ABSTRACT
The section of the E403 (A17) motorway between Bruges and Kortrijk was built in continuously reinforced concrete in the early nineteen eighties. The construction work was carried out in four phases with substantial differences between the phases with respect to the width of the pavement, the sub-base and the position of the longitudinal construction joint. For reasons of economy no intermediate bituminous layer between the pavement and lean concrete base was provided in any of the four sections. A combination of unfavourable conditions in the third section, between Ruddervoorde and Torhout, resulted in the systematic appearance of punch-outs over the entire length of the longitudinal joint in the right hand lane. A definitive and overall approach was needed for the restoration of the damaged zone. This paper describes the history of the E403 (A17) motorway, the evolution of the damage, the principles of the rehabilitation and the sequence of the works that were carried out in the summer of 2007.

KEY WORDS
CRCP / REHABILITATION / PUNCH-OUT / RECYCLED AGGREGATES

1. INTRODUCTION
The E403 or A17 is the motorway that connects Bruges and Tournai (Doornik) via Kortrijk (Courtrai) and offers connections respectively to the E40 south of Bruges and the E42 west of Tournai. The northern stretch between Bruges and Lichtervelde was built in continuously reinforced concrete in several phases during the 1980s. After a number of years damage began to occur, specifically punch-outs next to the longitudinal joint in the right hand lane. Other sections remained virtually free of damage. The holes were systematically repaired although the frequent repairs were time consuming and caused significant traffic nuisance. The required signing and the single lane traffic would give rise to long tailbacks and the associated dangerous situations and complaints from road users. Clearly a permanent integrated approach to the problem zone was needed.

2. BACKGROUND: CONSTRUCTION, MAINTENANCE, DEVELOPMENT OF THE DAMAGE (see annex A)
The construction of the A17 between Bruges and Lichtervelde dates from the 1980s. This stretch of roughly 17 kilometres of motorway was built in continuously reinforced concrete in four separate phases. What is striking is the large number of differences between each of the phases. The first two sections were built to an overall width of 11.25 m or 3 x 3.75 m; whereas the next two sections had an overall width of 3 x 3.50 m or 10.5 m. The idea of building three lanes was so that it would be possible to convert from two to three first class traffic lanes at a later date. The first two sections were constructed with an extra 20 cm thick layer of draining sand below the sub-base. This layer was not provided in the subsequent phases.
Furthermore the position of the longitudinal construction joint was not always the same either: in phases 2 and 4 the joint lay in the right hand lane. Such positioning is extremely unfavourable because of the heavy traffic in what is effectively the slow lane. In phases 1 and 3 the longitudinal construction joint was on the left and the two lanes to the right of it were laid together and separated by a longitudinal bending joint.

What was common to all four phases was that the intermediate layer of asphalt was not provided. This was characteristic of the "economy profile" adopted in the eighties.

Over the years various works have been carried out on the different sections of this part of the A17. With the exception of the first section, all the concrete has been overlaid with a porous asphalt. Section 4 was widened from 10.50 to 11.60 m and in various parts the longitudinal joint in the right hand lane was repaired with cement grout.

Virtually all possible unfavourable conditions converged in phase 3. These were no intermediate layer in asphalt, reduced lane width, reduced drainage, and the exposure of the longitudinal joint to traffic. The poor positioning of the joint was due to the fact that the three traffic lanes were redistributed to create two wide lanes and a narrower hard shoulder. In view of these unfavourable conditions it is not surprising that most damage occurred in the third section. The constant load and the pumping effect on the longitudinal joint led to numerous punch-outs occurring in this section. It should be stressed that this undesirable situation was not due to a single unfavourable factor but to the fact that several such detrimental factors were present at the time. Comparison with the concrete pavement laid in phase 1 makes this clear. Here too there is no intermediate asphalt layer and the longitudinal joint lies in the nearside traffic lane. Nonetheless this section has required no repairs and the pavement has not even been overlaid, furthermore no deterioration can be observed. The conclusion must therefore be that drainage and the water management in the road structure have the greatest impact on performance.

3. PRELIMINARY STUDY

As soon as the decision was made to tackle the damaged zone structurally (primarily section 3 in the direction of Kortrijk) cores were taken in order to obtain a better understanding of the underlying layers. Core I was taken immediately next to the longitudinal construction joint; core II in the hard shoulder between two repaired punch-outs and core III in the hard shoulder next to a punch-out.

![Figure 1 – Taking cores](image)

In core I we observed erosion and crumbling at the interface between the lean and pavement concrete. In Core II was taken in sound concrete, and we observed that the core of lean concrete remained intact up to the interface. However, the lean concrete in Core III, which was taken near a punch-out, had completely disintegrated.

This led to the decision that renovation work that included the sub-base was necessary.
4. DESIGN

The Roads and Traffic Department of West Flanders worked together with the Road Engineering Division, FEBELCEM and the Research Centre of the Cement Industry in order to establish the principles of the renovation. These principles were very similar to those adopted for the E 25 and E 411 motorways in Wallonia (i.e. French-speaking Belgium). It was decided to use the most complete and sustainable solution possible, whereby the existing problems with water in the structure had to be dealt with as effectively as circumstances permitted.

It was decided to include the entirety of the zone in which the majority of the punch-outs had occurred in the project (km 63.600 – km 56.900). The existing lean concrete sub-base was replaced by 15 cm of roller compacted concrete and a new intermediate layer in ABT-B1 asphalt. The thickness of the continuously reinforced concrete was maintained at 20 cm and the entirety of the carriageway would again be overlaid by a porous asphalt. For this reason transverse brushing was chosen for the surface finishing.

To eliminate future problems particular attention was given to the drainage near the longitudinal joint and next to the carriageway. Roughly every 5 metres drainage holes were bored close to the construction joint through the asphalt and the rolled concrete. A system of longitudinal and transverse polyethylene drain pipes was installed to ensure that any water in the structure was evacuated to ditches outside the motorway structure.

Special attention was also given to the position of the new longitudinal joints and the associated road markings in order to avoid past mistakes and to ensure that heavy traffic no longer runs on top of the longitudinal joint.
With respect to the composition of the concrete, the requirements were those determined in standard specifications 250 version 2.1 for construction class B1-B2. As the concrete was immediately overlaid with porous asphalt, roughness and rolling noise were not determinants for the composition of the concrete. For this reason the nominal grain size was fixed at 32 mm and the polishing stone value was not adopted as a criterion, so that softer aggregate, such as limestone, could be used.

However, a choice was made for a maximum of on-site recycling and for this reason up to 40% of coarse aggregate in the pavement concrete could be replaced by recycled concrete aggregate. It was therefore a matter of obtaining a good quality homogenous aggregate from the demolition works on the site. The asphalt debris, which came from the existing overlay, had to be limited to 5% of the aggregate.

Recycled concrete aggregate was also used in the roller compacted concrete.

Because only part of the width and the length of carriageway was being renovated it was decided not to provide new anchoring abutments but to attach the ends of the new pavement to the existing structure.

This was achieved as follows. At the end a groove was cut to a depth immediately above the reinforcement. A cut was made through the entire thickness at a distance of 1.2 m from the first cut. The concrete over this 1.20 m distance was then carefully broken up taking care not to damage the longitudinal reinforcement. The new longitudinal reinforcing bars were then attached to the reinforcing bars sticking out from the existing pavement. An additional reinforcing mesh was placed underneath the final 10 m.

The concrete of the end had to be laid in the morning to ensure that there already was good attachment between the reinforcement and the concrete by the evening. Furthermore the surface of the fresh concrete had to be insulated in order to limit shrinkage due to cooling during the first evening.

5. PERFORMANCE OF THE WORKS

A decision was made on the tenders on 3 April 2007. The time allowed for the works was extremely short, namely 50 working days. The works were awarded to the company ASWEBO NV. The works were completed in the period from 2 May to 6 July, representing a total of 44 working days.

Far-reaching planning and site organization was needed to ensure that the strict deadlines were met. The entire carriageway in the Kortrijk direction was designated as a works site, so that the demolition works and the removal of the concrete debris could take place safely. Traffic in both directions was thus restricted to the Bruges direction carriageway. Initially 2 x 2 traffic lanes were created, with use being made of the hard shoulder, but all too soon it appeared that the bearing capacity of the hard shoulder was insufficient for the heavy traffic heading towards Bruges and the carriageway was reorganized into 2 + 1 traffic lanes.

The demolition works started with milling works to remove the porous asphalt overlay. Difficulties were encountered with the SAMI asphalt that had been applied to the surface of the concrete. It had to be milled off separately because it could not be recycled in the porous asphalt.

No serious difficulties were encountered with the demolition of the continuously reinforced concrete. An excavator was used to raise the pavement until it broke into separate slabs. These were then broken into smaller fragments using a hydraulic hammer and the concrete and steel was taken to a crushing and sieving plant set up next to the site. The concrete was crushed and sorted into various sizes for recycling both in the new roller compacted concrete and in the new road concrete.

Visual examination of the condition of the reinforcing steel revealed that it had suffered little corrosion under the transverse cracks in the CRC, an observation that confirms earlier
investigations in this respect by the Belgian Research Centre for the Cement Industry (OCCN-CRIC).

A concrete plant was installed next to the site for the preparation of the roller compacted concrete and the pavement concrete to ensure unimpeded delivery during the concreting works. The roller compacted concrete was laid using an asphalt finishing machine, whereas the concrete was of course laid using a slip-form paver.

6. CONCLUSIONS

The construction of the A17 was based on the construction principles of “economy profile” of the nineteen eighties. A combination of unfavourable conditions had several negative consequences and lead to the local repairs and structural renovation works such as those described above. For the A17 between Bruges and Ruddervoorde the choice was made for a lasting repair. In the design phase a great deal of thought went into working out what the best possible solution would be and the work performed during execution was of the highest quality. As a result the works were highly satisfactory and the punch-out damage on this section of the A17 may be regarded as a thing of the past.

REFERENCES

Wegen en Verkeer West-Vlaanderen, specifications no. Z79/G63
Wegen en Verkeer West-Vlaanderen, specifications no. Z80/E3
Wegen en Verkeer West-Vlaanderen, specifications no. A82/I64
Wegen en Verkeer West-Vlaanderen, specifications no. Z81/B24
Wegen en Verkeer West-Vlaanderen, specifications no. A82/F74
Wegen en Verkeer West-Vlaanderen, specifications no. 1M3D8J/07/29

VERHOEVEN K., Het gedrag van doorlopend gewapend beton (“The behaviour of continuously reinforced concrete”), OCCN-CRIC, Brussels, 1992
<table>
<thead>
<tr>
<th>Annex A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Contractor:</td>
</tr>
<tr>
<td>Tender date:</td>
</tr>
<tr>
<td>Km points:</td>
</tr>
<tr>
<td>Place:</td>
</tr>
<tr>
<td>Constructed width:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Structure:</td>
</tr>
</tbody>
</table>

General Remarks:
Overlay using porous asphalt in the Bruges direction: from km point 52.750 to 66.193
Overlay using porous asphalt in the Kortrijk direction: from km point 52.750 to 65.967

Structural repairs: repair of punch-outs by Tibergyn nv:
* September 2003: Kortrijk direction between Ruddervoorde and Torhout (km point 61.000 to 58.000)
* March 2004: Kortrijk direction between Ruddervoorde and Torhout (km point 61.000 to 58.000)