History of Design and Construction Practice of CRCP in Belgium

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Belgian Road Network

<table>
<thead>
<tr>
<th>Type</th>
<th>Length</th>
<th>Concrete (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorways</td>
<td>1,726 km</td>
<td>35 to 40</td>
</tr>
<tr>
<td>Regional Roads</td>
<td>12,550 km</td>
<td>13</td>
</tr>
<tr>
<td>Provincial Roads</td>
<td>1,349 km</td>
<td>20</td>
</tr>
<tr>
<td>Municipal roads</td>
<td>138,000 km</td>
<td>15</td>
</tr>
<tr>
<td>Rural roads (agriculture)</td>
<td>5,000 km</td>
<td>60</td>
</tr>
</tbody>
</table>

Belgium
11 million inhabitants
32,820 sq km (12,672 sq miles)
Density of the road network: 5 km/sq km
CRCP-projects 2011

\[ \times \] : 1000 sq m CRCP
Principles of CRCP

- Absence of transverse joints
- Shrinkage controlled by longitudinal reinforcement
- Reinforcement % : 0.60 – 0.85 (today : 0.75 in Belgium)
- Pattern of fine cracks
  - Ideal distance between cracks : 0.7 to 1.5 m
  - Max. Crack width : 0.5 mm
- Transverse reinforcement supporting the longitudinal reinforcement
Principles of CRCP

Longitudinal reinforcement diam. 20 mm

Transverse reinforcement diam. 14 mm

170 mm

700 mm

Splicing of the rebars 35 x diameter (700 mm)

Two tied connections per splice

60°
History of CRCP
USA

- 1921: U.S. Bureau of Public Roads - first CRC - Columbia Pike near Washington (60 m)
- 1938: U.S. 40 at Stilesville, Indiana (400 m)
  Route 130 near Hightstown, New Jersey
- 1949: U.S. 40 near Fairfield, California
- 1950’s: Texas - Pennsylvania, Michigan, Maryland
- 1960: 162 km of lanes built
  CRCP is no longer considered experimental and becomes a current practice
Evolution of CRCP in the US

<table>
<thead>
<tr>
<th>Year</th>
<th>Km lanes of 7.32 m</th>
</tr>
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<tbody>
<tr>
<td>1959</td>
<td>162</td>
</tr>
<tr>
<td>1960</td>
<td>194</td>
</tr>
<tr>
<td>1961</td>
<td>445</td>
</tr>
<tr>
<td>1962</td>
<td>906</td>
</tr>
<tr>
<td>1963</td>
<td>1490</td>
</tr>
<tr>
<td>1964</td>
<td>2592</td>
</tr>
<tr>
<td>1965</td>
<td>3382</td>
</tr>
<tr>
<td>1966</td>
<td>4531</td>
</tr>
<tr>
<td>1967</td>
<td>6637</td>
</tr>
</tbody>
</table>
History of cement and concrete in Belgium

- 1824: Aspdin (UK) takes a patent on Portland cement
- 1872: First cement factory in Belgium
- Beginning of 20th century: First concrete pavements
  - Manual construction
  - Transversely poured slabs
  - Extra thickness near edges and longitudinal joint
1950: First Continuously Reinforced Concrete on the National Road 8 Brussels - Tournai in Leuze-en-Hainaut

- 584 m
- 0.5% and 0.3% longitudinal reinforcement
- Still in service, covered with asphaltic wearing course
History of CRCP
Belgium

- 1958 : Zonhoven, tank track, Ministry of Defense
  - 1200 m, including a curve
  - 0,34% longitudinal reinforcement

- 1961 : Stockem, tank track, Ministry of Defense
  - 350 m, including a curve
  - 0,34% longitudinal reinforcement

- 1964 : Brussels - Charleroi (Frasnez-les-Gosselies)
  - 3700 m
  - 0,7% longitudinal reinforcement

- 1965 : Velaine, municipal road
  - 1028 m
  - 0,7% longitudinal reinforcement
History of CRCP
Belgium

- 1967 : Bierwart
  - 1400 m
  - 0.7% longitudinal reinforcement
  - The design was considered as successful

Pictures from 2006
History of CRCP
Belgium

- 1968: Study tour to U.S.A. with the objective to collect all required information related to design, construction and behaviour of CRCP
  - Team composition:
    - Ministry of Public Works
    - Research Centre of the Cement Industry
    - Steel Research Centre
  - Visited authorities:
    - U.S. Department of Transportation
      - Bureau of Public Roads
      - Federal Highway Administration: Washington, Mississippi, Texas, Illinois
    - State Highway Departments: Mississippi, Texas
    - Texas University
    - CRP Group, Chicago
    - Wire Reinforcement Institute, Washington
    - Highway Research Board, Washington
    - Company T.L. James & Co, Inc.
    - Portland Cement Association, Illinois
History of CRCP
Belgium

- 1969 : Bury-Braffe
  - First overlay (3162 m)
  - Testing of different steel configurations
History of CRCP
Belgium

- 1969 : Boulevard du Borinage
  - Trials of concrete mixes for slipform paver
- 1969 : Thulin
  - 1884 m
  - Trials of concrete mixes for slipform paver
- 1969 : Laneffe-Somzée
  - 2500 m including a slope of 7%
  - Trials of tied bars and splicing lengths
Motorway network 1950-1970

- First plans for a motorway development plan in 1950

Construction of the motorway Antwerp-Liège in 1959
History of CRCP
Belgium

- 1970: extensive use of CRC for new motorway network
History of CRCP
Belgium

- 1970’s: Also the first use of slipform pavers in Belgium
History of CRCP
Belgium

- 1971: E40 (formerly E5) Brussels-Liège
History of CRCP Belgium

- Evolution of km of motorways in Belgium 1950-1978

600 kms of motorways in CRCP from 1970 to 1978
History of CRCP
Belgium

1970
History of CRCP
Belgium

- Evolution of the longitudinal steel reinforcement

  - From 1970 until 1977: thickness = 20 cm
    1 Ø 18 every 15 cm
    \( \rightarrow \text{LRR} = 0.85\% \)

  - From 1977 until 1991: thickness = 20 cm
    1 Ø 16 every 15 cm
    \( \rightarrow \text{LRR} = 0.67\% \)

LRR = longitudinal reinforcement rate
History of CRCP
Belgium

1981

- 0.75
- 2.25
- 3.50

5 cm Enrobé type I
15 cm Empierrement
25 cm Empierrement
20 cm Sous-fondation

20 cm Béton armé continu (BAC)
20 cm Béton maigre

#16 (BE 500) tous les 15 cm

Fondation en béton maigre
History of CRCP
Belgium

- 1981: Standard cross section “economic design” ????
History of CRCP
Belgium

- Study on the behaviour of CRCP

CRACKS

- Crack distribution
- Crack width

CORROSION

- Longitudinal bars

LOCAL DAMAGE

- Construction joints
- Punch-outs
CRCP Distress Types

- Punch-outs

Damage near the edge of the CRCP due to:
- Heavy traffic along the joint
- Presence of water and pump-effect
- Erodable base layer
- Small crack distance
CRCP Distress Types

- **Blow-ups**
  - Bad compaction of the concrete at construction joints
  - Discontinuities by earlier “temporary” repairs
CRCP - Corrosion
History of CRCP Belgium

- **Evolution of the longitudinal steel reinforcement**

  - From 1970 until 1977:  thickness = 20 cm  
    1 Ø 18 every 15 cm  
    $\rightarrow$ LRR = 0,85%
  
  - From 1977 until 1991:  thickness = 20 cm  
    1 Ø 16 every 15 cm  
    $\rightarrow$ LRR = 0,67%
  
  - From 1992 until 1995:  thickness = 23 cm  
    1 Ø 18 every 15 cm  
    $\rightarrow$ LRR = 0,72%
  
  - Since 1995:  thickness = 23 cm  
    1 Ø 20 every 15 cm  
    $\rightarrow$ LRR = 0,76%

LRR = longitudinal reinforcement rate
History of CRCP
Belgium

- 1995-2010: pavement structure for motorways
  - Importance of asphalt interlayer!
  - Extra width in order to avoid edge stresses
  - Quality of the base layer (erodability)

<table>
<thead>
<tr>
<th>CRCP – 23cm</th>
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<tbody>
<tr>
<td>5cm asphalt</td>
</tr>
<tr>
<td>Lean Concrete</td>
</tr>
<tr>
<td>20cm</td>
</tr>
<tr>
<td>Sub-base</td>
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</tbody>
</table>
COMPARISON OF PAVEMENT COST

COSTS IN EUROS

Years

CRC Case 1
CRC Case 2
CRC Case 3
CRC Case 4
Bitum. Case 5
Bitum. Case 6

CRCP
ASPHALT
Belgian CRCP-Projects
2000 - 2010
Belgian CRCP-projects 2000-2010

- 2003 : Ringroad of Ghent (170,000 m²)
- 2003 : Motorway E40 Brussels-Ostend (12 km - 300,000 m²)
Belgian CRCP-projects 2000-2010

- Minimising disturbance: working 24/24 – 7/7
  - ...or avoiding the problem of construction joints!
- Stringless paving
Belgian CRCP-projects 2000-2010

- 2004 -2005: Antwerp Ring Road (350,000 m²)
  - Large communication campaign
  - “less disturbance measures”
  - New CRCP-techniques
    - Terminal joint
    - Exit-lanes
    - Leave-outs
Belgian CRCP-projects 2000-2010

- 2004-2006: Rehabilitation of the motorways E411 and E25
  - 127.5 km
  - Slow lane + shoulder (punch-outs due to “economic” design)
Belgian CRCP-projects 2000-2010

- 2006 : Motorway E34 Antwerp – Knokke (55,000 m²)
- 2006 Motorway E313 Brussels – Liège (10,000 m²)
- 2007 : Motorway E34 Antwerp – Knokke (25,000 m²)
- 2008 : Motorway E17 Antwerp - Ghent (11 km - 165,000 m²)
- 2008 : Motorway E34 Antwerp – Knokke (33,000 m²)
- 2009 : Motorway E40 Brussels – Ostend (90,000 m²)
- 2010 : Motorway E17 Gent – Kortrijk (155,000 m²)
Other particular applications and developments
Thin white topping in CRCP

N7 Gaurain (1984)
- CRCP of 12 and 14 cm thick
- Longitudinal reinforcement
  - 12 cm: 0.62 % - 0.74 %
  - 14 cm: 0.59 % - 0.69 %

N501 Vaulx (1987)
- CRCP of 12 and 14 cm thick
- Longitudinal reinforcement:
  - 0.65 % - 0.75 % - 0.76 % - 0.88 %
- Comparable sections in steel fibre
Thin white topping in CRCP

Results from analysis after 14 years (2000)

• Gaurain
  • 12 cm : 18 punch-outs on 421 m or 10 % surface damaged
  • 14 cm : 3 p.o. on 453 m = good behaviour with bond between asphalt and concrete

• Vaulx
  • 14 cm : good behaviour, even without bond concrete-asphalt

• GENERAL RECOMMENDATION :
  • Minimum 14 cm thickness
  • Minimum amount of reinforcement steel: 0,80 %
Roundabouts in CRCP

- CRCP suitable for heavy traffic
- No end construction needed
- Extra transverse reinforcement
Roundabouts in CRCP

- Connection with road in CRCP without anchorage abutments or just with 1 lug
- Recommended to connect road with roundabout with anchorage bars
Tram-bus lanes in CRCP

- Total thickness 40 to 45 cm.

- Bottom layer in structural concrete – to provide resistance to the tram

- Top layer comparable to CRC pavements for roads

- Anchorage abutments needed at curves with small radius
Double-layered CRCP
(two lift paving)

- 1996: Herne – test sections of low-noise pavements
  - CRCP = bottom layer
  - Best performing top layer = fine exposed aggregate concrete (D= 6mm)

- 2001: Estaimpuis – test sections with different top layers (D= 7 – 10 – 14 – 20 mm)
Double-layered CRCP (two lift paving)

- 2007-2008 : E34
  - Use of recycled aggregates in the bottom layer
Double-layered CRCP (two lift paving)

- Placing of the concrete “wet in wet” by two slipform pavers (maximum time interval of 2 hours)
**Combined CR-SFR concrete pavement**

- First trials for a combined design are taking place
- Focusing on crack width
- Reduction of risk of punch-out
- **Standard CRCP**
  - 0.75% longitudinal reinforcement
  - Rebar diam. 20 mm – 180 mm
  - Calculated crack width 0.45 mm
- **Combined**
  - 0.65% longitudinal reinforcement
  - Rebar diam. 20 mm – 210 mm
  - 20 kg/m³ SF
  - Calculated crack width 0.30 mm
The future?
- Heaviest traffic classes: increased thickness up to 25 cm
- Rolling noise requirements: composite pavements (asphalt wearing course) or double-layered CRCP
- Enhancing quality
  - Control of concrete mixes
  - Increased evenness requirements
  - ...

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CRCP – 25 cm
Asphalt ABT-B1 – 5 cm
Roller compacted concrete 15 cm
Sub-base

CRCP
20 cm + 5 cm
Asphalt ABT-B1 – 5 cm
Roller compacted concrete 15 cm
Sub-base
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Thank you for your kind attention