INVESTIGATIONS' REGARDING VERY ACCESIBILE TECHNOLOGY TO REDUCE CONSTRUCTION COSTS AND IMPROVE THE QUALITY OF THE ASPHALT MIXES BY THE USE OF POLYMERS ADDED DIRECTLY AT THE PLANT MIX

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ABSTRACT

Polymers are widely used to improve the properties of asphalt mixes. The most popular is PmB modified bitumen by SBS (styrene butadiene styrene thermoplastic elastomer). This solution has some technology difficulties related to the compatibility of SBS with some types of bitumen and the stability of the modified bitumen.
For this reasons, thermoplastic plastomers which have polar groups actively interacting with bitumen elements ensuring a better compatibility, are easier to be used. The use of plastomer granules for asphalt mix production allows the reduction of construction costs. This is a very simple technology easy to apply in any conditions even in isolated arias.
In this paper we present some laboratory investigations and field applications regarding a procedure to modify asphalt mixes directly at the plant mix by using granular plastomers (polyolefines) added at the moment of the mix production.
We compared the performances of the asphalt mixes produced by plastomer addition at the plant after bitumen, with mixes produced with PMB modified bitumen. We also have studied the performances by using fibers in combination with thermoplastic elastomers and plastomers. We obtained best results for plastomers in combination with fibres.
The rheological properties of the asphalt mixes produced by the simplest technology of adding plastomers directly at the plant are meeting all the pavements performance demands. The stiffness is higher and all the other visco-elastic performances are generally very close to that obtained ones using PMB.

1. PERFORMANCE OF ASPHALT PAVEMENTS BY USING POLYMERS IN THE MIXTURE PRODUCTION

Asphalt proved to be ideal for road construction, due to the performance targeting technical, technological, economic and ecological aspects: resistance to mechanical stress, aggression of atmospheric factors, comfort and safety of traffic, simple and fast preparation and execution technologies, short execution time without disturbing traffic, reducing noise, fuel consumption, harmful emissions or the degree of wear of tires in service.

In order to ensure these requirements to a high level of performance, various technologies were researched, in particular on products that are added in the mixture composition, to improve some of its characteristics.
Researches and applications of these technologies are based on advanced methods of performance investigation in the laboratory. These methods, allow a detailed study of

fundamental properties of mixtures, which reflect the real way they respond to requests in service.

1.1. Aspects of using polymers in asphalt mixture production

The most commonly used polymers in the asphalt mixture production are the thermoplastic polymers. They are characterized by being able to reversibly change their state under the influence of temperature. In the domain of thermoplastic polymers there are two families that differ, mainly, by characteristics related to stiffness, elasticity, deformability: elastomers and plastomers.

1.1.1. Elastomers

Elastomers used in road works (SBS styrene-butadiene-styrene, styrene-isoprene-styrene, SIS, styrene-butadiene SB), have an heterogeneous structure consisting of clusters of polystyrene and polybutadiene chains. These polymers raise some issues related to:

- compatibility with the bitumen,
- storage stability
- high viscosity, that can cause problems during manufacturing and application of the mixtures.

Modified bitumens with elastomers are usually obtained by a strong mechanical mixing at a higher temperature than the flow temperature of the polymer. In some cases, dispersion chemical agents may be used, in order to optimize the operation, leading to more homogeneous mixtures.
Usually, the elastomer modified binders are kept at high temperatures (T>140ºC) with agitation.
Benefits of using elastomers are:

- considerable reduction of thermal susceptibility
- increased flexibility at low temperatures
- increased stiffness at high temperatures

Disadvantages in the use of elastomers are:

- increased viscosity at high temperatures
- limited stability at storage
- additional energy consumption for transport, storage and application

1.1.2. Plastomers

Plastomers used in road works are: EVA (ethylene and vinyl acetate), EMA (ethylene vinyl acrylate), EBA (ethylene and butyl acrylate). Their structure is composed of a hydrocarbon skeleton which provides rigidity and cohesion, including the crystalline fractions which regulate thermal susceptibility, on which is fixed the polar comonomer, allowing to control the compatibility of adhesivity and cristallinity. So, finally, the comonomer determines the basic properties of plastomers.
Benefits of using plastomers are:

- decreased thermal susceptibility
- increased stiffness at high temperatures

Disadvantages in the use of plastomers are :

- fragility at low temperatures

2. COMPARATIVE STUDY IN THE LABORATORY OF MIXTURES WITH ELASTOMER MODIFIED BITUMEN AND MODIFIED MIXTURES WITH PLASTOMER (MM)

To reflect the various issues related to the use of thermoplastic polymer modifiers, a comparison was made, between the classical solution of modified bitumen and the newest solution, of modified mix named in this paper MM. We present here the results of laboratory tests performed according to the Romanian norms.

2.1. The analysed asphalt mixtures and the characteristics of the components

In laboratory 6 (six) asphalt mixtures were analyzed with the same mineral grading. These mixtures are used for wearing courses according to the Romanian standards.
The bitumen content was 6,2 % from the total weight of asphalt for all the mixes. The fibre was added only in some mixes with a content of 0,4 % from the total weight and the granulated polymer added at ration of 5% in the bitumen. T

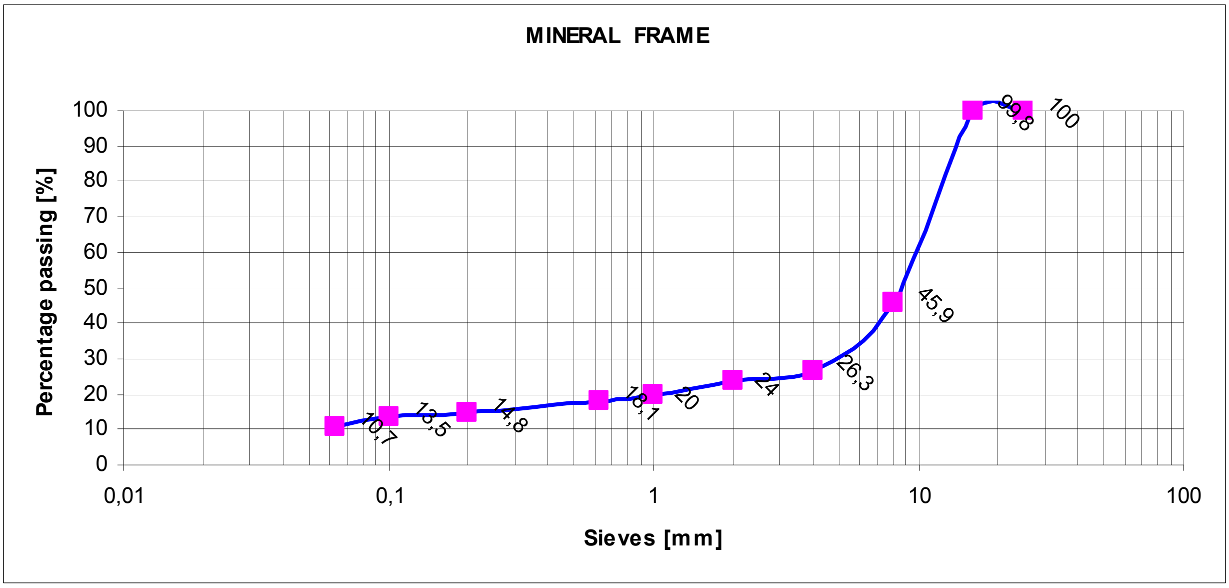

Figure 1- Aggregate grading

1. “A” Reference asphalt mixture
2. “B” Asphalt mixture with fibers
3. “C” Asphalt mixture with PmB 45/80-65 modified bitumen
4. “D” Asphalt mixture with PmB 45/80-65 modified bitumen and fibres
5. “E” MM -Modified asphalt mixture with granulated polymer
6. “F” MM -Modified asphalt mixture with granulated polymer and fibres

We have used 50/70 bitumen with 55,3 1/10 mm penetration and 51,9 ºC ring and ball temperature.
The ductility was more than 100 cm and the Frass breaking point near -13 ºC
The plastomer used was a compound formed with: LDPE, EVA and other polymers with low molecular weight.

The modified bitumen PmB 45/80-65 presents these characteristics:
- a penetration property: 45,3 1/10 mm,
- a ring and ball temperature at 70,2 ºC,
- an elastic recovery at 25 ºC : 82,5 %,
- a Frass breaking point : -16,4 ºC.

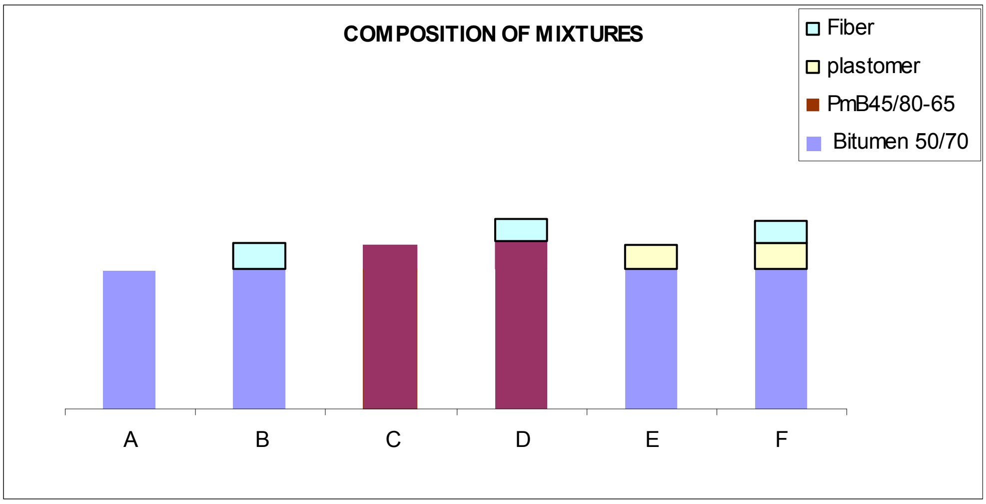

Figure 2- Analysed asphalt mixtures compositions

The purpose of the analysis was to highlight the influence of the fibres and the polymers.

The compaction of specimens for wheel tracking tests was made by means of rolling, with a plate compactor. Specimens for modulus, dynamic creep and fatigue tests were prepared with a gyratory press.

Laboratory tests on asphalt mixture specimens were conducted according to the Romanian standards. The test results are presented graphically and are set by fundamental characteristics: stiffness modulus, wheel tracking, dynamic flow and fatigue resistance.

2.2. The stiffness modulus

The stiffness modulus was established on the basis of indirect tensile tests performed at 15ºC. The tests were carried out by sinusoidal load pulses applied on cylindrical specimens having the diameter of 100 mm and the height of 60 mm.

Figure 3 - The measurement of the stiffness modulus

Table 1 - The values of the stiffness modulus at 15°C

Asphalt mixture	Stiffness modulus MPa
“A” reference : bitumen	4 995
“B” bitumen + fibres	5 195
“C” PmB	4 930
“D” PmB + fibres	5 128
“E” bitumen + granulated polymer (MM)	6 048
“F”bitumen + granulated polymer+fibres (MM)	6 654

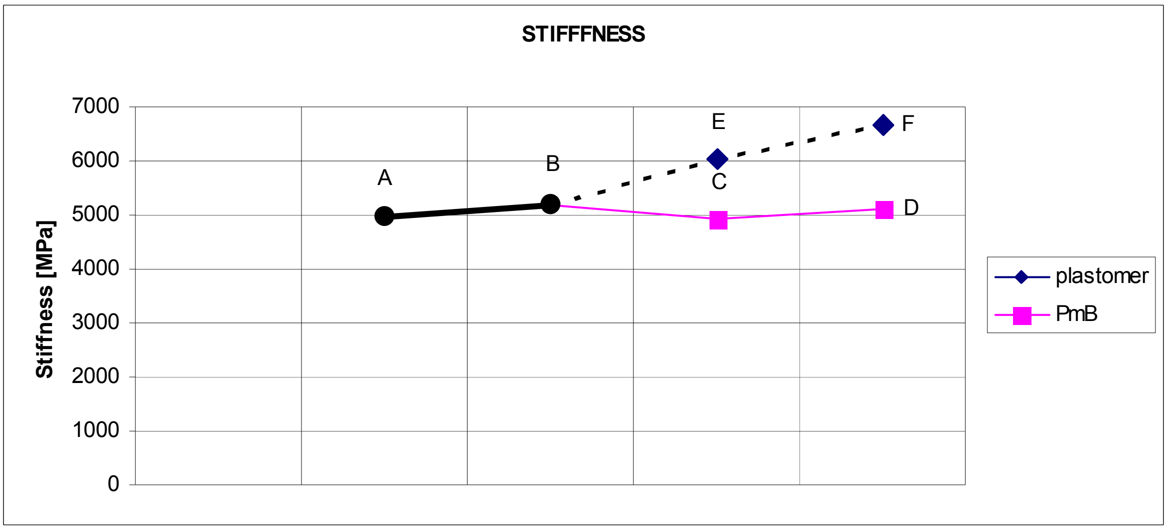

Figure 4 - The evolution of the stiffness modulus at 15°C

For the stiffness modulus (Figure 4) it came out:

- the plastomers added directly in the mixture had substantially increased the modulus (E),
- also the fibres alone(B), and with plastomers (F), had increased the modulus too,
- the PmB mixes had lower values of modulus (C), and the fibres added in the mixture with PmB had not a mighty effect (D).

2.3. The wheel tracking test

Figure 5 – The wheel tracking test device

The wheel tracking was conducted at 60 ºC, with the use of the small rut tracking test. The rut was produce by a small rubber wheel (like UK test according to the BS EN 12 697-22). The test result was the maximum rut depth denominated in percentage of the sample height (%) after 10 000 cycles and the rutting coefficient defined as an increase in rut depth (mm/1000 cycles), with represent the evolution of rut with time, during the end of test.

Table 2 - The wheel tracking test results

Asphalt mixture	Wheel Tracking %
“A” reference : bitumen	16,8
“B” bitumen + fibres	15
“C” PmB	4,2
“D” PmB + fibres	3,9
“E” bitumen + granulated polymer (MM)	9,8
“F”bitumen + granulated polymer+fibres (MM)	4

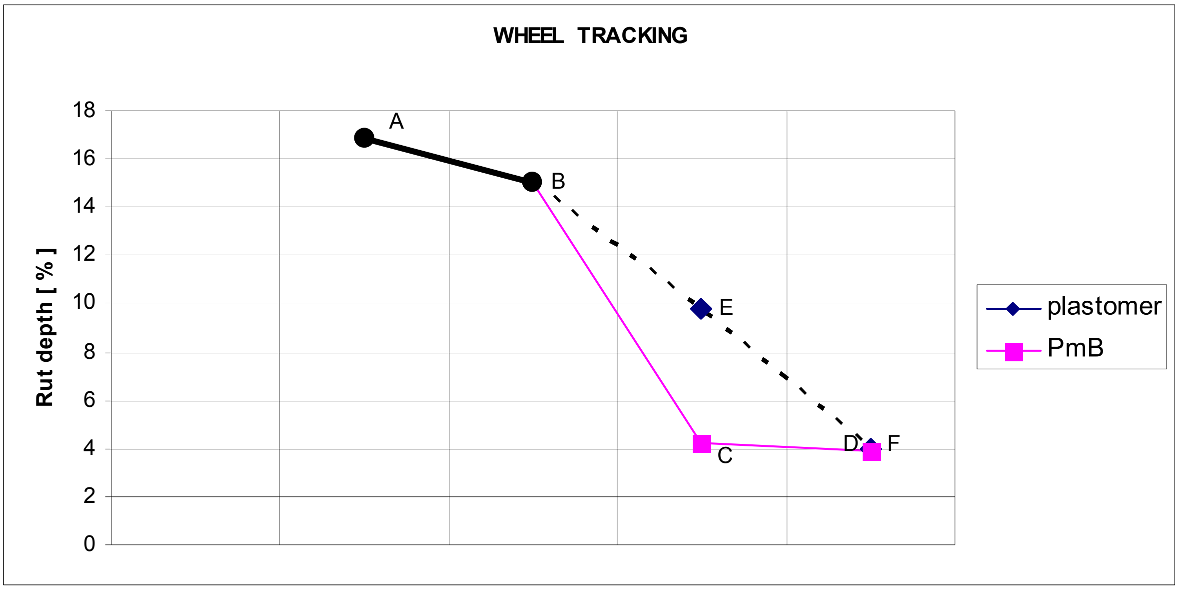

Figure 6 – The evolution of wheel tracking (in rut depth)

From the wheel tracking test (Figure 6) it came out :

- the only introduction of fibres had a relatively small contribution in the increase of the permanent deformation resistances (B)
- the elastomer had alone a good effect of increasing the rutting resistance (C)
- the plastomers alone had a moderate effect in increasing the rutting resistance(E)
- the plastomers in combination with fibres had a better performance in rutting resistance (F)
- the elastomers and plastomers in combination with fibres (D,F) had approximately the same rutting resistance
- using elastomers, the fibre supply does not improve the performance (C compared with D)

2.3. The dynamic creep test

Figure 7 - The dynamic creep test device

Table 3 - The results of the dynamic creep test

Asphalt mixture	Dynamic creep µm/m
“A” reference : bitumen	22 697
“B” bitumen + fibres	18 707
“C” PmB	16 190
“D” PmB + fibres	14 538
“E” bitumen + granulated polymer (MM)	15 656
“F”bitumen + granulated polymer+fibres (MM)	10 457

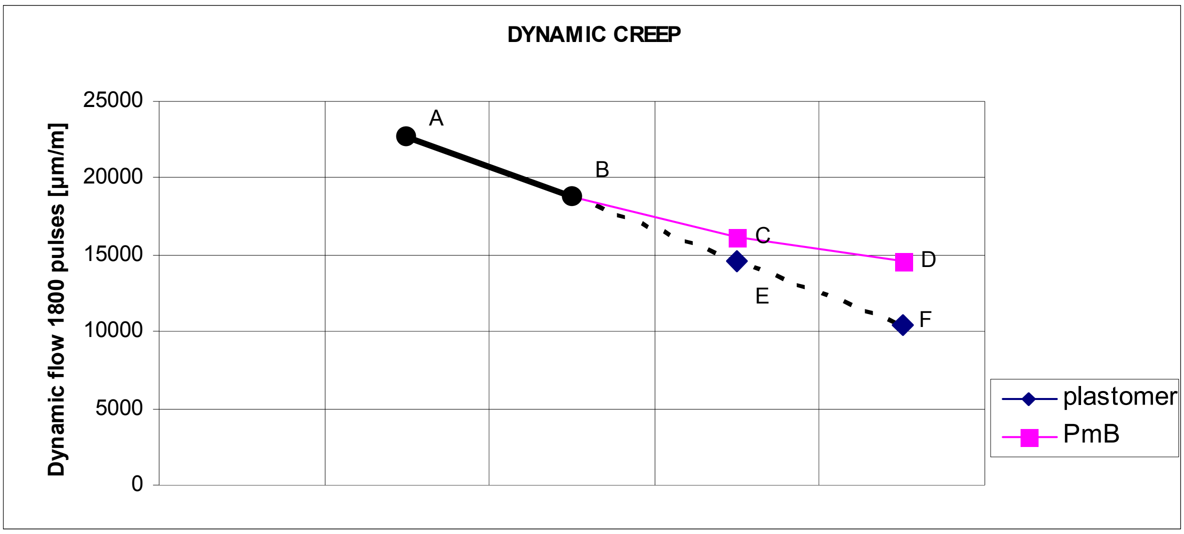

Figure 8 – The evolution of the dynamic creep results

Dynamic creep was conducted at 50 ºC. Specimens of the following size: diameter=100 mm, height=60 mm were exposed to cyclic axial loads of 300 kPa with partial vacuum confining pressure.(pulse duration 2 000 ms, pulse interval 1 000 ms). The number of load pulses was 1 800. In the test was determined the cumulate deformation expressed in µm/m

From the dynamic creep test (Figure 8) it came out :

- the mixes with plastomers (E,F) and elastomers (C,D) had a similar behaviour
- the mixes only with polymers (without fibres) had close values for both polymers used : elastomers and plastomers (C,E).
- the highest resistance to dynamic flow was ensured by the composition plastomers combined with fibres (F).

2.4. The fatigue test

The fatigue test was performed on cylindrical specimens having the diameter of 100 mm and the height of 60 mm exposed to a 300 kPa cyclic axial load applied at 15 ºC with a frequency of 2 HZ. The deformation, in mm, after 3 600 cycles applied was measured.

Figure 9 – The fatigue test device

Table 4 - The results of the fatigue test

Asphalt mixture	Fatigue mm
"A" reference : bitumen	1,3
"B" bitumen + fibres	0,8
"C" PmB	0,4
"D" PmB + fibres	0,4
"E" bitumen + granulated polymer (MM)	0,7
"F"bitumen + granulated polymer+fibres (MM)	0,6

About the fatigue resistance in accordance with the Romanian norms (Figure 10), the results can be analysed as follow :

- the plastomers added in mixes had a good effect of increasing the fatigue resistance (C), especially in combination with fibres (D)
- the mixture with PmB had better values of the fatigue resistance (C,D)

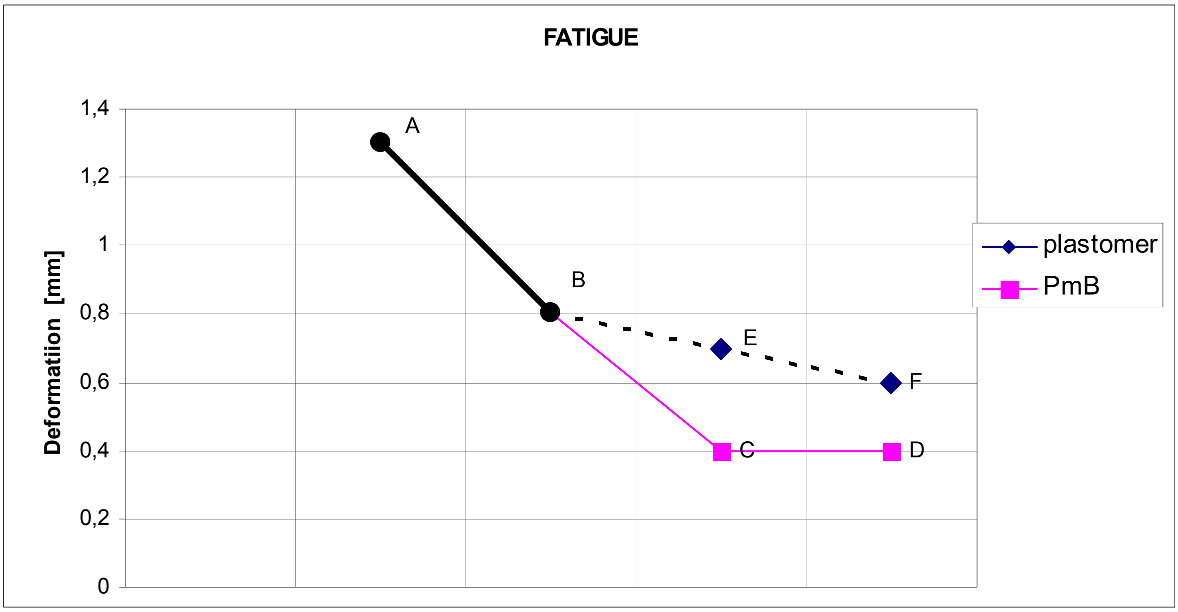

Figure 10 - The evolution of the fatigue resistance results

2.5. Comparison between the two alternative solutions who showed the best results

Table 5. Results comparison between mixes D and F

CHARACTERISTIC ***UM***	**Mixture D (PmB +fibres)**	**MM Mixture F (granulated plastomer)**
Stiffness modulus At 15º C in *Mpa*	**5 128**	**6 654**
Fatigue strain at 15 º C in *mm*	**0,4**	**0,6**
Dynamic creep at 50 º C Strain in *µm/m*	**24 538**	**20 457**
Dynamic creep at 50 º C Strain rate in *µm/m/cycle*	**1,9**	**1,5**
Wheel tracking test at 60 º C Rutting coefficient in *mm/ 1000 cycles*	**0,2**	**0,1**
Wheel tracking test at 60 º C Rut depth in *%*	**3,9**	**4,0**

In Table 5, the performances results of the analyses made on mixture with PmB (D) are compared with mixture MM added with granulated plastomer (F), both of them incorporate fibres.
The solution of previously modifying bitumen with SBS elastomer in order to obtain bitumen PmB, was more widespread before, due to the potential analysis of the properties of bitumen before use. Elastomers require a supply of higher mechanical energy in order to be mixed with the bitumen. For this reason, they are prepared in a specific mixer (generally with a special industrial unit plant) before the fabrication of bituminous mixture in hot mixing plant.

Plastomers do not require additional power for mixing, thus they can be previously mixed with bitumen or they can be introduced directly into the mixer of the hot mixing plant. The solution of introducing the modifier directly into the mixer can be adopted if there are only plastomers used. In case of plastomers with elastomers association, the bitumen will be previously modified.

The modifying solution is specific to each case, according to the technical requirements and economic possibilities.

The solution of modifying directly the mixture is newer, it is much easier and all the complications associated with the transport and storage of modified bitumen and also with the high energy consumption for its production are eliminated. In this case, the modifier is in the form of granules (Figure 10) which are inserted directly into the mixture, without changing very much the manufacturing process. Temperatures are generally the same, only the compaction temperature requires more attention, it should be at least 130 °C.

Following the comparative analysis of performance, advantages and disadvantages of these solutions in all stages of production and exploitation, it came out that the technology of modifying the mixture in the station is easier and more advantageous economically, offering the same level of performance with the use of modified bitumen solution.

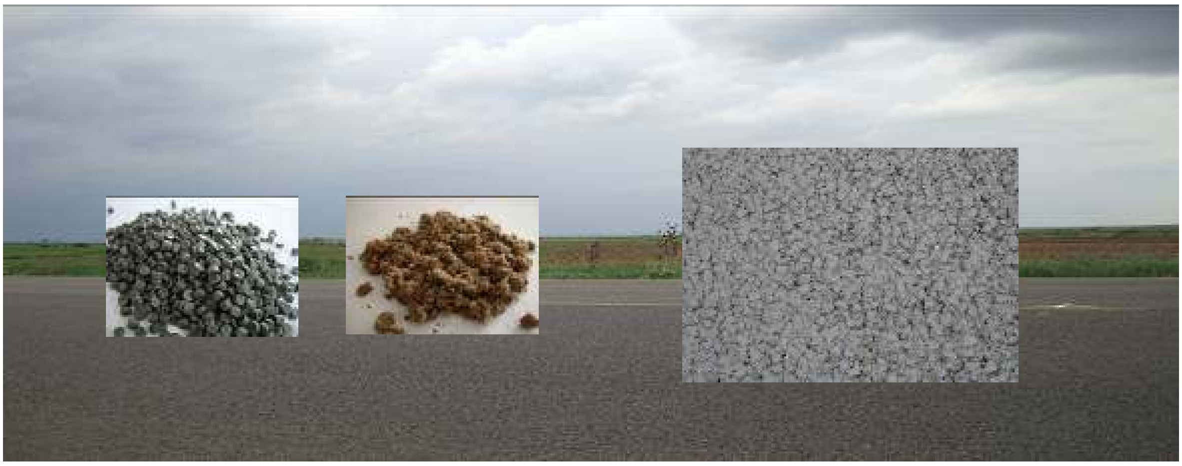

Figure 10 - Modified asphalt mixture MM with granulated polymers and fibres

3. CONCLUSIONS

According to this study it comes out that the solution of MM, modified asphalt mixture with polymers added in the mixture, could be a good solution for the quality improvement of the asphalt layers.
The use of granulated polymers allows the application even in isolated arias were the transport and storage of PmB are too difficult. The performances of the asphalt are similar with those obtained with PmB modified bitumen.
In “warm” arias it could be more recommended the solution E only with plastomer.
In cold and “temperate” arias, in order to eliminate the disadvantage related to the fragility at low temperatures of plastomers, it could be better to add also some fibres (solution F) so in this situation the mixture becomes more flexible.
We can see also that for elastomers, the association with fibres does not involve a substantially quality intake, so the PmB gives the best performances without fibres.

Modified mixture MM with plastomers added directly in the mixer is an economically advantageous solution, which can contribute to a faster execution and a higher level of performance for the road works. In Romania we have tested the performance of this solution in some temperate arias. We have used the combination of granulated polymers and fibres for wearing course, on a job site realized in the spring of 2010. Until now, the results are very good. The aria was exposed to a great variation temperature during a hot summer and a very cold winter.
It could be very interesting to carry out more studies in laboratory with some different compositions of asphalt mix for different wearing courses applications, to test these formulas in industrial conditions on the job sites, and to observe the behaviour during 3 years to extend this new technique in Romanian roads.

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