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Continuously reinforced concrete – State-of-the-art in Belgium

Introduction

Continuously reinforced concrete pavements (CRCP) are applied in Belgium for more than 50 years. In 1950, the first Belgian experience with CRCP was achieved in Leuze-en-Hainaut. The technique was really introduced after a site visit in America, where the first CRCP was installed in 1938. In the seventies, over 18 million m² of CRCP was placed in Belgium, mainly on primary roads. The idea of CRCP is to eliminate joints as much as possible, since dilatation joints are often the main cause for premature deterioration of the pavement. In CRCP, cracks will appear, but are very narrow and homogeneously distributed over the surface. The distance between the cracks and the crack width depend to a large extend on the amount of and distance between the longitudinal reinforcement. A good design of CRCP leads to fine water-impermeable cracks and durable roads.

This overview presents the history of the CRCP concept in Belgium, the results of a research towards crack width and distance in between the cracks in relation to the design and finally some new applications of CRCP on highways in Belgium. CRCP is nowadays frequently applied on highway roads in combination with a low noise producing surface such as exposed aggregates. The durability, the sustainability, low maintenance and low noise production of CRCP lead to long lasting applications.

History of the concept

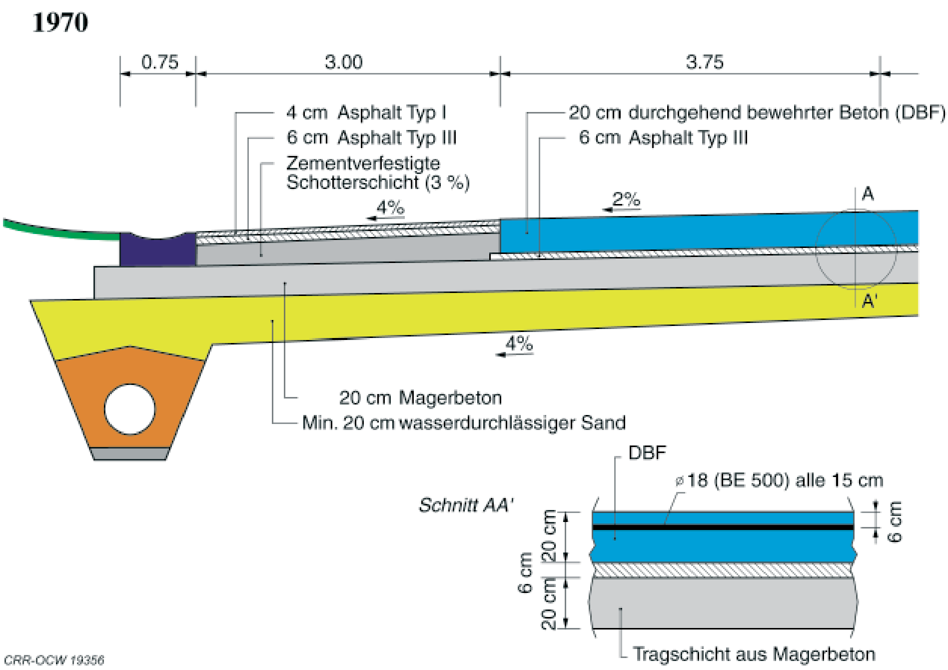
In 1950, the first test section in CRCP was placed in Belgium. A variation of the ratio of longitudinal bars between 0.3 and 0.5% was applied. However, it was only in the seventies that a break through in the application of CRCP took place, after a field trip to America, where by then more than 3800 km CRCP were realized. In 1968, the first overlay in CRCP was applied in Braffe on the RN61.

The first concept contained a ratio of 0.85% (surface of steel/surface of concrete in cross section) divided in rebars BE500, ø 18, every 15 cm, at 6 cm from the top surface. The thickness of the CRCP was 20 cm and a bituminous sandwich layer was placed between the base layer in lean concrete and the CRCP. An overview of this first concept is given in figure 1. This concept was generally applied from 1970 through 1977.

From 1977 till 1990, the concept was altered. Due to saving requirements, the width of pavements was kept to the absolute minimum required, the bituminous sandwich layer was avoided and the steel ratio was reduced to 0.67%, divided in rebars BE500, ø16, every 15 cm. The rebars were placed at 9 cm from the top to avoid reflection at the surface after placing and compacting of the concrete. This was sometimes the case when the rebars were only placed at 6 cm from the top. A cross-section of the second concept is given in figure 2.

Due to some severe damages with the second concept, where very rapidly punch-out problems occurred due to erosion of the base layer and due to very high stresses at the border of the CRCP, a new concept was applied, which is still in use today. In this concept, the reinforcement ratio is increased up to 0.72%, divided in rebars ø18, every 15 cm with a concrete thickness of 23 cm for highway

Figure 1: Cross-section of the CRCP road structure according to the first concept (1970-1977)



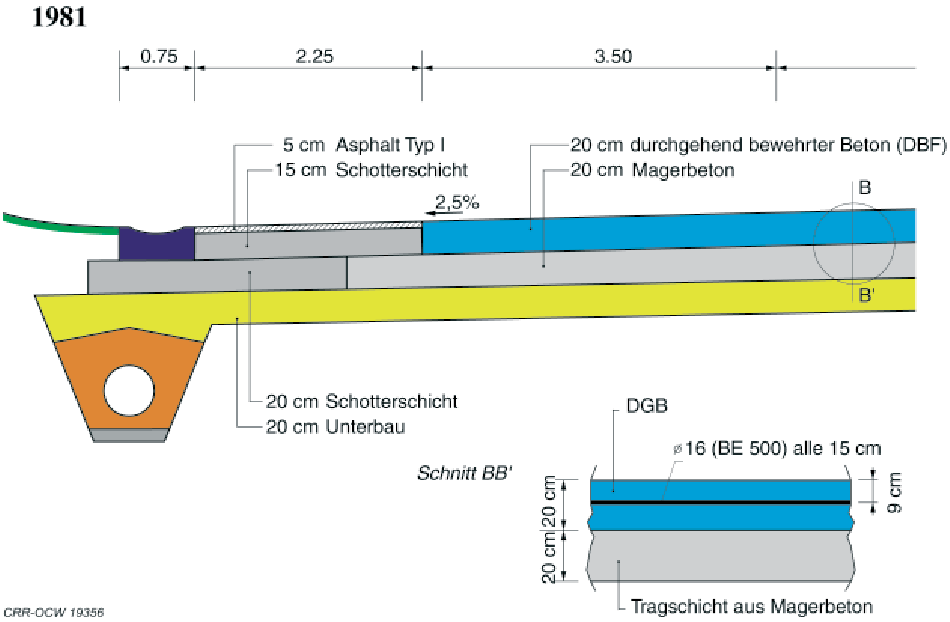


Figure 2: Cross-section of the CRCP road structure according to the second concept (1977-1990)

roads. This is altered in rebars ø 20, every 18 cm due to removal of the bar ø18 from the market. An overview of the parameters of the rebars in relation to the thickness of the CRCP is given in table 1. Emphasis was also placed on the overwidth of the heavy truck lane. To avoid traffic at the border of the concrete slab, an overwidth is produced by placing the marking line at the inner side of the slab.

Analysis of existing continuously reinforced concrete pavements

In 1992, a large research program was executed, where the parameters of the cracks, such as crack width and distance between the cracks were determined. Also the behaviour towards corrosion was investigated on different sections of CRCP in Belgium, designed following concept 1 and 2. In general some conclusions may be drawn. In concept 1, a very small distance between the cracks was measured. Depending on the time of placement (summer or winter), the crack distance varied between 40 and 60 cm. Nevertheless, no defragmantation , no punch-out was noticed on these highways, despite 20 years of service (at the moment of the research) and very heavy traffic. The good behaviour of these pavements can be among others, attributed to the good bond between the base layer and the CRCP due to the presence of the bituminous sandwich layer.

With the second concept (lower reinforcement ratio, no sandwich layer, no overwidth…) the repartition of the joints varied significantly. This is probably due to the different friction behaviour between the CRCP and the base layer in lean concrete or between the CRCP and the old concrete pavement without the sandwich layer. Although the distance between the cracks was more optimal (between 0.80 and 1.50 m), problems occurred very often on this type of pavement due to erosion of the base layer and consequently punch out of the CRCP.

From the same research, one may conclude that the corrosion of the longitudinal rebars is minimal. Inspection of the rebars in the cores, taken at the most widened cracks, indicated a very limited corrosion, especially if the rebars were placed 8 cm under the surface. In the case of a 6 cm cover, after 20 years, some minor corrosion was observed at the longitudinal reinforcement bars due to the penetration of salts. In general, the crack opening was very small and did not lead to corrosion of the rebars.

Table 1: Eigenschaften der Bewehrungsstäbe

Nominaldicke des Betons [cm]	18	20	22	23
Nominaldurchmesser der Längsbewehrungen [cm]	16	16	20	20
Zwischenabstand der Längsbewehrungen [cm]	15	14	18	18
Höhe des Bewehrungslagers [cm]	9	10	11	12
Nominaldurchmesser der Querbewehrung [mm]	12	12	12	12
Abstand von der oberen Manellinie der Längsbewehrung zur Oberfläche (einlagig) +/- 1cm [cm]	6.5	8.0	8.0	8.0
Abstand von der oberen Manellinie der Längsbewehrung zur Oberfläche (zweilagig) +/- 1cm [cm]	/	8.0	8.0	8.0

Severe damage however occurred at several CRCP sections, designed according to the second concept. Punch-out problems occurred quit soon after placement, due to water infiltration in the base layer and consequently erosion of the base layer. To avoid this type of damage it is advised

- to limit the stresses at the border as much as possible, by taking in account an overwidth at the site of the pavement by means of an adequate placement of the marking;
- to assure a longitudinal drainage at the interface pavement-base layer in order to avoid all entrapment of water;
- to place a bituminous sandwich layer in between the base layer and the CRCP, especially if the CRCP is placed on an existing layer.

In Belgium, as standard structure for highways (building class B1), a 23 cm thick CRCP is placed on a 6 cm bituminous layer on a 20 cm base layer in lean concrete.

Recent applications of CRCP in Belgium

Recently, some large rehabilitation works with CRCP are done on the E40/A10 (Brussels-Oostende), on the ring of Antwerp (R1) and on the E411-E25. In the latter case, the right lane as well as the security lane are rebuild in CRCP, in the former cases, the complete highway was redesigned with CRCP. On the E40, an overlay was placed on the existing pavement with a 6 cm bituminous sandwich layer. On the ring of Antwerp, the complete structure was renovated.

As example, the construction of the overlay on the E40 is reported. In this case, an overlay of 25 cm thick CRCP is placed on a 6 cm sandwich layer on the existing road, after milling the existing asphalt over 15 cm. Rebars ø 20 were placed every 18cm. The CRCP was installed by means of a slip form paver, guided by radar over a width of 7.25 m. This means that two lanes were placed at the same time. Tie-bars were used in between the adjacent lanes, ø 16, 60 cm long. Due to the very tight execution schedule the concrete was placed without interruption, 24/24 h, 7 days a week. This omitted the end-of-day joints, which is in favour for the quality of the work. To be able to produce 2000 m^3 concrete a day, two mobile concrete plants are used. By this 1200*7.25 m^2 CRCP was realized each day.

Figure 3 gives a view of the slip form paver at night. The illumination of the work is done by lights, placed in helium balloons to avoid dazzling of the drivers.

The concrete composition contained a minimum of 400 kg/m^3 cement, a maximum water-cement of 0.45, an air entraining agent and coarse aggregate 0/20 with additional 4/7 to obtain a noise reducing surface. After placing and compacting the concrete, a retarder was spread on the surface and washed off the following day in order to obtain an aggregate exposed surface, which leads to a low noise pavement.

The outstanding result of this work is among others the fast execution time, while offering to the users the full capacity of 3 lanes in both directions at all times. By placing the concrete non-stop, by using different techniques such as shields between the works and the ongoing traffic and

Figure 3: Slip form paver at night on the E40

by guiding and informing the drivers continuously, the disturbance to the users was reduced as not eliminated as much as possible.

Conclusions

CRCP has a long history in Belgium. Some crucial points in the design of CRCP are the amount of reinforcement in the CRCP and the bond between the base layer and the CRCP. Now, CRCP is used in Belgium with a reinforcement ratio of 0.76%, 23 cm thick with a bituminous sandwich layer between the base layer and the CRCP. A research on the distance between and opening of cracks as well as on possible corrosion of the rebars pointed out that even with a very small interdistance between the cracks, a good behaviour of the CRCP is obtained, as long as the bond between the CRCP and the base layer is assured. In any case, limited corrosion is noticed at the longitudinal reinforcement bars, even after 20 years of service. Ideally, the longitudinal rebars are placed at 8 cm from the surface. An overwidth of the right lane should be applied to avoid large stresses at the edge of the concrete pavement.

Recent developments in Belgium demonstrated that it is possible with CRCP to obtain a low noise road in a short execution time with limited disturbance to the users. The E40/A10 as well as the Ring of Antwerp are new examples of CRCP on highway roads.

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