CONSIDERATIONS ON USING SLAG STEELWORKS IN ROAD CONSTRUCTION

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1. GENERAL ASPECTS

13 million tons of slag were produced annually in Romania, resulting from production processes of iron and steel. Its storage in waste dumps involves serious environmental problems by occupation of large land areas and instability of dump layers, which can reach tens of meters in thickness. Therefore there was always a concern for the best use of this product. These efforts have led to almost total use of metallurgical slag, especially as construction mineral material and as fertilizer. By using different technologies, liquid slag can be processed to produce a wide range of products certified for use in road and hydrotechnical construction or agriculture. The high rate of use of metallurgical slag is not achieved by any other industrial product.

In metallurgy two major types of products (waste) are defined, named depending on the end product desired to be obtained, as follows:

a) high blast furnace slags obtained in the manufacture of iron in the crucible of furnace at temperatures of max. 1600 °C, consisting of impurities of iron ore (Si, Al) combined with calcium and magnesium oxides of mineral flux.

Depending on the cooling methods, there are three types of products:

- air-cooled blast furnace slag (gross) slowly solidified under atmospheric conditions;
- granulated slag, solidified rapidly under the action of water;
- expanded slag, obtained by successive treatment controlled: air/water.

b) steelworks slag, obtained in the manufacture of steel, composed of silicates and aluminoferits of calcium and oxides (of calcium, iron, magnesium, manganese).

Depending on the furnace used there are:

- converter slag (Oxygen insufflation) or Lintz - Donawitz process, called LD or BOF;
- electric arc furnace slag, called EAF;
- Siemens - Martin slag, which are no longer produced but still exist in the steel plants dumps [1].

Recovery of these by-products, in particular blast furnace slag dates back to 1900 (road foundations, cement fabrication, etc.). Used alone or mixed with other natural products.

Since the 1940s Germany, the main producer of iron and steel, began to use these products processed or raw in qualified areas (especially in construction), while imposing specific requirements of use.

In our country it has been shown by experimental works that slags are able to replace natural aggregates (totally or in a certain percentage). Yet the government interest was reduced because of the impossibility of processing them to improve their technical characteristics, though economically, financial effort required was reduced.

Processing slag stored in dumps of steel and iron production plants, for using the non-ferrous materials resulting after recovering iron is a concern of specialists from around the world.

Non-ferrous materials, from which the ferrous material was eliminated 100% are known in literature as 'by-products', separated in cathegories depending on the grain sizes. They can successfully replace natural aggregates used in road and hydraulic construction, civil engineering, railways and even can be used as fertilizer for acid soils. [2]

Their properties namely density, crushing strength, compressive strength, water absorption, resistance to freezing – thawing, resistance to abrasion and grinding, define the way of application and the scope of these sorted materials called *'artificial aggregates'*.

Use of steelworks slag aggregates in the roadside lead to numerous technical and economic advantages for both the user and the manufacturer by:

a) diversification of road construction materials;

b) reducing construction costs by replacing natural aggregates;

c) eliminating waste storage dumps obtained from steel works and therefore environmental protection;

d) maintaining the bearing capacity within the operating parameters of the road system, offered by the carbonic solidification of aggregates and the ease in achieving optimum compaction;

e) the properties of steelworks slag aggregates allow development of roads which does not influence the environment under the action of climatic factors (rain, freeze - thaw, etc.).

f) reducing the risk of permanent deformations due to stability to mechanical and thermal actions in service;

g) ensure the service life of roads, safe and comfortable, due to texture that gives roughness and high resistance to skidding.

The fundamentals of metallurgical slag plant-use are the technical regulations which set the properties, requirements and tests for these materials. [3]

2. CURRENT SITUATION REGARDING USE OF STEELWORKS SLAG IN ROAD STRUCTURES

It is estimated that worldwide since 1978, more than half of steelworks slag production has found an application in road construction, as follows:

- Basic layers: 35 - 57%
- Layers of foundation: 3-6%
- Bituminous layer: 7-13%

Germany, which is the largest steel-producing of all European countries, has used the steelworks slag since 1974 (currently being used 97% of the total production) [4]

At the European level a committee of representatives of 10 European countries was formed, aimed at investigating and implementing the use of slag, increasing the area of their use or application and last but not least development of common European standards based on research, country-specific rules and instructions. (European Project to develop the technical specification on the use of steelworks slag).

Because of the research in the last 30 years, almost 70% of slag resulting as a by-product of the electric arc furnaces and steelworks converter is used in qualified application areas by fulfillment the requirements of standards and/or national or international specific regulations. [5]

In Germany, steelworks slag aggregates are used frequently for mechanically stabilized foundations, execution of related works of roads or link and base layers with bituminous binders as well as for execution of wear layers with classic or special asphalt mixtures.

In conclusion, in many European countries steelworks slag have been used successfully as construction materials for roads, both in foundation and base layers and the upper layers of road structure [6].

3. CURRENT SITUATION OF SLAG DEPOSITS IN ROMANIA

In order to highlight the economic potential of a deposit area and to create an image on the changes caused to the environment, one of the existing slag dumps in our country, namely dump Buituri, will be presented.

3.1 General aspects regarding the formation of dump

Formation of the dump began in 1967 with the first slag deposits on the valley Hărăoani, deposits that were made from an average level of land of 255 m.

With the achievement of 321.93 m deposit level and the increasing of slag dump instability, expansion of deposit area to a new location was needed.

To ensure the stability of land in the area were executed development works consisting of construction of supporting spurs at the foot dump and water management works, that is conducting ditches and drains to collect rainwater.

The maximum deposit level currently averages 340 m and dump the slag is spread over an area of approx. 80 ha, totaling approx. 50 million m^3, ie approx. 150 million tons of slag.

Dump height is not uniform throughout the area occupied, steps with heights between 5 and 50 m and widths of 20-150 m.

Slag dump structure is varied and uneven, the slag mass consisting of approx 70%, steelworks slag, approx. 30% blast furnace slag, contamination with refractory broken brick and unselected steel scrap to dump 44, or mechanically driven as drops in the slag. [7]

By processing slag excavated from dump Buituri the following by-products are obtained:

- Scrap iron recovered

From the mass processed results about 6.5% scrap recovered with a purity of approx. 85-90%, the remainder - 15% - must be processed before placing in oven.

- Gross slag recovered

Gross slag recovered is 78.5% of slag processed. It was considered that 6.5% is the percentage of scrap and 15% are technological losses. Finished products made by processing slag and their use are:

- 10% iron slag, used in metallurgical processes
- about. 68.5% iron free slag, used in:
- Civil engineering 3%
- Cement industry 6%
- Construction of roads 1%
- Construction of highways 90%

4. TESTS CARIED OUT ON ASPHALT MIXTURES WITH STEELWORKS SLAG

For the beginning, two asphalt concrete compositions rich in pearls type BA 8 (Series I) using D 80/100 bitumen and type BA 16 (Series II) using D 100/120 bitumen were made.

Aggregates used were crushed slag (5-8 and 8-16 sort), natural sand river and limestone filler.

The physico - mechanical values were determined on cubic and cylindrical specimens made of mixtures (series I and II), prepared with different percentages of bitumen.

Then, two other asphalt concrete compositions, rich in pearls, type BA 8 (series III) and BA 16 (series IV), of crushed slag used as aggregate (sort 5-8 and 8 - 16), crushed sand 0-4, natural sand 0-4 and limestone filler, were prepared.

By analysing the results of determinations one founds that:

- By using sorts 0-5, 5-8 and 8-16 of crushed slag (LIDONIT) there resulted an optimum bitumen percentage of 7% for BA 8;

- By eliminating LIDONIT sort 0-5 and replacing it with crushed sand (0-4), the percentage of bitumen decreased to 5,75 % (using the same type of bitumen D 80/100), which shows high porosity and high specific surface of this sort. In addition, the high content of CaO (9.0%) results in swelling in the pavement layer after execution;

- Development of swelling for mixtures of type BA 8 and BA 16 (series I-IV) shows that the values recorded does not go beyond 1%, which shows a good behavior in time to water;

- Both bulk density values and Marshall stability values exceed the required minimum of SR174-1, which provides good resistance to the combination of traffic and climatic factors.

5. CONCLUSION

The experimental results presented confirmed the successfully use of slag by replacing the natural aggregates in pavement layer.

This provides a significant decrease in the cost of work (slag - an industrial waste - is much cheaper than natural aggregate).

The use of slag aggregates also results in environmental protection by removing slag storage areas and conservation of natural environment (extraction of natural aggregates may disrupt ground water, may increase erosion, etc.).

Disadvantages of using steelworks slag in road layers could be the following:

The risk of heavy metals in the composition of aggregates of steelworks slag, which could be washed by rainwater and could infest the groundwater. To eliminate this risk a leaching test should be performed by a specialized institute.

Possibility of changing the volume by increasing or decreasing the height of the layer due to free lime hydration. To eliminate this risk is recommended as good waterproofing the upper layers and appropriate drainage works to prevent entry of rainwater into the base or foundation layers of the road system as well as aging of slag before use.

References

1. Dosar Tehnic nr. 004-07/431 - 2001: LIDONIT - Agregate din zgură de oțelărie - DSU Galați.
2.Zgura de oțelărie în autostrăzi, drumuri şi lucrări hidrotehnice, Ed.Tehnică, Bucureşti.
3. ‚Colloque sur la router et l’energie, Association technique de la route.
4.Untersuchunger zur Erzeugung raumbestandinger Mineralstoffe aus Stahlwerksschlacken” Amt fur Veroffentlichungen der Europaishen Gemeinschaft, 1998, ISBN 92-828-4599-0.
5. Scories LD brutes vrac’, Lattier France, Groupe Usinor.
6. ***Motz, H., Geisler, J.*** *Products of Steel Slags and Opportunity to Save Natural Resources - Waste Materials in Construction.*
7. Studiu de fezabilitate pentru pregătirea şi exploatarea zgurii din halda Buituri - SC Geasol SA.

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