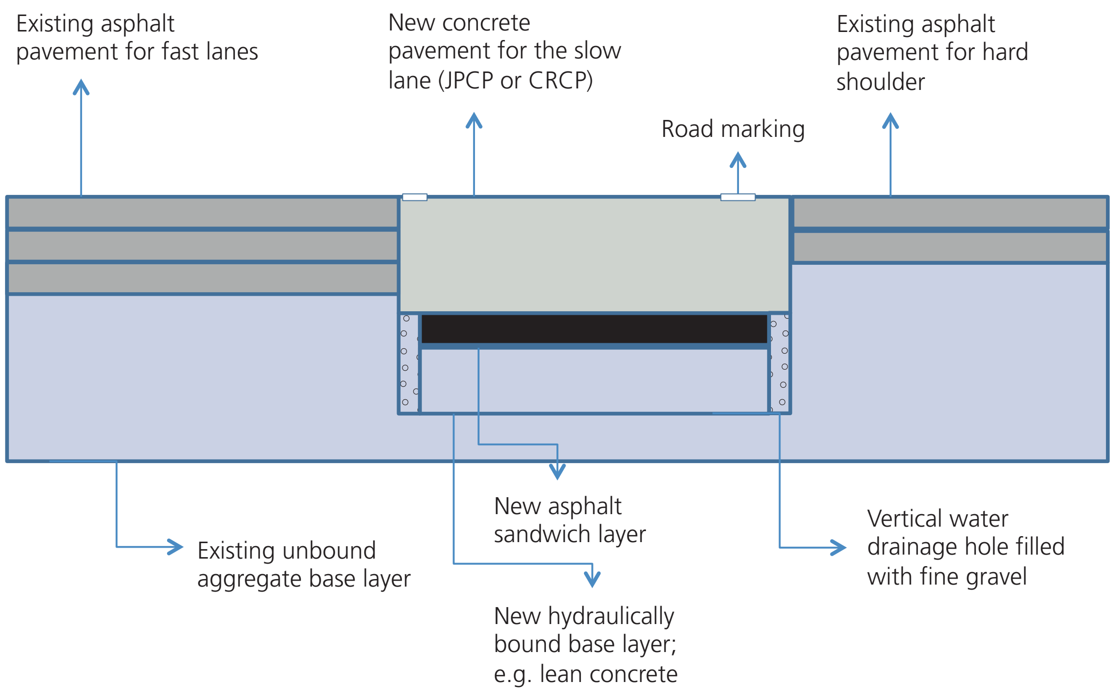
- The existing asphalt layers are entirely milled off and the existing base layer is kept in place.

- The existing asphalt layers are entirely milled off and the base layer is broken up and replaced. With regard to heavy traffic loads, this base layer can be a stronger type than the adjacent ones, e.g. lean concrete or even roller-compacted concrete.

In all three cases, assuming that the depth is available, the best solution is to provide a new asphalt binder course at least 5 cm thick beneath the new concrete surface course. For CRCP, this is often part of the standard design structures in several countries. Also for JPCP, it contributes to a long service life by protecting the base layer from erosion and by preventing pumping effects at the joints. In addition, it creates a uniform bond between the different layers.

Essential for the good performance of a concrete inlay is drainage of water infiltrated into the structure. Particularly along the new longitudinal joint between existing fast lanes and the concrete inlay, water infiltration and stagnation must be avoided. An open graded base layer or drainage holes, drilled in hydraulically bound base layers and filled with fine aggregate, can offer a solution.

Figure 1: Example of cross-section of a concrete inlay



CASE STUDY: AN EXAMPLE OF AN INLAY ON THE N31 BRUGGE – ZEEBRUGGE, BELGIUM [3]

The regional road N31 is a primary road in the Belgian province of West Flanders between Oostkamp and Zeebrugge. The average daily traffic intensity was between 16 900 and 37 000 vehicles in the year 2000. Over most of its distance, the road has two lanes in each direction.

With the development of Zeebrugge Harbour, the number of heavy trucks on the N31 also increased, leading to rutting in the right-hand, most heavily used, lane. An investigation by the Road Administration showed that the rutting was forming in the bottom layers of the asphalt so that structural renewal was needed to solve the problem.

To provide a definitive solution for the rutting problem, the authorities decided to construct a CRCP inlay in the right-hand lane between Brugge and Zeebrugge. The design included a 4-cm interface layer of asphalt (binder course 0/14) and a 20-cm CRCP top layer.

The design width was 4.25 m: the lane itself of 3.5 m, plus an additional width of 0.75 m. The extra width increases the distance from the axle-loads to the edge of the pavement in order to avoid the problem of punch-outs[3].

For the left lane, the renovation was limited to the replacement of the top layer of stone mastic asphalt (SMA). The longitudinal joint between concrete and SMA was executed by means of a hot extruded joint strip.

Over a part of the route, the thickness of the existing asphalt was insufficient to apply an inlay in CRCP and provision was made for a classic rehabilitation with bituminous layers.

[3] Punch-out: local distress for CRCP occurring at the edge of the pavement or along a longitudinal joint and typically related to crack spacing, pavement thickness, poor foundation support,and/or heavy truck loading.

A view of the N31 with the slow lane in concrete and the fast lane in asphalt (Ref: L. Rens)

The surface finishing was exposed aggregate concrete resulting in a low-noise surface with the fine stones appearing on top. The surface textures of the two lanes (stone mastic asphalt and exposed aggregate concrete) are comparable.

With this project, the West Flanders Highways Authority opted for a lasting solution to the problem of rutted asphalt lanes. The use of concrete for the slow lane and SMA for the fast lane clearly shows a conscious choice relating to the traffic intensity. In addition, the exposed aggregate surface of the concrete lane guarantees a good performance as regards skid resistance and rolling noise.

To conclude, this project is an example for many other situations where an inlay of CRCP can be an appropriate solution.

Longitudinal joint between asphalt and concrete, with similar textures for both pavements (Ref: L. Rens)

3. ROAD WIDENING

Construction site of road widening in Germany
(Ref: 7 and 9)

Road widening is one of the main options in increasing traffic capacity and so improving mobility. The design and construction of road widening projects and, in particular, the connection between the existing asphalt or concrete pavement structures and the widened road lane in concrete, need to be examined in detail. Several European countries have already had positive experiences with concrete road widening. [9].

DESIGN AND CONSTRUCTION ASPECTS

Before starting a road widening project, the existing pavement structures should be evaluated. Most motorways, trunk roads or regional roads are constructed using asphalt. Motorways with high intensity and heavy traffic have also been built in JPCP or CRCP, sometimes overlaid with stone mastic asphalt or a porous asphalt layer. The existing pavement is the starting point for any road widening project. The load bearing capacity of this pavement must in principle be adequate to enable major maintenance to take place at the same time as the widening. Bearing capacity measurements, core sampling and supplementary calculations can be used to investigate whether the existing pavement is likely to have a sufficiently long service life.

CONCRETE PAVEMENT WIDENING NEXT TO ASPHALT

Experience with concrete road widening projects on asphalt structures has been gained especially in Germany. The regional Road Administration "Landesbetrieb Strassenbau" in Nordrhein-Westfalen often uses a concrete right-hand lane with hard shoulder on heavily trafficked main roads. [6].

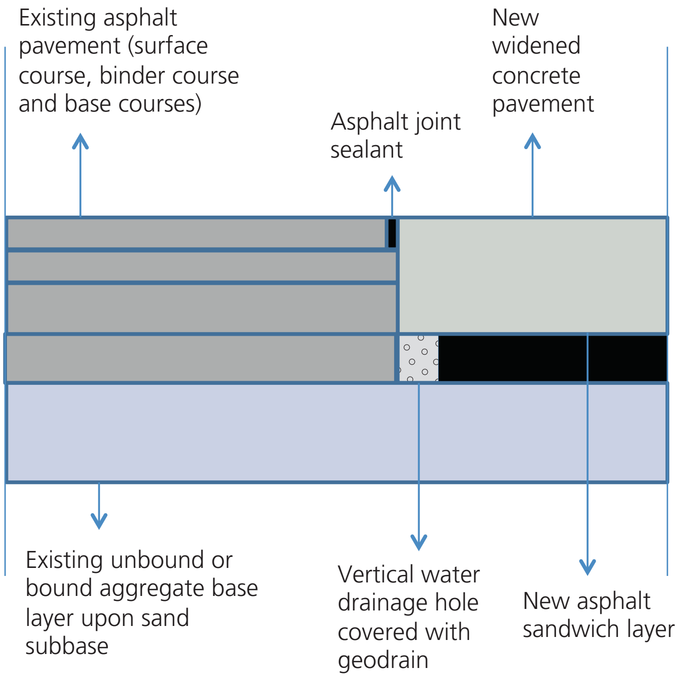
The concrete lane is constructed as an unreinforced double-layered concrete with an exposed aggregate concrete surface. For the less heavily loaded "fast" left-hand lanes an asphalt structure is used. This technique, known as 'Schwarz-weiss-bau' (black & white construction), is used for reconstruction (new construction) and when widening existing roads.

In early widening projects, moisture that penetrated through the joints became entrapped and caused erosion problems. The wash-out led to cavities, an uneven surface and finally resulted in crack formation. Water exiting the lower longitudinal joints also caused problems.

Structural modifications to the longitudinal joint were needed to enable penetrated water to drain away. A 15-cm-wide drain was made between the asphalt and the concrete structure. The drain is directly connected to the aggregate foundation so that the water can easily drain away. Both pictures relate to a reconstruction where, in addition to road widening using concrete, the asphalt pavement was also renewed.

A drain is being constructed to prevent water build-up (Ref: 7 and 9)

Figure 2: Cross-section of concrete pavement widening next to asphalt



When a road widening project is carried out next to an existing asphalt lane, the asphalt is sawn off at right angles and the drain is placed under the concrete section. A strip of filter cloth is placed over the drain to prevent contamination during construction.

Some experience has also been gained with concrete pavements constructed next to asphalt pavements, e.g. in the Netherlands. These are often for bus lanes, but motorway slip roads are another example. These pavements have performed well. Experience has also shown that no special measures are required when connecting asphalt to concrete pavements.

Key points to note when connecting to the existing asphalt pavement are:

- The inclusion of a drain at the joint that is directly connected to a permeable foundation and bottom layer. This prevents moisture entrapment and build-up and prevents erosion;
- To increase durability, the longitudinal joint is sealed with a joint sealant.

CONCRETE PAVEMENT WIDENING NEXT TO CONCRETE

The widening of existing concrete pavements is done in the same manner as for new construction. Concrete roads are often constructed in multiple concrete lanes at the new construction stage. The two lanes are tied together by tie bars in a longitudinal construction joint to prevent them moving apart. This also prevents height differences occurring between the two lanes.

Key points to note when widening concrete pavements are:

- The transverse joints of the old and of the new pavements should be aligned with each other and be of the same type and width. If this is not possible, a longitudinal isolation joint has to be provided by inserting a thin isolation sheet, e.g. a waffled plastic strip that will avoid "sympathetic" cracking in the young concrete of the widened lane.
- Expansion joints in the widening lane must be at the same location and be of the same width as those in the existing pavement.
- When ground anchors are used in the existing pavement these must also be used in the new section.
- The thickness of the widening must in principle be determined using structural calculations.
- It is preferable that the longitudinal joint is not situated in the wheel path. It should be close to but not at the edge of carriageway line, dotted line or centre line. The longitudinal construction joint is sealed using a joint sealant.

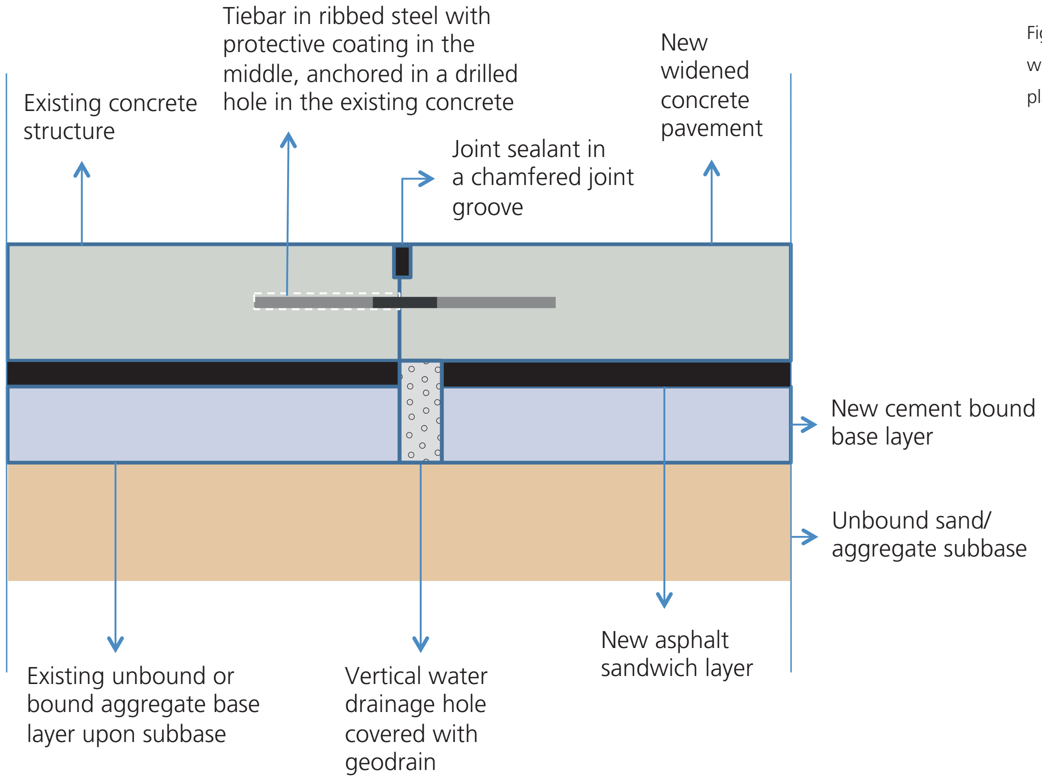


Figure 3: Cross-section of widened structure in jointed plain concrete

DECISION SUPPORT MODEL

In the Netherlands, a study on this subject was carried out by CROW (Technology Platform for Transport, Infrastructure and Public Space). The CROW decision support system for road construction (CROW-Afwegingsmodel Wegen, version 2008/2009) has been used to evaluate the "total cost of ownership" [6]. This integral assessment includes initial & maintenance costs, environmental & life cycle costs and social costs.

The study has compared non-project-specific examples of road widening in concrete with widening in asphalt. Equivalent road widening constructions with related maintenance regimes have been assumed in the period under consideration.

The choice of pavement type is not so obvious when using an integral assessment. This approach calls for a rational assessment of viable pavement solutions. In addition to construction, maintenance and life cycle costs, environmental aspects play a key role. Considering this, pavement variants in asphalt and concrete have been integrally and objectively assessed using a decision support system for road construction. It is mandatory to make use of the Total Cost of Ownership (TCO) approach as a basic premise for purchasing strategy. This kind of holistic decision support system for road construction is in line with the sustainable procurement policy of local, regional and central governments [8].

For the environmental assessment, use is made of environmental costs on the basis of life cycle analysis (LCA) data per material. With regard to the economic aspect, the construction, reconstruction, maintenance and demolition costs are automatically calculated per material [6]. Cost data are obtained from a database. The costs are calibrated at the current price level and are given as a net present value (NPV). Project-specific factors can also be included in the assessment. These are expressed in the multi-criteria analysis where they are assessed as "other factors".

A weighting triangle (Figure 4) is a tool to compare different weighting sets and indicates the degree to which the weighting set influences the final result. The sides of the

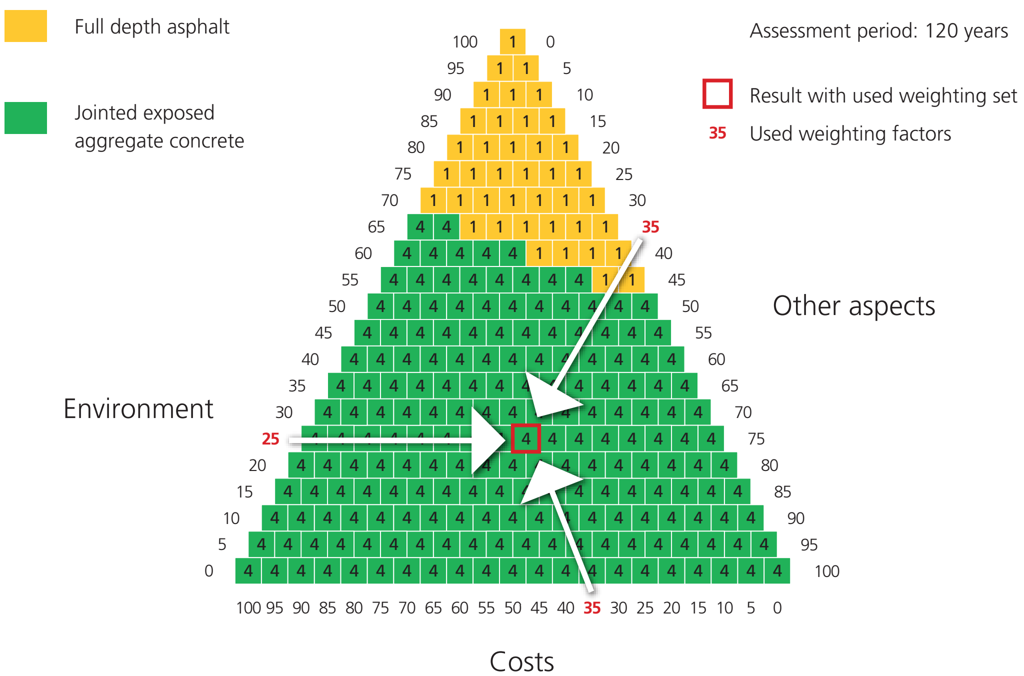


Figure 4: Example of a multi-criteria analysis weighting triangle for the comparison of two provincial road design options: either in full depth asphalt (yellow) or in jointed exposed aggregate concrete (green). (Ref: 7)

triangle represent the weighting factors for the "environmental impact", "costs" and "other factors" criteria, ranging from 0 to 100%. This enables the criteria to be compared. In Figure 4, the weighting set used is in proportions 2:3:3 for "environmental impact" (25%), "costs" (37,5%) and "other factors" (37,5%).

The location at which the weighting factor scores intersect reveals whether the weighting set selected falls squarely in the domain of a single road pavement option or near the interface of several road pavement options. While the former can be read as a clear preference for one type of road pavement (i.e. a slightly adjusted weighting set will not produce a different result), the latter signifies that different road pavements generate comparable scores and that there is no clear preference. This has always to be considered in conjunction with the results of the multi-criteria analysis itself.

In the cases that follow (Figures 6 and 7), the standard weighting set is used, which is an equal allocation of 33% for each of the three criteria.

CASE 1: WIDENING OF HIGHWAY

Two options are compared in this case. These are a widening in asphalt and a widening in continuously reinforced concrete (CRCP) with a layer of open asphalt (ZOAB). The latter layer is mandatory for motorways in the Netherlands. The widening takes place on the right-hand side of the road. In this example it is assumed that the hard shoulder is not suitable for future service as a heavily loaded lane. By removing the hard shoulder and constructing a new pavement, the other lanes do not require any additional strengthening. After the existing hard shoulder has been removed, a 7-m widening with a lane and a hard shoulder will be constructed.

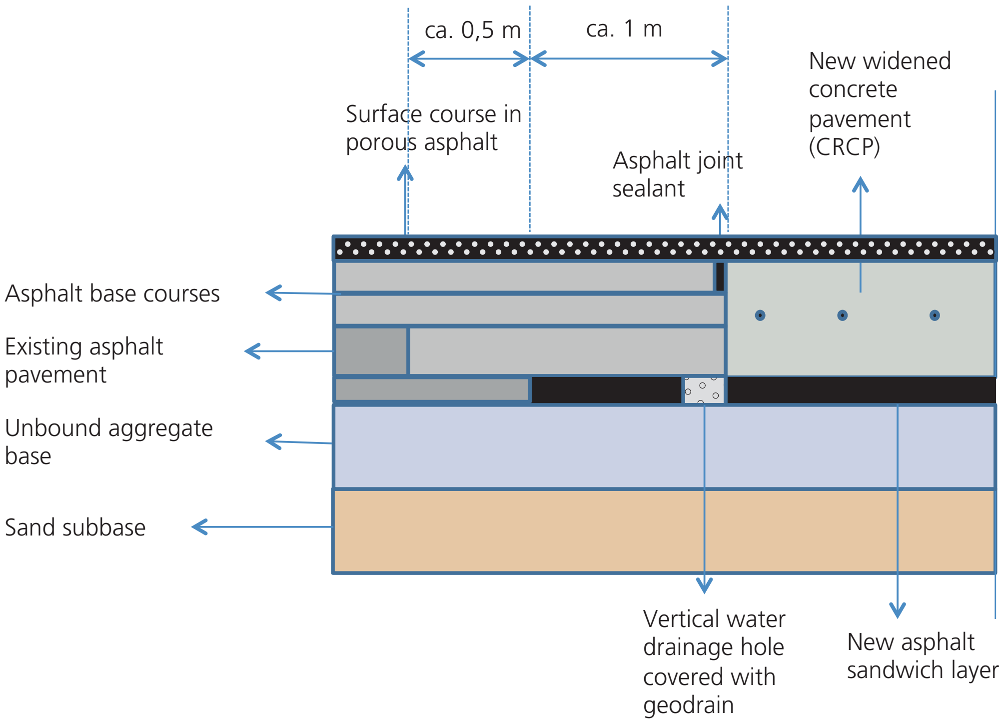


Figure 5: Cross-section of the widening structures in continuously reinforced concrete (Ref: 9)

An assessment period of 120 years is sufficient as in this period the pavement can be maintained and periodically be reconstructed. The pavement widening in asphalt will be re-constructed after 40 years in service and the widening in concrete will be reconstructed after 60 years. Due to the use of open asphalt (ZOAB), in principle the low maintenance CRCP requires a more intensive "asphalt pavement maintenance" regime, and hence becomes more expensive.

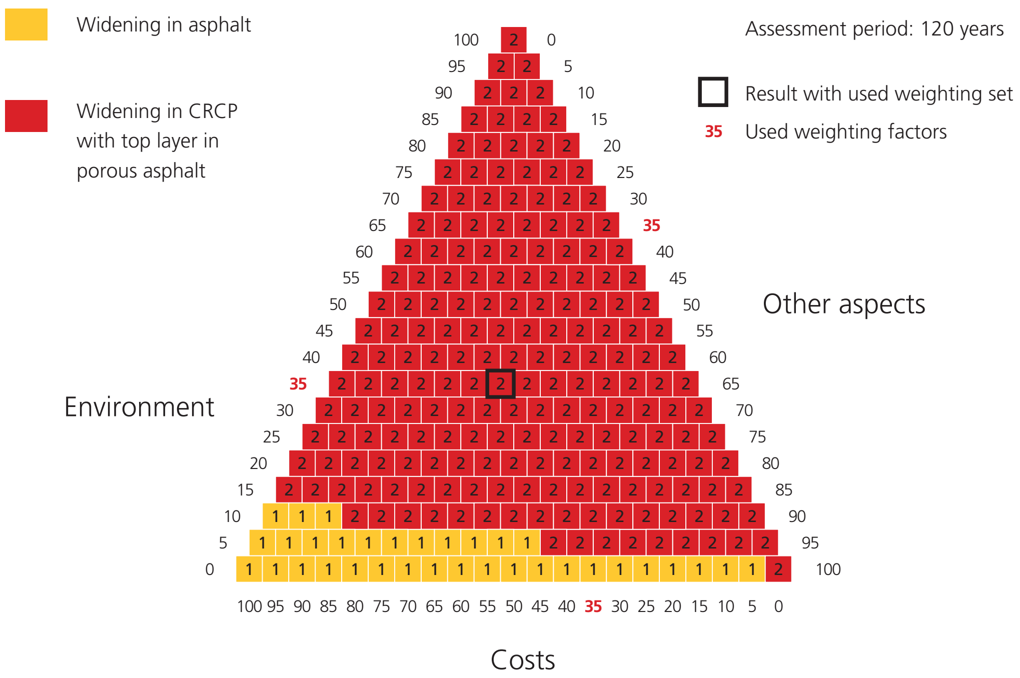
Results and conclusion:

Widening in continuously reinforced concrete offers environmental benefits. Benefits are gained in all aspects, but particularly the lower emissions during the use phase (thanks to a more favourable maintenance regime for the concrete structure) lead to lower environmental cost figures and thus give the advantage to widening in CRCP.

The construction costs for the widening in continuously reinforced concrete are higher than for the widening in asphalt but the demolition and reconstruction costs are lower. The maintenance costs, due to the open asphalt maintenance regime, are more or less equivalent. As an overall result, the net present costs over the period under consideration are not significantly higher for CRCP (+3.5%).

Based on multi-criteria analysis, the widening in continuously reinforced concrete has the lowest, i.e. the most favourable weighted score. Moreover, a widening in continuously reinforced concrete is not sensitive to the standard weighting set (since almost all of the boxes in the triangle are coloured red in Figure 6). Therefore it is concluded that a CRCP for widening motorways is a good decision.

Figure 6: Multi-criteria analysis weighting triangle for widening in asphalt (yellow) and continuously reinforced concrete (red).(Ref: 9)



CASE 2: WIDENING OF A REGIONAL ROAD

The second example relates to the widening of a regional road that has an unreinforced concrete pavement. The current 7.0-m wide concrete pavement is to be widened by a 3.5-m-wide concrete lane. The current pavement has slab measurements of 4.5 m x 3.5 m and is 0.25 m thick. The pavement is in good condition and has a remaining service life of more than 20 years.

The widening methods under consideration involve a widening in asphalt with a base layer of recycled concrete/brick aggregates and a concrete pavement with a broom or exposed aggregate finished surface. The slab pattern used in the existing road will also be used in the widening project. The slab length here is also 4.5 m. The width is 3.5 m. The transverse joints will be provided with dowels and the widening will be anchored to the existing pavement by tie-bars.

The maintenance regime for the asphalt pavement involves the replacement of the top layer once every 10 years. Every 20 years a reinforcement layer is applied over the entire width of the road. The maintenance of the unreinforced concrete pavement consists of the replacement of 0.4% of the slabs once every 10 years. In addition, in the 15th year, 5% of the joint edges and/or cracks are repaired, and every 20 years measures are taken to improve the surface roughness. Slab repairs are also carried out.

The widening using plain exposed aggregate concrete is the most favourable solution based on environmental cost figures. This solution is more or less the same as JCP widening with transverse brushed concrete.

Although the material costs for widening using asphalt are clearly lower than for widening using concrete, concrete scores much better regarding maintenance costs. In the integral cost assessment the initial preference is for plain (unreinforced) concrete with exposed aggregate finish.

Based upon the multi-criteria analysis, the widening in unreinforced concrete is clearly preferable. This applies both to the exposed aggregate concrete variant and to the brush finished variant.

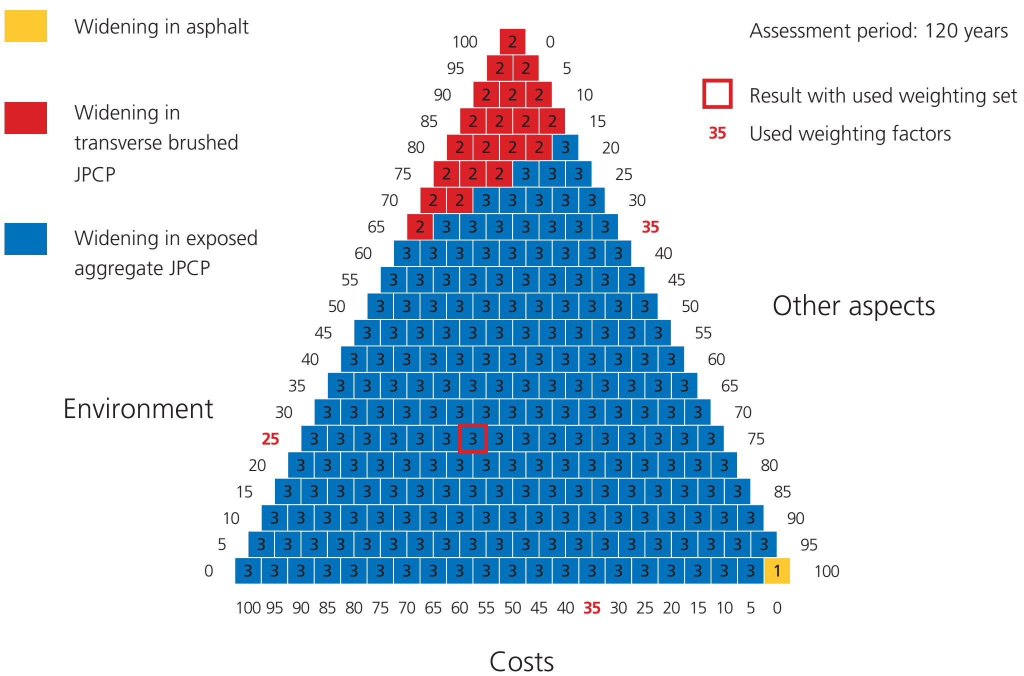


Figure 7: Multi-criteria analysis weighting triangle for widening in asphalt (yellow), jointed plain concrete with transverse brushed texture (red) and jointed plain concrete with exposed aggregate texture (blue). (Ref: 9)

4. SPECIAL APPLICATIONS

The techniques of concrete inlay and concrete road widening can also be used for special applications such as dedicated bus lanes or parking areas for trucks. These are applications where concrete is clearly the best pavement option because of the type of vehicles in question.

Examples of concrete inlay and road widening for the creation of dedicated buslanes
(Ref: Left: L. Rens - Right: A. Nullens)

Concrete inlay for a parking strip for heavy trucks
(Ref: P. Van Audenhove, CRIC)

5. FUEL CONSUMPTION

(Ref: 10)

Another benefit of concrete pavements, which may have a considerable positive impact on the use phase, is the reduced fuel consumption of heavy vehicles riding on a non-deformable pavement. This aspect has been the subject of a number of international studies and research. All studies and research on this subject show clearly that stiff and rigid pavements, such as concrete roads, markedly reduce the fuel consumption compared to flexible pavements. The findings of these studies and research show substantial fuel savings – up to 6 % - for heavy trucks riding on concrete pavements and consequently also a saving effect in terms of emissions and costs.

Every kilometre of concrete road instead of a flexible pavement can reduce the CO_2 emission, due to fuel consumption of heavy vehicles, over its 30 year lifetime by 1,000 to 4,000 tonnes. Even the smallest differences in fuel consumption of 0.02 litres/100 km result in huge savings of 376 million litres of diesel, €564 million and 1 million tonnes of CO_2 per year. This can already make a difference today [10].

In the aforementioned examples of road widening, the beneficial effect of reduced fuel consumption has not been taken into account. If it had been, the result would have been even more favourable for the concrete options. Smooth concrete pavements are therefore an easy and effective solution in the decarbonising of freight road transport.

6. CONCLUSIONS

- **Concrete inlays and road widening present a valuable opportunity to upgrade the whole of the existing pavement, in line with current standards.**
- The CROW decision support model for road pavements (DSMR) enables engineering designers, managers, consultants and decision-makers to give due weight to and make transparent various aspects - cost effects, environmental effects and effects on society - when considering apparently equivalent design variants. The DSMR enables these various criteria to be assessed over a longer analysis period so that a transparent and substantiated decision can be made. It responds to the current trend for green procurement and sustainable construction.
- **The examples indicate that road widening in concrete offers a sustainable solution, particularly with respect to environmental impacts based on life cycle analysis (LCA) and a life-cycle cost approach.**

Road widening for a new exit lane in Leuven, Belgium
(Ref: L. Rens)

Road widening on the M25 motorway in the UK
(Ref: Britpave)

Concrete inlay on the N31, Belgium
(Ref: L. Rens)

REFERENCES

[1] Autosnelwegen en overige toepassingen. (Motorways and other applications)
CROW publication 160, December 2001.

[2] Evaluatie onderhoudservaringen betonwegen. (Evaluation of maintenance experience with concrete roads) CROW report 03-08, CROW. Ede, The Netherlands, 2003.

[3] Sustainable road building with low noise CRCP on Belgian motorways.
Paper at the 22nd PIARC World Road Congres, Durban, 2003. Rens, Caestecker, Decramer.

[4] Design manual for roads and bridges, Volume 7, Section 2, Part 4 Widening of pavements. The Highway Agency; Scottish Executive; Welsh Assembly Government; The Department for Regional Development -Northern Ireland, 2004.

[5] Vencon 2.0. Ontwerpprogramma voor het dimensioneren van betonwegen.
(Design program for dimensioning concrete roads) CD-Rom D925. CROW, Ede,
The Netherlands, 2004.

[6] Afwegingsmodel wegen (AMW). (Decision support model for road pavements)
CROW computer program D926a. Ede, The Netherlands, 2008

[7] Wegverbredingen in cementbeton. (Road widening in concrete) CROW publication 286, issued May-2010.

[8] Duurzaam inkopen. (Sustainable purchasing) Senter Novem, 2010.
(visit:http://www.senternovem.nl/duurzaaminkopen/)

[9] Technical and economical feasibility of pavement widenings in cement concrete in the Netherlands. Paper at the 11th International Symposium on Concrete Roads, Seville, 2010.
Stet, Kramer, Nijssen, Jurriaans.

[10] Concrete pavements contribute to decarbonising of transport. EUPAVE, Belgium, 2011.

Road widening on motorway A4 in Germany
(Ref. 9)

Published by:

EUPAVE
European Concrete
Paving Association
Vorstlaan 68 boulevard du Souverain
1170 Brussels
T + 32 2 790 42 06
F + 32 2 640 06 70
info@eupave.eu
www.eupave.eu

Author: Luc Rens

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Widening project in double layered JPCP on motorway A9, Thüringen, Germany (Ref.: Wirtgen)