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THE PHYSICO-MECHANICAL PROPERTIES OF ASPHALT MIXTURES CONTAINING BITUMINOUS SAND

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Abstract: *The continuous evolution and development of the society caused a significant increase in the number of construction works. Regarding road works, in the recent years, these have escalated as the need for bitumen increased. Given Romania's conditions, for fulfilling the need of bitumen economy and thus reducing the costs correlated with road pavement, due to the fact that this material is currently brought only from abroad, it is desired to design an asphalt mixture with a smaller quantity of contained bitumen or even replacing it with bituminous sand, a solution which is advantageous in areas where one can find these natural resources. In Romania, bituminous sand or oil sand can be found in two geographic areas, namely: in Bihor County, Derna-Tatarus-Budoi in Prahova County, at Matita, and Pacureti. Further, these bituminous sands have a naturally occurring bitumen percentage of approximately 20% in their composition. In this context, this paper aims to emphasize, through static and dynamic methods, the physical and mechanical characteristics of two bituminous asphalt mixtures containing bituminous sand from Derna - Tatarus - Budoi. Both of asphalt mixtures have been designed based on departmental normative CD 42-85, containing various sorts of crushed gravel, natural sand and bituminous sand and are intended to be used for the base course of the road pavement. Furthermore, one of bituminous mixtures is performed with bituminous sand and hard paving grade bitumen compared with the second one, which only contains bituminous sand, in this case the bituminous binder consisting in the bitumen contained into the oil sand.*

Keywords: NATURAL AGGREGATES, BITUMEN, BITUMINOUS SAND, ASPHALT MIXTURE, PHYSICAL AND MECHANICAL PROPERTIES

1. Introduction

The progressive demand increase for asphalt mixtures and consequently for road bitumen, correlated with the quantitative and qualitative deficiency of this essential material for road works, highlighted the importance of using bituminous mixtures with unconventional components such as bituminous sand. The use of bituminous sands is imposed by the significant increase in the price of bituminous binders, together with the gradual degradation of the road network in Romania, as well as the increase in the degree of motorization and thus the limitation of the rehabilitation possibilities mainly due to the high costs. By incorporating bituminous sands in the asphalt mixture, a significant reduction in the amount of conventionally bitumen used is achieved, this binder currently only being imported. Further the quantification of specific benefits related with the use of bitumen sands in Romania in terms of bitumen content are presented. The results are obtained through specific tests carried out in the Roads Laboratory of the "Gheorghe Asachi" Technical University of Iasi, for further development of effective asphalt recipes that incorporate these materials and, finally, to implement this procedure into practice.

According to specialized literature, bituminous binders represent complex mixtures of animal origin hydrocarbons or being obtained through a pyrogenic reaction, often accompanied by their combinations with oxygen, nitrogen, sulfur, etc. They are in the form of liquid, viscous or solid, having a dark brownish and black color and being completely soluble in carbon disulfide (Mătăsaru et al., 1966, Ionita et all, 2016).

In order to fulfill their role as road binders, bituminous materials must have a bond strength or agglomeration. This condition is satisfied only by two categories of compounds, namely natural bitumen and tar. Bituminous binders, which occur in nature, are most often associated with minerals and also are used from ancient times (Les ENROBES bitumineux - Tome 1 + 2, 2005).

The largest oil field is located near Athabasca, Alberta Canada, but there are significant oil reserves located in Venezuela (Lake Bermudes), Cuba, Madagascar, Syria, Albania (SELENE) (Joseph K. Anocha -Boateng, Erol Tutumluer, 2012).

Bituminous sands represent sand deposits impregnated with a thick, viscous material called bitumen (James G. Speight, 2009). If we were to give a definition of bituminous sand, it would be a mixture composed of 80 % quartz sand and fine particles, a thin water cover representing 5% from their total composition, and 15% bitumen that fills the pore spaces between the sand granules, as can be seen in Fig. 1 (Ronald F. Probstein E. Edwin Hicks, 2006).

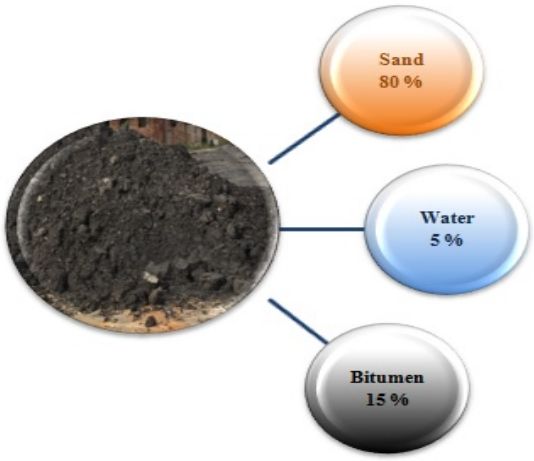

Fig. 1 *Bituminous sand composition (Dayna Linley, 2010).*

In Romania, bituminous sands or oil sands are found in two geographical areas, namely: in Bihor County, at Derna - Tatarus - Budoi and Prahova County, at Matita and Pacuret (Fig.2). These bituminous sands have an average of 10 to 20% pure bitumen in their structural composition and are used for road works. Depending on the road works to which these bituminous sands are used, the bituminous mixtures can be designed only with bituminous sand or bituminous sand and additional hard paving grade bitumen (Nicoară şi colab., 1985).

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***Fig. 2** – The geographic location of the bituminous sand areas in Romania (Source: google maps.com)*

2. Laboratory studies

In order to highlight the physical and mechanical characteristics of bituminous sand mixtures, two technological asphalt mixture recipes containing this type of material have been designed in the road laboratory in the frame of "Gh. Asachi" Technical University. The first recipe designed is for asphalt base associated with road pavements for light traffic (A.31.nb.), containing bituminous sands and hard paving grade bitumen. The second warm asphalt mix recipe, namely asphalt concrete (open graded concrete) with crushed gravel (B.a.31.nb.f), have only bituminous sand, without additional hard paving grade bitumen and it is envisaged to be used for the binder course.

Laboratory studies conducted for these two alternatives of unconventional asphalt mixtures complies with the directions of departmental normative CD 42-85 concerning the direct use of bituminous sands with and without adding hard bitumen for the execution of warm asphalt mixtures for road pavements.

The materials used for the bituminous mixes are represented by crushed sand and gravel delivered from Cristesti (Iasi), natural sand from Boureni (Iasi) quarry, filler originated from Bicaz (Neamt County), bituminous sand from Derna Tatarus (Bihor County) career and the hard paving grade bitumen have been supplied by OMV Refining & Marketing GmbH (Austria). The preparation of asphalt mixtures in the laboratory is carried out by heating and mixing the mixture components for 10-15 minutes at 170-180°C in the case of the bituminous mixture A.31.nb (asphalt mix with bituminous sand and hard paving grade bitumen) and at 175 – 190 ºC for Ba.31.nb.f (asphalt mix with only bituminous sand) (CD 42 – 85 Norm). Based on laboratory tests performed previously, the natural bitumen content in the used bituminous sand is 19.39%. The particle size distribution curve of natural aggregates and bituminous sand is shown in the graph below (Fig. 3).

The hard paving grade bitumen characteristics, used for the preparation of the asphalt mixture envisaged for asphalt base associated with road pavements for light traffic A.31.nb are presented in Fig. 4.

For each of the two bituminous mixtures conducted in the roads laboratory, five bitumen dosages have been made and, based on the measurement results, the optimal bitumen dosage have been determined. For the asphalt base concrete with crushed gravel, designed for road pavements with light traffic A.31.nb, have been used bitumen percent of: 5.00%, 5.20%, 5.40%, 5.60%, 5.80% (the recommended values ranging between 5.00% and 6.00%), resulting an optimal bitumen dosage of 5.40%. In the case of the asphalt concrete (open graded concrete) with crushed gravel for the binder layer B.a.31.nb.f, have been used bitumen percent of: 4.00%, 4.20%, 4.40%, 4.60%, and 4.80% (the recommended values ranging between 4.00% and 5.00%) resulting an optimal dosage of 4.40%.

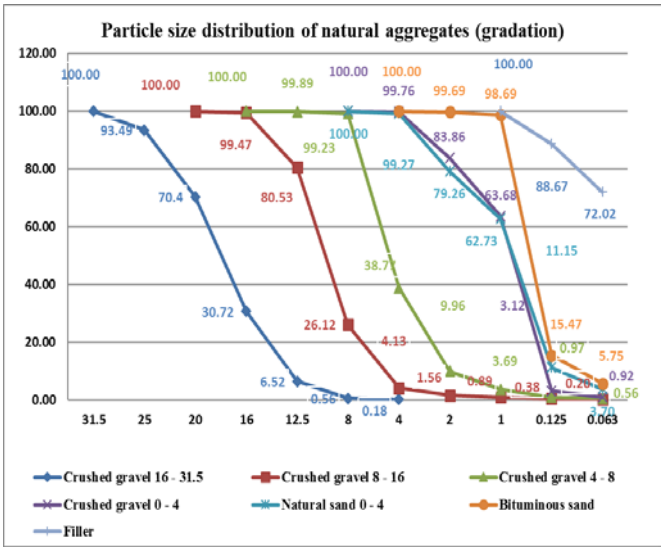

***Fig. 3** – Particle size distribution of natural aggregates (gradation)*

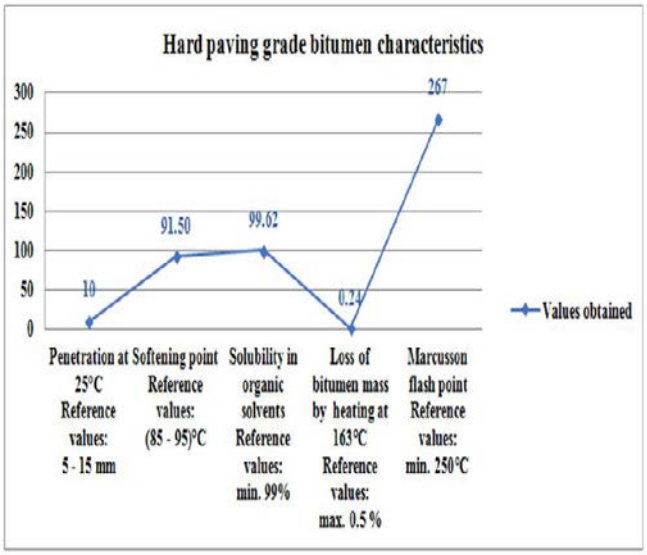

***Fig. 4** – Hard paving grade bitumen characteristics*

The calculation of the additional hard paving grade bitumen value required in the case of asphalt base concrete with crushed gravel, designed for road pavements with light traffic A.31.nb has been performed based on CD 42-85 Romanian Norm, as follows: the natural bitumen contained in the mix is required to be 70% and the hard bitumen is 30%.

For each type of mixture performed in the laboratory five binder dosage have been calculated as presented below:

- ✓ natural bitumen percentage: binder percentage x 0.7 = a%;
- ✓ hard bitumen percentage: binder percentage x 0.3 = b%;
- ✓ dosage of bituminous sand: = c %;
- ✓ dosage of natural sand contained in the bituminous sand: c – a = d %.

The dosage of natural aggregates used in the asphalt mixes and the aggregates curve for each type of mixture is represented in the tables below as follows: Table 1 for A.31.nb and Table 2 for Ba.31.nb.f.

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Table 1: *The natural aggregates dosage for asphalt base concrete with crushed gravel, designed for road pavements with light traffic A.31.nb (Ionita G., Gugiuman Gh., 2016)*

Aggregate	[%]	Percentage of weight passing sieve, [%]										
		31.5	25	20	16	12.5	8	4	2	1	0.125	0.063
Crushed gravel 16 – 31.5	25.37	25.37	23.72	17.86	7.79	1.65	0.14	0.05	-	-	-	-
Crushed gravel 8 – 16	10.57	10.57	10.57	10.57	10.51	8.51	2.76	0.44	0.16	0.09	0.04	0.02
Natural sand 0 – 4	39.92	39.92	39.92	39.92	39.92	39.92	39.92	39.63	31.64	25.04	4.45	1.48
Bituminous sand	17.80	17.80	17.80	17.80	17.80	17.80	17.80	17.80	17.74	17.57	2.75	1.02
Filler	6.34	6.34	6.34	6.34	6.34	6.34	6.34	6.34	6.34	6.34	5.62	4.57
Total		100.00	98.35	92.49	82.36	74.22	66.96	64.26	55.88	49.04	12.86	7.09
Limits particle size area		90…100	85…100	77…94	70…90	63...86	55...80	46...65	39...59	36...56	12...26	-

Table 2*. The natural aggregates dosage for asphalt concrete (open graded concrete) with crushed gravel for the binder layer B.a.31.nb.f (Ionita G., Gugiuman Gh., 2016)*

Aggregate	[%]	Percentage of weight passing sieve, [%]										
		31.5	25	20	16	12.5	8	4	2	1	0.125	0.063
Crushed gravel 16 – 31.5	26.15	26.15	24.45	18.41	8.03	1.70	0.15	0.05	-	-	-	-
Crushed gravel 8 – 16	15.69	15.69	15.69	15.69	15.61	12.64	4.10	0.65	0.24	0.14	0.06	0.03
Natural sand 0 – 4	35.89	35.89	35.89	35.89	35.89	35.89	35.89	35.89	35.63	28.45	4.00	1.33
Bituminous sand	19.13	19.13	19.13	19.13	19.13	19.13	19.13	19.13	19.07	18.88	2.96	1.10
Filler	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	2.78	2.26
Total		100.00	98.30	92.26	81.80	72.50	62.41	58.60	50.90	44.67	9.80	4.72
Limits particle size area		90…100	85…100	77…94	70…90	57...81	40...70	33...61	29...56	26…52	9...25	-

3. Results and discussions

For the two mixtures carried out in the roads laboratory physical and mechanical characteristics have been determined through static and dynamic tests. Fig. 5 presents the physical-mechanical characteristics determined by static methods for both mixtures: A.31.nb and B.a.31.nb.f.

As can be seen in the Figure 5, the values for both mixtures carried out in the laboratory are within the limits imposed by the actual norms, showing thus that both mixtures exhibit good physical and mechanical characteristics determined through static methods.

In Figure 6 below, the physical and mechanical characteristics, determined through dynamic tests, are presented for both bituminous mixtures: A.31.nb and B.a.31.nb.f.

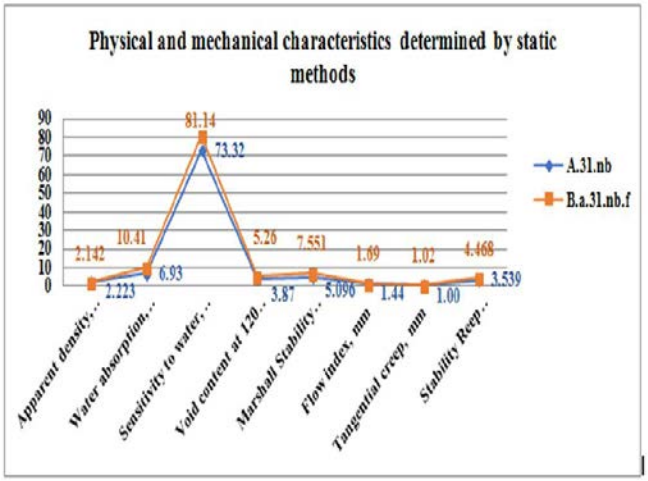

Fig. 5 *– The values of physical - mechanical characteristics determined by static methods*

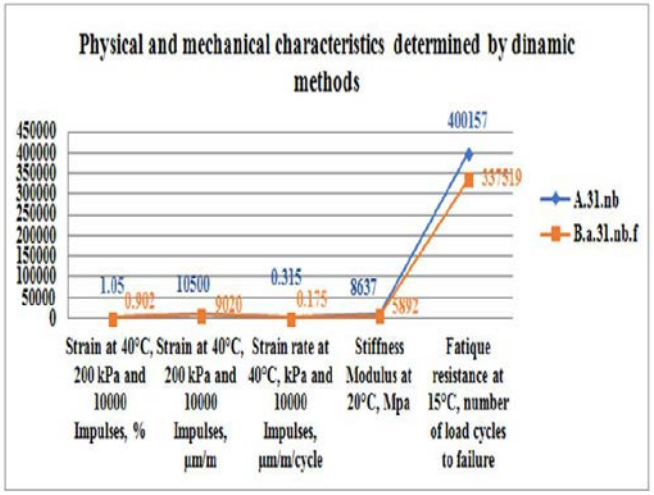

Fig. 6 *– Values of physical and mechanical characteristics determined by dynamic methods*

Based on the results obtained from the dynamic tests performed on both asphalt mixture containing bituminous sand one can notice that the asphalt concrete (open graded concrete) with crushed gravel for the binder layer B.a.31.nb.f as well as asphalt base concrete with crushed gravel, designed for road pavements with light traffic A.31.nb have physical and mechanical characteristics within the norms limits.

4. Conclusions

Analyzing the results obtained from the studies conducted in the roads laboratory in the frame of "Gh. Asachi" Technical University of Iasi, the asphalt base concrete with crushed gravel, designed for road pavements with light traffic A.31.nb. (asphalt mix containing bituminous sand and hard paving grade bitumen) as well the asphalt concrete (open graded concrete) with crushed gravel for the binder layer B.a.31.nb.f. (asphalt mix carried out only with bituminous sand and without added bitumen) have physical and mechanical characteristics determined by static and dynamic methods which respect the limits set by the actual norms. Based on these positive results obtained through laboratory analyzes we can state that the use of bituminous sands in the production of asphalt mixtures, especially in the areas near natural deposits, presents an

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advantageous solution, significantly reducing the costs compared with a typical asphalt mix in which only bitumen is used.

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