Towards an improved behaviour of CRCP thanks to active crack control

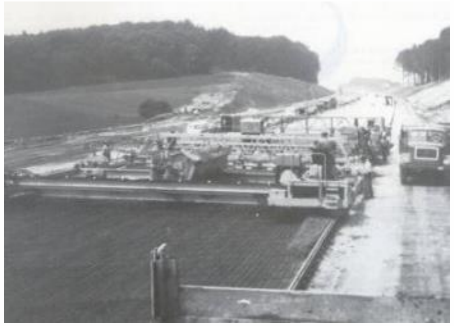
Luc Rens
Consulting Engineer – FEBELCEM
Managing Director – EUPAVE
l.rens@febelcem.be

FEBELCEM

EUPAVE
EUROPEAN CONCRETE PAVING ASSOCIATION

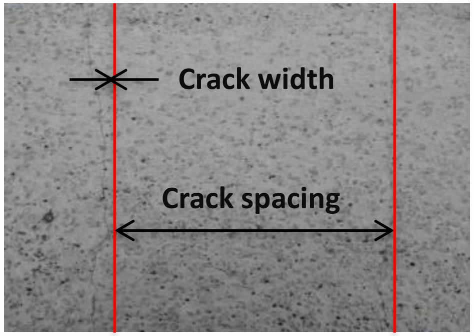
Introduction

- CRCP =
  - Durability
  - Longevity
  - Driving comfort
    - Thanks to absence of transverse contraction joints
    - Fine transverse shrinkage cracks
      - Spacing distance – ideally [0.8 -3.0 m]
      - Opening width < 0.5 mm



Motorway E40/A3, BE – 1971-1972

2021



Introduction

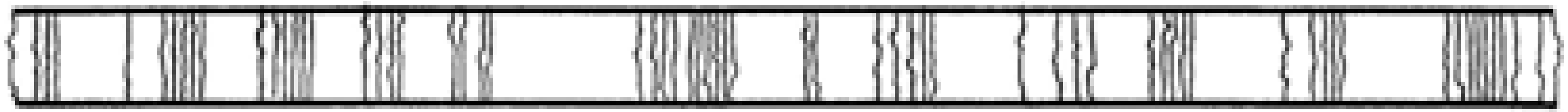
- However, real life is not ideal
  - Crack spacing from 0.10 m to 15 m
  - Irregular cracks
  - Too widely opened cracks
- CRCP distresses
  - Punch-out = most commonly
    - Heavy wheel loading on longitudinal joint
    - Weak base layer, sensitive to erosion
    - Water infiltration (widely opened longitudinal joint)
    - Absence of drainage facilities
    - Closely spaced cracks

Long tradition of CRCP in Belgium

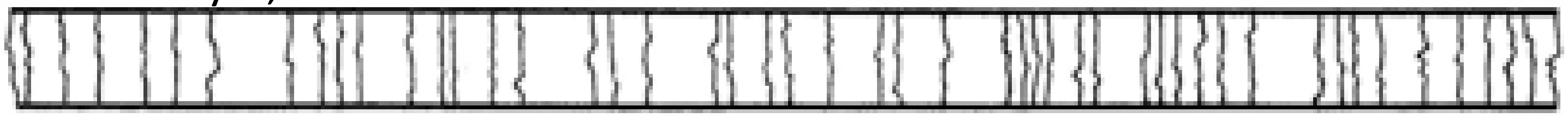
- 1950 : first section of CRCP on N8
- 1960's : several test sections
- 1970's : extensive use on motorways
- 1980's : numerous distresses (punch-out) due to a more economic design
- End 1990's – today : revival of CRCP with adapted design (2001-2013 : > 3 million m²)

Evolution of the concept

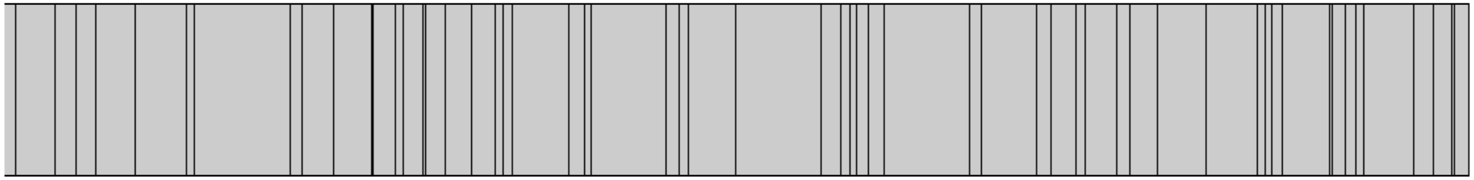
- Concept 1 (1970-1977) : 20 cm thick, 0.85% reinforcement, asphalt interlayer, concrete cover 6 cm



- Concept 2 (1977-1995) : 20 cm thick, 0.67% reinforcement, no asphalt interlayer, concrete cover 9 cm



- Concept 3 (1995-...) : 23 to 25 cm thick, 0.75% reinforcement, asphalt interlayer, concrete cover 8 cm

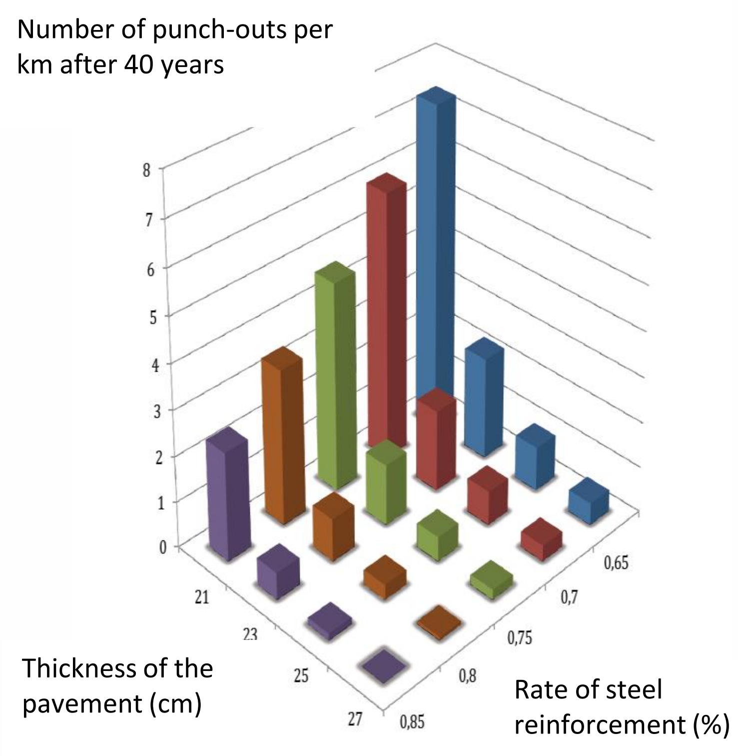


Shortcomings of concept 3

How to avoid/reduce the clustered cracks?

Research & monitoring to improve the cracking behaviour

- Various dissertations and doctoral theses
  - Monitoring of CRCP behaviour
  - Study of the influence of parameters
  - Simulation with MEPDG, using Belgian conditions
- Slab thickness and longitudinal reinforcement are determining parameters
- Decision to keep the 0.75 %

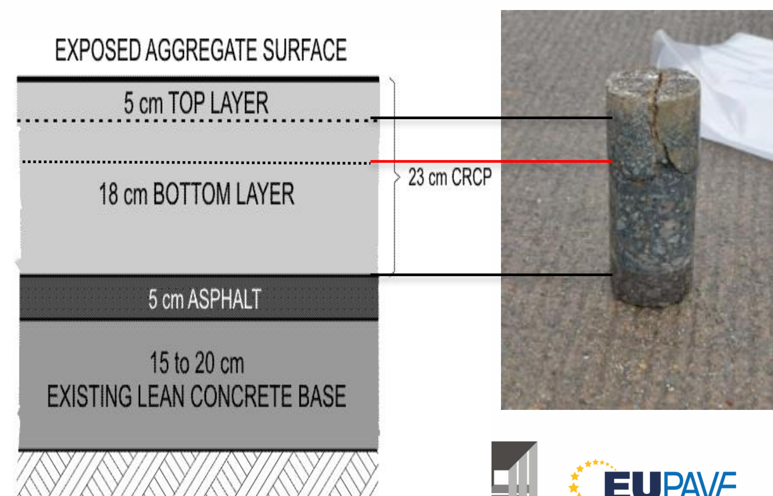


Case-study of N49 rehabilitation, Zwijndrecht, BE

- 2007 WB-2008 EB
- CRCP + 2lift + use of RCA in bottom layer
- 2011: fragmentation in WB – no damage in EB (hydrophobic impregnation?)
- Cores + MIRA: HC + corrosion
- Overlaid with bituminous wearing course – relatively good performance

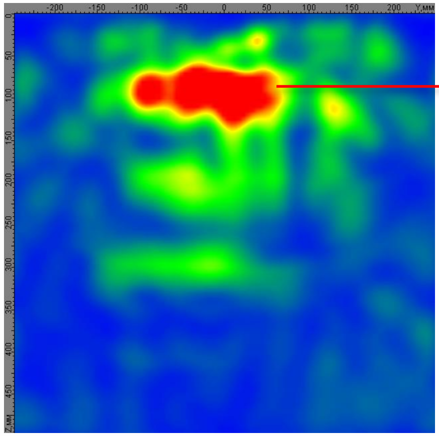
Case-study of N49 rehabilitation, Zwijndrecht, BE

- Damage after only 3 years : fragmentation between closely spaced cracks in the middle of the lane in combination with horizontal crack
- Horizontal cracks at the height of the steel reinforcement (not between the concrete layers !)



Case-study of N49 rehabilitation, Zwijndrecht, BE

- Investigation with ultrasonic tomography (MIRA)



Adapted design for a next worksite

- Worksite BE motorway E313 in 2-layer CRCP/EAC in 2012
  - No use of recycled concrete aggregate
  - No air entrainer in bottom layer (in order to increase bond between concrete and steel)
  - Reinforcement 1 cm lower (9 cm from surface, 4 cm from interface between bottom and top layer)
  - Active crack control (or induced cracking vs. passive crack control or naturally cracking)

Active crack control of CRCP

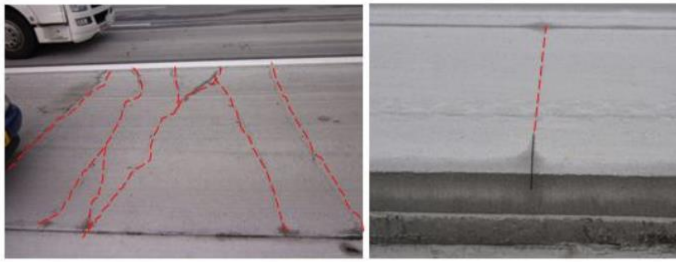
- U.S. Experiences (Texas-1990's, Illinois-2004)
  - Automatic insertion of a plastic tape to a depth of approx. 75 mm
  - The application of a shallow saw cut (approx. 37 mm – 1.5 inch) in the young concrete, about 4 hours after laying, using a light "Soff-Cut" type sawing appliance
  - Cracks originated faster and with a more regular pattern than for naturally cracking
- U.S. solutions were very inspiring but not convenient for Belgian construction practice (exposed aggregate concrete – plastic sheet)
- My observation on CRCP roundabouts

Active crack control of CRCP

- Proposal for the E313 Worksite in 2012
- Sawcut at the edge of the concrete strip :
  - 40 cm long
  - 3 to 6 cm deep
  - spaced at 1.20 m (= average crack spacing)
  - within 36 hours after concreting (when brushing off the concrete mortar for exposed aggregate finishing)

Active crack control of CRCP

- Monitoring in framework of doctoral thesis – D. Ren, 2015, Delft University
- Results (after first winter)
  - 67 % of the notches were effective, thus initiated a crack
  - Of all cracks, 56% for 30 mm depth and 78% for 60 mm were located at notches
    (Remark: in case of 60 mm, also earlier sawcut - within 24h)
  - Reduced risk of clusters of closely spaced cracks



Active crack control of CRCP

- Results (after first winter)
  - Reduced risk of clusters of closely spaced cracks ...which was the main goal!!

Table 7.6 Probabilities of Cluster Cracks.

	Road section	Age (days)	Reinforcement	PROB (2 Consecutive cracks, spacing< 0.6m)	PROB (3 Consecutive cracks, spacing< 0.6m)	PROB (4 Consecutive cracks, spacing< 0.6m))	PROB (5 Consecutive cracks, spacing< 0.6m)
Active crack control – 30 mm	E313-30 mm	123	0.75%	23.56%	6.75%	1.45%	0.48%
		263	0.75%	29.23%	14.14%	5.06%	1.62%
		436	0.75%	29.34%	13.97%	5.01%	1.61%
Active crack control – 60 mm	E313-60 mm	4	0.75%	0.00%	0.00%	0.00%	0.00%
		65	0.75%	7.52%	1.20%	0.00%	0.00%
		204	0.75%	13.27%	5.93%	1.98%	0.40%
		378	0.75%	13.31%	6.07%	2.07%	0.39%
Passive crack control	E17-De Pinte	4	0.75%	12.50%	1.15%	0.00%	0.00%
		60	0.75%	40.93%	18.22%	7.78%	3.13%
		223	0.75%	44.13%	17.93%	7.58%	3.66%
		370	0.75%	50.77%	25.84%	12.44%	5.97%
		587	0.75%	51.76%	31.13%	16.55%	8.77%

Active crack control of CRCP

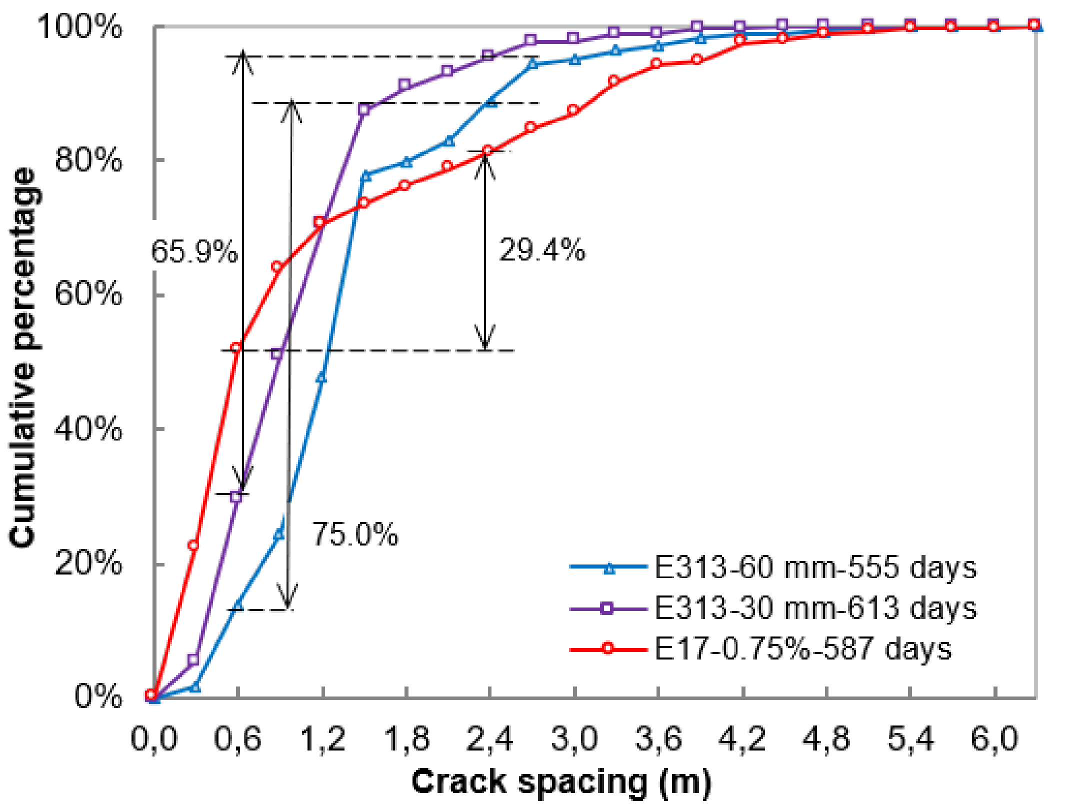
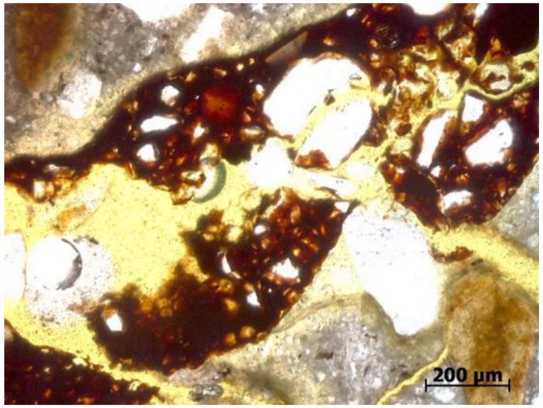


Figure 5 - Comparison of cumulative crack spacing distribution at the test sections on E17 and E313 after about 20 months, including 2 winters; the arrows represent the percentage of the crack spacings in the preferred range 0.6 – 2.4 m (Belgium) ¶

Back to the worksite on the N49 with HC distress

- Use of RCA was assumed cause of HC and related damage of N49, Zwijndrecht, 2007
  - Higher shrinkage
  - Wide open cracks
  - Water infiltration
  - Corrosion



Microscopic image of horizontal crack filled with corrosion particles

Distress due to horizontal cracking

- New type of CRCP distresses
  - Observed at other BE worksites, following all best practices
    - Horizontal cracking at level of steel reinforcement
    - Similarities with punch-out
      - Between closely spaced cracks
    - But also differences with punch-outs
      - In wheel track
      - Not only in heavy duty lane
      - Only upper part of concrete layer is fragmented
    - How is this caused??
    - Which are influencing parameters??

Cases observed in other countries

- A. Texas, U.S.
  - Ref: Prof. Moon Won
  - HC observed since 1999
  - Research & recommendations
    - Concrete: low E, low COTE
    - Steel: amount + 2 layers of reinforcement for thick CRCP
    - Construction: curing effectiveness, temperature variations through slab depth, consolidation of concrete

Cases observed in other countries

- B. Japan
  - Ban-Etsu expressway
  - Study by T. Nishizawa
    - Transverse curling of CRCP

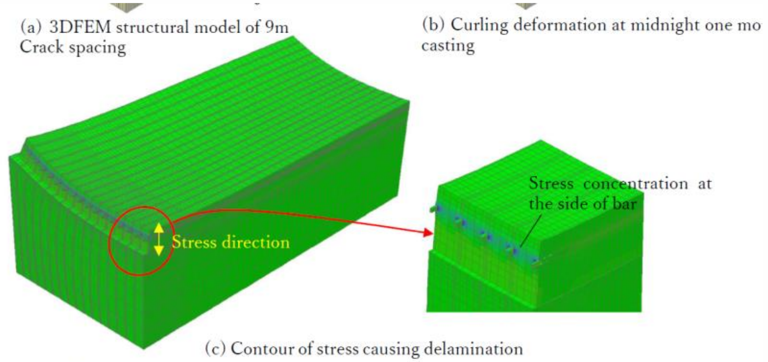


Fig 1 3DFEM analysis

Distress mechanism of HC

- What is (almost) sure:
  - Creation of HC happens:
    - At young age
    - Due to environmental loading
    - Even before opening to traffic
    - At primary cracks at a distance of 10 to 15 m
  - Propagation of HC happens:
    - Under heavy traffic loading
  - Prevention: ACTIVE CRACK CONTROL!

Closing remarks

- Active crack control = simple and efficient technique
  - Depth and timing of sawcut are important
  - BE specs: spaced 1.20m – 4cm deep – 40 cm long – within 24h
  - Faster crack development
  - More equal crack spacing - Straighter cracks - Less Y-cracks
  - Reduced risk of clustered cracks AND of widely spaced cracks !!!
- Mandatory for CRCP in Belgium
  - In standard specifications for Flemish and Walloon Region
  - Except for roundabouts
  - Control of execution!

Thank you for your kind attention