CRACKING AND CORROSION IN CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

by **K. Verhoeven**
Belgian Cement Industry Collective
Research Centre

INTRODUCTION

The Belgian ancestor of continuously reinforced concrete (CRC) dates back to as early as 1950. However, the technique did not definitely break through until the late sixties. A number of trial sections were built at that time, in preparation of the construction of a good 275 km of motorways between 1971 and 1974. More than 5.000 km of CRC had been laid by then in the United States. Since then the CRC procedure has been used on a large scale in Belgium. Over 18 million m^2 of CRC pavements, including 3.5 million m^2 of overlay on old concrete and bituminous road surfacings, were constructed between 1970 and 1990.

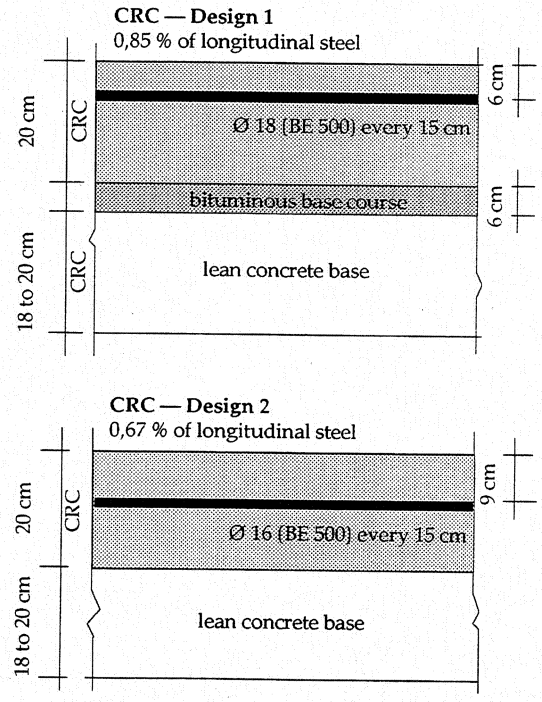
Initially, the percentage of reinforcements in Belgian concrete was set at 0.85 % (compared to the concrete section) on the basis of semi-empirical formulas. This quantity was achieved using BE 500 18 diameter rods placed at 15 cm intervals (design type 1). The increasing use of slipformpavers and plasticizers, as well as ever more constraining productivity considerations, have led to a certain shifting of the consistency limits of fresh concrete. The standard values of fresh concrete of close to 20 s have been brought down to values of around 5 s. This resulted in a reduction (± 10 %) of the average tensile strength, so that the reinforcement percentage mentioned above was regarded as too high. The transverse reinforcement is placed obliquely in order to prevent ill-timed initial cracking above the transverse rods. A 6 cm sandwich ayer of a bituminous mixture was systematically placed between the lean concrete foundation and the continuously reinforced concrete pavement (figure 1).

It was observed that the average distance between cracks was low, that the distribution of cracks was too heterogeneous, and that there were imperfections in the levelness of the surface above the reinforcement rods, all due to the secondary effects during the internal vibration compacting. Between 1977 and 1979 this led to a modification of the design. The reinforcement percentage was reduced to 0.67 %; it was achieved with 16 diameter rods placed every 15 cm (design type 2). At the same time, one lowered the level of the reinforcements (which had initially been placed 6 cm below the surface) to 9 cm. Because of the constant improvement of the surface levelness of foundations made of lean concrete, and as a result of economic considerations, the initial 6 cm sandwich layer of a bituminous mixture was almost systematically abandoned (figure 1).

In spite of the wide use of the technique, few studies exist on the cracking behaviour of CRCP's. Crack patterns are generally characterized only by an average spacing of cracks, while relations with a more extensive set of parameters remain superficial. Data on possible corrosion of reinforcements are also scarce.

As a number of CRC sections were gradually reaching a respectable age and cracks observed in certain sections were sometimes wider than expected, the Belgian Cement Industry Collective Research Centre undertook an investigation in 1990 on the general behaviour of this type of pavement, especially on crack spacing and on possible corrosion of reinforcements.

Figure 1 - Road structures with CRC pavement



1. TEST SECTIONS

Twenty stretches of road were selected : four from the oldest experimental phase (1966-67), five from the 1971-1973 period constructed according to design 1, and eleven more recent stretches built between 1977 and 1985 according to design 2 (table 1). A total of 92 core samples were drilled in order to assess corrosion behaviour ; they were all taken at cracks that were found to be relatively wide.

The experimental phase is in fact little relevant to conclusions because the reinforcing meshes used were quite different from those used later on in design 1 and design 2. The experimental meshes were rectangular with Ø 14 longitudinal bars (0.62 %) at Bierwart, Ø 12 bars (0.62 %) at Velaine and Ø 20 bars (1.05 %) at Bury. It was nevertheless included in the investigation, as it relates to the very oldest stretches in CRC (about 25 years old). Additionally at Bierwart the concrete was poured in two layers, with the reinforcing mesh placed in between. This practice was soon abandoned because of the risk of delamination.

For the five sections of design 1 it was considered that a limited number of cores would do. In each of these sections the cracks are very closely spaced. Furthermore, they were all constructed on the same bituminous base course. The roads concerned are heavily to very heavily trafficked and have been intensively spread with de-icing salts over the years.

The eleven sections of design 2 were divided into three categories : direct overlays on old concrete pavements, overlays on bituminous courses, and new structures in which CRC was constructed directly (without underlayer) on a lean concrete base. This distinction was made because friction on the underlying layers was believed to be an important parameter in cracking behaviour. The sections are roughly ten years old, which is about half the age of the sections of design 1.

A 200 m section, possibly constructed under definite winter and/or summer conditions, was delimited in each selected stretch of road. Cold-weather concreting leads to fewer cracks, while summer construction gives rise to severe shrinkage resulting in "initial cracks" which are invariably subject to the heaviest loads during the life of the pavement. It is those "wide cracks" which were considered in selecting the spots for drilling control cores.

A total of 92 control core samples were drilled for evaluation of corrosion behaviour. All these cores were taken in the right wheel track (at ± 75 cm from the longitudinal joint with the shoulder or emergency lane) at cracks that were considered to be the "ugliest" or "widest" over a stretch of a few kilometres of road.

TABLE 1 Test sections

Ref.	Section	Road nr.	Construction			Number of cores
			Period	Max. °C	Min. °C	
Experimental phase						
1	Bierwart A	N921	9/1967	19	4	6
2	Bierwart B	N921	11/1967	9	3	3
3	Velaine	county	4/1966	18	7	3
4	Bury	N50	6/1966	20	12	1
DESIGN 1 : Ø 18 - 0,85 % longitudinal bars All on a bituminous base course						
5	Bertem A	E40	11/1971	14	4	3
6	Bertem B	E40	7/1971	31	7	3
7	Turnhout A	E34	8/1972	24	14	3
8	Turnhout B	E34	9/1972	19	13	3
9	Retie	E34	1/1973	5	0	4
DESIGN 2 : Ø 16 - 0,67 % longitudinal bars Direct overlays on old concrete pavements						
10	Baugnies	N50	9/1977	23	15	3
11	Pecq	N50	12/1977	8	3	10
Overlays on bituminous courses						
12	Mohiville A	N4	6/1979	19	7	6
13	Mohiville B	N4	10/1979	11	1	2
14	Lamain	N7	6/1980	17	8	3
New structures on a lean concrete base						
15	Bernissart	N505	10/1979	21	14	4
16	Templeuve	N509	4/1985	14	7	3
17	Ieper Zuid	A19	9/1979	22	4	14
18	Recht	E42	7/1982	17	14	5
19	Vaux-Chavanne A	E25	10/1982	16	4	11
20	Vaux-Chavanne B	E25	9/1982	15	11	3

2. CRACK PATTERNS

The free cracking which, as a result of the interaction between the climatic conditions, the characteristics of the materials and the traffic loads, develops in a continuously reinforced concrete pavement, can be regularised and one can achieve an "optimal cracking pattern" by correctly setting the percentage of reinforcements. Average distances between cracks of 1 m to 1.50 m are generally regarded as ideal. By contrast, distances between cracks which are too small are apt to create high transverse tensile stresses, due to bending under major wheel loads. A quite uniform cracking pattern guarantees limited opening cracks, which ensure a correct transfer of loads by the interlock of granulates of the crack walls at the same time as by the presence of reinforcement rods. Fine cracks will limit any chipping of the lips of the crack. These chips can be caused by material trapped in the crack, by low-resistance surface concrete and, above all, by the combined action of shearing strains and tensile stresses induced by the horizonal thermal movements and the vertical traffic loads.

The distances between cracks were determined for each of the sections observed (150 to 200 m). At the same time, an evaluation was made of the width of the cracks and any chipping was noted. Nevertheless, one must not forget, when examining cracking patterns, that they correspond in each case to a precise moment in the execution of a specific section of a roadway. The intrinsic characteristics of the concrete are in fact capable of varying. That is one of the reasons why we chose test sections located as far as possible from the day's end joints.

For each test section an average crack spacing, an average thickness and a crack spectrum were recorded (table 2). To enable all sections to be evaluated in relative terms with respect to one and the same length of road, the distances in each "class" were cumulated so as to be able to speak each time of a given length of road (or corresponding surface area). Thus for instance for section 1 in table 2 it can be said that it has cracks spaced less than 40 cm apart over 1 % of its length, and that cracks spacings between 80 cm and 3 m are observed over 75.9 % of its length. This "class 3" is generally accepted as the ideal cracking class.

A good cracking pattern (such as that shown in figure 5, for example) presents few small cracks distances; in this way, the danger of fragmentation due to longitudinal cracks is minimized. Since the class 4 population is low in any case, it is certain that the steel is not subjected to excessive stresses. Looking at Table 2, one is immediately struck by the impact of the design modification on cracking behaviour. Compared with design type 1, the class 1 cracking of design type 2 has fallen from an average of 49.3 % to 4.5 %. By contrast, class 3 (which is the ideal class) has risen on average from 18.9 % to 70.0 %. It is true that with this new design type there are greater distances between cracks, but this is probably due in part to the age of the pavement, meaning that the cracking pattern has not yet been entirely stabilised.

TABLE 2 Characteristics of crack formation

Ref.	Average crack spacing (m)	Average thickness (cm)	Real % of long. steel	Crack spectrum (% of surface)			
				class 1 0 - 40 cm	class 2 40 - 80 cm	class 3 80 cm - 3 m	class 4 > 3 m
Experimental phase							
1	1,77	20,3	0,61	1,0	2,8	75,9	20,2
2	1,70	20,3	0,61	4,3	8,2	53,9	33,6
3	1,47	21,2	0,59	5,2	12,4	55,0	27,4
4	1,04	21,0	1,00	10,5	23,4	51,0	15,0
DESIGN 1							
5	0,57	20,7	0,82	32,6	32,1	35,3	—
6	0,37	20,7	0,82	64,2	30,1	5,7	—
7	0,39	22,1	0,77	64,5	29,1	6,5	—
8	0,40	21,6	0,78	57,9	34,1	8,0	—
9	0,61	22,5	0,75	27,4	33,5	39,1	—
DESIGN 2 — CRCP/concrete							
10	1,71	27,4	0,49	3,9	7,3	56,3	32,4
11	1,17	22,2	0,60	5,2	13,1	78,4	3,3
	— CRCP/bituminous course						
12	0,79	24,6	0,54	11,1	34,2	54,7	—
13	1,06	24,0	0,56	6,0	30,0	70,9	3,0
14	1,35	23,2	0,58	5,2	12,4	66,3	16,1
	— CRCP/lean concrete						
15	1,46	23,8	0,56	3,5	8,2	64,5	23,7
16	2,35	19,5	0,69	1,6	1,1	52,5	44,8
17	1,61	21,2	0,63	2,6	4,1	87,8	5,5
18	1,36	21,1	0,64	3,5	9,4	85,2	2,0
19	1,86	21,1	0,64	3,0	3,9	67,8	25,3
20	1,36	22,2	0,60	4,1	9,5	85,2	2,0

TABLE 3 Evolution of the crack spectrum

Design	Ref.	Section (period of construction)	Real % of steel	Age	Measured crack spectrum (% of surface) class 1 0 - 40 cm	class 2 40 - 80 cm	class 3 80 cm - 3 m	class 4 > 3 m
1	6	Bertem B (summer)	0,82	18	64,2	30,1	5,7	—
				9	21,0	36,8	42,2	—
2	12	Mohiville A (summer)	0,54	10	11,1	34,2	54,7	—
				1	5,0	14,2	71,4	9,4

Table 3 shows how much a cracking pattern can still develop over time, even between 9 and 18 years after the surfacing was created. For Bertem B (ref. 6), class 1 cracking thus increased from 21.0 % to 64.2 %, while in the case of Mohiville A (ref. 12), class 4 completely disappeared after 10 years. The predominant role of a high and uniform friction on the asphalt can be deduced from an additional comparison of the sections of Table 3 - both constructed during the summer on a similar bituminous bottom layer. Although the steel percentages differ significantly (ref. 12 involves a very thick overlay), the cracking patterns are practically identical when one compares them after 9 and 10 years of age, respectively.

2.1 Sections with 0,85 % longitudinal steel

Figure 2 representing the crack patterns of the sections of design 1 clearly shows that the bituminous base course systematically used in the initial period has a marked influence especially on closely spaced cracks. Depending on concrete laying temperature, two totally different executions turn out to behave identically after twenty years of service. In the sections constructed in summer more than 90 % of the cracks are spaced less than 80 cm apart. In case of winter construction the proportion is still more than 60 %. This is immensely high, and in theory should be indicative of poor behaviour. There is nothing of the kind, however. The fine crack pattern behaves very well : there is no longitudinal cracking at all which could point to disintegration. Moreover, there is little or no spalling to be observed at crack edges. In contrast with a commonly accepted ideal average crack spacing of 1 to 1.5 m a 40 to 60 cm spacing is recorded here, with about 50 % of the cracks spaced less than 40 cm apart.

2.2 Sections with 0,67 % longitudinal steel

Figure 3 relates to new CRCP's laid directly on a lean concrete base. This category being most represented among the existing range, most of the measuring and core sampling was done here. A first observation is the wide variety of recorded crack spectra. The cause of this inconsistent behaviour probably lies among other things in friction with the underlying lean concrete base. Depending on the surface qualities of this base, which are greatly determined by adequate protective measures being taken or not during construction, there will be some adhesion to the lean concrete. This adhesion may be durable or not, according to whether the available bond strength is able to resist the stresses generated by shrinkage and traffic-induced vibrations.

Figure 2 - Crack patterns as a function of construction conditions (warm or cold weather) — Design 1 — 0,85 % longitudinal steel - bituminous underlayer

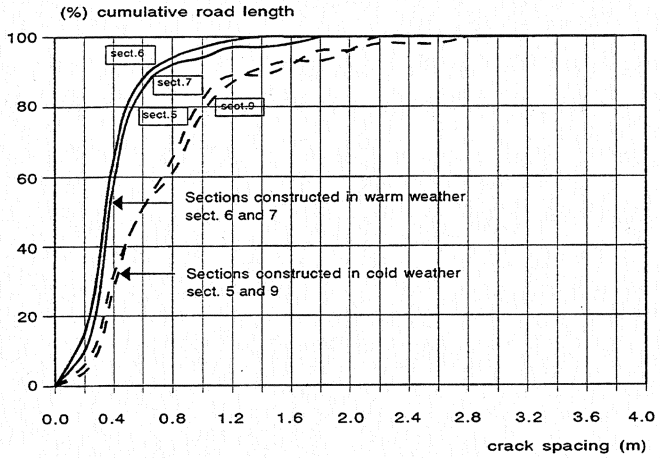
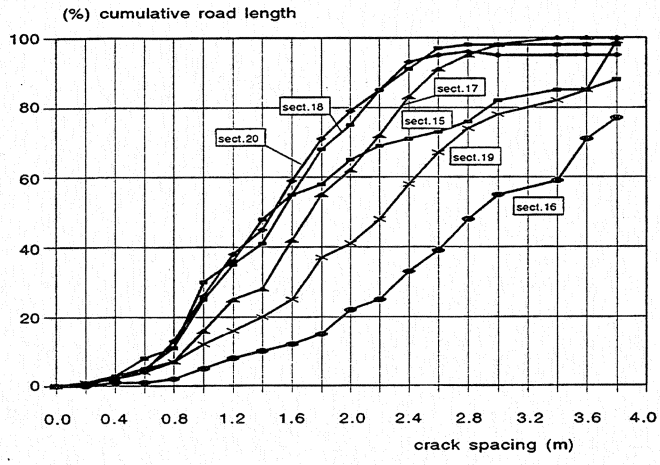


Figure 3 - Crack patterns with CRC directly on lean concrete — Design 2 — 0,67 % longitudinal steel



2.3 Horizontal cracks in the plane of the reinforcement

Horizontal cracks were found at the reinforcing steel in the control cores from a number of sections. These cracks are often fine, but usually attended by more active corrosion. Core samples were taken in the immediate vicinity of those control cores which revealed the presence of horizontal cracks in "ugly" transverse cracks ; they show that the horizontal cracks have not propagated more than 15 cm away from the transverse cracks.

Horizontal cracking occurs only in very active transverse cracks initiated in the earliest contraction stage of the pavement. It is most often accompanied by more or less severe spalling of the edges of the transverse crack (figure 4).

Figure 5 shows how the bulk of the concrete is disturbed at a highly active crack. The consequent slip between the concrete and the reinforcement results in widening the crack.

The investigation has shown that the phenomenon is a combined effect of poor quality of the cement mortar and lack of bond to the lean concrete base. No horizontal cracking occurs in the presence of a bituminous interlayer.

Figure 5 - Disturbed concrete and consequent slip

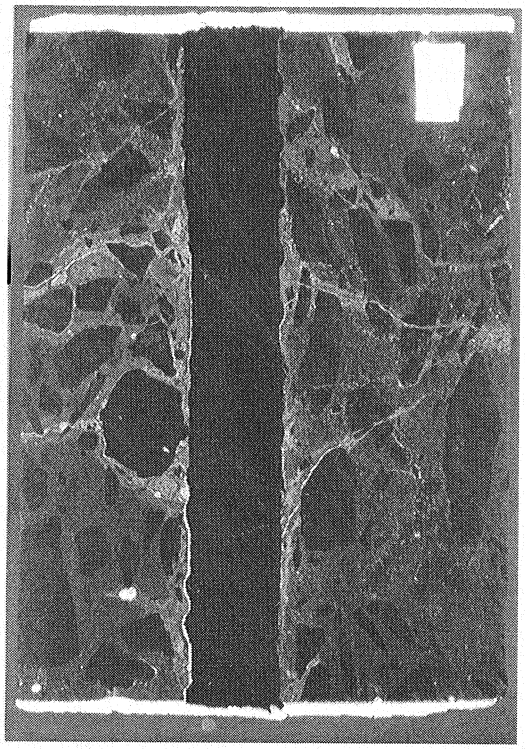
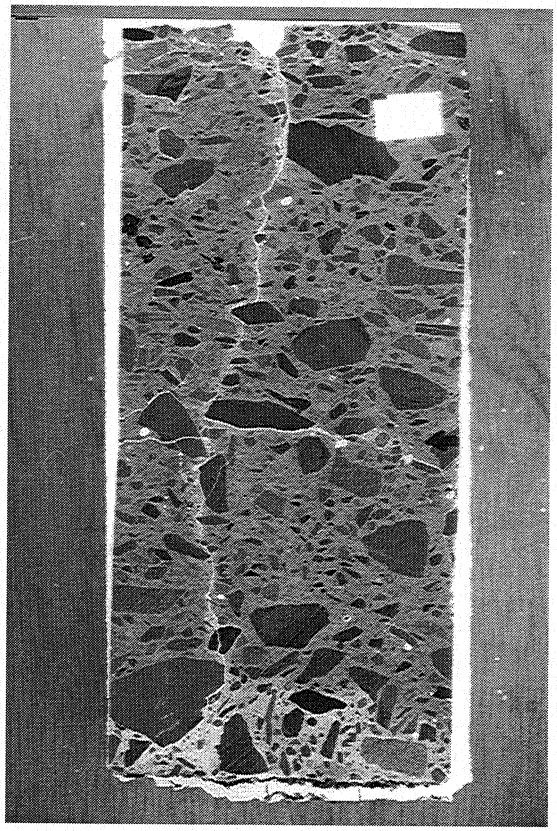


Figure 4 - Fine horizontal crack in the plane of the reinforcement. Rather severe, but superficial spalling of crack lips



3. CORROSION BEHAVIOUR OF LONGITUDINAL BARS

A total of 92 control core samples were drilled from the twenty selected road sections, in the nearside wheel track. The reinforcement was freed by crushing the concrete. Any concrete still sticking to the samples of reinforcement was further removed by means of a solution of HCl. Mostly the bars were submerged during about 30 minutes until rust had disappeared. Strong corroded bars however needed sometimes up to 5 hours to free the rust particles.

The investigation for corrosion on a naturally limited number of samples has nevertheless made it possible to draw a number of conclusions. This is because the samples were in fact not taken at random but selected each time at cracks that were considered to be the "ugliest" or "widest" over a stretch of a few kilometres of road.

Since the cores were, moreover, drilled from the nearside wheel track (at ± 75 cm from the longitudinal joint with the shoulder or emergency stopping lane), the corrosion observed in some sections should be considered as a local maximum. In fact, on this spot, water and thawing salts are present in large quantities, and the cracks are therefore subject to greater stress as a result of higher loads on the edges, plus erosion due to the suction of vehicle tires.

3.1 Visual scale of the observed corrosion

It is clearly not easy to quantify the observed corrosion. Research work conducted in the United States has shown that the best solution consists of making comparisons with a subjective visual scale. Nevertheless, it is tempting to determine the area of each spot of corrosion and the maximum reduction of the steel section

The visual scale of the observed corrosion was obtained on the basis of 5 samples of steel which are representative of all the drilled core samples.

Figure 6 represents the samples retained for establishing the scale :

"1" : very slight corrosion, or even non-existent
"2" : slight corrosion, either on a greater length of rod, or the presence of little "pits"
"3" : moderate corrosion and more pronounced "pits"
"4" : moderate corrosion and deeper "pits" and/or light to moderate corrosion over the entire length of the rod
"5" : heavy corrosion (in most cases due to a horizontal cracking at the level of the reinforcement).

Table 4 shows, per roadway section, the average values of the distances between cracks, the heights of the core samples, and the covering of concrete above the reinforcement. It also shows the number of samples with horizontal cracking, and the number of cases of corrosion classified according to the visual scale. If one ignores the cases of insignificant "very slight" and slight" corrosion, moderate to heavy corrosion was found on only 14 % of the samples. If one takes into account the problems already mentioned of implementation in two layers of the Bierwart roadway section (ref. 1 and 2), this percentage falls to 11 %.

Figure 6 - Visual evaluation of corrosion behaviour

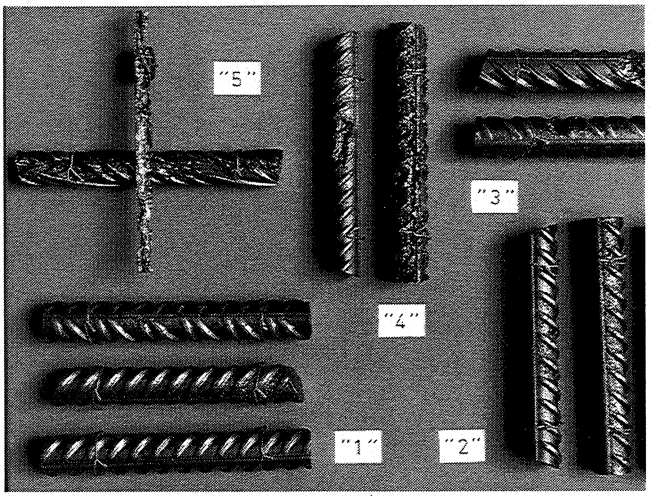


TABLE 4 Visual evaluation of corrosion

Ref.	Mean distance between cracks (m)	Number of cores	Mean thickness of cores (mm)	Mean depth of bars (mm)	Number of cores with horiz. cracks	Number of cores with corrosion for each class				
						5	4	3	2	1
Experimentale phase										
1	1,77	6	205	86	3	2				
2	1,70	3	200	97	1		1			1
3	1,47	3	212	70	—					
4	1,04	1	210	68	—					
DESIGN 1 - 0,85 % longitudinal bars										
5	0,57	3	208	62	—				3	
6	0,39	3	206	58	—			1	2	
7	0,39	3	221	72	—					2
8	0,40	3	216	65	—				1	
9	0,61	4	225	75	1			1		
DESIGN 2 - 0,67 % longitudinal bars										
10	1,71	3	268	150	2		2		1	
11	1,17	10	221	95	2				2	3
12	0,79	5	246	134	—			1	1	1
13	1,06	2	240	123	—			2		
14	1,35	3	232	95	1			1		
15	1,46	4	237	126	—					
16	2,35	3	195	98	—					
17	1,61	14	212	103	7			1	3	3
18	1,36	5	211	101	1			1		
19	1,06	11	211	99	3					1
20	1,36	3	222	112	3				1	
Σ		92			24	2	3	8	14	11

3.2 Corrosion in the sections of the experimental phase (after 25 years)

The test sections at Bierwart (ref. 1 and 2) are subject to moderate or even severe corrosion. The cracks are often very wide at the surface. This is connected with the presence of horizontal cracks in the plane of the reinforcement.

These horizontal cracks are undoubtedly due to the pavement being constructed in two layers.

No corrosion was found on the two other experimental sections. Visual inspection had already led the Velaine roadway section (ref. 3) to be judged as perfect : the cracks are all fine to very fine. Nevertheless, this involves a communal roadway with local traffic and a limited use of ice-thawing salts.

On the Bury section (ref. 4), the absence of corrosion is not really surprising, given the very high percentage of longitudinal steel (1,05 %).

3.3 Corrosion after 20 years (design 1 - 0,85 % long. reinf.)

Very short average distances between cracks were found on the 5 roadway sections using design type 1 (0.85 % of longitudinal reinforcements and a concrete covering of 60 to 70 mm). The surface cracks are all fine to very fine; at the base, they are all closed. Obviously, we drilled into the largest cracks, so that not even the small amount of corrosion that was observed would be found in the majority of other cracks, which were much finer (figure 7).

Eight out of the sixteen cores from the twenty-year-old sections exhibit a light to very light degree of corrosion. Two more samples were rated moderate in this respect.

This negligible corrosion is to be explained by a carbonation process which has unavoidably developed down to the bottom a fine crack in twenty years.

In addition, it should not be forgotten that invariably the "severest" cracks were selected, so that it can be reasonably assumed that only a limited number of cracks have led to this kind of corrosion.

3.4 Corrosion after 10 years (design 2 - 0,67 % long. reinf.)

Of these younger sections - the oldest were constructed in 1977 - with only 0,67 % of longitudinal steel (Ø 16) instead of 0,85 % (Ø 18), eleven in total were examined for corrosion.

The maximum corrosion values found are round about 5 % loss in steel section (table 5).

Moderate corrosion was observed in eight and light to very light corrosion in sixteen of the 63 core samples. It must be recognized that this result is slightly less favourable than for design 1, especially when considering the average age of the sections (only ten years). Moreover, there should be a connection with fine horizontal cracks observed in the plane of the reinforcement which may have affected corrosion behaviour.

The relatively large opening of the crack over the entire height of figure 8 (ref. 11) shows that some slippage must have occurred at this point on the concrete bottom layer; for this reason, some cracks inevitably open up more than others.

Figure 7 - Design 1 — No corrosion after 20 years of performance

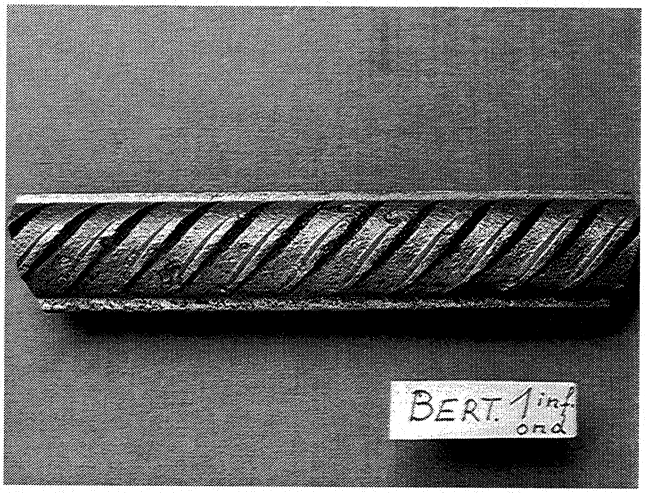
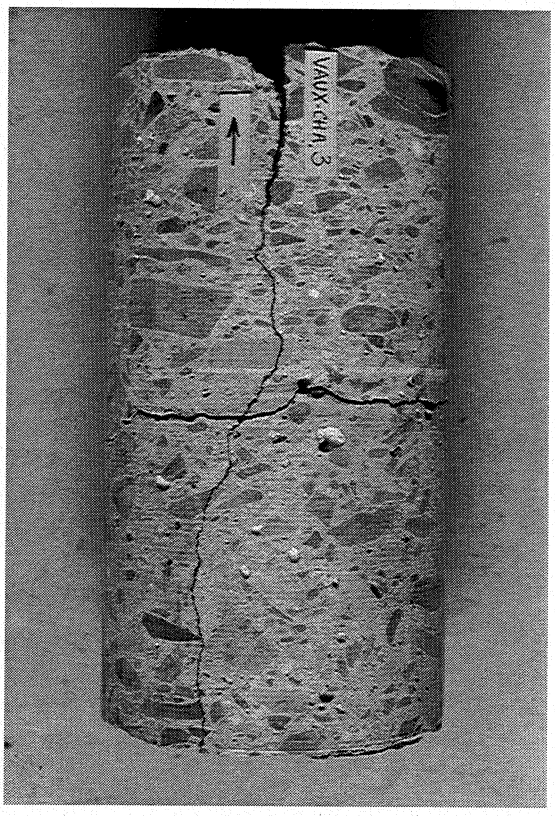


Figure 8 - Design 2 — Pronounced crack opening over the entire depth of the core



3.5 Evaluation of the corrosion by measuring the reduction of the section of the longitudinal reinforcement

The visual grading of the corrosion was supplemented by quantitative measures of the rod section reduction. To do this, we used a Nikon Profile Projector, which allowed us to measure both the area and the depth of the corrosion spots (figure 9).

Table 5 offers a summary combining the visual gradation (determined as described in paragraph 3.1) with the maximum measured rod section reductions.

Figure 9 - Detail of measurement of a particular corrosion spot

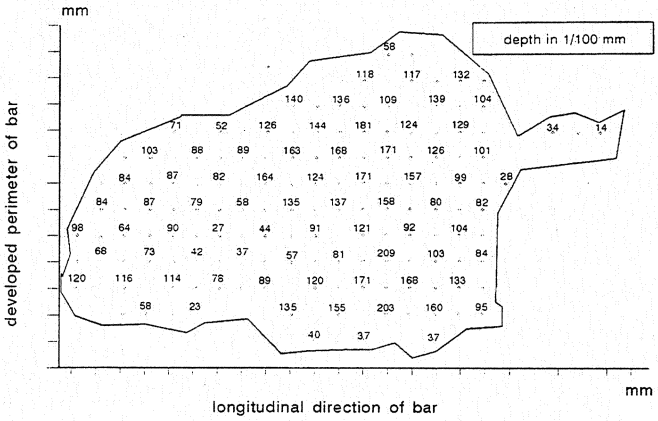


TABLE 5 Synthesis of maximum corrosion values

Ref.	Number		Maximum reduction of bar section (%)				
	Cores	Cores exhibiting corrosion	Degree 5	Degree 4	Degree 3	Degree 2	Degree 1
			Strong	Moderate		Light to very light	
Experimental phase							
1+2	9	4	14,46	6,70	—	—	0,16
			12,00				
3	3	—	—	—	—	—	—
4	1	—	—	—	—	—	—
DESIGN 1 : Ø 18 mm - 0,85 % longitudinale bars							
5+6	6	6	—	—	4,01	3,75	1,16
						6,62	1,00
						1,51	
7+8+9	10	4	—	—	6,46	1,41	1,19
						1,26	
DESIGN 2 : Ø 16 mm - 0,67 % longitudinale bars							
10	3	2	—	6,91	—	2,65	—
11	10	4	—	—	—	2,43	0,48
							0,32
							0,15
12+13	7	3	—	—	4,38	—	—
					3,94		
					3,55		
14	3	1	—	—	—	2,33	—
15	4	—	—	—	—	—	—
16	3	—	—	—	—	—	—
17	14	3	—	—	4,75	1,28	0,75
18	5	1	—	—	6,65	—	—
19+20	14	1	—	—	4,70	—	—

4. CONCLUSIONS

4.1 Cracking patterns

The extremely low average distance between cracks for design type 1 pavements with 0.85 % longitudinal reinforcements and an intermediate bituminous layer is surprising. The average distance between cracks varies between 40 and 60 cm, depending on whether the surface was laid during summer or winter. Any handbook dealing with continuously reinforced concrete would describe this as a curiosity which should not be imitated. At that time, moreover, one shifted to a lower reinforcement rate (design type 2, with 0.67 % longitudinal reinforcements, and without an intermediate bituminous layer) due to fears of fragmentation. Nevertheless, no fragmentation could be observed 20 years after execution. It is clear that the dense cracking pattern which was recorded is due to the high reinforcement rate and, probably to a substantial degree, to the high and homogeneous adhesion with the bottom layer. The design type 2 roadway sections with a similar intermediate layer lead to the same conclusions.

The cracking pattern of design type 2 surfacings show a high level of diversity (average overall distance between cracks of 1.50 m). It is probably due to the variable friction on the bottom layer in lean concrete or on the former slab concrete. The friction on lean concrete depends in fact to a considerable degree on the means of protection applied after execution. Any possible adhesion will only prove durable to the extent that it is capable of resisting the stresses which develop under the effect of thermal movements and traffic vibrations.

The cracking pattern stabilises slowly to very slowly. A significant development in the number of cracks still occurs, for example, between 10 and 20 years of age for design type 1 sections. This development is less marked for design type 2 sections.

At the same time, it is remarkable and reassuring that the roadway sections in question (design type 1) were never deteriorated by "punchouts", despite the earlier fears about fragmentation caused by longitudinal cracking between transverse cracks located very close to one another.

Every cracking pattern identified is in fact related to a particular moment in the execution phase of a specific roadway section. The intrinsic characteristics of the concrete, the curing conditions and the friction on the bottom layer are thus decisive influencing factors.

The determination and the evaluation of a cracking pattern are, in the case of a high reinforcement percentage and a large friction coefficient, heavily conditioned by the traffic factor. In fact, only the slight chipping which appears over time makes it possible to detect extremely fine cracks.

4.2 Corrosion of the longitudinal reinforcement

In general, one can say that the corrosion is minimal. This confirms the positive findings resulting from a first study conducted by the CRIC in 1974. The reduction observed in the section of the reinforcements corresponds to a maximum reduction of the reinforcement rate of around 0.04%.

The observation of a certain degree of corrosion in the design type 1 roadway sections, despite the extreme fineness of the cracks, was somewhat unexpected. The explanation for this should be sought in a greater influence of the calcium chloride of the thawing salts on the reinforcement layer which is located relatively high, and in the inevitable carbonation of the walls of the cracks. The degree of corrosion is nevertheless extremely low for a pavement service life of 20 years.

The study was based on a non-random sampling which led us to focus only on the worst-looking cracks. Moreover, one can say that all the rods are not corroded in the same manner in the observed crack. The clogging that one observed towards the middle of the roadway probably significantly reduces the corrosion risk there.

A priori, constructing a continuously reinforced concrete pavement directly on a foundation of lean concrete should produce good results. In this case, it is necessary nevertheless and in principal to pay sufficient attention to the surface qualities of this layer (protection and intrinsic quality of the concrete). Most of the roadway sections show that there is no need for concern. Several sections display heavy chipping of crack lips, as well as a limited amount of horizontal cracking at the level of the reinforcement and perpendicular to very active cracks. This phenomenon must be linked to a localized lack of adhesion with the bottom layer and to a lower quality of the mortar in the surfacing layer.

The overlays, occasionally created (locally or not) with a significant excess thickness, display a moderate form of corrosion after 10 years.

Except for the Bierwart roadway section (which dates from 1967 and was created in 2 layers), the sections of the 25-year old experimental phase display no corrosion.

Reference

K. Verhoeven
"Le comportement du béton armé continu" (french)
"Gedrag van doorlopend gewapend beton" (dutch)
Brussels, Belgian Cement Industry
Collective Research Centre, 1993, 37 p.