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ECOLOGICAL SOLUTIONS APPLIED TO HOT MIX ASPHALT

Cătălina Lixandru, PhD. Student, Technical University of Civil Engineering Bucharest, e-mail: lixandru_catalina@yahoo.com

Mihai Dicu, Prof. PhD Eng., Technical University of Civil Engineering Bucharest, Department of Roads, Railways and Construction Materials, e-mail: mdicu@cfdp.utcb.ro
Carmen Răcănel, Assoc. Prof. Dr. Eng., Technical University of Civil Engineering Bucharest, Department of Roads, Railways and Construction Materials, e-mail: carmen@cfdp.utcb.ro
Adrian Burlacu, Lecturer Dr. Eng., Technical University of Civil Engineering Bucharest, Department of Roads, Railways and Construction Materials, e-mail: aburlacu@cfdp.utcb.ro

Rezumat

Mixturile asfaltice sunt materiale compozite realizate din amestecuri de agregate naturale sau artificiale, filer și bitum, având la baza dozaje bine stabilite și o tehnologie adecvata astfel încât să rezulte un material rutier cât mai durabil posibil.

În urma studiilor efectuate pe plan internațional cât și pe plan național, s-a demostrat că se pot înlocui cu succes agregatele naturale cu zguri siderurgice sau de oțelărie, care prin prelucrare și sortare la dimensiuni necesare sunt cele mai adecvate din punct de vedere al proprietăților fizico-mecanice.

Mixturile asfaltice ecologice obținute prin înlocuirea agregatelor minerale cu zguri siderurgice vor intra în alcătuirea structurii rutiere, începand cu studiul pentru un strat de bază. Pentru evaluarea performanțelor mixturilor asfaltice în care agregatele naturale sunt înlocuite cu agregate artificiale, se va studia o mixtură asfaltică pentrul stratul de bază respectiv AB 31.5 pentru care se vor face încercări pentru trei rețete de mixturi asfaltice: mixtura asfaltică cu agregate minerale de carieră, mixtura asfaltică în care agregatele minerale vor fi înlocuite în proporție de 50 % cu zguri siderurgice și o mixtură asfaltică care va conține zguri siderurgice în proporție de 100%.
Încercările de laborator se vor face în cadrul Laboratorului de Drumuri din cadrul Facultății de Căi Ferate, Drumuri și Poduri, Universitatea Tehnică de Construcții București; rezultatele obținute vor fi detaliate sub forma de tabele și grafice, concluziile urmând a face aprecieri asupra performanțelor mixturilor asfaltice ecologice. Astfel, se vor stabili performanțele mixturilor asfaltice ecologice comparativ cu calitățile mixturilor asfaltice clasice, folosind următoarele încercări: determinarea densității aparente, a volumului de goluri, caracteristicilor Marshall și a modulului de rigiditate.

Cuvinte cheie: mixturi asfaltice ecologice, deșeuri industriale, zguri siderurgice

Abstract

Asphalt mixtures are composites materials made from blends of natural or artificial aggregates, filer and bitumen with well-established based dosages and appropriate technology with the purpose to determine a road material as sustainable as possible.

After internationally and nationally studies, it has been demonstrated that it can successfully replace natural aggregates with steel slags, which by size-sorting and processing are the most appropriate in terms of physical and mechanical properties.

Ecological asphalt mixtures obtained by replacing mineral aggregates with steel slag composition will enter the road structure, starting with the study for base coat. To evaluate the performance of asphalt mixtures in which natural aggregates are replaced with steel slag, the asphalt mixture will be studied for a base layer respectively AB 31.5 and will be made testing for three different recipes: asphalt mixture with 100% mineral aggregate, asphalt mixture in witch the mineral aggregates will be replaced with a proportion of 50% steel slag and asphalt mixture that will contain steel slags 100%.

Laboratory tests will be done in the Laboratory of Roads in the Faculty of Railways, Roads and Bridges at Technical University of Civil Engineering Bucharest; the results will be detailed in tables and graphs, the findings will make assessments on the ecological performance of asphalt mixtures. Thereby will be determined the performance of asphalt mixtures with artificial versus conventional aggregates using the following tests: determination of bulk density, the volume of voids, Marshall characteristics and rigidity.

Keywords: ecological asphalt mixtures, industrial wastes, steel slags

1. INTRODUCTION

Appreciating the properties of the materials that compose the asphalt mixes, even if we speak about the classical asphalt mixes or the ecological asphalt mixes, it is required both for the composition and dimensioning of road structure. The quality of the road structure is determined by the quality of each road layer, which requires the quality for the composing materials.

In many developed countries, concern over the waste production, conserving resources and reducing materials costs has focused on reusing solid waste. Processing waste properly can meet various specifications in construction. Thus, the recovery of useful materials from industrial waste provides not only environmental gains, but also helps conserving natural resources.

It became therefore necessary that the research efforts in using different kind of solid waste are in need for more attention. Slag is a by-product of the manufacture of iron and steel. The iron in the furnace can be prepared without producing blast-furnace slag as a by-product. Similarly, the steel can be prepared in a basic oxygen furnace (BOF) or an electric arc furnace (EAF) without producing the steel slag.

The use of slag aggregates in asphalt mixes by replacing natural aggregates is a promising concept. Slag aggregates are already used in asphalt mixes for a long time due to their mechanical properties, improved stiffness, porosity, wear resistance and resistance capacity. There were studies and tests on how useful the steel slag aggregate and the steelworks are for asphalt. The only possible problem of slag aggregates is represented by their expansive features and reactions of the slag with other ingredients of asphalt mixture.

In recent years, the studies on environmental quality showed that the steel industry is one of the industries whose activities involve a significant consumption of natural resources and energy, and is also generating waste that because of the recovery potential can be transformed into secondary products. Numerous studies have demonstrated that recovery by recycling provides optimum environmental benefit and economic benefits. Therefore, talking about waste as a source of profit, must consider two issues: the effect on the environment and the economy. It has been shown, especially in developed countries, that steel slag remaining after the extraction of iron wastes can be processed and sorted at the proper dimensions and this can successfully replace current natural aggregates in road construction works.

Natural aggregates (gravel, sand and crushed stone) are essential non-renewable resources that can be used for infrastructure and civil engineering. It is estimated a foreseeable growth of the construction industry that will complicate the aggregate supply, management and quarry activities that are still associated with local phenomena of illegality and / or strong environmental effects. Moreover, a significant additional problem that may be associated to aggregates industry is the wasting of potential resources through inert waste dumping, especially the ones that come from the steel industry. Thus inert waste may be actually processed in the technically available recovery unit, sustainable economic and social opportunity, to become recycled aggregates, which could be used as an additional resource for the supply of aggregate.

In the metallurgical industry in Romania, there are defined two major types of by-products (wastes):

a) ballast furnace slags obtained in manufacturing the iron production in blast furnace crucible at a temperature of max. 1600 ° C, made up of impurities in the iron ore (Si and Al) combined with calcium and magnesium oxides, mineral flux;

b) steel slag obtained from iron making, composed of silicates, calcium aluminoferite and oxides (from calcium, iron, magnesium, manganese).

2. THE PURPOSE OF THE STUDY

The primary objective of this study is to replace natural aggregates with artificial aggregates obtained from slags, in varying percentages, with the purpose to determine the performances of asphalt mixtures which has in composition such aggregates. The scope of this research was to analyse the behavior of an asphalt mixture in which was replaced a certain percentage of aggregates, as follows: first recipe in which the mixture is composed of 100% calcareous aggregates, the second recipe has in composition 50% calcareous aggregates and 50% artificial aggregates, and the third recipe consists 100% of slag aggregates.

This paper presents a comparison of results obtained in the Laboratory of Roads of Technical University of Civil Engineering on an asphalt mixture for base course – AB 25- with two different types of aggregates, varying the percentages used.

3. LITERARTURE REVIEW

This chapter describes the results of a detailed documentation study in order to determine the available information on the use of aggregates obtained from blast furnace slags or steel slag. The main components of the slags are CaO, SiO_2, Al_2O_3, MgO and Fe_2O_3. The chemical composition of the slag is highly dependent on the manufacturing of steel or cast iron, as well as the use of additives. Various additives and different amounts used (used for processes such as cooling and subsequent treatment of slags) can influence the properties of slags.

A study conducted in Malaysia, in order to determine the properties of asphalt mixtures when using steel slags aggregates, shows that asphalt mix obtained with steel slags aggregates have a higher content of optimum bitumen compared with the same asphalt mixture but with conventional aggregates. This is possible due to the greater porosity of slag aggregates. Test results for stiffness modulus show that the slag mixture has a higher value compared to conventional aggregate mixture. Regarding rutting, the mixture prepared with slag aggregate has higher force of cohesion than conventional mixture. Creep test shows us that slag mixture has lower permanent deformation than mixture with conventional aggregates. The reason behind these results is due to the properties of steel slags which has a greater adherence to the asphalt mixtures. [1]

In Indonesia, following a study by researchers, determined that the use of steel slag aggregates in porous asphalt mixtures offers the best performance of mix asphalt, both for stability and permeability. [2]

In Croatia was studied at the University of Zagreb the possibility of using steel slag in the production of asphalt mixtures and from numerous laboratory tests performed on such mixtures (comparison of physical properties of steel slags aggregates and the classical ones: rutting, resistance to slippage and the surface texture of asphalt mix) and concluded that the steel slags used in this study can successfully replace natural aggregates and that the evaluation of the slags has like results the mechanical properties that meet the necessary features for use them in asphalt mixes. [3]

Researchers in India conducted a study analysing furnace slag and steel slag as a material component in the road structure. They say after the tests carried out that the slag can be used in asphalt mixes and that the mixtures has acceptable properties that meet at least the minimum requirements for certain qualities. [4]

In Saudi Arabia, annual production in 2002 was 350 000 tonnes and they estimate that in 2003 the production will increase to 500 000 tonnes. The big problem in Saudi Arabia is the climate, due to high temperatures which greatly influence the permanent deformations/rutting and the fatigue resistance in flexible road structures; these are extremely common phenomena in flexible structures. The use of steel slags aggregates in asphalt mixes can be beneficial in many ways. They may outperform in terms of natural aggregates the skid resistance and a better fatigue life. [5]

In Canada, based on studies on asphalt mixtures litter on highways and asphalt mixtures made in the laboratory, it appears that asphalt mixes containing steel slags offers very good slip resistance for most types of asphalt mixtures.

Deneele and others conducted a study in the Central Laboratory of Bridges and Roads in France in order to increase the knowledge about the asphalt mixes that have in composition steel slags that come from industrial waste exploitation. Thus, after numerous studies on asphalt mixtures with different percentages of steel slag they concluded that it may be beneficial used in road construction. However, the technical requirements should be checked more intensively, especially for sections of roads in order to improve mainly the economic and ecological benefits. [6]

In Romania all existing types of slag were studied (from Resita, Galati, Campia Turzii, Targovişte), but the demand for this type of aggregates in our country still remains low, and it is a particularly interest for the small grain size like 1.6- 8 mm, which is also a low amount in the road structure. Tests showed that can be used slag aggregates for the size 4-8 mm in a percent of 25% in an asphalt mixture. Through this study has shown that it can improve the quantity of slag aggregates from 10% to about 55-60%. [7]

4. EXPERIMENTAL PROGRAM

4.1. Used materials and the recipe of asphalt mixtures

The study was conducted on the same recipe but the asphalt mixture made up with two different types of aggregates in percent and different grain sizes on asphaltic mix type AB 25 for the base layer, according to the normative AND 605 and the European Standard SR EN 13108-1 in order to determine an optimal mix of aggregate, filler and bitumen were chosen materials that meet specific quality standards. [8], [9]

The aggregates used (size 0/4, 4/8, 8/16 and 16/25 mm) were calcareous aggregates from Hoghiz quarry, crushed aggregates from slag ArcelorMittal Galati, Lafarge limestone filler and bitumen D50/70 OMV.

Materials and percentages used in the recipe of the asphalt mix study are presented below:

- crushed stone 16/25 mm: 20.06%
- crushed stone 8-16 mm: 19.10%
- crushed stone 4/8 mm: 15.28%
- crushed sand 0/4 mm: 22.92%
- Natural sand 0/4 mm: 15.28%
- filler: 2.87%
- Bitumen: 4.5% at mixture

For this recipe were prepared three types of asphalt mixtures, following precisely the percentages shown above, wherein the first mixture comprises 100% calcareous aggregates, the second contains 50% of the calcareous aggregates and 50% steel slag aggregates and a mixture of 100% of slag aggregates.

In order to achieve laboratory tests were made cylindrical samples of asphalt mix compacted with the Marshall hammer, to which were applied 50 strokes on each side of the sample, and manufacturing was done at 160 ... 175°C.

The steel slag used in asphalt mix composition is a blast-furnace slag, and it is added in the mix without requiring a special pre-washing or special mixing equipment.

Experimental study followed that through the results of laboratory tests may reveal which is the performance of the asphalt mix that has in composition artificial aggregates obtained from slag, according to the used proportion.

4.2. Laboratory tests

In order to highlight the performance of AB 25 asphalt mix steel slag aggregates, laboratory tests were conducted, for which the conditions are stipulated in the European Standards.

The study includes tests carried out on the AB 25 asphalt mix with a 50% calcareous aggregates and 50% steel slag aggregates (noted with the A mixture), the mixture with 100% steel slag aggregates (noted B mixture) and an asphaltic mixture with the mineral skeleton consisting of 100% calcareous aggregates (noted by C mixture).

To highlight the performance of asphalt mix for the base layer AB 25 having in composition various combinations of calcareous and slag aggregates, the following tests were conducted in the Laboratory of Roads from Faculty of Railways, Roads and Bridges:

- Marshall test on cylindrical samples, according to SR EN 12697-34, at a temperature of 60°C resulting the values for Marshall stability and the flow index;
- The indirect tensile test IT-CY on cylindrical samples according to SR EN 12697-26 Appendix C at a temperature of 20°C and is resulting the stiffness modulus of asphalt mixture;
- Determination of the water sensitivity of asphalt mixtures, according to SR EN 12697-12;
- Determination of the water absorption according to Normative AND 605.

The results of the laboratory tests reveal the influence of modified aggregates with recycled products, such as slags. It was elected an asphalt mixture with calcareous aggregates, which was previously studied in laboratory and has achieved satisfactory results for its using as a base layer mixture.

The results are presented as graphs in Figure 1 (bulk density), Figure 2 (Marshall characteristics), Figure 3 (stiffness modulus on cylindrical samples IT-CY) and Figure 4 (water sensitivity ITSR and water absorption).

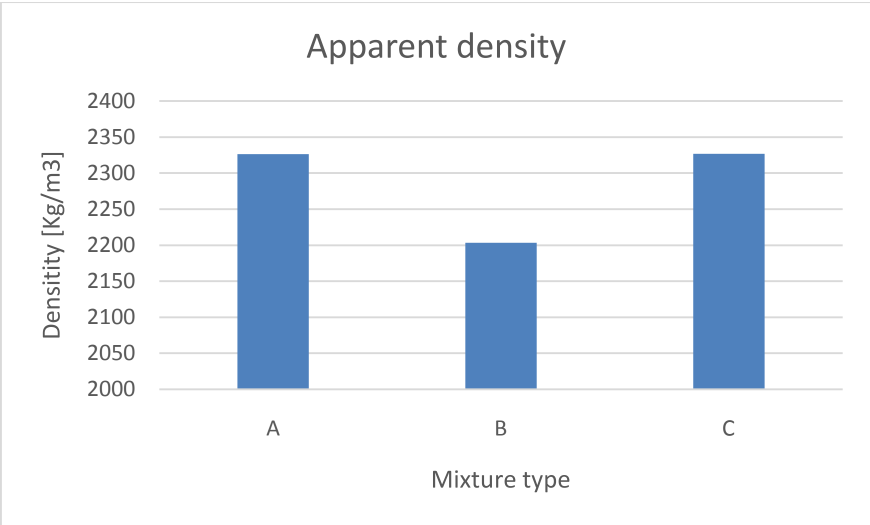

Figure 1. The influence of slag percentage on the asphalt mixture density

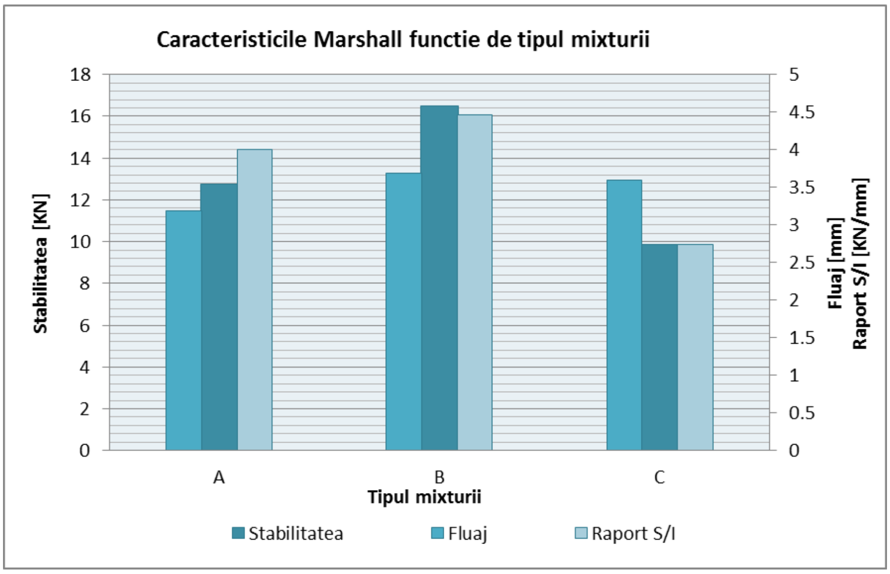

Figure 2. The influence of the slag percentage on the Marshall characteristics

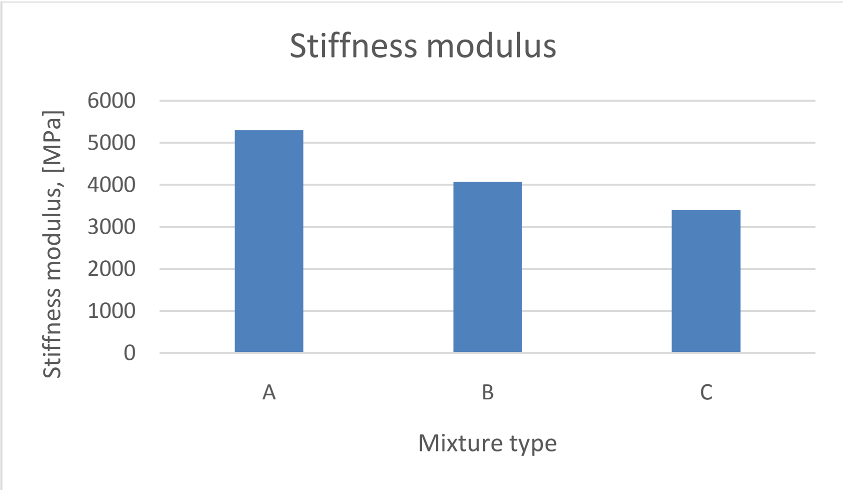

Figure 3. The influence of the slag percentage on the stiffeness modulus

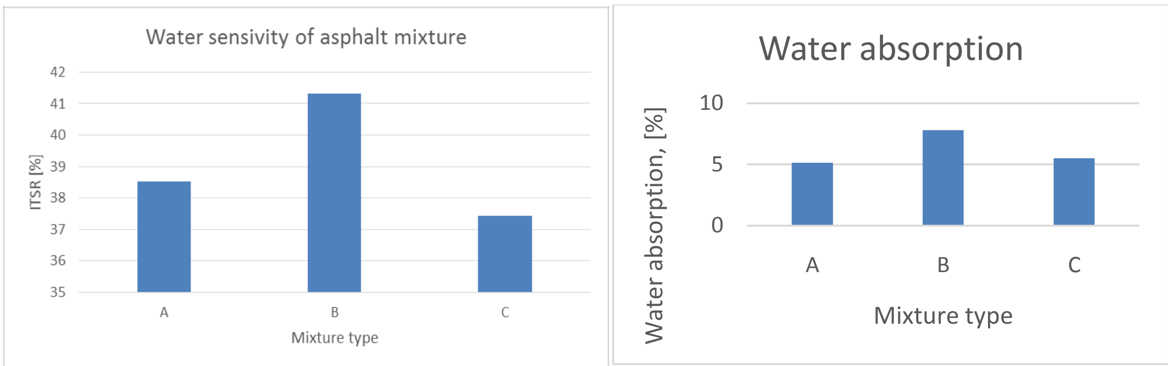

Figure 4. The influence of the slag percentage on the water absorption and water sensivity, ITSR

5. CONCLUSIONS

This study reveals important conclusions regarding the possibility of replacing natural aggregates with steel slag aggregates.

Marshall stability determined in the laboratory indicates the classification in the same category values for mixtures with 50% and 100% steel slag ($S_{min12.5}$ and S_{max15}) and in a lower category to mix with calcareous aggregates (S_{min10} and $S_{max12.5}$). All values meet the minimum requirement for stability in current standards (min. 6.5 kN). For the Marshall index flow, the values obtained fit into the category F3 for the asphalt mix with calcareous aggregate and for the mixtures containing slag aggregate in category F5.

The stiffness modulus, an important feature of the asphalt mix, since it is considered in the calculation of the dimensioning of the flexible and mixt road structures has values ranging from 3400 MPa (for the mixture with the calcareous aggregates) to 5,300 MPa (for the mixture with 50% steel slag aggregates). From the study of obtained results on the stiffness modulus appeared that the asphaltic mix AB 25 made with calcareous aggregates presents enough rigidity and can be used only in base layers for roads with technical class IV or V (roads with light traffic) and reduced service life, the blend between calcareous aggregate with steel slag aggregates is greatly improving the rigidity modulus of the asphalt mix.

Resistance to water was determined by two existing methods in our country: water absorption and water sensitivity ITSR. All the tested mixtures are fitting in the same category for ITSR (ITSR90) and water absorption exceeds the limits imposed by current regulations (1.5 - 5). Thus, a special attention should be paid to the layer which will be put into practice in the presence of water, the water must be prevented to reach the base layer through the execution of some bituminous pavements watertight.

The main conclusion arising from this study is that partial or total substitution of calcareous aggregates significantly affects physical and mechanical characteristics of the asphalt mix. It is primarily essential that asphaltic mix to have well established dosages that are leading to a material with satisfactory behavior over time. Considering the availability of slag stored in heaps in several areas of our country, they can be incorporated into the road structures, both in the layers of granular materials of foundation road - a situation quite common already - but even in the asphalt mixtures for road base layers for roads with IV technical class.

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