# USE OF RECYCLED GLASS AND PLASTIC MATERIALS IN ASPHALT MIXTURE RECIPES

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**Rezumat:** *Lucrarea prezintă compoziţia unei mixturi asfaltice (beton asfaltic) pentru stratul de bază compus dintr-un amestec bituminos care conţine agregate derivate din sticlă concasată și sortată reciclată și plastic mărunţit reciclat pentru a fi utilizată în structura rutieră. Utilizarea acestei rețete are câteva avantaje importante pentru protecția mediului, reducând astfel depozitele de deșeuri reciclabile de sticlă și plastic existente în țara noastră și economisind resursele locale. Rezultatele indică faptul că amestecul de mixtură cu agregate reciclate din sticlă și plastic poate fi o resursă valoroasă în proiectarea amestecurilor de asfalt și s-au obținut performanțe satisfăcătoare care respectă cerințele din normativele naționale.*

**Abstract:** *The paper presents the composition of an asphalt mixture (asphalt concrete) for the base layer composed of a bituminous mixture containing aggregates derived from recycled and sorted recycled glass and recycled shredded plastic to be used in the road infrastructure. The use of this recipe has several important advantages for environmental protection, thus reducing the existing recyclable glass and plastic landfills in our country and saving local resources. The results indicate that the mixture of asphalt with recycled glass and plastic aggregates can be a valuable resource for using in asphalt mixtures and satisfactory performance has been achieved that meet the requirements within national regulations.*

**Keywords**: *Bituminous mixture, Glass, Plastic, Recycling.*

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## 1. Introduction

Natural quarry aggregates are natural resources of the environment that cannot be regenerated and given the expansion and modernization of road

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networks it becomes necessary to look for alternative solutions for the production of high-performance asphalt mixtures that meet the requirements of national technical standards and regulations.

Asphalt mixing recipes with natural or artificial aggregates must be tested and comply with the technical regulations in force, namely the standard SR EN 13108 and AND 605:2016 "*Normative on the execution of hot asphalt mixtures. Technical requirements for design, preparation and implementation works* "[2].

Only a part of all plastics produced worldwide end up in a recycling process. Common recycling of plastics involves a huge number of resources to separate and clean a mixture of plastic waste (Resin Identification Code 1, 2, 3, 4, 5, 6, 7 and ABS) and turn it into pellets usable of their specific type, to make new plastic products, which in turn become waste after their recycled use.
Then the complexity of recycling begins again. In addition, not all types of plastic are suitable for recycling and are dumped directly in landfills or incinerated. The complexity and low cost-effectiveness of joint recycling compared to the lower price of new plastics explains the minimal efforts made to collect and use huge quantities of mismanaged plastics.

A similar complex process is involved in the recycling of glass waste, in particular the color separation of glass waste in order to make new products. Most of the glass waste collection in the world is done in bulk, where no distinction is made between color, leaving the collector with a mixture of unusable waste that mostly reaches landfills. In addition, the impurity of glass waste can be a problem for glass product manufacturers, leading to low commercial interest for these huge quantities of glass waste.

Strategies for the use of plastic (waste) in asphalt materials have been disclosed in the prior art, such as the use of plastic as a modifier, which is found in the works of McDonald, C. H (1975, U.S. Patent No. 3,891,585), Winters R E (1975, U.S. Patent No. 3,919,148), Nielson D. L (1978, U.S. Patent No. 4,068,023) and Forgac J. M (2005, U.S. Patent No. 6,844,418). Another strategy is the use of plastic and glass waste as a partial substitute for mineral aggregates in asphalt mixtures, as disclosed by Brown H. J (1974, U.S. Patent No. 3,852,046), Fishback G.M (1997, U.S. Pat. 5,702). 199) and Partanen, J. E (2010, U.S. Patent No. 2010/0022686) [1].

The use of glass (waste) in asphalt materials has been disclosed in the prior art by Sutton, P & Weston, S (2010, EP 2162490) in which glass waste is used as a partial replacement of mineral aggregates to create a mixture of asphalt mixture.

Another strategy for incorporating glass (waste) into mixtures of asphalt mixtures was disclosed by Pyeongjun, Y (2015, U.S. Patent No. 2017081516) in which glass fibers are coated with polypropylene resin, after which they are used as a substitute for mineral aggregates [1].
However, none of the technical studies describes a mixture of asphalt mixture with a combination of glass and plastic waste of all types (RIC) in exclusively granular form as total or partial replacement of mineral aggregates, without the need for custom equipment or additional process steps using conventional recycling machines, hot mix stations for asphalt mixtures and road asphalting equipment.

The surfaces of the road structure are subjected to daily moving traffic loads. This induces tensile stresses in the wear and bonding layer and / or the base of the asphalt mixture which, over time, causes irreversible deformations in the foundation layer of ballast or crushed stone. The deformations of the foundation cause, in turn, weak points and finally, large pits or cracks and deformations in the wear layer of the surface, being some of the most common, annoying and expensive problems of any road system.

In addition, the exploitation of mineral aggregates requires the opening of quarries, labor and emissions, while shredded plastics and crushed glass waste are abundantly available locally. The mixture of plastic and glass is a pragmatic solution to the problem of non-recycled waste, as well as improving infrastructure. It can be produced using existing (local) resources, such as waste collection and crushing / crushing facilities, asphalt mixing plants and road construction machines.

## 2. EXPERIMENTAL STUDY

### 2.1 Used materials

Within the laboratory of INCERTRANS S.A., a study was carried out between 22.07.2021-27.08.2021 regarding the elaboration of a bituminous mixture composed of a mixture of glass and plastic in proportion of 100%.

The works that were the object of the present study, consisted of performing physical-mechanical and dynamic tests on the mixture of glass and plastic, the recipe being made available by the beneficiary.The dosage of the components of the mixture with glass and plastic is set out in Table 1.

**Table 1.** Recipe with a mixture of glass and plastic

| Used materials | Percentages [%] |
|---|---|
| Plastic 0-10 mm | 31,5 |
| Glass 0-4 mm | 61,0 |
| Bitumen 50/70 | 7,5 |

Materials (Fig.1…Fig.3) used in this mixture are the following:

**Fig. 1.** Plastic 0-10 mm

**Fig. 2.** Glass 0-4 mm

**Fig. 3.** Bitumen 50/70

The plastic was mixed with preheated bitumen at $180^0$ C and glass heated to $220^0$C.
Cylindrical specimens were made on the Marshall impact hammer by applying 50 blows to each face within 50 to 60 seconds, with the sliding weight falling from a height of 460 ± 3 mm.

**Fig. 4**. Marshall impact hammer

**Fig. 5.** Compaction sample with 50 blows on each side of the glass and plastic mixture

Table 2 summarizes the results obtained from the physical-mechanical and dynamic tests on the bituminous mixture made of glass and plastic in a proportion of 100%.

**The conclusions of the first experimental study were the following:**
The density valuesof the mixture obtained for the mixture with glass and plastic are lower than those obtained for the mixture with traditional aggregates. The result is explained by the fact that the density of the mixture of glass and plastic is lower than that of classical aggregates. Also, the lower values of Marshall stability compared to the conditions imposed by AND 605:2016 are explained by the fact that the mixture of glass and plastic has a lower tensile strength than traditional aggregates.

**Table 2.** Values of characteristics considering the physical-mechanical and dynamic tests

| Nr. crt | Determined characteristics | UM | Determined average values | Test method |
|---|---|---|---|---|
| 1 | Bitumen content | % | 7.5 | |
| 2 | Apparent density | $Mg/m^3$ | 1258 | SR EN 12697-6 |
| 3 | Marshall stability | KN | 4.8 | SR EN 12697-34 |
| 4 | Flow rate | mm | 10.0 | SR EN 12697-34 |
| 5 | Maximum density (volumetric method) | $Mg/m^3$ | 1.402 | SR EN 12697-5 |
| 6 | Volume of voids on Marshall cylinders | % | 10.3 | SR EN 12697-8 |
| 7 | Percentage of volume of voids in the VMA mineral skeleton | % | 19.5 | SR EN 12697-8 |
| 8 | Percentage of voids volume in the mineral skeleton filled with VFB binder | % | 47.4 | SR EN 12697-8 |
| 9 | Resistance to permanent deformations (dynamic creep) | | | SR EN 12697-26 |
| | - deformation at $40^0$C, 200 KPa and 10000 pulses | µm / m | 23839 | |
| | - deformation speed at $40^0$C, 200 KPa and 10000 pulses | µm / m / cycle | 0.6 | |
| 10 | Stiffness modulus at $20^0$C, 124 ms | MPa | 1571 | SR EN 12697-26 |

**This mixture can be used as a base or bonding layer for sidewalks, alleys or other similar applications**. The layer is made by completely replacing the natural aggregates in the composition of an asphalt mixture, with materials from the recycling of glass and plastic waste. This layer will be covered with the next layer provided in the technical project or specifications.

At the same time, it was proposed to continue the study in the laboratory on an improved recipe by partially replacing the mixture of glass and plastic with a natural aggregate. Thus, the partial replacement of the glass-plastic mixture would lead to satisfactory results of the Marshall stability, the modulus of rigidity and the resistance to permanent deformation of the glass-plastic mixture.

**This asphalt concrete can be used as a base layer in the composition of a road structure for roads.** This layer will be used for roads of technical class III, IV and V according to normative AND ind 605:2016. The base layer will be covered with the next layer provided in the technical project or specifications.

The proposed recipe is BA 22.4 base 50/70 for the base layer so the mixture of glass and plastic was in proportion of 35% and the rest up to 100% were classic aggregates (quarry aggregates).

The asphalt mixture BA22.4 base 50/70 obtained by experimental studies consists of the following:

- **glass aggregates class granularity 0/4 mm and 4/8 mm,** representing 25% of the total mass of the mixture;
- **plastic aggregates granularity class 0/10 mm,** representing 10% of the total mass of the mixture;
- **crushed sand granularity class 0/4 mm and crushed aggregates granularity class 8/16 mm and 16/22.4 mm** (sand and aggregates represent a percentage of 61% of the total mass of the mixture);
- **filler,** in a percentage of 4% of the total mass of the mixture;
- **road bitumen type 50/70 pen** – 4,6 %.

Table 3 summarizes the results obtained from the physical-mechanical and dynamic tests on a bituminous mixture BA22.4 base 50/70 with quarry aggregates without glass and plastic and a bituminous mixture BA22.4 base 50/70 with glass mixture and plastic in the proportion of 35% and quarry aggregates up to 100%.

**Table 3.** Comparison of results according standards

| Nr. crt | Characteristics | Determined average values | | Test method | References according AND 605: 2016, for BA 22.4 base 50/70 |
|---|---|---|---|---|---|
| | | BA22.4 50/70 base with quarry aggregates without glass and plastic | BA22.4 50/70 base with glass and plastic mixture and quarry aggregates. | | |
| 1 | Bitumen content, % | 4,4 | **4,6** | SR EN 12697-1:2020 | Base layer minimum 4 |
| 2 | Apparent density, $Mg/m^3$ | 2319 | **1976** | SR EN 12697-6.2020 | - |
| 3 | Water absorption, % | 4,0 | **4,9** | Normativ AND ind 605 | |
| 4 | Marshall stability, KN | 8,1 | **12,8** | SR EN 12697-34:2020 | 6,5. . .13 |
| 5 | Flow rate, mm | 3,8 | **4,0** | | 1,5. . .4,0 |
| 6 | Maximum density (volumetric method) $Mg/m^3$ | - | **2.141** | SR EN 12697-5.2019 | - |
| 7 | Volume of voids on Marshall cylinders, % | 6,4 | **7,7** | SR EN 12697-8:2019 | Road technical class III-IV maximum 10 |
| 8 | Percentage of volume of voids in the VMA mineral skeleton, % | 16,4 | **16.6** | SR EN 12697-8:2019 | - |
| 9 | Percentage of voids volume in the mineral skeleton filled with VFB binder, % | 60,7 | **53,7** | SR EN 12697-8:2019 | - |
| 10 | Resistance to permanent deformations (dynamic creep)<br>- deformation at $40^0$C, 200 KPa and 10000 pulses, µm/m<br>- deformation speed at $40^0$C, 200 KPa and 10000 pulses, µm/m/cicle | 10453<br>0,5 | **16128**<br>**0,6** | SR EN 12697-25:2016 | Road technical class III-IV<br>Maximum 30.000<br>Maximum 3 |

| | | | | | |
|---|---|---|---|---|---|
| 11 | Stiffness modulus at $20^0$C, 124 ms, MPa | 7456 | **5709** | SR EN 12697-26:2018 | Minimum 5600 |

## 3. CONCLUSIONS

The use of asphalt mixtures containing recycled glass and plastic aggregates has some important advantages for environmental protection, thus reducing existing landfills in our country and saving local resources. As is well known, hot asphalt mixing is a building material made by a process that involves heating natural aggregates and bitumen, mixing the mixture, transporting it and putting it into operation by hot compaction [2].

In order to produce asphalt mixtures, a wide variety of mineral aggregates are used, both natural and from unconventional (artificial) sources, respectively recycled construction aggregates, glass and plastic aggregates, as well as blast furnace or steel slag aggregates.

The study carried out in the laboratory of INCERTRANS S.A., presents the composition of an asphalt mixture (asphalt concrete) for the base layer composed of a bituminous mixture containing aggregates derived from crushed and sorted recycled glass and recycled shredded plastic to be used in the road structure.

The use of this recipe has several important advantages for environmental protection, thus reducing the existing recyclable glass and plastic landfills in our country and saving local resources.

The results indicate that the mixture with recycled glass and plastic aggregates can be a valuable resource in the design of asphalt mixtures and satisfactory performance has been achieved that meets the requirements of the respective national regulations and normative AND 605:2016.

The density values obtained for the mixture with natural aggregate are higher than those obtained for the bituminous mixture with glass and plastic. The result is explained by the fact that the density of the mixture of glass and plastic is lower than that of classical aggregates. Both recipes gave a good value to the Marshall stability test, the best value is 12.8 KN for the glass and plastic recipe which means that it can be used with excellent results in asphalt concrete. Both recipes comply with the requirements imposed by the rules in force, respectively a minimum of 6.5 KN and a maximum of 13.0 KN.

The results indicate satisfactory values of the Marshall flow index in both recipes. The results were within the required minimum of 1.5 mm and the maximum of 4.0 mm imposed by normative AND 605:2016.

The volume of voids at 80 gyrations, for the 2 recipes falls within the condition imposed by normative AND 605:2016 respectively maximum 10% for a road of technical class III-IV.

In the future it is necessary to study other percentages of replacement of natural aggregates with recycled aggregates of glass and plastic but also the use of additive bitumen in the mixing recipe and see what improvements this aspect brings on new mixtures to be used in the bonding layer.

## 4. REFERENCES

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