Asphalt mixtures for bituminous coatings with BF slag filler

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Abstract. Asphalt mixtures, as a construction material intended to produce bituminous coatings, consists of a homogenous mixture made from natural aggregates and bitumen. Replacing one of the natural rocks, the filler with artificial filler, a metallurgical industry waste material, will determine a saving of material and financial resources. This can be used as an actual method of environmental protection by conserving the relief, protecting localities from noise produced in stone quarries and reusing a waste material. The processing of granular blast furnace slag from the Liberty Galati plant by grinding it exceptionally fine, into filler and their subsequent use in the preparation of asphalt mixtures, leads to obtaining favourable results on two of the most used currently in the country, AC16 surf50/70 and AC 22.4 bin50/70. These values will provide an image on the behaviour resistance and their deformability under traffic. A high-water absorption can indicate a porous mixture and favours the penetration of water into the layer, water that can change its volume during freezing-thawing and can lead to cracks in the bitumen film, stripping, dislocation of pieces in the layer. A high creep can indicate a mixture which will deform under traffic, will form slopes, or will favour the phenomenon of exudation.
High stability may indicate a rigid mixture and under traffic does not have an elastic conduct, which can lead to cracks in the road surface.
Framing of the results and the appreciation of this conduct of asphalt mixture made with bf slag filler compared to a standard, leads us to the finding that the mixture is accurate and will withstand environmental factors.

1. Introduction

Asphalt mixtures, as a construction material, are obtained by mixing mineral aggregates with a bituminous binder, based on predetermined dosages, to obtain their best properties and good operating behaviour. Considering that the properties of the materials of which the asphalt mixtures are composed are different, depending on the physical-mechanical characteristics of the rocks, the size and the granularity, the properties of the bituminous binder, then the asphalt mixture formed by these components may have different properties. influenced by the properties of the component materials.
Regardless of the type of asphalt mixture to be prepared, the component materials must be:

- The natural aggregates should have the size and shape of the maximum layer size to be made of the respective asphalt mixture.
- The natural aggregates should have the shape as close as possible to the cubic one, so as not to crumble under the action of traffic.
- Its aggregates have a good mechanical strength, to give strength to the layer.
- The binder can coat all the granules, to unite them in a compact mass, in which the granules adhere to each other.
- Its filler does not react with the binder, to increase its viscosity, to give the mixture a higher resistance and a small deformation.

All these properties are directly influenced both by the characteristics of the component materials from the asphalt mixture, but also by the percentages with which each material participates in the mixture. This is an important aspect of a recipe study, to design an asphalt mixture, on this criterion depending mostly on the success of the recipe.
Given that the goal of an asphalt mixture is to be used in a communication path, as a road layer, the best behaviour will be observed both by laboratory study, in the design and testing stage, material, but also by compacting information in situ.

These are the starting premises based on which this study is made.

2. Design
To design the asphalt mixture recipe, respectively to establish the best proportions of the component materials to obtain its best characteristics, all its components were studied, both mineral and artificial aggregates and binder according to the provisions of norms, [7], [8], [9].

2.1. Mineral aggregates
Different properties of aggregates influence their performance in the composition, [14].

Regarding the maximum size, this feature is defined for the destination of the layer: a mixture will be made with the aggregates and they should be evenly distributed throughout the mass, compact, with a remaining void volume, without segregated granules or agglomerations of particles, [15].

To prepare an asphalt mixture we used mineral aggregates with continuous granularity, which will form asphalt mixtures on the principle of concrete, respectively small granules to fill the gaps between large granules, so that the volume of gaps is minimal. This involved the use of mineral aggregates with a wide granularity, distributed on each sieve that falls into the field $d_{\text{min}} - d_{\text{max}}$, and which includes a whole suite of fractions but also rich in exceptionally fine fractions, with a size below 0.063 mm. This distribution of the granules, characterized by the granulometric curve of the mineral aggregate, will also influence the granularity of the total mineral mixture in the composition of the asphalt mixture.

In the present study, mineral aggregates from the Suseni quarry - Harghita county and natural sand from the Tupilați gravel pit - Neamt county will be used. The aggregates consist in: Grade 0/4 mm crushed stone – Tupilati gravel pit, grade 0/4, 4/8, 8/16 and 16/22,4 mm crushed stone - Suseni quarry.

2.2. Bitumen
To obtain an asphalt concrete, this being a mixture of agglomerated mineral materials with a bituminous binder, plain petroleum bitumen for roads, non-paraffin, class 50/70 was used.

2.3. Filler
Added to the asphalt mixture, the filler will influence its properties, [10], [11], such as:

- stability and creep of asphalt mixtures varies significantly with filler dosage.
- improves binder viscosity, this being given primarily by its granularity.
- reduces the volume of gaps in the asphalt mixture.
- the filler ratio influences significantly the physical-mechanical properties of the mixture, as follows:
  - if the filler-binder ratio is increased by keeping the percentage of binder constant, then the obtained mixture will be more rigid, will have a high stability and low creep, and during the execution the mixture will require mixing and a more energetic compaction. The increased rigidity is given by the increase of the softening point of the fillerised bitumen as well as by the reduction of the volume of apparent gaps. Excess filler generally leads to a hard-to-work mixture, possibly even with uncoated granules, which also favours water penetration.
  - if the filler-binder ratio decreases while keeping the percentage of binder constant, then the mixture will be more elastic, will have a low stability and a high creep. The mixture will deform under the action of a low force, and especially at high temperature. Also, a low filler content favours the leakage of the binder from the surface of the granules due to its low viscosity.

For the present study we used blast furnace slag filler from the Liberty Galati plant and limestone filler.
3. The proportion of mineral aggregates in asphalt mixtures.

A high-performance asphalt mixture was made with a mineral skeleton consisted of sorts of chipping (Suseni quarry) and bf slag filler from Liberty Galati plant, the types as followings:

- AC 16 surf50/70 and AC 22.4 bin50/70, of asphalt concrete type with chipping - hereinafter referred to as standard asphalt mixtures for surface and binder layers of road systems.
- AC 16 surf50/70 and AC 22.4 bin50/70, asphalt concrete type with chipping - hereinafter referred to as asphalt mixtures with slag filler for surface and binder layers of road systems.

The granulometric curves obtained for the four types of asphalt mixtures are shown in figures 1, 2, 3, 4.

Figure 1. Granulometric curve of AC16 surf50/70 standard

Figure 2. Granulometric curve of AC22,4 bin50/70 standard
The asphalt mixtures prepared in the laboratory consists in the following batches:

- AC16 surf50/70 standard for surface layers with different bitumen dosage: 5.7%, 5.9% and 6.1%.
- AC22.4 bin50/70 standard for binder layers, with different bitumen dosage: 4.3%, 4.5% and 4.7%.
- AC16 surf50/70 with slag filler for surface layers, with different bitumen dosage: 5.7%, 5.9% and 6.1%.
- AC22.4 bin50/70 with slag filler for binder layers, with different bitumen dosage: 4.3%, 4.5% and 4.7%.
4. Tests
Tests were performed and the values obtained of the physical-mechanical characteristics on Marshall cylinders of the standard asphalt mixtures compared to those prepared with slag will be compared and interpreted. On each batch and each series of cylinders in the batch, the following determinations of the physical-mechanical characteristics were performed, in accordance with the provisions of the actual norms, to highlight the performances of the asphalt mixtures, [1]. Characteristic variations of the asphalt mixture and the regulated limits are shown in table 1 below.

| Physical-mechanical characteristics | Requested values\(^{(1)}\) \([9]\) | Results on asphalt mixture |
|-------------------------------------|----------------------------------|-----------------------------|
|                                    | AC 16 surf50/70 standard | AC 16 surf50/70 BF slag | AC 22,4 bin50/70 standard | AC 22,4 bin50/70 BF slag |
| Apparent density, kg/m\(^3\)       | Not imposed                | 2,376                      | 2,375                      | 2,368                      | 2,324                      |
| Stability at 60 degree C, KN       | 6,5...13                   | 10,30                      | 9,70                       | 8,30                       | 9,30                       |
| Marshall flow, mm                  | 1,5...4,0                  | 3,70                       | 3,70                       | 3,30                       | 3,20                       |
| S/I report (rigidity) min, KN/mm   | 1,6                        | 2,80                       | 2,70                       | 2,50                       | 2,90                       |
| Water absorption, % vol            | 1,5...5,0                  | 1,80                       | 1,70                       | 2,90                       | 4,20                       |

\(^{(1)}\) Values regulated by the norm, [9]

5. Conclusions
The results interpretation was performed based on the provisions of the norm, [9], by reporting to its limits and by comparing the two types of asphalt mixtures and issuing opinions and interpretations. This interpretation represents a first stage in the evaluation of the behaviour of asphalt mixtures in traffic, compared to the current requirements on the Romanian market.

Based on the performed measurements, a first difference was observed between the apparent densities obtained on the asphalt mixture with artificial filler (bf slag filler) compared to those with natural filler, this being due to the difference in density between artificial rock and natural rock. The apparent density of filler from natural rock is higher than the filler obtained from high furnace slag filler.

There was a relatively small decrease in the stability of mixtures with artificial filler compared to those with natural filler, this being due to the fineness of the filler but also to its density.

The asphalt mixtures were deformed relatively in the same way, the flow values falling mainly in the same interval, of 3 ... 4%. However, given that the flow of asphalt mixtures prepared with artificial filler is located at the minimum end of this range, respectively close to 3% compared to those with natural filler, which have a value close to the maximum end of the range, and by reporting creep stability, it can be concluded that the stiffness is approximately constant regardless of the type of mixture used. The S / I ratio in all cases is in the range of 2 ... 3%.

A significant difference is also observed in the water absorption process, this may be due to the granularity and porosity of the filler.

Regarding with the compliance with provisions of current standards, we conclude:
• the values obtained comply with the provisions of current technical regulations according to the information related in table 1, which leads us to assess their quality, up to this point of testing, as compliant.

Regarding with comparative analysis of the two types of asphalt mixture, we conclude:
• The density of the mixtures increases as the binder dosage increases.
• Water absorption decreases as the binder dosage increases.
• Stability increases as the binder dosage increases.
• The creep increases as the binder dosage increases.
Analysing in parallel the standard asphalt mixtures and those prepared with slag filler, the same tendency of increasing / decreasing the characteristic values can be observed, along with the variation of the binder dosage which will lead us to the conclusion that bf slag mixture will have a behaviour in traffic similar with a standard one, made with natural filler.

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