SUSTAINABLE ROAD BUILDING WITH LOW-NOISE CRCP ON BELGIAN MOTORWAYS

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ABSTRACT

For more than 30 years, a large proportion of the Belgian motorway network has been built using CRCP. As the motorway network in Belgium is now nearly complete, a large share of current road investment is allocated to the renovation of the oldest concrete pavement. Some asphalt roads are also being replaced with concrete, sometimes via the complete reconstruction of the road structure, sometimes by an inlay (of the slow lane).
This paper describes some of the renovation carried out in Flanders (the north of Belgium) in 2001. Common to these works is the use of CRCP and exposed aggregate concrete as a surface finishing in order to provide a low-noise surface. In order to achieve this noise reduction, the maximum size of the exposed aggregate has for more than 10 years been limited to 20 mm and generally more than 20 % of these aggregates consist of the fraction 4/7.
The first project involves an inlay of the right lane of a heavily trafficked main road (N31) where rutting has been a major problem. General recommendations for concrete inlays will be presented as well as the specific data of the case (traffic, geometric design, concrete specifications, concrete mix and test results).
The second case is the reconstruction of a section of a 40-year-old motorway (A12) in jointed undowelled concrete to create a comfortable new road.
Apart from the low-noise characteristics, other aspects of sustainable construction will be highlighted throughout this project (recycling, safety aspects, choice of cement type).
While most people are now convinced that concrete can be a preferred solution in economical terms, when taking into account the whole-life cost including maintenance and if possible costs to the user, it has certainly become just as important to show that concrete roads are environmentally friendly and sustainable.

KEY WORDS

CONTINUOUS REINFORCED CONCRETE PAVEMENT / SUSTAINABLE / ROLLING NOISE / INLAY

1. HISTORY

There is already a long history of concrete road-building in Belgium. The Avenue de Lorraine in Brussels, constructed in 1925 and still in service today, bears witness to this. It is the more remarkable since the road was built using concrete slabs with a thickness of only 15 cm laid on an old base layer of aggregate. Despite the current bad condition of the road, it is still a heavily used through route in the Brussels conurbation. Figure 1 shows that technical design was already important in these days. The thicker sections on the edges of the road profile show that the border effect – the appearance of maximum stresses on the border of a stiff slab – was already well known.

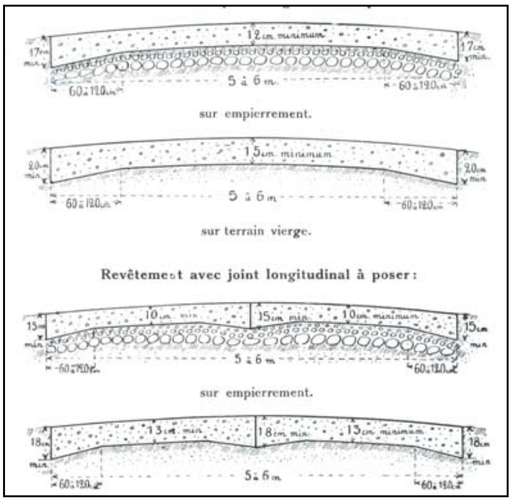

Figure 1 - Technical design details from 1930

The Avenue de Lorraine is not an exceptional case; many concrete roads can be found in Belgium which are over 50 years old, although some of them have been overlaid with a bituminous layer for reasons of comfort and noise.

Since the end of the 1960s, the CRCP technique, adopted from the USA, has been widely used in the construction of motorways and main roads.
Today, the Belgian motorway network is as good as complete and in addition, for political and environmental reasons, it has become very difficult to build new roads. On the other hand, a number (of sections) of motorways are in need renovation. Some of them are in concrete (slabs over 30 years old), others in asphalt. Rutting is often the reason why relatively new asphalt roads need rehabilitation. The presence of CRCP motorways that are up to 30 years old and still in good condition simplifies the choice for the highways authorities, especially when life-cycle costs are taken in to account when considering alternatives.

2. INLAYS

2.1. Introduction

Overlays and inlays are two important techniques for the renovation of major roads. Both can be executed using CRCP or JPCP. 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.

Obviously, the right hand 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 right hand lane with a concrete pavement is an ideal solution.
When an inlay is contemplated, some design details need particular attention.
Firstly we have to be sure that the remaining structure has a bearing capacity adequate to ensure that the new road will last for the desired lifetime. The most important thing is to always provide a new asphalt binder course at least 5 cm thick. This layer is always required in Belgium when CRCP is used and it should also be so for concrete slabs to ensure a high-quality and durable design. With inlays in particular, the remaining lowest asphalt layers which have suffered worst from fatigue and are therefore less resistant to erosion cannot be relied upon.

2.2. Case-Study N31 Brugge-Zeebrugge

The regional road N31 is a primary road in the province of West Flanders between Oostkamp and Zeebrugge. The average daily traffic intensity was in 2000 between 16 900 and 37 000 vehicles. For 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 highways 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 execute a CRCP inlay in the right-hand lane between Brugge and Zeebrugge. The design made provision for a 4 cm interface layer of hot rolled asphalt (binder course 0/14) and a 20 cm CRC top layer.
The design width was 4.25 m including the lane itself of 3.5 m plus an additional width of 0.75 m. The extra width increases the distance from the axle-roads to the edge of the pavement in order to avoid the problem of punch-outs.
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.
For the composition of the concrete mix, the conditions of the Standards Specifications in Flanders (SB 250) were respected. These are:

- a minimum cement content of 375 kg/m³
- a water-cement ratio below 0.45
- a characteristic compressive strength on cores = 113 mm, height ∅= 100 mm after 90 days of 60 N/mm²
- maximum water absorption of 6% average and 6.5% individual.

The contractor proposed the following concrete mix:

Porphyry 20/32	290 kg/m³
Porphyry 7/20	570 kg/m³
Porphyry 2/7	395 kg/m³
River Sand 0/5	580 kg/m³
CEM III A 42,5 LA	390 kg/m³
Water	167 l/m³
Plasticizer	1 l/m³

Control testing was done on cores to check the compressive strength and water absorption requirements.
The mean of 50 samples gave a characteristic compressive strength of 62.2 N/mm² (> 60 N/mm²).
The mean water absorption by immersion was 5.77% (<6%). Two (out of 50) values were higher than the required maximum of 6.5%.

The chosen surface treatment was aggregate exposure consisting of:
- the spraying of a setting retarder immediately after concreting
- the protection of the newly poured concrete against drying and rain by covering it with a plastic sheet
- cleaning out the surface using a stiff brush

Despite of the use of aggregates of a size up to 32 mm, the result is a beautiful low-noise surface with the fraction 2/7 appearing on top.
The noise level of the two lanes (stone mastic asphalt and exposed aggregate concrete) do indeed seem to be comparable. (Noise measurements have not been carried out).
Because of the volume of tourist traffic to the Belgian coast during July and August, working was not permitted during these months. In addition, work was only permitted on one direction at a time. To reduce the problem of accessibility during the works, passing constructions were provided in certain places. Unfortunately it was not always possible to avoid damage to the reinforcing steel.
For various reasons, the road crossings were reopened to the traffic after 70 days. The mean compressive strength at that moment was 45 N/mm².

With this project, the West Flanders highways authority opted for a lasting solution to the problem of rutted asphalt lanes. The differentiated use of concrete for the slow and SMA for the fast lane clearly shows a conscious choice relating to the traffic intensity. In addition, the exposed aggregate surface 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.

3. SUSTAINABLE ROAD BUILDING

3.1. Aspects Of Sustainable Building

Sustainability over time – quality in both technical and economic senses, together with well-planned functions – is a concept which has earned its spurs in the world of concrete and one which concerns us directly.
A broader concept of sustainability is used in an environmental context: account is taken of the use of non-renewable raw materials, energy usage, and the impact on air, water and soil. "Sustainable development" in this extended sense means thought for the future, for the generations to come, even after the year 2050, when the population of the world could well have grown to 12 billion people. As well as the economic and ecological meaning, the social significance of sustainability will play an increasingly important role.

The Belgian concrete industry has an annual production of the order of 30 million tons of concrete and concrete products. Thirty million tons of concrete is enough to make a cube 230 m along each side. For concrete, the raw material stream is also the most clearly environmentally harmful. These raw materials all undergo processing, the concrete is manufactured, transported and put into use; and sooner or later reduced to rubble that can be reused. This "cradle to grave" sequence can be seen as a life cycle.

Using a scientifically based method, life cycle-analysis or LCA, all this environmental information can be quantified and ordered.
Life cycle-analysis is defined as an objective instrument to assess the environmental damage associated with a product by identifying and quantifying the energy and materials used and emissions into the environment. Prospects for the development of environmentally friendly improvements can assessed on the basis of the results.
Since concrete pavement can have a long lifespan in the economic production and consumption cycle, they can achieve positive results under a life-cycle analysis.

An LCA is always carried out on a functional unit within which the material is produced, e.g. 1 m² of pavement. When an LCA is carried out for a highway including the traffic, it appears that fuel consumption accounts for 90% of its environmental impact. Lighting (5%) and the building material (5%) account for the rest of the environmental impact. (reference (3)). This of course sets the importance of the material used in context. Nonetheless any positive contribution to sustainable development is a step in the right direction.

In the final phase of the life cycle, i.e. recycling, concrete has a good reputation. In Flanders today around 85% of all rock-like building rubble is recycled. Dozens of crushing plants handle the breaking up and screening of the rubble so that it can be reused for various applications. At present this is still largely in the pavements for our roads. It is clear that this saves an enormous quantity of natural raw materials.
But there is more that can be done. Concrete rubble can also be used as a raw material for new concrete, in particular as a replacement for gravel or chippings. The Flemish standard specification 250 already permits the use of concrete rubble in lean mixed concrete for road pavement. In the interim completed and current design and research projects are establishing to what extent this would also be possible for construction and road concrete, without compromising the qualities which have always distinguished concrete. Undoubtedly there is still much progress to be made here. Selective recycling on site – “mobile crushing” – of old concrete roads with reuse in situ for the creation of a new high-grade road concrete is certainly one of the possibilities. It is primarily 2-layer concrete technology which has possibilities here. In the lower layer it is always easier to use “lower value” recycled aggregates while reserving higher quality material for the top layer which meet the stringent requirements for resistance to polishing.

Recent Belgian research (by OCCN, the cement industry research centre) has also shown that the leaching behaviour of a traditional Belgian concrete pavement is completely harmless to the environment. The quantities of leached heavy metals were less than the quantities present in mineral water on sale for human consumption.

Another important environmental issue is that of noise. Concrete roads have a bad reputation for being very noisy by comparison with asphalt. However, modern techniques of chemical washing out of the upper surface of the concrete and the use of fine grit (0/20 with a high proportion of 4/7) mean that this idea is now out of date. This is in fact a technology where Flemish implementations are a model for road builders all over the world. With surfaces in washed concrete, sound levels comparable with silent asphalt. In addition the acoustic characteristics of washed concrete are constant over time while in the case of open structures (porous asphalt, porous concrete) the pores become filled after a few years.

The safety aspects of a road surface can also be considered a criterion for sustainable development.
The texture of the concrete and the proper finishing of the surface area guarantees optimal skid resistance, even in the rain. The complete absence of rutting is a trump card, particularly for very heavily loaded surfaces of major arterial roads.
Perfect evenness provides good ride comfort. With modern slipform pavers, CRCP road surfaces can be laid with the certainty of evenness that meets this need.
Good night visibility is likewise an important factor in traffic safety. Its high reflectivity means that a concrete road is clearly demarked for the road user and obstructions can more easily be avoided.

3.2. Case-study A12 Meise

During summer 2001 the A12 Brussels-Antwerp regional motorway near Meise (north of Brussels) was completely rehabilitated over a distance of around 3 km in both directions. The existing surface was in concrete slabs around 40 years old.
The most important data on this project are summarised below :

- The concrete surface and base layer were completely broken up and replaced.
- The concrete slabs (20,000 tons in all) were broken up on site and screened to provide reusable aggregates, used in the new base layer.
- There was a computer controlled concrete plant on site with a theoretical capacity of 120 m³/h.
- The concrete mix used two types of sand (river sand 0/5 and fine Schelde sand 0/1) and 4/7, 7/14 and 14/20 porphyry fractions in order to produce a continuous grain distribution.
- An air entrainer was used to achieve a good resistance to scaling by chemical deicing agents. Average air content was measured at between 3.5 and 5.5 %. Tests to ISO/DIS 4846.2 standard produced an average loss of 2.6 g/dm² after 30 cycles, which shows exceptional resistance. (For regional motorways a loss of up to 5 g/dm² is acceptable, but there is no provision for this in standard specification 250). Even on new concrete (20 days old) a loss of only 4.7 g/dm² was measured. Road salt can thus already be used for the first frost after laying with no danger of scaling.
- The old steel crash barriers were replaced with new "New Jersey" type F barriers with a height of 80 cm.
- The surface finishing consisted of the washing of the concrete. At least 25 % of the inert substances consisted of fraction 4/7, so a structure of fine grit was exposed, which produces very little rolling noise.

  Noise levels have been measured (see table 1) on the new concrete pavement with fine aggregate, on an older concrete section with coarse aggregate on the surface, on an old dense asphalt section and on a section of new stone mastic asphalt. The measurements were done with the acoustic trailer method, equipped with four different tyres and at a speed of 80 and 120 km/hr.

  The conclusion was that the new fine concrete (ca. 102,5 db(A)) and the new stone mastic asphalt sections (ca. 102 db(A)) were very comparable. A difference of 0,5 db(A) is indeed not audible.

  The noise levels of the old asphalt and concrete sections were 3 to 4 db(A) higher what shows again that rolling noise increases with the aggregate size on the surface.

- The compressive strength characteristics achieved fluctuated between 58.0 and 75.7 N/mm², comfortably higher than the required 52,5 N/mm². This shows clearly that, despite the use of an air entraining agent, a very high resistance concrete pavement can be created by a correct composition and an adequate cement content, in this case 400 kg/m³.

	Direction Brussels - Antwerp	Direction Antwerp - Brussels
Dense asphalt 0/22	105.5	105
Exposed aggregate concrete (coarse 32/40)	105.7	105.6
Exposed aggregate concrete (fine 4/7)	101.8	102.1
Stone mastic asphalt 0/10	102.4	102.6

Table 1 - Noise measurements on the A12
(average noise levels in db(A) at a speed of 120 km/h)

4. CONCLUSIONS

Various projects which have used the inlay technique have demonstrated its feasibility. There are various design options: concrete slabs with dowels, continuous reinforced concrete, low-noise washed concrete or a composite surface (top layer in (open) asphalt). Nonetheless it very important to assess the structure to be overlaid for its residual load capacity and always to make provision for a new intermediate asphalt layer. The structural reinforcement of the most heavily loaded right-hand lane may in many cases be economically advantageous.
The environmentally friendly features of concrete, the modern road surfaces in washed concrete with their attributes of skid resistance, light colour, good noise characteristics and the total absence of rutting are all factors which support the choice of CRCP**.**

Sustainable development will be an increasingly important issue in road building, so an effort is called for from all parties involved. LCA studies make it possible for anyone to optimise environmental performance.

REFERENCES

FUCHS, F. & JASIENSKI, A. (2001) Concrete Road paving. FEBELCEM Cement Information nr. 26. Belgium

FUCHS, F. & JASIENSKI, A. (1996) Concrete Inlays on heavily trafficked lanes. Belgium

HENDRIKX, L. (1998) Low-noise concrete pavements. FEBELCEM Cement Information nr. 18. Belgium

JASIENSKI, A (1998) Concrete overlays and inlays. FEBELCEM Cement Information nr. 14, Belgium

LOFSJOGARD, M. (2000) Functional Properties of Concrete Roads- General Interrelationships and Studies on Pavement Brightness and Sawcutting Times for Joints. Royal Institute of Technology, Department of Structural Engineering. Stockholm

MARION, A.M. & DE LANEVE M. & DE GRAUW A. Research to the leaching behaviour of road concrete. CRIC-OCCN Report 1999-2000. Belgium

KOLMANN, A. (2002) Measurements and evaluation of rolling noise on different test sections on the A12 near Meise, RWTUV Fahrzeug GmbH, Germany