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REPLACEMENT OF NATURAL AGGREGATES USED IN ROAD STRUCTURES WITH STEEL SLAG

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Abstract. This work facilitates the application of modern technologies for road construction, by using steel slag instead of natural stone aggregates. This procedure will result in a significant decrease in the cost of works (slag, being an industrial waste, is much cheaper than natural aggregate). In the same time, the use of slag aggregates can result in protection of the environment, by eliminating slag storage spaces and by preserving the natural environment (extraction of natural aggregates may disturb groundwater and intensify erosion etc). Marshall stability, flow index and bulk density were determined for both kinds of aggregates, in order to find if the steel slag can safely replace the natural aggregates. By comparing the experimental results obtained for the two kinds of aggregates, it was confirmed the possibility of successfully using of steel slag as a substitute for natural aggregates in the base layer of a road structure.

Keywords: *aggregate, environment, replacement, road structures, steel slag.*

Introduction

Road construction involves large quantity of construction materials, most of them obtained from natural sources. To achieve a sustainable development, using the steel slag as a substitute for natural aggregates must be taken very seriously. More than 90% of this is asphalt pavement, which has the advantages of low vibration, low noise, short construction time and convenient maintenance [1]. Expressway need lots of construction and maintenance, and more than 90% of the components of asphalt pavement are aggregates, which causes the depletion of natural resources [2]. Therefore,
capacity of recycling solid waste and industrial smelting waste are becoming an effective option to relieve the supply pressure of natural aggregate resources [3].

Steel slag is the main solid waste in steel industry, accounting for more than 10% of the steel production [4]. According to the different steelmaking processes, steel slag can be classified into three types: Electric arc furnace (EAF) slag, basic oxygen furnace (BOF) slag and ladle furnace (BF) slag. The large steel slag can meet the needs of aggregates for road construction, and it has good mechanical properties and high alkalinity [5]. The steel slag asphalt mixture has become an increasingly popular research topic in the field of environmental protection road materials in recent years [6].

1. Field of application

According to the provisions of the technical approval no. 004-07/666-2002, steel slag aggregates can be used for roads of technical class II - V or streets of technical category II – IV, in order to reduce execution costs by replacing the ballast used for the base layer [7].

If some of the determined values do not fall within the limits set out in legislation, it is possible to improve the behavior of these materials by using a certain additive or a mixture of additives [8].

For steel slag aggregates, both chemical stability, as an essential condition, and storage and preparation of the material (permanent spraying with water for a period of at least six months after their production) must be monitored [9].

2. Description of works and materials

In order to determine to what extent the steel slag can replace the natural aggregates in the asphalt mixtures, specific tests were performed on samples made of both types of materials.

At the beginning, two asphalt concrete compositions type BAD 25 were made with 6.3 % bitumen, using 0-8 crushed stone (samples B1, B2 and B3) and 0-8 steel slag (samples D1 and D2). The average values of the physical and mechanical characteristics determined on cylindrical specimens made of asphalt mixtures are shown in Figures 1, 2 and 3.

In Figure 1, the graphic colored in blue shows the Marshall stability determined on 0-8 control samples, while the graphic colored in violet shows the stability determined on 0-8 slag samples (for both kinds of samples, the content of bitumen was 6.3%).

The values of Marshall stability obtained when using slag as an aggregate were 1000,00 daN, 1005,20 daN and 1010,00 daN and by statistical processing we got an average value of 1005,00 daN, which is bigger than the value obtained when using the natural aggregate (946,67 daN).

In Figure 2, the graphic colored in blue shows the flow index (deformation) determined on 0-8 control samples, while the graphic colored in violet shows the flow index (deformation) determined on 0-8 slag samples (for both kinds of samples, the content of bitumen was 6.3%).

The deformation values obtained when using slag as an aggregate were 220,25 mm, 224,45 mm and 228,75 mm and by statistical processing we got an average value of 224,50 mm, which is lower than the value obtained when using the natural aggregate (229,33 mm).

In Figure 3, the graphic colored in blue shows the bulk density determined on 0-8 control samples, while the graphic colored in violet shows the bulk density determined on 0-8 slag samples (for both kinds of samples, the content of bitumen was 6.3%).

The values of the bulk density obtained when using slag as an aggregate were 2487 kg/m^3, 2488 kg/m^3 and 2491 kg/m^3 and by statistical processing we got an average value of 2489 kg/m^3, which is much bigger than the value obtained when using the natural aggregate (2345 kg/m^3).

The result of the tests show that using the aggregate of BOF slag can significantly enhance the Marshall stability, the flow index and bulk density, when comparing with the natural stone.

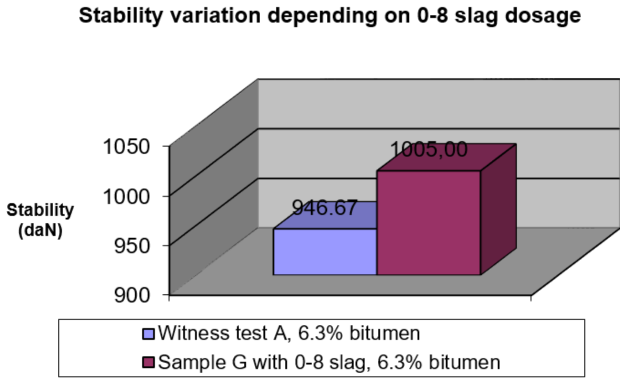

Figure 1. Comparison between Marshall stability determined on control and 0-8 slag samples.

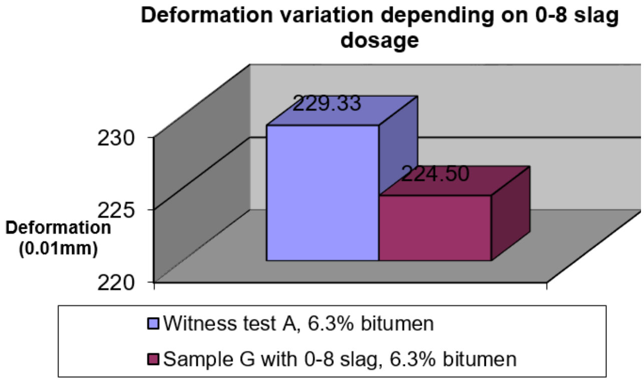

Figure 2. Comparison between the flow index determined on control and 0-8 slag samples.

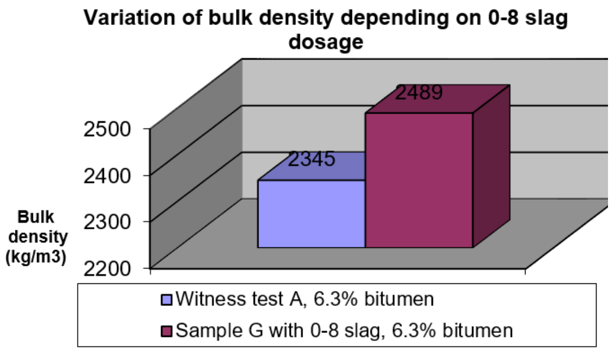

Figure 3. Comparison between bulk density determined on control and 0-8 slag samples.

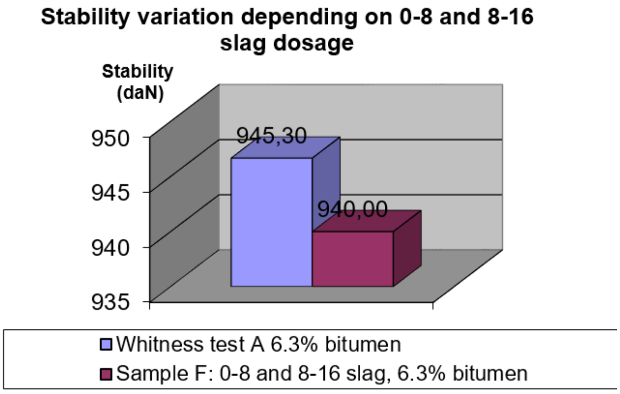

Figure 4. Comparison between Marshall stability obtained on control and 0-8+8-16 slag samples.

Two other BAD 25 asphalt concrete compositions were than made with 6.3 % bitumen, using 0-8+8-16 crushed stone (samples B1, B2 and B3) and steel slag 0-8+16-25 (samples E1 and E2).

The average values of the physical and mechanical characteristics determined on cylindrical specimens made of asphalt mixtures are shown in Figures 4, 5 and 6.

In Figure 4, the graphic colored in blue shows the Marshall stability determined on 0-8+0-16 control samples, while the graphic colored in violet shows the stability determined on 0-8+0-16 slag samples (for both kinds of samples, the content of bitumen was 6.3%). The values of Marshall stability obtained when using slag as an aggregate were 937,40 daN, 940,30 daN and 942,60 daN and by statistical processing we got an average value of 940,00 daN, which is a little bit lower than the value obtained when using the natural aggregate (945,30 daN), but still acceptable.

In Figure 5, the graphic colored in blue shows the flow index (deformation) determined on 0-8+0-16 control samples, while the graphic colored in violet shows the flow index (deformation) determined on 0-8+0-16 slag samples (for both kinds of samples, the content of bitumen was 6.3%). The deformation values obtained when using slag as an aggregate were 210,00 mm, 214,45 mm and 219,00 mm and by statistical processing we got an average value of 214,50 mm, which is lower than the value obtained when using the natural aggregate (227,40 mm).

In Figure 6, the graphic colored in blue shows the bulk density determined on 0-8+0-16 control samples, while the graphic colored in violet shows the bulk density determined on 0-8+0-16 slag samples (for both kinds of samples, the content of bitumen was 6.3%). The values of the bulk density obtained when using slag as an aggregate were 2460 kg/m^3, 2461 kg/m^3 and 2464 kg/m^3 and by statistical processing we got an average value of 2462 kg/m3, which is much bigger than the value obtained when using the natural aggregate (2350 kg/m^3).

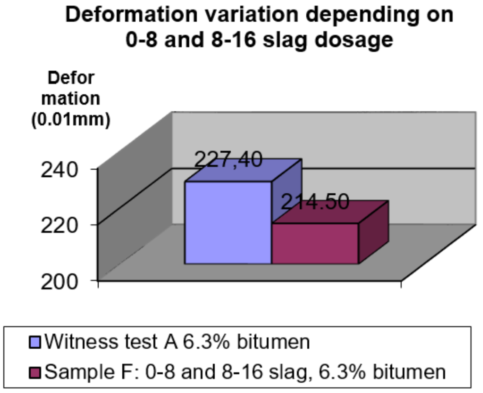

Figure 5. Comparison between the flow index determined on control and 0-8+8-16 slag samples.

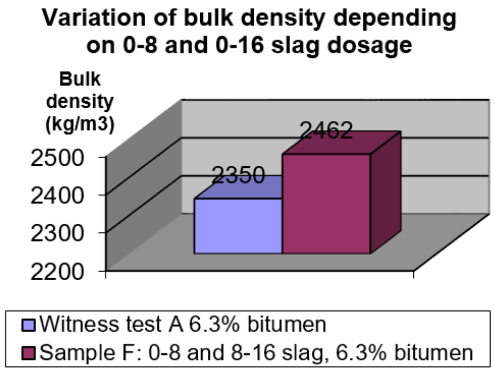

Figure 6. Comparison between bulk density determined on control and 0-8+8-16 slag samples.

3. Final considerations

When producing BOF slag coarse aggregates, the excessive angularity of the aggregates should be controlled. This will help to improve the service life of BOF slag layers and the promotion of slag [10].

The BOF slag coarse aggregates have a higher water absorption and a higher effective density, among which the pyrolytic BOF slag has the largest effective density [11].

The rough surface texture (high water absorption) of BOF slag and good adhesion with asphalt result in a good moisture resistance property of the asphalt mixture [12].

Using BOF slag coarse aggregates will result in a significant increase in the percentage of air voids in asphalt mixture. The rough surface texture and higher sphericity of BOF slag will cause the increase of the air voids of asphalt mixture. Besides, if the BOF slag has excessively high angularity, it will have an adverse effect on the increase of air voids. Also, if BOF slag has excessive angularity value, the edge angle of BOF slag would be destroyed during the compaction of the asphalt mixture, which would result in the decrease of the air voids of the asphalt mixture [13].

The disadvantages of using steel slag in road layers are as follows:

a) The risk of heavy metals in the steel slag aggregates, which could be washed away by rainwater, thus infesting the groundwater [14]. To eliminate this risk, it is recommended that a leaching test be performed by a specialized institute.

b) Possibility of volume change (increase or decrease in road layer height) due to hydration of free calcium oxide [15]. To eliminate this risk, the best possible waterproofing of the upper layers and appropriate drainage works are recommended, in order to prevent the penetration of rainwater into the base or foundation layers of the road system, as well as the maturation of the slag before use, by storage in outdoors and periodic spraying with water.

4. Conclusions

The results of the tests show the following:

Marshall Stability and bulk density are greater than the minimum values provided in SR 174-1 (500 daN and 2250 kg/m^3), while the flow index falls within the range established by SR 174-1: 150 …450 (0,01 mm). As a result, we can conclude that steel slag can safely substitute the natural aggregates for the base layer of a road structure, with all the benefits mentioned above.

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