THE RECONSTRUCTION OF HIGHWAY A1 VILNIUS-KAUNAS-KLAIPėDA FOR THE CONSTRUCTION OF BASE COURSE BY USING THE COLD RECYCLING TECHNOLOGY

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ABSTRACT

Road A1 Vilnius-Kaunas-Klaipėda is the main east-west transit highway connecting the three largest cities of Lithuania. The total length of this highway is about 302 km and its highest annual average daily traffic AADT on the busiest road section in the year 2009 reached up to 39617 veh/day and the number of heavy vehicles made up 4930 veh/day. The construction of this road was conducted in two phases. The second phase of motorway Kaunas-Klaipėda was completed in 1987. Since the road construction was designed more than 20 years ago, the structural strength of the road does not satisfy the current day road traffic loads. Particularly serious road distresses occurred on the way to Klaipėda. Reflecting cracks over the whole height of the road construction was the biggest problem. These distresses arose due to the experimental section, the base of which was stabilized with fly ashes. To resolve this problem it was decided to conduct the reconstruction of highway A1 Vilnius-Kaunas-Klaipėda (road section km 216,95-220,3). Since the replacement of stabilized base and underlying layers would be too complicated and uneconomic, the problem had to be solved by other means. The occurrence of cracking problem in pavements was solved by laying a 12 cm thick stress absorbing interlayer (unbound mixture) and a 20 cm thick layer of cold recycled asphalt mixture. The road base was constructed using a technology of cold recycling. The mixture of recycled pavements with the base was improved by new mineral materials and was stabi-lized with "Nyrec" emulsion.

Keywords: cold recycling, road distresses, cracks, base course, fly ash stabilization

1. INTRODUCTION

That Lithuania is among leading players in the development of cold recycled asphalt technology is being made clear during refurbishment of the country's principal and most heavily trafficked motorway. Cold mix asphalt containing recycled asphalt pavement and stress absorbing interlayer has been installed in a new base course overlay for a section of the road A1 Vilnius-Kaunas-Klaipeda (216,95-220,3) km, to overcome problems with carriageway cracking. The cold recycling solution is providing an answer that is technically competent, economically favorable and environmentally beneficial.

The road A1 Vilnius-Kaunas-Klaipeda is Lithuania's main cross country route, linking Vilnius – the capital in the east – westwards to Kaunas and then Klaipeda by the Baltic sea. Maximum traffic density along the 300 km long, dual four lane highway is 40,000 vehicles per day.

It is towards Klaipeda that a 3.4 km stretch of the motorway's eastbound carriageway was giving particular trouble. This portion of the road had been built in the mid 1980s with an experimental 200 mm thick base course of fly ash stabilized gravel, mixed to meet the then prevailing Soviet standards. Twenty five years on, the bitumen bound layers above the base course displayed extensive reflected cracking (see Figure. 1).

Figure. 1. Road A1 Vilnius-Kaunas-Klaipeda (216,95-220,3) km pavement structure before repair

The main reason for the occurrence of reflective cracking is the effect of multiple freeze-thaw cycles on the rigid base layer. In Lithuania such temperature fluctuations occur from 40 to 70 times per year (Laurinavičius et. al. 2008). Due to the recurrence of reflective cracking affecting the overall road pavement structure, it was necessary to look for unconventional solutions in order to repair the road section. It was important to find the solution to solve the following two main problems: the elimination of recurring reflective cracks right at the base course of ash stabilized gravel and the construction of road pavement in economically favorable and environmentally beneficial way.

The removal of the base course was not really an option. The construction of new layers on fly ash stabilized gravel would only lead to the recurrence of reflective cracks. So it was decided to leave the original base course in situ, but to cap it first with a 120mm thick unbound layer of crushed stone to form an anti-cracking and leveling medium, and then a new 200 mm base course of cold recycled asphalt.

The Lithuanian Road Administration has used cold mix recycling on a number of road projects since the early 2000s, prompted by European bitumen specialist Nynas. Although the roads involved were of a lesser nature than the road A1 Vilnius-Kaunas-Klaipeda, their successful refurbishment has bred sufficient confidence for a more substantial challenge to be undertaken. Certainly, the motorway A1 Vilnius-Kaunas-Klaipeda is the big one, in terms of cold recycling.

Roads civil engineering contractor responsible for the road A1 Vilnius-Kaunas-Klaipeda (216,95-220,3) km recycling was JSC “Zemaitijos Keliai” which has invested substantially in the technology. It owns trailer mounted cold mix plant designed by Aneco of Sweden and has a licence from Nynas to produce Nymuls RX, the premier bitumen emulsion binder used in cold mix.

The laboratory of JSC “Problematika” selected the composition of cold-recycled asphalt mixture. Problematika is a road laboratory responsible for the road A1 Vilnius-Kaunas-Klaipeda mix design. A lot of knowledge about cold mix came initially from Sweden. However, a large part of the experience was gained through the practice of road building in Lithuania. Since leaving the Soviet Union in 1991, Lithuania’s road construction standards have been based on German DIN standards and regulations, more latterly on European ones. Following input by Nynas, Lithuanian standards now accommodate cold mix recycling technology.

2. ROAD SECTION UNDER REPAIR AND CONSTRUCTION SOLUTIONS

2.1 The overall situation of a road section under construction and road pavement design

The Lithuanian Road Administration created a task regarding the design of the road section under repair and regarding the performance of repair works. The decisions taken had to solve the root causes of the recurrence of reflective cracking in the road pavement and to prevent the formation and development of reflective cracks in the future.

The following works were performed to meet the objectives set out in the design: the strengthening of the right-hand lane pavement, the construction of road drainage system and storm water drainage system on the central lane of the road A1 Vilnius–Kaunas–Klaipeda (216,95–220,30) km. The current situation and the existing road construction were analyzed. The road structure was composed of the following layers: a frost resistant layer (0-0,30) m, a capping layer (0,50-0,60) m, a 20 cm thick base course of fly ash stabilized gravel, which was constructed instead of a 27 cm thick base course of gravel and crushed stone, a 8 cm thick course of macadam, a 5 cm thick binder course of asphalt pavement and a 4 cm thick surface course of asphalt pavement. The existing structure of the road A1 Vilnius–Kaunas–Klaipeda is presented in Figure 2.

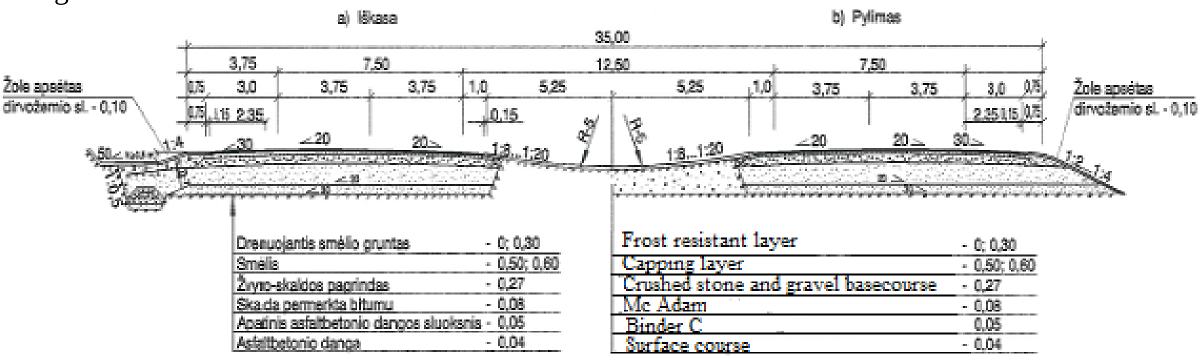

Figure 2. The existing structure of the road A1 Vilnius–Kaunas–Klaipeda.

A digital surface model, created on the basis of the obtained geodetic data, was applied to design the road section under repair works A1 Vilnius–Kaunas–Klaipeda. Measurements were made using Total Station Topcon GPT 3005 LN (2009).

The design process of the new pavement structure included the evaluation of traffic intensity on the road A1 Vilnius–Kaunas–Klaipeda and the selection of road structure class. Accordance to the observations performed by “Transport and Road Research Institute”, in the year 2008 the road traffic intensity in both directions made 9419 vehicles per day, heavy traffic made 21,3 % (2005 vehicles per day). The determined AADT (annual average daily traffic) growth rate of 3 percent allowed calculating AADT for the year 2029 (i.e., after 20 years), which makes A 1-20 (million) – 9,76. In compliance with the existing regulations defined in KPT SDK 07, (Regulations for the Design of Standardized Pavement Structures of Motor Roads), the selected pavement structure corresponds to class II road.

The existing pavement condition and the roughness of pavement surface were also studied. The research has shown that asphalt concrete pavement is rutted and cracked. In accordance with IRI data of the year 2007, the roughness of pavement surface of the road section under construction in the first lane was 1,94 m/km, and in the second lane was 1,56 m/km. Following the existing Specification of Technical Requirements TRA ASFALTAS 08, pavement roughness measured for highways in accordance with IRI requirements should not exceed 1,5 m/km. Rutting resistance of pavement was also measured on the road section under repair works. The rut depth in the first lane was 17,64 mm, and in the second lane was 15,36 mm. In order to study the condition of the road pavement, cores were taken and thickness of the existing asphalt courses was determined. The asphalt layer ranges in thickness from 5-28 cm (normally 10-13 cm), the average thickness of the layer is about 11,1 cm. The largest thickness of asphalt course was found at the beginning of the road (STA 2170+50) and at the end of the road (STA 2202+00).

2.2 Repair works and construction solutions

There is a base course of fly ash stabilized gravel (the presence of this course, stressed under cyclic freezing and thawing conditions, causes the formation and the development of cracks and ruts) under the existing asphalt and macadam course on the road section under construction A1 Vilnius–Kaunas–Klaipeda. Having studies the engineering geology report, the Technical Council of the Lithuania Road Administration under the Ministry of Transport and Communications took the decision to mill off and to remove the existing asphalt concrete pavement together with underlying macadam course, and to lift the design line of the road in order to stop the negative effect of stabilized course on the road pavement. Having removed the existing road pavement structure up to the stabilized base course, an absorbing interlayer of unbound binder and a recycled base course were constructed. The existing road pavement is destroyed, therefore the cross slope of 2,5 % is constructed on the entire route (except for banks). The existing asphalt pavement and the underlying macadam were milled off and stockpiled at a temporary mixing plant (about 3 km from the site) (see Figure 3). The stockpiled material was screened to remove any oversize material. All the delivered material was homogenized.

Figure 3. KVM mobile cold mix asphalt plant of JSC "Žemaitijos keliai".

A new road pavement was designed and constructed on the entire width of the road. The newly designed road pavement structure consisted of the following layers: a leveling base course of natural gravel, base course of crushed dolomite mix 0/45 (unbound mixtures - SAI), emulsion and cement stabilized base course, binder and surface asphalt courses (see Figure 4).. The thickness of newly constructed courses:

when the average thickness of a leveling course is ≥ 0,19 m:

– leveling course of natural gravel is 0,04–0,14 m;

– base course of crushed dolomite mix 0/45 is 0,15 m,

when the average thickness of a leveling course is ≤ 0,18 m:

– leveling course of crushed dolomite mix 0/45 is 0,12–0,18 m;

– emulsion and cement stabilized base course (cold recycling) is 0,20 m;

– binder asphalt course of mix AC 22 AS with SZ 22 and PMB 45/80-55 is 0,08 m;

– surface asphalt course of mix SMA 11 S with SZ 18 and PMB 45/80-55 (the width of 8,65 m) is 0,04 m.

A surface asphalt course of mix AC 11 VN (the thickness of 0,04 m) is constructed on the emergency stop lane (the width of 2,45 m).

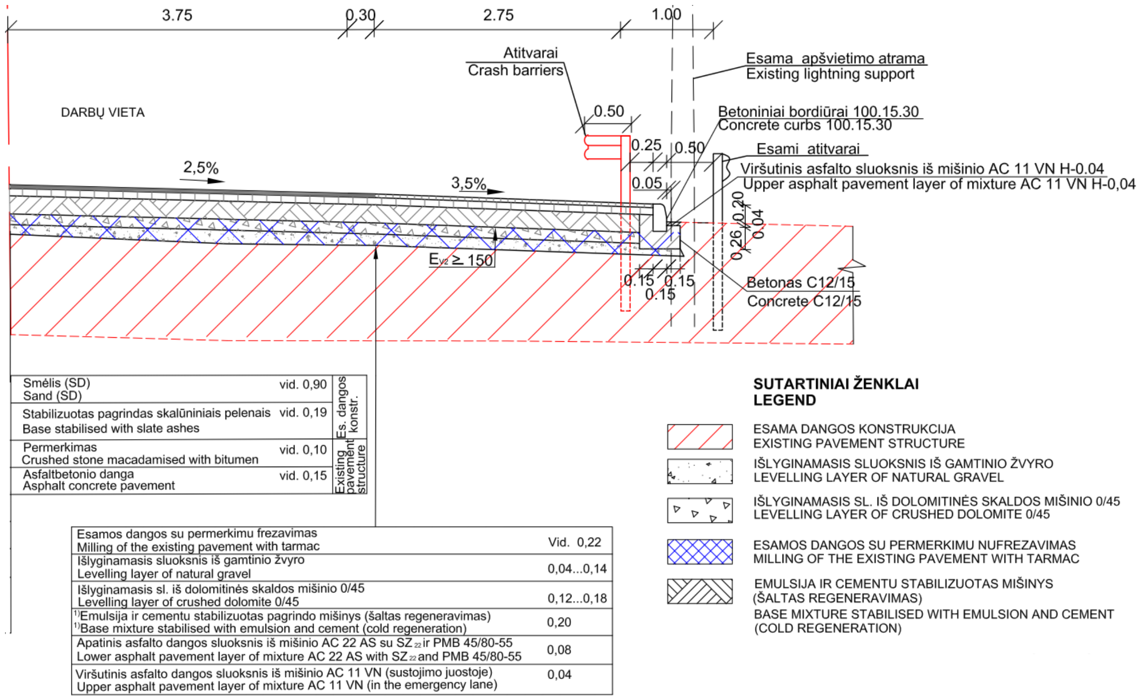

Figure 4. The newly designed road pavement structure layers

Having strengthened the road structure with the emulsion and cement stabilized base mixture and by the construction of stress absorbing interlayer, old as well as new reflective cracks, which tend to recur on the entire height of the road structure, do not develop in the road pavement of the reconstructed section. The condition of the road pavement after repair is given in Fig.5.

Figure. 5. Road A1 Vilnius-Kaunas-Klaipeda (216,95-220,3) km pavement structure after repair

The warranty period of 5 years is provided for the performed road reconstruction works. The service life of the constructed road section should make 20 years.

3. SELECTION OF THE COLD MIX RECYCLED ASPHALT BASE AND CONTROL TESTS

3.1 General

To ensure the durability, the resistance to environmental conditions and to the traffic load effects of cold recycled road base, and with the application of optimal investment, it is necessary to choose the proper composition of the base course. The selection of the cold mix recycled asphalt base should be justified by the suitability tests. The performance of these tests is impossible in situ; therefore the composition of a cold recycled mix is selected in the laboratory. The mix should be appropriately selected for a particular road structure and should satisfy the particle size distribution, deformation modulus and strength indices. In Lithuania, the requirements for the cold recycled base courses are given in Recommendations R 34-01 “Roadway basics”. The composition of cold mix recycled asphalt concrete pavement base was selected in the laboratory of JSC “Problematika”. The base course of macadam was laid during the construction works on the road A1 Vilnius–Kaunas–Klaipeda using as many of old road pavement materials as possible. This shall satisfy the main objectives such as the environmental friendliness and economic favourability of the road construction. However, the use of only recycled material will not help to achieve the main structural properties of base mix such as strength, stability and durability. In order to improve the mixture it was decided to add new material as well as hydraulic and bitumen binders. The base mixture consists of various mineral materials and binders, therefore the laboratory tests are conducted in order to study the individual constituents of the mixture. The optimal composition of the mixture was selected. The selection of optimal mixture is divided into the following phases:

1. Initial testing of materials,
2. Selection of various mix compositions,
3. Strength tests,
4. Evaluation of test results and decision-making.

3.2 Study of materials and study of results

3.2.1 Initial test of material and selection of mix compositions

In order to provide a strong framework for the cold recycled base course, crushed dolomite 16/45 and fine aggregate were added into the mixture. Road construction practice in Lithuania has shown that the stabilization of road base mix works best when bitumen binder is added together with hydraulic binder-cement. The particle size distribution composition was studied for all unbound composite materials of the base mixture in compliance with LST EN 933-1, LST EN 933-1:2002/A1:2005. The selected particle size distribution composition of base mix should meet the requirements of the current construction regulations given in R 34-01 “Roadway basics”. The particle size distribution compositions of the selected base mix and its constituents are provided in Table 1. The selected particle size distribution curve of base mix and the requirements of R 34-01 “Roadway basics” are demonstrated in Figure 6.

Type and fraction of the material	%	**0,09**	**0,25**	**0,71**	**2**	**5**	**8**	**11,2**	**16**	**22,4**	**31,5**	**45**	**56**	**63**
Fine aggregate	**8**	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
Crushed dolomite 16/45	**20**	0,3	0,6	0,8	1,1	1,6	2,4	3,5	15,9	64,2	90,6	100,0	100,0	100,0
Crushed asphalt concrete	**70**	0,6	2,5	8,0	20,1	34,5	48,7	58,9	70,2	79,3	84,7	90,5	95,6	100,0
Aggregate	**2**	93,6	98,6	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
Percentage passing through the sieve	**100**	**10,3**	**11,9**	**15,8**	**24,3**	**34,4**	**44,6**	**51,9**	**62,3**	**78,3**	**87,4**	**93,3**	**96,9**	**100,0**

Table 1. The particle size distribution composition of the designed cold recycled base mix and its constituents.

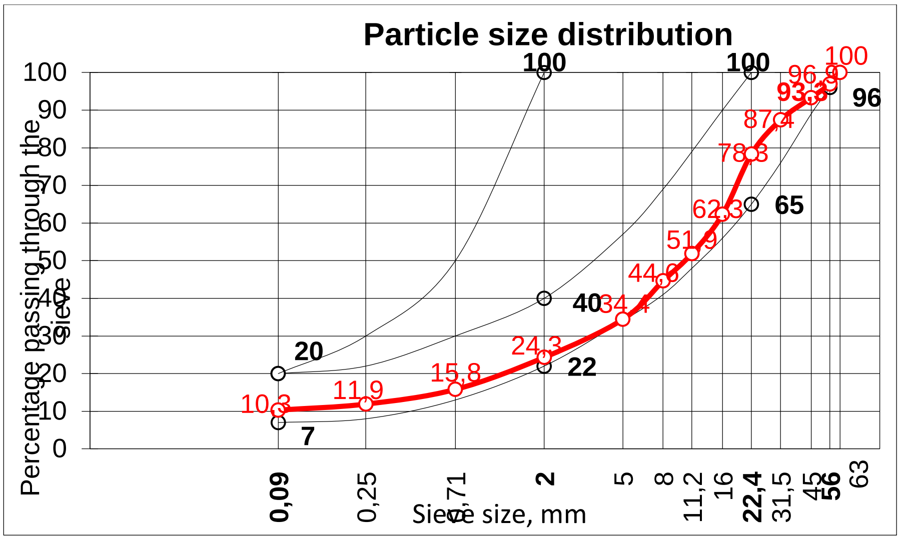

Figure 6.The particle size distribution composition of the selected base mix.

For the selected mix without bituminous binding material the determined modified Proctor density was 2,127 g/cm^3 and optimal moisture content was 4,9 %, in accordance with LST 1360.2:1995. It was decided to bind the base mixture by additionally adding bituminous binders. Bitumen emulsion "Nyrec" was tested; the consistency obtained - 59,7%.

Three variants of base mix with various binder contents were selected (see Table 2) on the basis of performed initial testing of the material.

Cement content, %	Residual bitumen content (em.)%	Water content (0,9 W_{Pr}-W_{Em}), %	Variants
2	1,70	3,26	I
2	2,40	2,79	II
2	3,10	2,32	III

Table 2 The selected binder content.

3.2.3 Specimen preparation and strength tests

Having selected the composition of the mix and three variants of different binder contents, specimens were prepared for the performance of strength tests. Specimens must be produced within 90±30 minutes after the mixing. At least 4 specimens were produced for each of bituminous binder content. Specimens were compacted up to modified Proctor density of 0,97. The compacted specimens were kept at room temperature for 24 hours, and then cured in the oven for 72 hours at the temperature of 60°C. Having removed them from the oven, half of the specimens were kept at room temperature for 48 hours; the other part was kept in water at the temperature of 22°C. Right before the performance of a splitting strength test, all the specimens were kept at the temperature of 22±2°C for one hour. Splitting strength was determined for all the cured specimens (in accordance with "Determination of the strength of mixes with binders during breaking", Instruction). Splitting strength was determined for dry specimens and for soaked specimens. Splitting strength for specimens from the selected base mix is given in Figure 7. The figure shows the strength of specimens in relation to bituminous binder content. Splitting strength for the soaked specimens and dry specimens are marked in different colours.

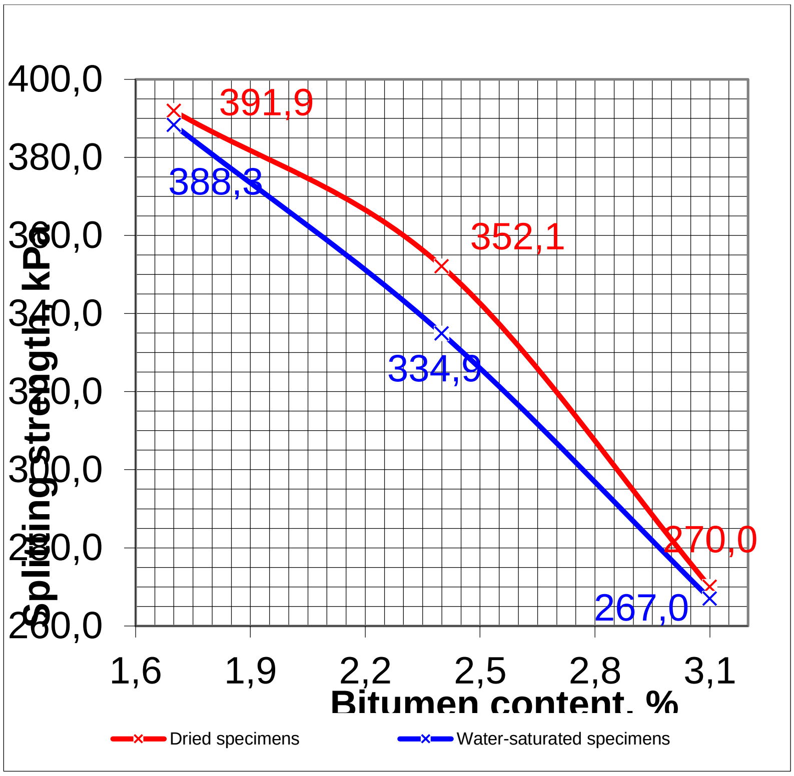

Figure 7. Splitting strength of specimens.

3.2.4 Evaluation of test results and decision-making.
The base mixture is selected in accordance with the obtained test results and requirements. The requirements for cold recycled base mixtures are indicated in R 34-01 "Roadway basics" (see Table 3). While selecting the appropriate composition of the base mixture it is very important to pay attention not only to its strength, but also to its resistance to water, and to consider the economic factors.

Recommended course thickness	Average compaction index	Splitting strength kPa (dry specimen)	Resistance to water effects	Moisture tolerance of the mix during the construction
(12,5-30,0) cm	≥ 97% (mod. (Proctor density)	250-900	≥ 0.6	From -2% to +1.2 x OPD%

Table 3 Requirements for the base mixtures with bituminous binding materials.

Having performed all the required tests and having taken into consideration the requirements of R 34-01 "Roadway basics" for base mixtures from cold recycled pavement, the optimal base mix composition was selected. Having evaluated the obtained results of the designed mixtures, variant II of base mix composition was chosen. The composition of the chosen base mix variant is provided in Table 4.

Variant II
Splitting strength of dry specimen - 352,1 kPa
Splitting strength of soaked specimen - 334,9 kPa
Ratio of splitting strength (soaked/dry) - 0,95
Density of dry mix - 2,127 g/cm^3
Bitumen (emulsion) added - 2,4 (4,02) %

Table 4 The selected variant of base mix.

The construction of cold recycled base course was accompanied by the performance of control tests of the mixture and of the constructed course. The obtained test results satisfied the governing values of the existing Lithuanian normative documents.

CONCLUSIONS

1. The practice has shown that the construction of rigid pavements or the construction of structural layers is not suitable for the Lithuanian roads due to the weather conditions. Aggressive weather conditions and multiple cycles of freezing and thawing cause the occurrence of longitudinal cracks in the pavement, the formation of a network of cracks and other surface distresses.

2. Lithuanian roads with rigid structural layers undergo the deformation of pavement and the formation of other distresses which tend to increase in the course of time and to expand until reaching critical limits. Distresses can spread deeper into the underlying layers of the road structure due to the untimely elimination of damages or untimely determination of root causes of their occurrence. Upon the development of undesirable road damages or the achievement of unallowable road deformation level, it becomes necessary to repair the road by strengthening the entire road pavement structure and to look for the appropriate means to solve a specific problem.

3. Major problems for the design of the road section A1 Vilnius-Kaunas-Klaipeda (216,95-220,3) km were: particularly large pavement distresses, and cracks recurring on the entire height of the road structure. These distresses arose because of the experimental section, the base of which was stabilized with fly ash.

4. Since the replacement of stabilized base and underlying layers would be too complicated and economically unfavourable, the problem had to be solved by other means, that is, by the construction of an absorbing interlayer of unbound mixture and the construction of cold recycled base course on the existing stabilized base course.

5. The optimal composition of cement (2 %) and "Nyrec" emulsion (4.02 %) stabilized base mix was selected in the laboratory of JSC "Problematika". The construction of cold recycled base course was accompanied by the performance of control tests of the mixture and of the constructed layer. The obtained test results satisfied the governing values of the existing Lithuanian normative documents. The performance of repair works on the road section A1 Vilnius-Kaunas-Klaipeda (216,95-220,3) km improved the condition of the pavement, that is, the recurrence of pavement distresses is prevented and pavement roughness meets the requirements specified in the Specification of Technical Requirements TRA ASFALTAS 08.

6. Having strengthened the road structure with the emulsion and cement stabilized base mixture and by the construction of stress absorbing interlayer, old as well as new reflective cracks, which tend to recur on the entire height of the road structure, do not develop in the road pavement of the reconstructed section. The service life of the constructed road section should make 20 years.

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