CEMENT CONCRETE PAVEMENTS IN THE HUNGARIAN ROAD POLICY

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ABSTRACT

The paper presents the main steps of modifying the Hungarian road policy to include also cement concrete pavements after several decades of its exclusion. The results of preliminary laboratory tests are shown. A test section on the road 7538 was built in 1999 which consisted of three cement concrete subsections of various techniques and an asphalt pavement control subsection. Their performance has been monitored since then. The time data series of several condition parameters and the results of visual condition survey permitted to evaluate and to compare with each other their performances. Besides, a rigid, a semi-rigid and a composite test section were constructed on a Hungarian main road in 2003. These sections are also monitored. A third cement concrete pavement trial section on main road 4 was built in 2004 with an asphalt pavement control section. Its initial condition parameters were also evaluated. Using the performance results of these sections, a new Hungarian road policy was set up including the basic principle of pavement type selection.

1. Background

Concrete pavements have been tested in Hungary since 1911, and constructed since 1927. The first sections had plain concrete pavements with a thickness of 150 mm, later with a thickness of 200 mm laid in two courses. In 1927, a 600 m long main road section was constructed using Rhoubenit-concrete with a width of 6 m. Between 1926 and 1933, cement concrete pavements laid mainly directly on sub grade were constructed with a total length of 103 km.

The period of 1933-1944 can be considered as the ”golden age” of cement concrete constructions in Hungary (with 1088 km total length). The pavements were designed to 30 kN wheel load. Their typical sizes: 130 mm thickness directly on sub grade, 6 m width, longitudinal joints, transversal joints in 8-12 m, laid mainly in a single course. They performed fairly well, their overlaying using asphalt layers was done in the 50's and 60's.

After World War II, the construction of the roads with cement concrete pavements played an important role in the modernisation of the Hungarian main road system. Over 300 km cement concrete pavements were built with a width of 6.50-7.00 m, and with a thickness of 180 mm on sandy gravel base.

The first Hungarian motorway M7 (between Budapest and the lake Balaton), was built using rigid pavement from 1958 on. Its typical pavement structure constructed before 1972 is as follows:

- 200 mm jointed plain cement concrete pavement (with basalt aggregate),
- 50 mm bituminous base course,
- 20 mm bituminous sand,
- 150 mm mechanical stabilisation.

Pavement structure after 1971:

- 240 mm jointed plain cement concrete pavement,

- 20 mm bituminous sand,
- 50 mm bituminous base course,
- 150 mm cement stabilization.

The width of cement concrete pavement on motorway M7 is typically 8.5 m with longitudinal joint. Transversal joint spacing is 5.0 m, no dowels were used in transverse joints. From 1972 on, also air-entraining agent was applied to withstand the detrimental effects of de-icing agents.

The highest total length of cement concrete pavements in Hungary attained 1250 km in 1965 [1]. From that time-point on, the length has been gradually decreased due to rehabilitation with asphalt pavements.

Some sections of the motorway M7 had shown early deterioration signs due to various construction failures. It was one of the reasons why the Hungarian Ministry of Transport decided to continue the motorway programme using exclusively asphalt pavements from 1976 on. As a consequence, the construction of cement concrete pavements came to an end on other roads, as well. The material supply, the development of machinery, the training of experts and the research activities also stopped in this area.

It was only in 1998 – after a break of 22 years – that a ministry decision was made on the preparatory activities to restart cement concrete pavement construction in Hungary [2].

2. Preliminary tests

KTI (Institute for Transport Sciences), in Budapest was commissioned with the preparatory works of cement concrete trial sections. First, the latest foreign experience on the basic materials, recipes, machinery, design and construction methods of cement concrete pavements were gathered.

A few recipes and technical solutions appropriate for the Hungarian climate and traffic conditions were selected. After the consideration of the realistic possibilities, three alternatives were elaborated:

- jointed and dowelled cement concrete pavement,
- jointed and dowelled cement concrete pavement with "exposed aggregate" surface,
- continuously reinforced cement concrete pavement.

A PIARC-publication [3] on the design and construction experience, as well as cement concrete pavement specifications in several countries was utilized when selecting the most appropriate recipes for the three concrete options. Table 1 presents the KTI compressive strength test results and the respective PIARC-recommendation.

Table 1. KTI compressive strength test results vs. PIARC-recommendations

	28-day compressive strength (MPa)		
	Jointed cement concrete	Jointed cement concrete with "exposed aggregate" surface	Continuously reinforced cement concrete
KTI test results	35.3	42.2	37.2
PIARC-recommendation	35.0-40.0		min 40.0

The concrete types selected had to be resistant to expected traffic and environmental loads. That is why, W/C-ratios between 0.40 and 0.42 were chosen as a function of weather condition and of the actual water content of the fine aggregate fraction. A plastificator was added in 0.10-0.12 % of water, as well as air-entraining agent in 0.04-0.08 % of water.

3. Design and construction of the trial section on road 7538

As a site for the experimental (trial) section, a heavily trafficked secondary road 7538 between Lenti and Letenye was selected.

Three cement concrete subsections were built between km 8+600-10+100 (500 m each), while the control section with modified bitumen asphalt pavement was constructed between km 14+000-14+000 on road 7538.

As a consequence of the extremely high lorry traffic (above 1110 heavy vehicles/day), the two-lane pavement sections had been severely damaged. That is why, the removal of the whole pavement structure was decided before constructing the experimental structures.

The pavement structure variants to be tested (Figure 1) were as follows:
- subsection 1
  - 220 mm jointed and dowelled cement concrete pavement,
  - 150 mm mixed-in-plant cement stabilisation base course,
  - 100 mm mixed-in-place cement stabilisation sub-base,

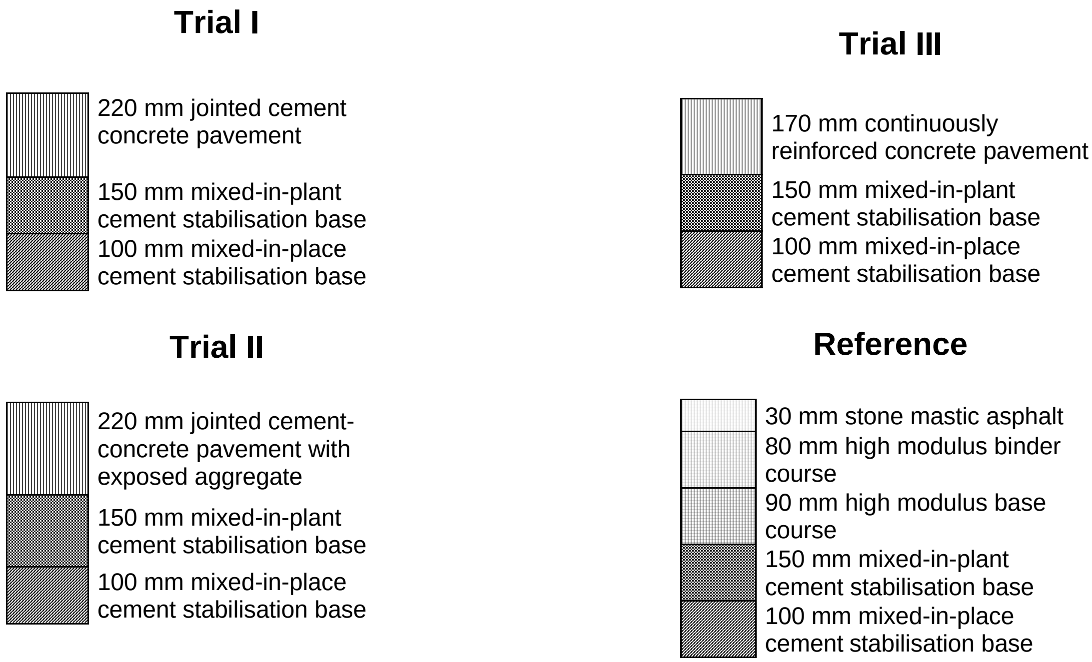


Figure 1. Pavement variants of the experimental section on road 7538

- subsection 2

- 220 mm jointed and dowelled cement concrete pavement with "exposed aggregate" surface,
- 150 mm mixed-in-plant cement stabilisation base course,
- 100 mm mixed-in-place cement stabilisation sub-base.

- subsection 3

- 170 mm continuously reinforced cement concrete pavement (CRCP),
- 150 mm mixed-in-plant cement stabilisation base course,
- 100 mm mixed-in-place cement stabilisation sub-base.

- subsection 4 (control)

- 30 mm stone mastic asphalt with modified binder,
- 80 mm asphalt binder course with modified binder,
- 90 mm asphalt base course with modified binder,

- 150 mm mixed-in-plant cement stabilisation base course,
- 100 mm mixed-in-place cement stabilisation sub-base.

The flexible pavement structure of control section was designed using asphalt layers with high resistance to deformation and it was considered as of identical bearing capacity to the cement concrete variants. The mixture design of upper asphalt layers was carried out by SHRP Superpave design method.

The pavement width of the trial sections (and the whole road 7538) amounts to 6.00 m. (This width is typical for Hungarian secondary roads).

The construction of the experimental section was basically influenced by the extremely rainy spring and summer of 1999. Only one of the traffic lanes was allowed to be closed during the construction period.

As a consequence of the repeated rains, the design bearing capacity level of 50 MPa could not be ensured on the surface of sandy gravel capping layer. So, its stabilisation with cement was decided by the Client.

The 6 m wide cement concrete pavement was laid as a single layer in two lanes of 3 m width. One of the jointed concrete subsections had "exposed aggregate" surface in order to decrease rolling noise and to increase macro roughness [4].

No continuously reinforced cement concrete pavement was built in Hungary before the experimental section on road 7538. The pavement with a thickness of 170 mm and 0.67 % reinforcement was constructed without transversal joints, only construction joints were applied at the end of the day's work. The relevant foreign literature [5-7] was utilized in the design of the subsection (dilatation structure, anchor to prevent CRCP end movement, positioning of reinforcement etc).

Intensive quality control was performed during the whole construction period of the experimental section. Table 2 shows the laboratory test result ranges.

Table 2. Laboratory test results during construction

Cement concrete subsection	Air void content (V%)	Hardened concrete at the age of 28 days			
		Density (kg/m^3)	Compressive strength (MPa)	Bending strength (MPa)	Splitting tensile strength (MPa)
Jointed	4.1-5.2	2390-2465	41.3-54.2	4.15-6.02	2.95-3.92
Jointed with exposed aggregate	4.2-5.0	2314-2356	37.4-56.2	4.17-4.50	3.36-3.84
Continuously Reinforced	4.3-5.0	2412-2498	50.3-67.0	4.58-6.92	3.27-7.49

4. Monitoring of the trial section on road 7538

The main aim of the experimental work was to evaluate and to compare the performance of various pavement structures including three rigid ones under "canalised" heavy traffic. (The lorries run in very narrow wheel paths due to the pavement width of 6 m). That is why, the monitoring of the pavement subsections was decided with a frequency of 6 months, later of 12 months.

The condition evaluation methodology comprised every theoretically possible failure type for the pavement variants. Table 3 presents the distress types and the condition parameters evaluated for each pavement type.

Table 3. Possible distress types of the pavement variants and their characterised condition parameters.

Failure type	Condition parameter	Asphalt Pavement	Concrete Pavement	Spacing of evaluation
Longitudinal deformation	Unevenness	X		Continuous
Slab faulting	Unevenness		X	Continuous
Rutting	Transverse profile	X		In 3 fixed cross sections for each subsection
Loss of skid resistance	Skid resistance	X	X	Every 50 m, in alternate traffic lanes
Wear of aggre-gate grains	Macro roughness	X	X	Every 50 m, in alternate traffic lanes
Surface defects	Visual condition evaluation of surface defects	X	X	Continuous
Poor bearing capacity	Bearing capacity	X	X	In 3 fixed cross sections deter-mined for each subsection
Pavement edge distress	Pavement width	X	X	In cross sections with a spacing of 100 m

Location of the measuring points were marked by painting applied on the pavement surface. The following measurement types applied were designated for the comparison of the performance of various pavement types:

- Skid Resistance Tester (English pendulum) for the characterisation of the skid resistance of pavement surface,
- sand patch method (texture depth) for the evaluation of pavement macro roughness,
- ÚT-02 type manually operated, 3-wheel unevenness measuring device for the characterisation of longitudinal pavement unevenness,

- measuring tape for the determination of pavement width,
- visual pavement survey for detecting pavement defects,
- boring cores to measure the thicknesses of pavement structural layers.

The visual pavement survey resulted in a distress map with the locations, types and severities of various defects identified.

Besides, some special measurement types were also selected to evaluate a single pavement type:

- counting the number of aggregate grain peaks in assigned areas of the jointed cement concrete pavement subsection with "exposed aggregate" surface,
- rut depth measurement on the asphalt concrete reference subsection,
- dynamic bearing capacity measurement using KUAB type Falling Weight Deflectograph.

The first survey was done in mid-November 1999 to characterise the initial (0) condition of the experimental section. Its main results can be summarised as follows:

- jointed cement concrete pavement subsection: high skid resistance (mean SRT-value: 79), fairly high texture depth (0.70-1.27 mm), rather even surface, mean pavement width of 6.18 m, pavement thickness very close to the design value (average: 223.6 mm),
- jointed cement concrete pavement subsection with exposed pavement surface: reasonable skid resistance (SRT=62), very high texture depth (1.00-2.60 mm with 1.78 mm mean value), relatively different numbers of aggregate grain peaks between the two traffic lanes, rather even surface, mean pavement width of 6.19 m, pavement thickness very close to the design value (mean: 219.7 mm),
- continuously reinforced cement concrete subsection: high skid resistance (mean SRT-value: 74), average texture depth (0.57-0.96 mm), even pavement surface, mean pavement width of 6.17 m, pavement thickness close to the design value (mean: 173.3 mm),

- asphalt pavement subsection: relatively low skid resistance (mean SRT-value: 50), fairly high texture depth (0.53-1.16 mm), relatively even pavement surface, mean pavement width of 6.05 mm, the average thickness of asphalt layers slightly below the design value.

Some remarks based on the comparison of the initial condition of various subsections:

- the skid resistance of every cement concrete pavement section was above that of the asphalt control section (partly due to the still unworn bituminous film on the surface of aggregate grains), while the asphalt surface showed skid resistance with lowest standard deviation,
- the texture depth values of CRCP subsection were relatively uniform compared to those of other subsections; the standard deviations of the two traffic lanes of the jointed cement concrete pavement with exposed aggregate were considerably different due to some laying problems,
- unevenness measurement results were almost identical on the jointed cement concrete and the CRCP subsections, while that with exposed aggregate was more uneven, the asphalt control section happened to be the most even, however a single wave height of 25 mm was measured there,
- the deflection values on cement concrete pavements were in the range of 0.18-0.19 mm, while on the control subsection between 0.29 and 0.35 mm. (100 KN load was applied).

The monitoring of each subsection has been carried out in the following time points:

- August 1999 (initial condition),
- April 2000,
- October 2000,
- April 2001,
- October 2001,
- April 2002,
- October 2002,

- October 2003,
- October 2004.

The evolution changing of mean SRT-values on every subsection can be seen in Figure 2. The initially, basically different SRT-values (50-80) have become almost identical (57-65) after 5 years.

Similar time data series of mean texture depth values are presented in Figure 3. The extremely high macro texture of the subsection with exposed aggregate started to decrease considerably after a 4-year operation period. The texture depth of asphalt subsection has been only slightly reduced. The CRCP surface has reached a fairly low macro roughness by now.

Figure 2. Evolution of SRT-values on four experimental subsections (road 7538)

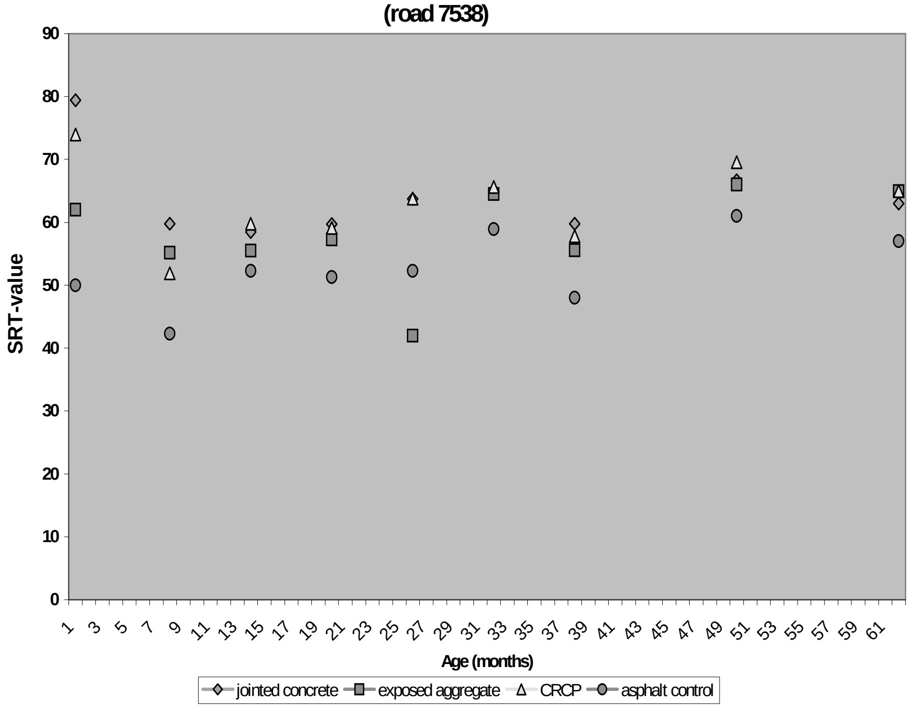
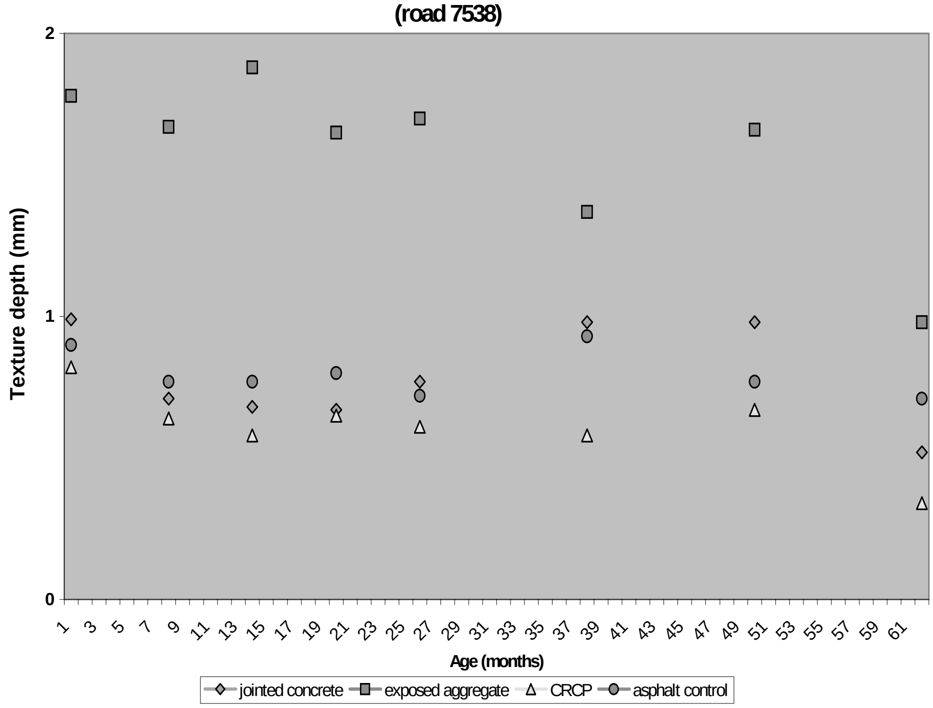


Figure 3. Evolution of texture depth values on four experimental subsections (road 7538)



The unevenness (roughness) of experimental subsections were evaluated using a measuring device type ÚT-02 which integrates the wave heights of the pavement surface along a 100 m-long section. Figure 4 presents the changing of the average integrated unevenness value on the pavement variants during the first 5 years of operation. A slight deterioration can be observed on the control section, while the exposed aggregate surface has become less uneven due to the wear of protruding aggregate grains. The unevenness of other variants has changed only slightly. It is striking that the levels of unevenness are much more homogeneous after 5 years than in new condition.

Figure 4. Evolution of integrated unevenness value on four experimental subsections (road 7538)

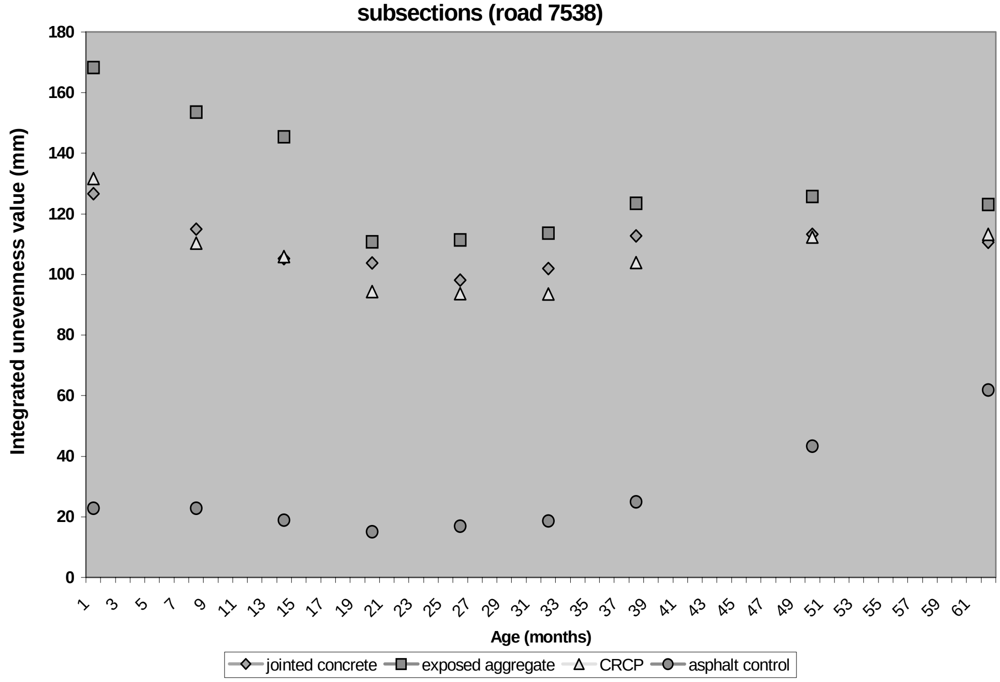
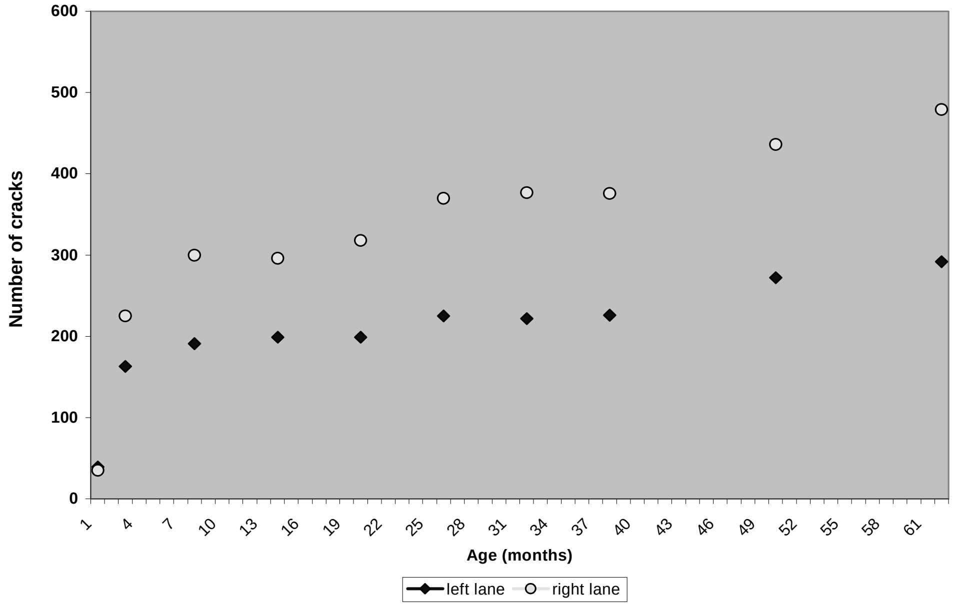


Figure 5 illustrates the evolution of the numbers and the spacing of transverse cracks on CRCP subsection. The intensive growth in the number of cracks during the first 8 months has been decreasing afterwards. The average spacing amounts to 1,0-1,7 m slightly below the optimum according to the literature [8]. The basic difference between the deterioration of the two traffic lanes can be explained by the fact that the right lane has been loaded by "full" lorries carrying goods to Adriatic harbours, and most of the vehicles return empty.

Figure 5. Evolution of the number and the spacing of transverse cracks on CRCP experimental subsection (road 7538)



After some 10 months of operation, several punchouts (Figure 6) were exhibited along the longitudinal joint of CRCP caused by the following factors:

- too thin (170 mm) slab,
- narrow pavement width (2x3.0 m) combined with intensive lorry traffic resulting in a "canalized" traffic directly along longitudinal joint,
- heterogeneous, usually weak support of concrete slab (cement stabilisation).

Transverse crack spacing before punchout distress is in the range of 0.3-0.4 m, when a longitudinal crack is formed between two adjacent transverse cracks. 7 punchouts have been exhibited so far and have been repeatedly repaired using asphalt mixture.

5. <u>Further experimental sections</u>

In 2003, a trial section was built on the road 44. (AADT=9804 unit vehicles/day with 1981 heavy vehicles/day). It comprised the following pavement structural variants with a length of 350 m each:

- rigid pavement structure

  250 mm jointed cement concrete pavement,

200 mm mixed-in-plant cement stabilisation base,

150 mm mixed-in-place cement stabilisation base,

100 mm sandy gravel sub-base,

- composite pavement structure

  40 mm high-modulus asphalt wearing course

  20 mm SAMI (double surface dressing)

  250 mm continuously reinforced concrete pavement,

  200 mm mixed-in-plant cement stabilisation base,

  150 mm mixed-in-place cement stabilisation base,

  100 mm sandy gravel sub-base,

- semi-rigid pavement structure

  40 mm stone mastic asphalt wearing course with modified binder,

  80 mm asphalt binder course with modified binder,

  80 mm asphalt base course with modified binder,

  200 mm lean concrete base course,

  150 mm mixed-in-place cement stabilisation base,

  100 mm sandy gravel sub-base.

The condition of the trial section was evaluated before opening to traffic. The survey included unevenness, rut depth, skid resistance and bearing capacity measurements as well as the visual survey of surface defects. The monitoring of condition was repeated after 12 months of operation. The following performance data were obtained:

- the distribution of the spacing of transverse cracks on CRCP, two months after its completion and before the laying of asphalt wearing course on it, is shown in Table 4,
- the mean skid resistance value of the subsections changed during the first 12 months:
  - rigid SRT=60 $\rightarrow$58,
  - composite SRT=60 $\rightarrow$ 57,
  - semi-rigid SRT=84 $\rightarrow$ 67,
- the evolution of texture depth:

- rigid 0,66 mm → 0.51 mm,
- composite 1.49 mm → 0.84 mm,
- semi-rigid 1.48 mm → 0.91 mm.

Table 4 Transverse crack spacing of CRCP trial section on road 44

Crack spacing range (m)	Spacing frequency (%)		
	Traffic lane I	Traffic lane II	Belgian recommend-ation (9)
Below 0.4	0	0	8
0.4-0.8	10	2	21
0.8-3.0	54	27	63
above 3.0	36	71	7

- the rolling noise values of subsections were evaluated and compared some weeks after the completion of the trial section:
  - in the low frequency range (below 50 Hz), the noise level of rigid pavement was between those of the two asphalt wearing courses,
  - in the medium frequency range (250-2500 Hz), the noise level of the jointed cement concrete pavement was higher than those of the asphalt layers by 3-5 dB at 90 km/h,
  - in the high frequency range (above 2500 Hz), the rigid pavement variant is slightly (by 1.0-2.5 dB at 90 km/h) noisier than the subsections with bituminous wearing course.

Another trial section was built on road 4 in 2003. (AADT=16 651 unit vehicles/day with 2154 heavy vehicles/day). The actual experimental section (500 m) comprised the following pavement structure:

- 260 mm jointed cement concrete pavement,
- 200 mm mixed-in-plant cement stabilisation base,
- 200 mm sandy gravel sub-base.

The structure of the reference section (500 m) is as follows:

- 40 mm stone mastic asphalt wearing course with modified bitumen,
- 80 mm asphalt binder course with modified bitumen,
- 120 mm asphalt base course with modified bitumen,
- 200 mm mixed-in-plant cement stabilisation base,
- 200 mm sandy gravel sub-base.

The cement concrete pavement of 8.25 m width was laid in a single slip-form paver pass. The skid resistance and macro roughness mean values obtained on the newly laid concrete layer can be seen in Table 5 compared to the relevant specifications of several European countries.

Table 5 Skid resistance and macro roughness values on cement concrete pavement surface [11].

Location/ specification	Surface finish	SRT-value	Texture depth (mm)	SFC measured by SCRIM
Trial section on road 4	brushed	71	0.48	0.60
Hungarian specifi-cation (EME-1/2004)	brushed	≥ 55	0.5-1.0	≥ 0.50
Austrian specification	brushed		≥ 0.4	
German specification	any	≥ 65		≥ 0.56
English specification	any		0.62-1.35	
Swiss specification	any	≥ 65		
Belgian specification	exposed aggregate			≥ 0.55
French specification	any		≥ 0.50	
Italian specification	any			≥ 0.55
Spanish specification	any		0.7-1.0	

6. Recent Hungarian road policy on pavement type selection

Of course, a lot of factors influence the proper selection of a pavement type (flexible, rigid, semi-rigid, composite, etc) in a given case. Among others, traffic, material, climate/drainage, environment, construction, operational and economic (whole life costing) factors can effect this decision [10]. However, the traffic parameters (e.g. AADT, heavy vehicles, heavy axle loads, traffic growth factor) are of extremely high importance. That is why, a new Hungarian road policy on pavement type selection is based on cumulative axle loading of the section. After almost 30 years of hegemony of flexible pavements, the policy mentioned comprises also jointed cement concrete pavements and continuously reinforced concrete pavements in case of high heavy traffic load.

Table 6 presents the recommended and the possible pavement variants as a function of traffic categories A-R. (Traffic categories are defined by the expected number of 100 kN-standard heavy axle loads passed during the lifetime). The pavement types in the table can be considered as preliminary options, local conditions and other considerations can influence basically the final decision in the topic.

The guideline should be modified in the future as a consequence of new trial experience, performance information of built and operated sections, as well as the eventual development in foreign practice. The first "real" project with jointed cement concrete pavement is being carried out as a part of the extremely heavily trafficked ring-road (beltway) M0 around Budapest.

Table 6. Guideline for pavement type selection as a function of traffic load

Traffic category		Pavement type	
sign	100 kN standard axle load range	recommended	possible
A-D	max. $3x10^6$	asphalt	jointed cement concrete
E	$3x10^6$-10^7	asphalt with modified bitumen	asphalt; jointed cement concrete
K	10^7-$3x10^7$	jointed cement concrete	asphalt with modified bitumen
R	min. $3x10^7$	continuously reinforced cement concrete*	jointed cement concrete

*A thin (30-40 mm) asphalt wearing course is recommended.

7. Conclusions

Some important steps have been taken in Hungary to "revitalize" the construction of cement concrete pavements. Before 1976, several 1000-kms of cement concrete pavements had been built in Hungary which had generally fair or good performance. Since then, only asphalt pavements have been constructed on the whole national highway network. In 1998, after a ministerial decision, preliminary activities started to prepare the preconditions to use cement concrete pavements again. Based on the results of these activities, the following conclusions can be drawn:

- the construction of cement concrete pavements can and should have an important role in future Hungarian highway projects,
- the ambitious Hungarian motorway construction projects for the next coming decade offer a good opportunity for building rigid pavements again,
- several trial sections were built and have been monitored in Hungary lately; their positive results and experience can already provide the base for the present construction of the first motorway section with cement concrete pavement,

- the monitoring results of experimental sections show that the skid resistance and rolling noise data of the rigid variants are not necessarily less favourable than those of the asphalt pavements.

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