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THE INFLUENCE OF GRAIN SIZE COMPOSITION ON THE STIFFNESS MODULUS OF MINERAL-CEMENT-EMULSION MIXTURES (MCEM) WITH THE RUBBER POWDER ADDITION

WPŁYW SKŁADU UZIARNIENIA NA SZTYWNOŚĆ MIESZANEK MINERALNO-CEMENTOWO-EMULSYJNYCH (MMCE) Z DODATKIEM MIAŁU GUMOWEGO

STRESZCZENIE. Celem pracy jest określenie wpływu składu uziarnienia MMCE modyfikowanych miałem gumowym na ich moduły sztywności przy takiej samej ilości dodatku środków wiążących. Mieszanki wykonano zgodnie z instrukcją z zastosowaniem różnych destruktów asfaltowych zawierających 5,6% i 10% asfaltu w ilości odpowiednio 45% i 51% (m/m), kruszywa doziarniającego w ilości 53% i 47%, miału gumowego 0/1 mm w ilości 2% (m/m), cementu CEM I 42,5 w ilości 4% (m/m) i emulsji asfaltowej w ilości 2% (m/m). Wilgotność optymalna mieszanek określona w badaniu Proctora wynosiła 6% i 7%. Wykonano badania laboratoryjne modułu sztywności metodą 4-punktowej zginanej belki w temperaturach 0ºC, 20°C i 40°C w przypadku mieszanek gruboziarnistych i 10°C, 20°C i 40°C w przypadku mieszanek średnioziarnistych przy zadanym stałym odkształceniu 50 μm/m.

SŁOWA KLUCZOWE: mieszanka mineralno-cementowo-emulsyjna, miał gumowy, sztywność, krzywe uziarnienia.

ABSTRACT. The aim of the work is to determine the influence of the grain composition of MCEM modified with rubber powder on their stiffness modulus with the same amount of binders added. The mixtures were made in accordance with the instruction [6] using various reclaimed asphalt materials containing 5.6% and 10% of asphalt in the amount of 45% and 51% (m/m), respectively, grading aggregate in the amount of 53% and 47%, rubber powder 0/1 mm in an amount of 2% (m/m), CEM I 42.5 cement in an amount of 4% (m/m) and asphalt emulsion in an amount of 2% (m/m). The optimal moisture of mixtures determined by the Proctor test was 6% and 7%. Laboratory tests of the stiffness modulus were performed using the 4-point bending beam method at temperatures of 0°C, 20°C and 40°C in the case of coarse-grained mixtures and 10°C, 20°C and 40°C in the case of medium-grained mixtures at a given constant strain of 50 μm/m.

KEYWORDS: mineral-cement-emulsion mixture, rubber powder, stiffness, grain size curves.

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1. INTRODUCTION

The reuse of materials recovered from asphalt layers of road pavements has been the subject of many studies and experiments, foreign and domestic. The need to strengthen and repair rutted asphalt pavements in Poland was the reason for the development of technical conditions in No. 61 of Road and Bridge Research Institute (RBRI) published in 1999 [1], to make mineral-cement-emulsion mixtures, which described the procedures for designing the composition and the requirements for making pavements bases from them. On their basis, General Technical Specifications [2] were developed, which provide contractors with a description of the implementation of construction works and the requirements for their acceptance, which should be compatible with current regulations.

The assessment of completed projects based on technical specifications for MCEM bases was carried out in 2006 at the commissioned work of General Directorate for National Roads and Motorways [3]. In the 80 sections assessed, the addition of fine-grained aggregate ranged from 20% to 77%, the asphalt emulsion content ranged from 1.5% to 5.9%, and the cement content ranged from 2.5% to 7%. Such a large variability of the designed mixture compositions resulted from the requirements regarding the content of old reclaimed asphalt and stability according to Marshall at a temperature of 60°C. Asphalt content and other factors were the reason that before 2006, according to survey research, more than 50% of grading aggregate was used on 21 sections of roads with MCEM subbase out of 56 surveyed. On approximately half of the analyzed sections with MCEM subbases, transverse cracks ranging from 1 to 6 per kilometer were observed. The conclusions stated that the cracks in the pavement should rather be classified as reflected from MCEM subbases.

Extensive MCEM research carried out in the work in 2007 [7] concerned: complex stiffness modulus and phase shift angle, NAT stiffness modulus, Black curve and isotherm, Cole-Cole curves, leading curves and fatigue life, low-temperature cracking resistance, acoustic emission in the study limited contraction (TSRST). Research on the influence of grain size on MCEM is described in [8]. Experimental work was carried out to assess water and frost resistance, compressive strength, indirect tensile strength (ITS) and bending strength. The author compared the characteristics of mixtures containing equal amounts of asphalt emulsion and cement tested at temperatures of -20°C, 10°C, and 40°C. It was found that fine-grained mixtures 0/16 mm and 0/22 mm are more resistant to thermal cracking than coarse-grained mixtures 0/25 mm, and at the same time the brittleness index of the 0/16 mm mixture is approximately twice as high as that of the 0/25 mm mixture.

Reports on research work commissioned by General Directorate for National Roads and Motorways, carried out in 2011 and 2012 at the Gdańsk University of Technology [4, 5], constituted the basis for the recommendation of new requirements for MCEM included in the instruction [6]. The work included an analysis of Polish, German, Japanese, Norwegian, American, and British experiences as well as PIARC and PARAMIX recommendations. The existing requirements regarding grain size and MCEM tests have been changed.

New grain limit curves according to the instruction enable the use of higher fraction content <2 mm in relation to the technical conditions contained in RBRI No. 61.

An example of determining the optimal moisture of designed MCEM (Fig. 1) is presented in common Fig. 2 in the report from the second stage of work [5].

The charts concerned 6 designs of mixture grain size with optimal moisture w_{opt}=7.4÷8.7%, dry bulk density ρ_{dmax} =2.055÷2.084 g/cm^3 with a total asphalt content in the reclaimed material of 4.4%.

Designing the grain size curves of the mixtures in the middle position between the limit curves for low traffic category (TC1÷2) guaranteed that after the dynamic method of compacting the samples using the Marshall method and the possibility of crushing the reclaimed grains, the increase in the smallest fractions would not exceed the upper grain size limit.

According to the instructions, the natural moisture content of the mixture, the water content from the asphalt emulsion and the half-content of asphalt from the asphalt emulsion are subtracted from the optimal moisture.

German regulations already in 2005 stipulated that limit curves of fractions <0.85 mm from 10 to 37% allowed a significant increase in the share of the powder fractions in MCEM [9].

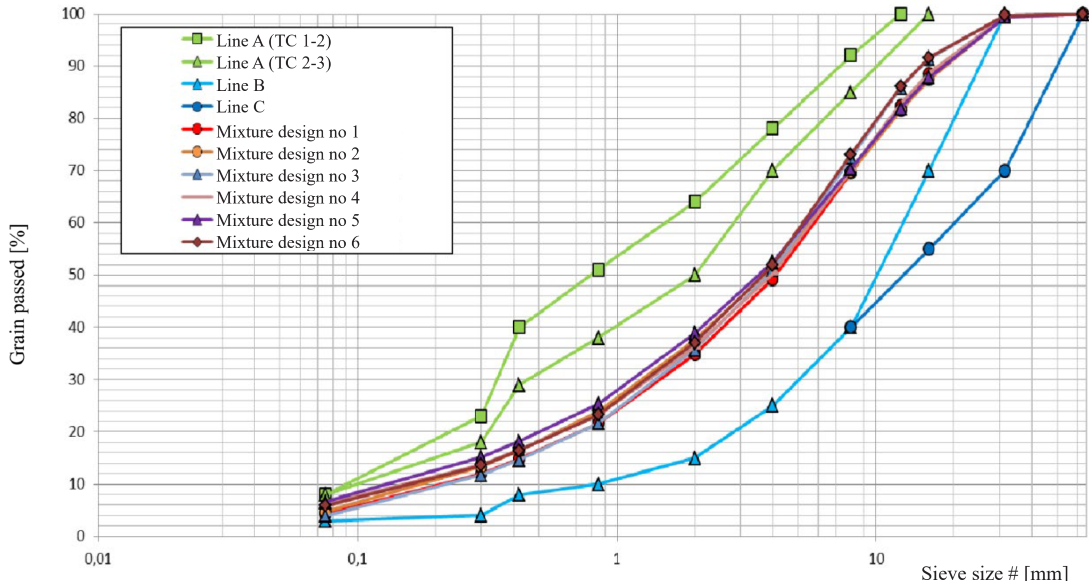

Fig.1. Graining of mineral-cement mixtures [5]

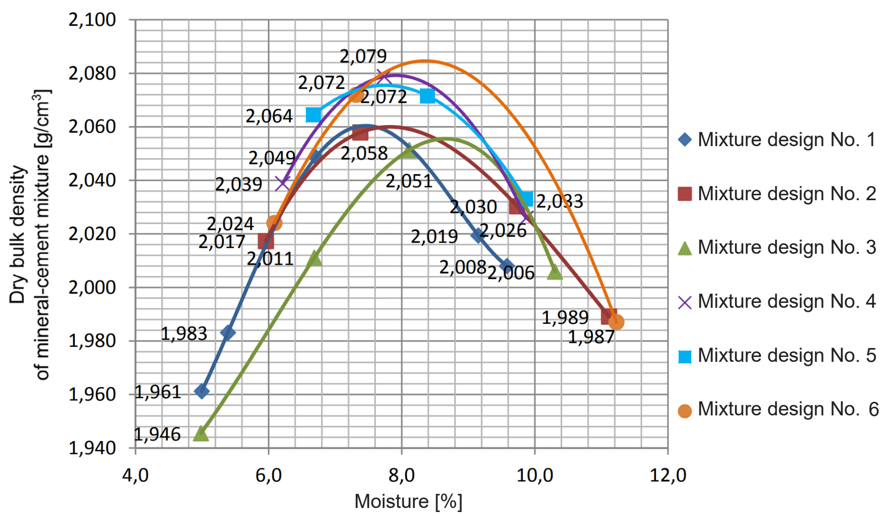

Fig. 2. Determination of the optimal moisture of the designed mineral-cement mixtures [5]

The area below the lower grain limit curve has been considered disallowed since the beginning of MCEM due to excessive stiffness, the position of the lower limit curve was lowered in 2014 instruction and the upper limit was slightly increased compared to previous regulations.

Most research work on the properties of MCEM concerned the content of binders and their impact on stiffness and durability [10-16]. The aim of this work was to determine the minimum and maximum addition of cement and asphalt emulsion that would guarantee the achievement of features ensuring the base layer's resistance to cracking and, at the same time, high fatigue durability. It was found that MCEM have very diverse rheological, mechanical and fatigue properties. Depending on the proportion of binding components, the behavior of MCEM can be similar to that of elastic or viscoelastic materials. In the case of a higher cement content, the MCEM layer shows dominance of hydraulic bonds and becomes semi-rigid, in the case of a higher content of emulsion and reclaimed asphalt, it shows dominance of viscoelastic bonds and becomes flexible. In MCEM fatigue life tests, a significant influence of the asphalt emulsion content and a smaller influence of cement content is observed. The work verified the validity of the recommendations adopted in the manual regarding the cement content from 1 to 4% (m/m) and asphalt emulsion from 3 to 6% (m/m) [17].

The first research work on the addition of rubber powder to MCEM was carried out at the Lublin University of Technology [18] in 2016, carrying out tests in accordance with the requirements in the instruction. In the tests of the influence on the ITS of rubber granulate mixtures with three fractions: 2/4 mm, 0.8/2 mm and 0/0.8 mm in the ratio 1:1:1, it was noticed that it is significantly lower than the recommended one. The addition of rubber powder to MCEM makes it possible to control the ITS which after 28 days at 5°C should not exceed 1.6 MPa for medium traffic category (TC3÷4) and 1.4 MPa for low traffic category (TC1÷2).

The requirements according to the instruction in 2014 were supplemented with MCEM fatigue life tests performed with the addition of 2%, 3%, 4% and 5% of 0/1 mm rubber powder with a grain size in accordance with the manufacturer's data. In publication [19], MCEM samples with the following composition were tested: asphalt emulsion in the amount of 2%, cement 42.5 in the amount of 4% and 6% and rubber powder 0/1 mm in the amount of 2%, 3%, 4%, 5%. The volume density of rubber powder is 1.14 g/cm^3 and its high content of the 0/0.85 mm fraction results in a favorable increase in the volume proportions of the powder MCEM fractions. Based on the tests carried out, it was found that the addition of rubber powder to MCEM causes a decrease in the ITS and the stiffness modulus of IT-CY tested in accordance with the instruction at a temperature of 5°C. The required ITS of 0.7÷1.6 MPa for TC3÷4 is met by an MCEM mixture containing 4% cement, 2% asphalt emulsion and 2% rubber powder. The tested fatigue life of MCEM beams with the addition of rubber powder (N50=602,089÷2,520,408 at deformations ε_r=144 μm/m ÷ 103 μm/m) meets the requirements of medium traffic category TC3÷4. The observed increase in fatigue damage with increasing temperature may contribute to the formation of micro-cracks in the MCEM base at temperatures <0°C, the effects of which depend on the total amount of asphalt in the mixture. The fatigue damage of the beams after 1 million load cycles using the 4 PB-PR method at 10°C and 10 Hz was characterized by high variability but was much more favorable than mixtures without the addition of rubber powder.

The obtained patent P 410 929 "Mixture for road pavement bases" in 2015 regarding MCEM modified with rubber powder, was implemented based on a license agreement of the Lublin University of Technology with the CEBEL company in Lublin in 2017. The company obtained financing under the Regional Operational Program of the Lublin Voivodeship, for the purchase of a license and equipment for making mixtures for "cold" recycling and the building of an experimental section of a road. A trial section with a MCEM base modified with 0/1.0 mm rubber powder was built on a district road in 2018, and then several sections of municipal roads. The intended tests and drilling from the surface were not carried out to a significant extent for objective reasons. Obtaining further orders by the contractor and access to completed sections is limited. Observation of the influence of negative temperatures on the construction of sections of substructures made of MCEM with the addition of rubber powder should clarify whether there is a similarity of the test results described in publication [19].

2. STRUCTURE OF MCEM SAMPLES WITH THE RUBBER POWDER ADDITION

The importance of structural tests for diagnosing, for example, cement concrete is known from the IPPT PAN project, financed by NATO at the beginning of the 21st century, carried out under the supervision of A. M. Brandt [20] and an earlier publication [21]. The publications describe examples of structures made of aggregate grains and mortar that influence the workability and segregation of mixtures:

- excess matrix and lack of small inclusion grains,
- aggregate with discontinuous grain size,
- high volume fraction of particles,
- separation of grains and mortar.

It is known from experiments carried out on cement concrete that large aggregate grains cause local stress concentrations, especially in the grain corners, which may be several times higher than the average stress values

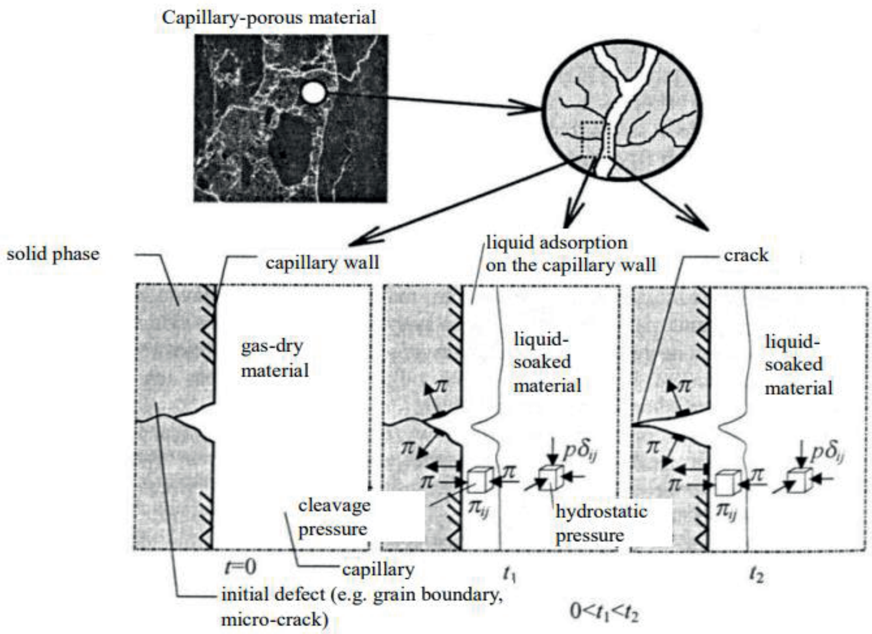

Fig. 3. Graphical diagram of the Rebinder effect - action of cleavage forces [21]

(calculated, e.g., using mechanistic methods). The corners of thick grains may therefore cause the destruction of the matrix, resulting in the formation of scratches and micro-scratches that begin to destroy the material. A further process may be the enlargement of cracks and micro-cracks as a result of the so-called Rebinder effect. The graphical diagram of this effect is given in Fig. 3.

The corners of thick but weak grains may crack, for example, when the mixture is compacted.

Cement-asphalt slurry or mortar of 0/1 mm rubber powder covered with cement and asphalt from emulsion partially fills the free spaces between the grains of reclaimed asphalt and grading aggregate in MCEM.

Reclaimed grains covered with a thick layer of asphalt mastic remaining in direct contact may cause internal friction to change as the ambient temperature decreases.

Macroscopic assessment of the sample surface after splitting allows us to observe that the coarse grains of the grading aggregate are often only slightly bonded to the mixture matrix. In publication [22], MCEM components and contact zones of mixtures were isolated. In the description of the structure, the following can be distinguished: inclusions as a skeleton made of aggregate grains, matrix formed by hardened cement paste, asphalt from asphalt emulsion and reclaimed material, pores and voids, scratches and cracks. MCEM samples examined in a scanning microscope reveal, for example, cracks in the aggregate in the matrix, on the surface of the aggregate covered with the matrix, and cracks in the matrix. Monochromatic and colored cuts enable the assessment of large grains of aggregate and matrix. The lack of extensive cognitive research on the structure of MCEM means that only elements at the macro and meso-level have been recognized. At the micro level, it would be necessary to determine, for example, the influence of emulsion asphalt on cement binding.

3. MATERIALS TO MCEM WITH THE ADDITION OF RUBBER POWDER

3.1. RECLAIMED ASPHALT PAVEMENT

The grain size and content of asphalt in RAP have been the subject of numerous studies, especially at the beginning of the 21st century, when deep "cold" recycling was often used in Poland on sections of national and provincial roads. Reclaimed material taken from a landfill used to make MCEM layers on the pavement of district or municipal roads often contains over 5% and exceptionally 10% of asphalt. The grain composition of RAP depends on the technical condition and type of milling equipment. The reclaimed material, sometimes sorted and processed into asphalt granules, could be obtained from the stocks of some companies, currently it is most often used for "hot" mineral-asphalt mixtures, for hardening ground roads or road shoulders, for strengthening the pavement of municipal and district roads with MCEM, also with the addition of rubber powder at the exploration stage in experimental sections. The texture of reclaimed grains >4 mm is characterized by partial covering of the crushed aggregate with asphalt mastic, which ensures its variable viscoelastic properties depending on the temperature. Uncovered, coarse reclaimed grains, similarly to the grains of grading aggregate, despite the asphalt precipitated from the emulsion on their surface, may have a significant impact on the stiffness of MCEM, which increases with the increased amount of cement in the mixture.

An example of the grain size of RAP from Lublin street pavement was presented at the 2nd international scientific and technical conference in Poznań in 2001 [23]. The reclaimed material from the milling of asphalt layers has a grain size similar to the examples in Fig. 4. The large variability of RAP granulation, especially the coarse grain and small amount of fine grain, is characteristic.

Currently, due to the high costs of new materials, the availability of reclaimed materials, even for research purposes, is limited.

There are numerous studies of mixture grain size curves, the location of which, as a necessary condition, is determined by the limit curves given in standards and regulations. Sufficient conditions for MCEM are most often requirements for samples regarding the void content, ITS, stiffness modulus and water resistance [6].

RAP is most often the main component of MCEM, and its grain size was not subject to requirements, such as the grain size of aggregate supplied by the manufacturer with a narrower required grain size area (SDV tolerance) for the mechanically stabilized base layer.

3.2. RUBBER POWDER

The obligation to recycle rubber waste, e.g. from used car tires, had a positive impact on the establishment of companies producing: rubber dust <0.085 mm, rubber powder 1/4 mm and 1/10 mm granules, using room temperature cutting technology or cryogenic grinding. Recycling of rubber waste contributed, among other things, to the development of technologies for mixtures produced using the "wet" and "dry" methods, which initially used rubber dust and powder, granules and grit. After the authors' initial research in publication [18] regarding the use of granules and rubber powder to test their addition to MCEM, it was decided to use only 0/1 mm rubber powder with a bulk density of 1.07

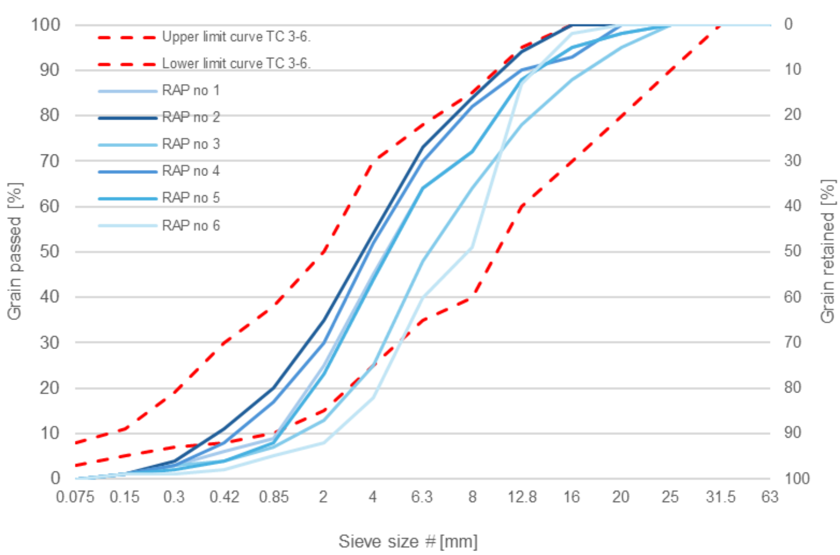

Fig. 4. Granulation of RAP from Lublin streets: 1, 2, 3, 4, 5, 6. I-II – boundary curves of reclaimed material size to MCEM for road bases with medium traffic category TC3÷6 [23]

g/cm^3. The mortar was made by adding rubber powder to the cement slurry and then mixing it with the asphalt emulsion. After mixing all the mortar ingredients, it was added to the mineral mixture with reclaimed asphalt.

3.3. ASPHALT EMULSION

The dispersing phase of the emulsifier in the emulsion is water and hydrochloric acid. The temperature of 100°C during heating (up to 150°C) prevents it from foaming. Deep "cold" recycling is performed using a slowly disintegrating super-stable emulsion C60B10 ZM/R. The emulsion should meet the conditions of PN-EN 13 808:2013-10.

3.4. CEMENT-ASPHALT MATRIX WITHOUT AND WITH THE RUBBER POWDER ADDITION

Gravitational compaction of the matrix in free spaces of MCEM constituting up to 15% of the volume in the case of medium traffic category (TC3÷4) and up to 18% in light traffic category (TC1÷2) its adhesion to the surface of reclaimed grains initiated in the work concerned mixtures using only cement and emulsion. Good adhesion is ensured by a matrix with a low pH [24].

The addition of rubber powder to cement-asphalt matrices was presented in publication [25]. The cement-asphalt matrix covers the particles of rubber powder, contributing to uniform mixing in the MCEM. In publication [26], the DIC system was used to assess die cracking processes. The following matrices were tested:

- W:CEM=0.5 – cement matrix with known characteristics in the case of concrete is also used in lean concrete and aggregates stabilized with hydraulic binders,
- CEM:RP=1.5:1 – cement matrix with the addition of rubber powder (RP) used in ordinary and lean concretes,
- CEM:AE=5:3 – cement-asphalt matrix (from asphalt emulsion AE) with a dominant share of cement, which is present in most mixtures used in the “cold” recycling technology in Poland,
- CEM:AE:RP=1:1:1 – cement-asphalt matrix with the addition of rubber powder 0/1 mm with the same share of ingredients (m/m),
- CEM:AE:RP=1.5:1:1 – cement-asphalt matrix with the addition of 0/1 mm rubber powder with an increased proportion of cement (m/m),
- CEM:AE:RP=2:1:1 – cement-asphalt matrix with the addition of 0/1 mm rubber powder with a cement content corresponding to the content of other ingredients (m/m).

The bending strength tests of 4PB-PR were carried out at temperatures of 5°C, 23°C and 50°C, which allowed to assess the influence of temperature on the formation of cracks and bending stresses at the moment of crack formation, the highest values of which occurred at a temperature of 5°C. The ITS = 2.97 MPa at 5°C of the matrix containing approximately twice as much cement as the asphalt emulsion exceeded the permissible ITS according to the instructions (ITS = 1.6 MPa) and met the requirements when the addition of rubber powder was equal to the content of the asphalt emulsion.

The viscoelastic properties of mastic with rubber powder have a beneficial effect on the decrease in the IT-CY stiffness modulus of MCEM samples, with the increase in the addition of rubber powder in the mixture with cement content in the amount of 4% recommended in the instruction [6] as the maximum.

4. TWO GRAIN COMPOSITIONS OF MCEM WITH THE RUBBER POWDER ADDITION

A commonly used grading aggregate in the Lublin region due to the availability and cost, including rail transport, is aggregate of various fractions of medium hardness from dolomite or limestone. An advantageous feature of alkaline rocks is good adhesion of asphalt, while the disadvantage is the possibility of crumbling during the preparation of dynamically compacted samples in a Marshall hummer, as well as in the layer during compaction with vibrating rollers.

The first grain composition of MCEM with the addition of rubber powder was designed near the lower limit curve in the initial section of 0/1 mm, then it approaches the middle position between the limit curves and the upper limit in the final section (16/31.5 mm) in Fig. 5. The second grain composition was designed in the middle position between the limit curves in the 0/8 mm section, then it approaches the upper limit in the final section (16/31.5 mm) in Fig. 6.

Table 1. Materials for the mineral mixture made of dolomite aggregate and the composition of MCEM with rubber powder (MCEMRP1) at the lower grain size limit

Sieve size # [mm]	Mixture components retained [%]					
	0/4 mm	2/8 mm	8/16 mm	16/31,5 mm	RAP with 5,8 % asphalt	Rubber powder 0/1 mm
63	-	-	-	-	-	-
31.5	-	-	-	-	-	-
16	-	-	6	88	13	-
8	3	4	88	10	31	-
4	1	61	6	2	26	-
2	13	30	-	-	15	-
1	27	3	-	-	8	15
0.5	23	1	-	-	5	47
0.125	25	1	-	-	2	37
0.063	4	-	-	-	-	0
0	4	-	-	-	-	1
Materials dosing	15	15	10	11	45	4

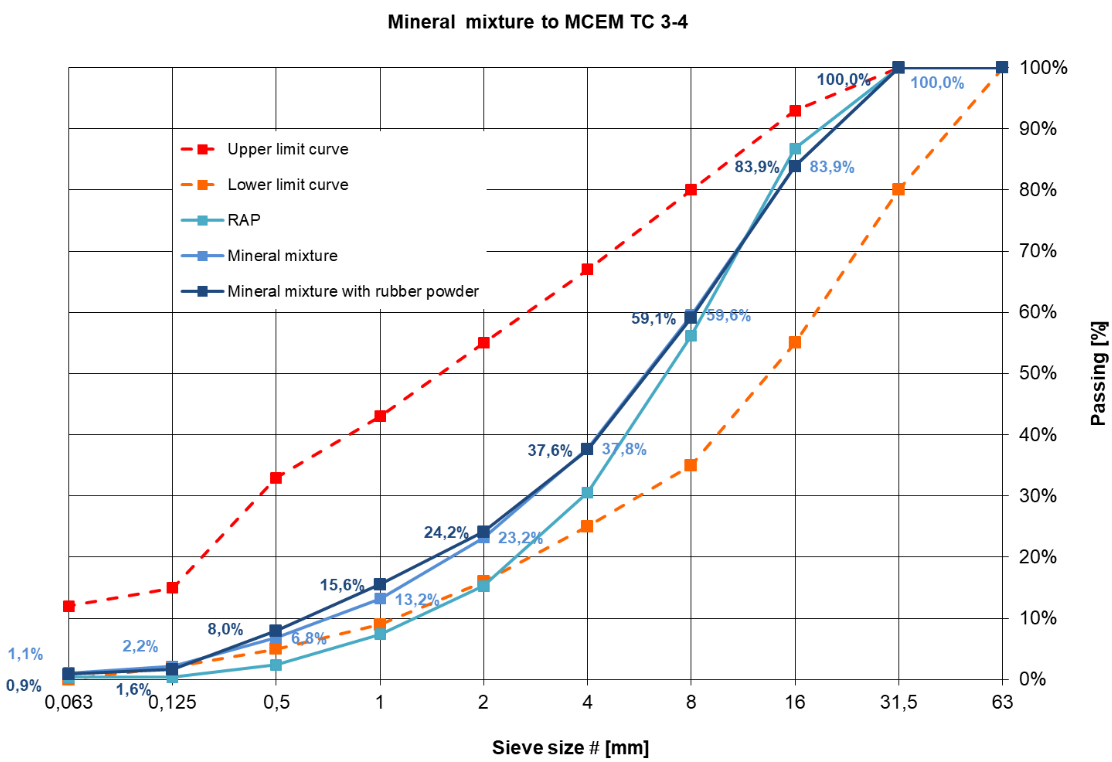

Fig. 5. MCEMRP1 coarse-grained with 0/1 mm rubber powder at the lower grain size fraction < 4 mm for medium traffic category TC3÷4

Table 2. Materials for the mineral mixture made of dolomite aggregate and the composition of MCEM with rubber powder (MCEMRP2) in the middle position between the grain size limit curves

Sieve size # [mm]	Mixture components retained [%]		
	0/31,5 mm	RAP with 10 % asphalt	Rubber powder 0/1 mm
31.5	-	1	-
16	17	8	-
8	26	26	-
4	16	27	-
2	8	15	-
1	6	11	15
0.5	6	6	47
0.125	9	5	37
0.063	1	0	-
0	10	1	1
Materials dosing	47	51	2

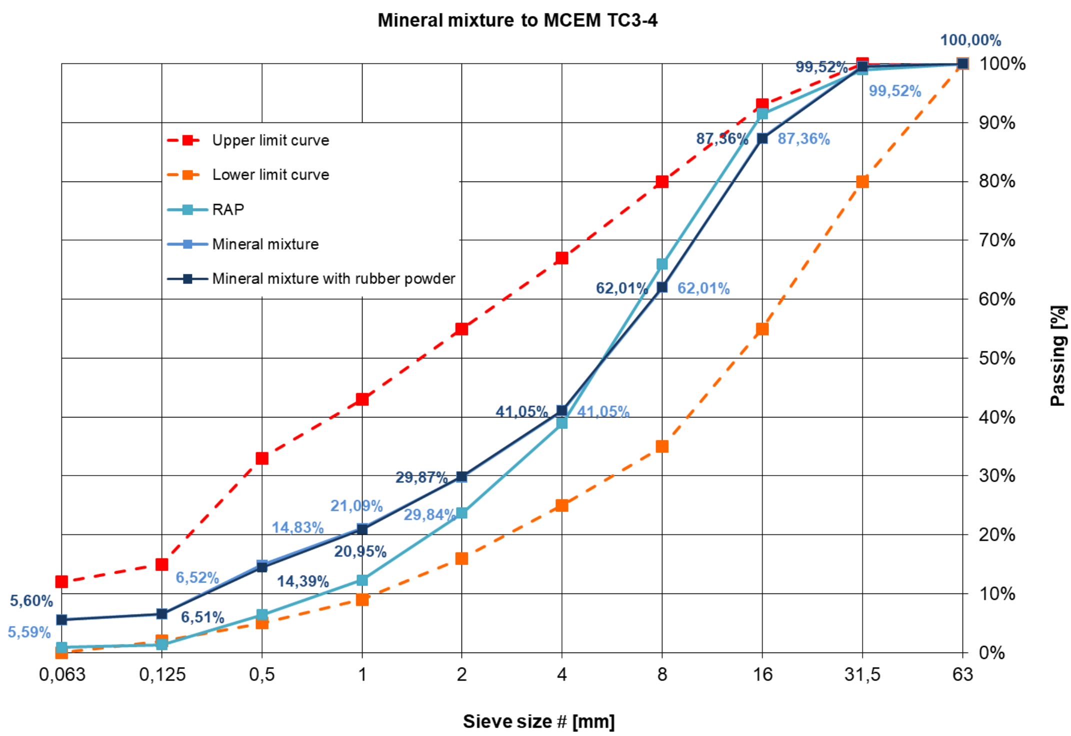

Fig. 6. MCEMRP2 medium-grained with 0/1 mm rubber powder in the middle position between the limit curves for medium traffic category TC3÷4

5. STIFFNESS MODULUS TESTS OF MCE MIXTURES WITH RUBBER POWDER

The stiffness modulus test using the 4PB-PR method was performed in accordance with the EN 12697-24:2003 standard. Designed mixtures with grain size curves as in Fig. 5 and 6 with the same amount of binders were based on previous research [10] and contained: 4% of cement 42.5, 2% of asphalt emulsion and 2% of rubber powder 0/1 mm. Beams with dimensions of 380×63×50 mm for testing were made by cutting from plates with dimensions of 300x400x70 mm prepared in a plate compactor. The plates were stored for 28 days in air-dry conditions and a room temperature of approximately 20°C. Four beams were cut from two plates and their test results were summarized in Fig 7.

Exploratory research on the influence of grain size composition on the stiffness modulus of 4 MCEMRP1 beams was performed at temperatures of 0°C, 20°C and 40°C. The average value from 4 tests had a large variability of results at 0°C. In the case of MCEMRP2, tests were performed at temperatures of 10°C, 20°C and 40°C. Based on the results obtained and the influence of grain size on stiffness modulus, it can be observed that coarse-grained mixtures have higher modulus values than medium-grained mixtures at temperatures <10°C, while at higher temperatures there are differences not exceeding 15% of the lower result.

Comparing the slope of the stiffness modulus graphs in Fig. 7, it can be concluded that the MCEMRP1 coarse-grained mixture is more sensitive to temperature changes than the MCEMRP2 mixture, which had approximately twice the asphalt content in the reclaimed material.

6. CONCLUSIONS

At the beginning of the first decade of the 21st century, a review of MCEM design procedures in the world and experiences with pavements in Poland was carried out, based on, among others, the MCEM grain size limit curves in the instruction [6] have been adjusted. The upper limit has been raised mainly in the 0/2 mm fraction range compared to the previous limit curves included in the technical conditions [1].

Analyzing publications on MCEM in terms of the amount of grading aggregate, it can be noted that reducing it, e.g. for further savings and increasing the RAP content above 45%, could contribute to a fulfilled requirement for low traffic category TC1-2 when indirect tensile strength should be 0.4 MPa < ITS < 0.8 MPa and the stiffness modulus 1500 MPa < IT-CY < 5000 MPa at 5°C after 28 days of curing.

At the beginning of the second decade of the 21st century, the first laboratory tests of MCEM with the addition of rubber powder were performed, including fatigue tests of four-point bending samples and the

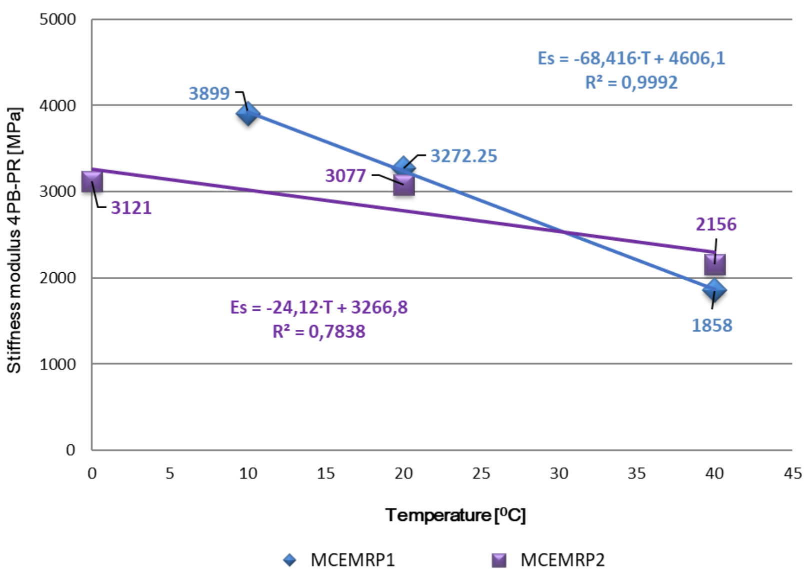

Fig. 7. Correlation between temperature and the stiffness modulus of the beams at the lower grain limit of MCEMRP1 and the middle position between the grain limit curves of MCEMRP2

first examples of their use on sections of district and municipal roads.

This paper compared the stiffness of two mixtures with different grain sizes with the same addition of binding agents: 4% cement 42.5, 2% asphalt emulsion and 2% rubber powder 0/1 mm. Tests of stiffness modulus using the 4PB-PR method in accordance with the EN 12697-24:2003 standard allowed the following conclusions to be formulated:

1. The designed coarse-grained and medium-grained MCEMG compositions meet the requirements of stiffness modules 2000÷7000 MPa in 5°C according to instruction for medium traffic category TC3-4.
2. Coarse-grained mixtures have higher stiffness modulus values than medium-grained mixtures at temperatures <10°C, while at higher temperatures there are differences not exceeding 15% lower results.
3. Based on the slope graphs comparison of the stiffness modulus, it can be concluded that a coarse-grained mixture is more sensitive to temperature changes than a medium-grained mixture.

MCEM without or with the addition of rubber powder can be used to strengthen sections of district and municipal roads and rebuild street pavements as an ecological and economic technology ensuring the use of heterogeneous reclaimed material. It is possible to use MCEM with the addition of rubber powder for bases planned for heavier traffic category, especially rebuild street pavements, after expanding the scope of technological tests and fatigue life assessment.

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