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THE USE OF STEEL WORKS CRUSHED SLAG (LIDONIT) IN THE PREPARATION OF ASPHALT MMIXTURES

BY
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The high costs of the quarry crushed aggregates (producer costs to which additional railroad transport costs are taken into account) result in the fact that at large distances away from the quarry lesser amounts of chippings and crushings sands are provided only. The initiation of the crushed aggregates production manufactured out of steelworks crushed slag – Lidonit, at a competitive delivering price, has led to the first series of laboratory tests. In the first stage two asphalt concrete mixtures rich in chipping: BA 8 and BA 16 with different bitumen percentage. Two mixtures were made in cube-shaped and cylinder-shaped (Marshall) test-tubes on which physical and mechanical characteristic values are determined. The results of these first tests outlined the real opportunity of using this products in supplying the roads and streets with asphalt mix for pavements.

1. Introduction

The high cost of supply with natural quarry aggregates in the eastern districts of Romania, does not allow the use of large amounts of chippings and crushed sand in bitumen road coatings in urban environment.

The initiation of crushed aggregates production manufactured out of steelworks crushed slag (Lidonit) at a competitive delivering price has led to the first series of laboratory tests as to ways to use them in asphalt mix for pavements [1].

2. Laboratory Tests

Although Lidonit type aggregates can be used from as deep as sub-base to pavements, because of their susceptibility to structural instability, these steelwork crushed slag products resulted from the Linz-Donawitz should be used in asphalt layers where grains are covered with a bitumen film to prevent contact with water and manifestation of structural instability.

A first set of laboratory tests was initiated in order to assess the characteristics of asphalt mixtures made from Lidonit-type aggregates. The aim of tests was to establish a manufacturing network of asphalt concrete rich in chipping in variants: BA 8 and BA 16. The used materials were as follows: 8...16 mm, 5...8 mm sort crushed slag, 0...5 mm crushed sand, all of Lidonit-type products, natural river sand, calcareous filler and D 80/100, D 100/120. Granulometric curves of artificial and natural aggregates are shown in Table 1 and bitumen characteristics in Table 2.

Table 1

Characteristics of Aggregates and Aggregate Mixtures

Aggregates	Passing sieve, %, [mm]									
	16	10	8	5	3	1	0.63	0.2	0.09	0.071
Lidonit 8...16	100.00	34.53	6.47	0.91	0.37	–	–	–	–	–
Lidonit 5...8	–	100.00	83.87	44.59	7.79	2.81	2.07	1.42	0.87	0.65
Lidonit 0...5	–	–	–	100.00	89.47	39.18	26.06	11.57	5.95	4.23
Natural sand 0...7 (I)	–	–	100.00	99.06	98.43	86.84	82.63	17.34	1.93	0.86
Natural sand 0...7 (II)	–	–	100.00	98.38	96.36	57.88	43.14	6.06	0.54	0.16
Calcareous filler (I)	–	–	–	–	–	–	100.00	97.45	83.43	68.80
Calcareous filler (II)	–	–	–	–	–	–	100.00	97.89	84.77	67.44
Granulometric curve	–	100.00	91.94	72.04	52.41	41.65	38.79	18.42	11.59	9.25
Granulometric curve	100.00	73.18	61.36	48.99	40.00	26.90	22.79	14.28	11.04	8.67

Table 2

Characteristics of Bitumen Used

Characteristics	Values	
	D 80/100 (I)	D 100/120 (II)
Penetration at +25°C, 1/10 mm	84	118
Softening Point (R.B.), [°C]	48.1	43.6
Penetration index, I.P.	−0.38	−0.72
Heat susceptibility, a	0.042	0.045
Type of structure	Sol – gel	Sol – gel

Two compositions of asphalt concrete rich in chippings were made: BA 8 (series 1) with D 80/100 and BA 16 (series II) using bitumen D 100/120; both compositions are shown in Table 1 as well as granulometric curves of aggregates mixtures.

The values of physical and mechanical characteristics determined in the cube and cylinder shaped test simples made out of series I and II of mixtures made in different proportions with bitumen are shown in Table 3, and the variation of the cylinder-shaped test tubes swelling in time for the series III and IV of mixtures, in Table 4.

Table 3

Physical and Mechanical Characteristic Values for Mixtures in Series I and II

No.	Tipe of mixture	Bitumen percentage %	$\rho_{a\,cube}/\rho_{a\,cyl}$	Absorption volume %	Swelling in 28 days volume %	Resistance to compression, [N/mm^2], at: 22°C	50°C	K_T	Red. R^{28}_{c22}, [%]	Marshall Test S kN	I mm	S/I kN/mm
1	BA 8	6.50	2.447/2.384	6.393/6.903	0.000/0.179	3.463	1.289	2.687	6.09	13.1	2.00	6.55
2		6.75	2.435/2.442	5.457/5.921	0.000/0.668	3.899	1.441	2.757	8.21	10.9	2.38	4.58
3		7.00	2.469/2.486	3.642/3.061	0.000/0.937	3.935	1.435	2.742	3.05	12.9	2.87	4.50
4		7.25	2.492/2.510	3.669/1.629	0.000/0.059	3.675	1.306	2.814	0.00	12.3	3.60	3.32
5		7.50	2.468/2.477	3.518/1.521	0.000/0.000	3.008	1.009	2.981	0.00	10.9	3.75	2.91
6	BA 16	5.75	2.540/2.634	5.048/2.146	0.872/0.314	2.932	0.834	3.516	9.11	10.4	2.95	3.53
7		6.00	2.544/2.638	4.900/1.522	0.490/0.177	3.131	0.823	3.804	6.70	8.7	3.05	2.85
8		6.25	2.598/2.658	3.092/1.010	0.181/0.083	3.079	0.854	3.610	4.32	9.3	3.40	2.74
9		6.50	2.608/2.644	2.633/0.769	0.000/0.000	2.720	0.664	4.096	0.90	9.0	3.87	2.33
10		6.75	2.633/2.659	0.779/0.218	0.000/0.000	2.234	0.647	3.453	0.00	8.4	4.05	2.07

Table 4
The Variation of the Cube and Cylinder-shaped Test Tubes Swelling in Time for the Series II and III of Mixtures

Type of mixture	Bitumen percentage %	Test tubes	No. of days 7	14	21	28	Red. R_{c22}^{28} [%]
BA 8 series 1	6.50	cube	0.000	0.156	0.000	0.000	6.09
		clylinder	0.000	0.000	0.000	0.179	
	6.75	cube	0.000	0.000	0.000	0.000	8.21
		cylinder	0.000	0.295	0.422	0.668	
	7.00	cube	0.000	0.000	0.000	0.000	3.05
		cylinder	0.000	0.658	0.130	0.937	
	7.25	cube	0.000	0.000	0.000	0.000	0.00
		cylinder	0.000	0.000	0.000	0.059	
	7.50	cube	0.000	0.000	0.000	0.000	0.00
		cylinder	0.000	0.000	0.000	0.000	
BA 16 series 2	5.75	cube	0.000	0.000	0.096	0.387	9.28
		clylinder	0.000	0.000	0.000	0.000	
	6.00	cube	0.059	0.059	0.063	0.079	9.48
		cylinder	0.000	0.020	0.000	0.000	
	6.25	cube	0.208	0.000	0.011	0.044	6.37
		cylinder	0.000	0.000	0.000	0.010	
	6.50	cube	0.000	0.089	0.000	0.000	1.32
		cylinder	0.000	0.000	0.000	0.000	
	6.75	cube	0.000	0.000	0.000	0.000	0.00
		cylinder	0.000	0.000	0.000	0.000	

Fig. 1.- A map of the climate zones in Romania.

Other two asphalt concrete rich in chippings were made: type BA 8 (series III) and type BA 16 (series IV). The following aggregates were used: crushed slag (5...8, 8...16 sorts), 0...4 mm crushing sand, 0...4 natural sand and calcareous filler granulometric curves are shown in Table 5. These two types of mixtures were made with two types of D 60/80 bitumen each for the warm Romanian zone and D 80/100 bitumen for the cold zone (Fig. 1).

Table 5

Characteristics of Aggregates and Aggregate Mixtures

Aggregates	Passing sieve, %, [mm:]									
	16	100	8	4	2	1	0.63	0.2	0.1	0.071
Lidonit 8...16	100.00	45.48	8.39	0.29	–	–	–	–	–	–
Lidonit 4...8	–	100.00	86.30	6.52	0.72	0.42	–	–	–	–
Crushing sand 0...4 Turcoaia	–	–	100.00	97.52	69.72	44.31	28.30	5.50	1.99	1.44
Natural sand 0...4 (III)	–	–	100.00	94.47	80.77	60.96	47.96	8.83	2.08	1.36
Calcareous filler (III)	–	–	–	–	–	–	100.00	97.30	77.85	64.88
Granulometric curve	–	100.00	93.84	56.16	44.84	35.07	28.69	14.81	10.22	8.39
Granulometric curve	100.00	80.92	65.20	45.03	37.14	29.70	24.88	14.10	10.01	8.25

Table 6 shows the main characteristics of bitumen.

Table 6

Characteristics of Bitumen Used

Characteristics	Values	
	D 60/80(III)	D 80/100(IV)
Penetration at +25°C, 1/10 mm	78	97
Softening Point, (R.B.), [°C]	50.4	45.0
Penetration index, I.P.	0.03	−0.88
Heat susceptibility, a	0.040	0.046
Type of structure	Sol – gel	Sol – gel

The physical and mechanical characteristics of these mixtures made with different bitumen percentages, tested in cylinder-shaped test tubes are shown in Table 7; the variation of the cylinder-shaped test tubes swelling in time is shown in Table 8 (only for mixtures made with D 80/100 bitumen).

Table 7
The Variation of the Cylinder-shaped Test Tubes Swelling in Time for the Series III and IV of Mixtures

Type of mixture	Bitumen percentage, [%]	Type of bitumen	ρ_a kg/m^3	Absorption volume %	S kN	I m	S/I kN/m
BA 8	4.75	D60/80	2.538	5.211	10.6	2.67	3.970
		D80/100	2.571	4.283	8.5	1.76	4.830
	5.00	D60/80	2.553	4.071	9.4	2.68	3.507
		D80/100	2.585	3.242	8.8	2.00	4.400
	5.25	D60/80	2.576	3.027	8.2	2.75	2.982
		D80/100	2.593	3.060	8.3	2.40	3.458
	5.50	D60/80	2.587	2.243	8.3	2.80	2.964
		D80/100	2.616	1.846	9.1	2.78	3.273
	5.75	D60/80	2.591	1.137	9.7	3.54	2.740
		D80/100	2.622	1.066	9.6	3.15	3.048
	6.00	D60/80	2.606	0.344	9.2	3.73	2.466
		D80/100	2.613	0.681	7.8	3.52	2.216
BA 16	4.00	D60/80	2.701	4.075	15.7	1.85	8.486
		D80/100	2.735	3.073	11.8	2.70	4.370
	4.25	D60/80	2.711	2.239	11.9	2.40	4.958
		D80/100	2.751	2.939	11.8	3.05	3.869
	4.50	D60/80	2.740	1.299	10.6	2.50	4.240
		D80/100	2.754	2.076	9.9	2.95	3.356
	4.75	D60/80	2.751	0.279	11.3	2.63	4.297
		D80/100	2.757	0.808	12.9	3.26	3.957
	5.00	D60/80	2.759	0.146	12.1	3.05	3.967
		D80/100	2.754	0.405	9.9	3.30	3.000
	5.25	D60/80	2.745	0.000	10.8	3.24	3.333
		D80/100	2.753	0.302	9.9	3.62	2.753

Table 8
The Variation of the Cylinder-shaped Test Tubes Swelling in Time for the Series III and IV of Mixtures

Type of mixture	Bitumen percentage, [%]	Type of bitumen	Swelling at, [days]			
			7	14	21	28
BA8 (series III)	4.75	D80/100	0.000	0.079	0.000	0.072
	5.00	D80/100	0.000	0.000	0.000	0.668
	5.25	D80/100	0.093	0.093	0.000	0.737
	5.50	D80/100	0.013	0.020	0.000	0.689
	5.75	D80/100	0.033	0.153	0.265	0.338
	6.00	D80/100	0.000	0.033	0.000	0.244
BA 16 (series IV)	4.00	D80/100	0.000	0.000	0.175	0.000
	4.25	D80/100	0.040	0.322	0.060	0.294
	4.50	D80/100	0.069	0.352	0.000	0.155
	4.75	D80/100	0.007	0.357	0.000	0.000
	5.00	D80/100	0.093	0.285	0.027	0.000
	5.25	D80/100	0.000	0.000	0.020	0.000

3. Conclusions

The analysis of the obtained results has led us to the following conclusions:

1. The use of 0...5 mm crushed slag (Lidonit) for the BA 8 asphalt mixtures (series I) gave an optimal bitumen percentage, about 1% higher than in the similar mixture in series III (in which 0...4 crushing sand/granite was used). This points out the high porosity and the large specific surface, respectively, of the 0...4 Lidonit. Moreover, the high percentage of CaO (9%) risks to be the cause of some swellings in the wearing course of the bitumen coating after it has been made.

2. The evolution of swelling for the BA8 and BA 16 type mixtures (series I...IV) shows that the recorded values do not exceed 1%, which in its turn shown a good behaviour in time to water.

3. Both the values of apparent density, water absorption and of the Marshall test exceed the minimal values demanded by SR 174-1/2002 (Table 9), which ensures the mixtures good resistance to the combined action of traffic and climate factors.

Table 9
The Values of Physical and Mechanical Characteristics According to SR 174-1/2002

Type of mixture	Type of bitumen	Technical class	Average annual daily traffic car	Characteristics in Marshall cylinder-shaped test-tubes:				
				S- stability at +60°C kN.min	Flowing index, I mm	S/I ratio kN/mm	Apparent gravity kg/m^3.min	Water absorption % volume
BA 8	D 60/80	IV...V	<4,500	6.0	1.5...4.5	1.3...4.0	2,300	2...5
	D 80/100	IV...V	<4,500	5.5	1.5...4.5	1.2...3.6		
BA 16	D 60/80	II	11,001... 21,000	8.5	1.5...3.5	2.4...5.6	2,300	2...5
		III	4,501... 11,000	7.5	1.5...4.0	1.8...5.0		
		IV...V	<4,500	6.5	1.5...4.5	1.4...4.3		
	D 80/100	II	11,001... 21,000	8.0	1.5...4.0	2.0...5.3		
		III	4,501... 11,000	7.0	1.5...4.0	1.7...4.6		
		IV...V	<4,500	6.0	1.5...4.5	1.3...4.0		

We can state with perfect certainty that the Lidonit type aggregates can successfully replace crushed natural aggregates in the preparation of asphalt mixtures; this means less environmental pollution by the reduction of land occupied by steelworks waste storehouses.

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FOLOSIREA AGREGATELOR DIN ZGURĂ DE OŢELĂRIE (LIDONIT) LA PREPARAREA MIXTURILOR ASFALTICE

(Rezumat)

Costul ridicat al aprovizionării cu agregate concasate (costul producţiei, preţul de transport), precum şi distanţa mare de aprovizionare, nu permit utilizarea unor cantităţi mari de cribluri şi nisipuri de concasare. Inceperea producţiei de agregate din zgură de oţelărie Lidonit, la un preţ competitiv, a dus la iniţierea unor prime serii de incercări de laborator. In prima fază s-au preparat două reţele de beton asfaltic bogate in criblură: BA 8 şi BA 16, cu diferite procente de bitum.

S-au efectuat incercări pe cuburi şi pe cilindri Marshall, stabilindu-se pentru cele două mixturi caracteristicile fizice şi mecanice. A rezultat o primă serie de rezultate care deschide o adevărată oportunutate in folosirea acestor produse pentru realizarea de mixturi asfaltice pentru străzi şi drumuri.