Jan Kukiełka
Lublin University of Technology
Poland

Cold recycling of bituminous pavement with cement additive in quantity of ≥5%

1. Preamble

Bituminous pavements constructed in Poland in the past (before 1990) were most often characterized be an excessive asphalt content (D70 or D100) and a participation of chippings fractions lesser than 50%.

Single and double road retreating with a use of stabilized tar or asphalt emulsion was also applied in order to improve pavement coarseness and durability.

The topic of application of tars in construction and maintenance of roads was still being discussed in 1960 at a conference in Warsaw with participation of road engineers from England, Belgium, Holland, FRG, Yugoslavia and USSR [1].

In Poland before 1990, there were very rarely constructed base courses of asphalt concrete, and the binder courses – only in case of newly constructed pavements.

A high variation in grading of mixes can be observed in street pavements made of the asphalt concrete courses. Periodical repairs of such pavements, especially when cast asphalt is used to fill punch-outs, repairs of pavement in place of cuts from works on buried facilities and other kinds of repairs resulted in the irregularity of pavement texture and the structure of debris received from milling of those courses.

An example of grading of debris from pavement of 6 streets is given on fig. 1 and 2.

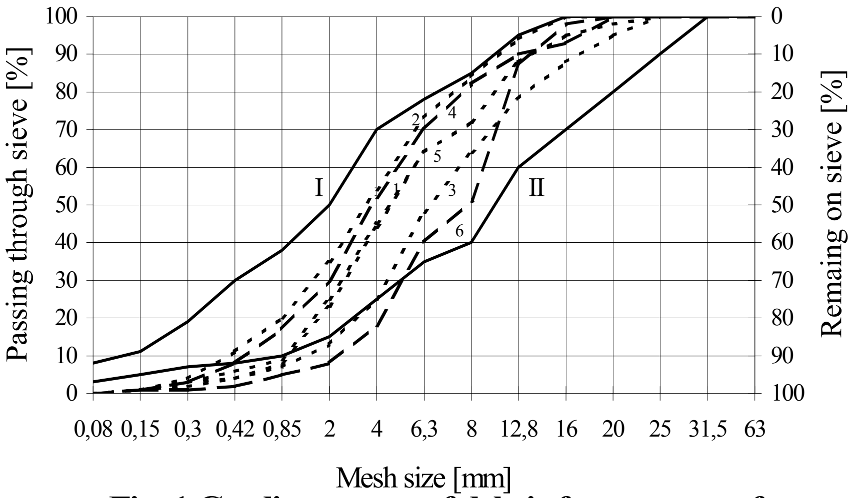

Fig. 1 Grading curves of debris from streets of Lublin

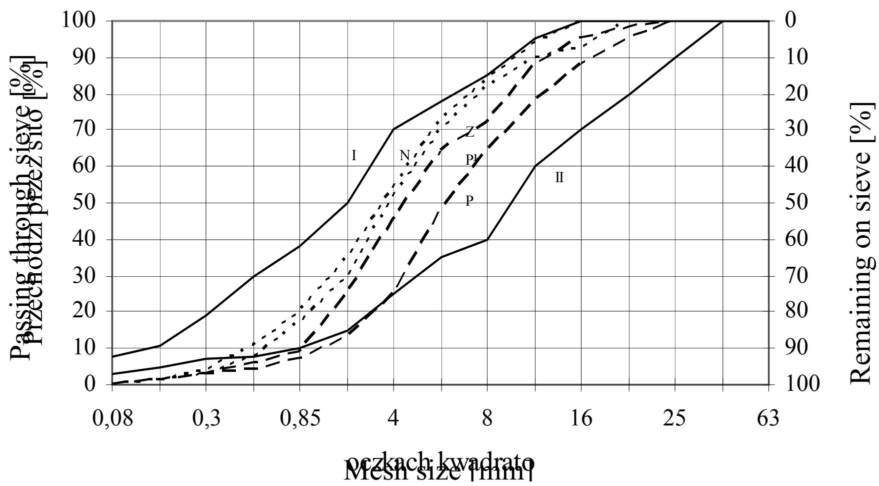

Fig. 2 Grading curves of debris from streets of Lublin

A common feature for the grading is a very small content of fraction of up to 0,42mm, a small content of fraction of up to 0,85mm (up to 50% of the permissible per limiting curve of grading for mineral-cement-emulsion mix) and a relatively small content of fraction of up to 2mm.

Fine grains, bound with asphalt, are ground only partly during milling process, and coarse chippings, coated with a sand-mastix mortar, only appear to be greater size during the sieve analysis on debris from milling.

2. Base courses of mineral-cement-emulsion (M-C-E) mixes

Poland's first practical experience started at the beginning of the 1990s. The works were executed using Wirtgen 2100VC, with a cement spreader since 1994.

On a fresh base course there were laid (on the same day) two layers of asphalt concrete of total thickness of just 8cm. In 1995, HPM-100 recycler was used and the base course of a M-C-E mix used to be covered after 7 days of its curing [2].

Many foreign publications deal mainly with practical experience connected with deep recycling. There is a relatively small number of research and development works, in Poland as well, especially study works.

The research carried out under the leadership of J.Zawadzki [3] commissioned by the GDDP (General Directorate for Public Roads) revealed that the increase of emulsion's content in the M-C-E mix has a significant influence on the decrease of Marshall's stability – but it does not have any significant influence on the strength of indirectly stressed samples.

The optimum asphalt content in the mix is approximately 4% according to the research carried out in the Wrocław University of Technology, in the case when the cement additive was 3,0-4,0%. According to the said research work, an increase of asphalt content in the mix from 4,0 to 6,0 results in a decrease of stability of samples from 14,5kN to 5,8kN, in the case when the cement additive c=4,0% [4].

In order to ensure Marshall's stability greater than 8,0 kN, with the base course for roads of KR3-6 traffic there is sometimes used cement additive in quantity of ≥ 5 %. However, it should be noted that Polish requirements concerning stability are relatively high when compared with requirements of other countries.

An increase of total content of asphalt in samples of the M-C-E mix results in a decrease of rigidity tested using NAT method, in particular at the temperature of 23^{o}C.

The first extensive evaluation of the M-C-E mix base course was carried out in 1996-97 by J.Matras [5] on a section over 12km long on national road no. 817. A crushed stone base course app. 10cm thick and 5cm bituminous course had been graded up with aggregate (h=8cm after compaction), and milled using 2100DCR recycler by Wirtgen. The base for the M-C-E mix base course was a part of the former base course of crushed stone and cement stabilization h=15cm in area of executed widenings. During implementation of the works there was observed a regular stability of samples per Marshall (despite the irregular feature of milled layers):

$$S = 12,2 \pm 2,5 \times 2 = 7,2 \div 17,2 \text{ kN}$$

Voids ranged from 9,16% ±0,82x2 = 7,52 ÷ 10,8%.

Average deflection in autumn 1998 was **0,30 mm.**

Similar analysis has been carried out on national road no. 19. In 2000, on a 5,0 km long section there was constructed an M-C-E base course app. 19 cm thick of a mix with 40÷50% content of debris, grading-up crushed aggregate 0÷31,5mm, emulsion and cement 32,5 in quantity of ≥ 5%.

The relatively high content of cement in the M-C-E mix enabled obtaining the required stability S≥9,0kN and strength of the samples.

The M-C-E mix base course was designed with following assumptions:

V_B = 12 % - total, by volume content of asphalt (old adn from emulsion),

V_V < 12 % voids in the M-C-E mix base course.

Stability of Marshall samples, made of the mix collected from the course was on average 10,2 kN and ranged from 10,0 to 11,6 %.

The whole works including the binder course (h=8cm) and wearing course (h=5cm) were finished in autumn 2000.

The base for the M-C-E mix base course is the former pavement of crushed stone tarred half-depth in the upper section, of modulus E_{v2} > 120 MPa.

On the basis of extensive pavement research carried out in 2001, it has been specified that the load capacity of the pavement conforms to traffic laod greater than KR4.

The reference deflection at temperature of 11°C was U_m = 0,30 mm, and at temperature of 18°C U_m = 0,41 mm.

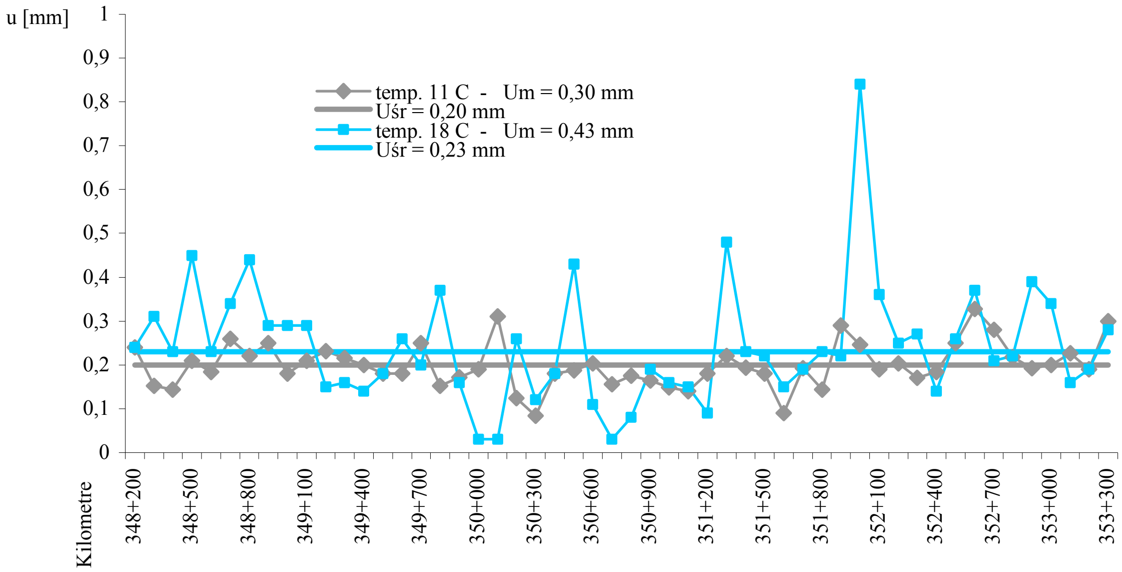

Fig. 3 Deflection measured using Benkelman's beam on road no. 19 section Borki - Kock 2001.

Results of deflection tests performed using Benkelman's beam (fig. 3) at temperature of 18°C are highly different, probably due to viscosity features of the M-C-E mix base courses which disclose at higher temperatures.

Dynamic deflections in axis of load by FWD plate presented in table 1, are a confirmation of a high dependence of results on temperature of structure courses, including the base course of the M-C-E mix.

Results of FWD deflection tests carried out at temperature of 5°C during spring and autumn are very similar, slightly higher for March than October of 2001.

Table no 1. Dislocation in FWD axis of pavement of road no. 19 Radzyń - Kock, km 348+300 - 353+300 converted into load 0,7 MPa.

Test temperature [^{0}C]	$u_{śr}$ [mm]	σ [mm]	υ [%]	u_m [mm]
4	0,122	0,017	13,7	0,156
6	0,133	0,018	13,6	0,169
7	0,133	0,018	13,6	0,169
8	0,133	0,018	13,6	0,169
9	0,133	0,018	13,6	0,169
11	0,136	0,019	13,7	0,174
11'	0,137	0,019	13,6	0,175
20	0,190	0,025	13,3	0,240
23	0,198	0,029	14,7	0,256
23'	0,204	0,028	13,8	0,260
29	0,226	0,030	13,4	0,287
31	0,249	0,040	15,8	0,329

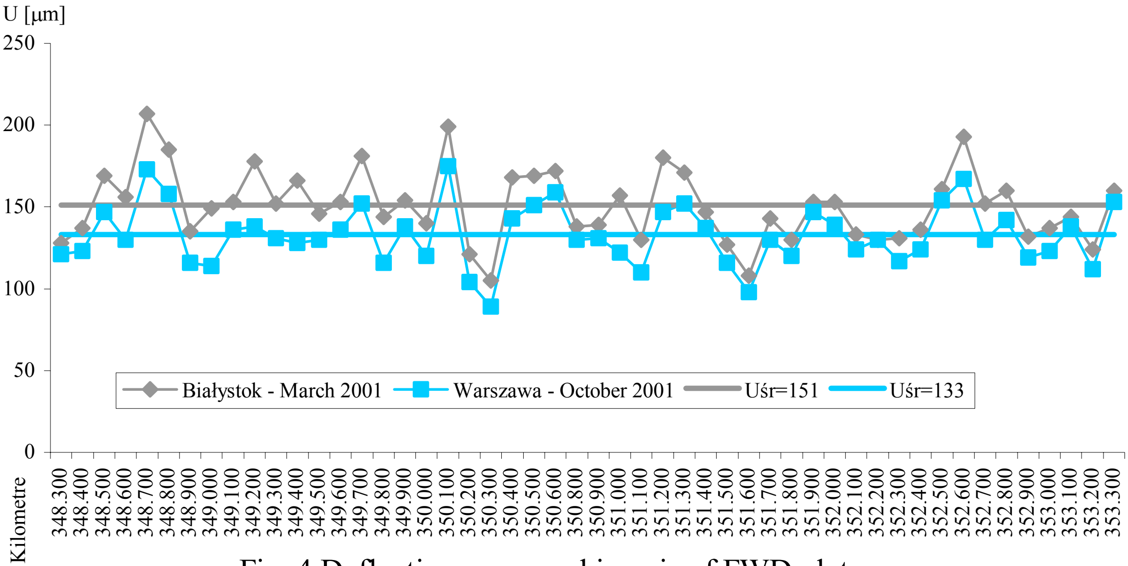

Fig. 4 Deflection measured in axis of FWD plate in test temperature of 5^{0}C

Analyses of results, including calculation of rigidity moduli of courses, using reversed calculation, allow making a conclusion that the M-C-E mix base course with cement content ≥ 5% is characterized by intermediate features of both the flexible and semi-rigid courses.

3. Asphalt-cement concrete (ACC)

The ACC is produced by mixing a sand-cement or an aggregate-cement mortar of relatively high strength with debris from cold milling of layers of concrete asphalt or cast asphalt.

Until now (since 1997), the ACC was applied in execution of base courses and binder courses of pavements of municipal bus stops and lanes for traffic inclusion and exclusion on intersections. The ACC mix has so far been produced in stationary plants, and from 2003 an in-situ method is planned.

On basis of tests on samples executed on various mixes, it has been specified that the sand-cement or aggregate-cement mortar should make 15-20% and the debris 85-80% of the mix composition.

Cement 52,5 constitutes 50-30% of mortar composition i.e. ≥ 7,5 % in the mix.

The author recommends using an aggregate-cement mortar in quantity of 18-20% of the mix composition, in case when debris originates from cast asphalt layers, or when it includes 7 – 9 % of asphalt.

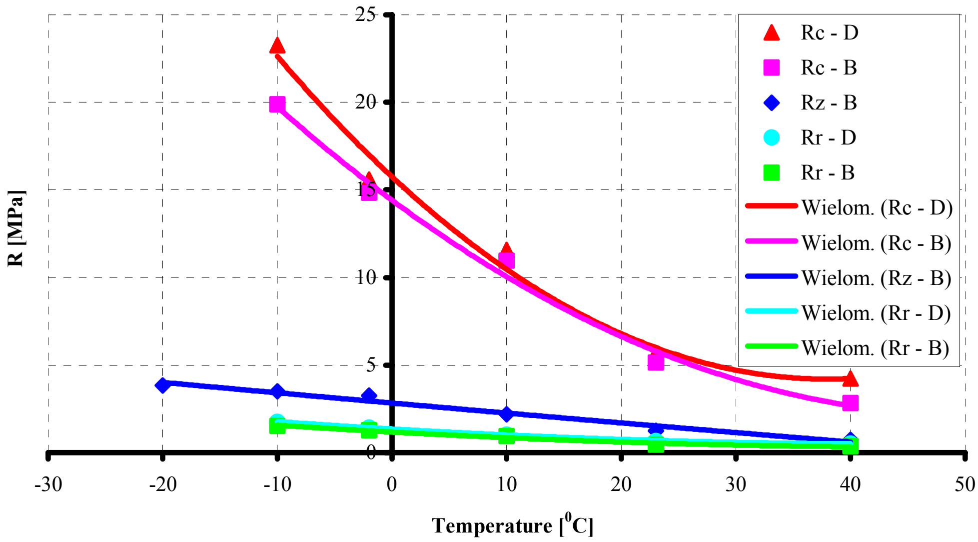

Fig. 5 Influence of temperature on strenght of samples to axial compression (R_c), tension with bending (R_z) and intermediate tension (R_r) after 28 days of curing.

Fig. 5 presents selected examples of tested ACC samples.

4. Conclusion

Base courses of the M-C-E mix with increased cement content or the ACC have properties similar to those of asphalt concretes, when their temperatures are app. 10^{o}C. At temperatures above 20^{o}C the rigidity of asphalt concrete courses is weaker than that of the discussed courses. The courses of M-C-E mix and ACC are characterized by a relatively high irregularity.

In addition, one must take into consideration the difference in the fatigue strength between the asphalt concrete courses and the said courses.

The problem of performance of ACC courses under influence of a sudden temperature drop during winter season requires further studies.

The higher rigidity of ACC and M-C-E mix courses exceeding that of the asphalt concrete during summer season should be met by a higher rigidity of underlaid courses.

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