DEVELOPMENT OF STANDARDS FOR THE REUSE OF STEEL CO-PRODUCTS IN ROADS AND RAILWAY BALLAST*

Maria Berenice Sandobal[1]
Elisabeth Williams[2]
Beatriz Dogliani[3]
Carina Bertino[4]

Abstract

The environmental management of steel mill slag should be understood as a management philosophy, observing technical, economic and environmental criteria associated with their generation, storage and final destination. The slag can be considered as a synthetic mineral resource and become a very useful co-product in different areas. The Argentinean steel industry prioritizes the efficient environmental management of its waste, thus contributing to its own survival taking into account the sustainable development. In the world, the slag produced by the steel industry has been used as steel aggregate for road bases, railway ballast and filling material among others. Any factor that influences the economy of the country affects all branches of society, mainly public agencies, whose financial resources are increasingly scarce to deal with all public works. It is necessary to join efforts of private and public initiative in the adoption of alternative materials that replace the use of finite natural resources. This presentation aims to show the work done by private companies together with public bodies and universities to obtain a regulatory document for the management of slag as steel aggregates for three different uses, namely: road use, railway use and general use.

Keywords: slag; ballast; rail, steel aggregatesl

1 *Electromechanical Engineer, Environmental Leader, Tenaris, Argentina.*
2 *Environmental management Bachelor, Environmental Manager, Arcelor Mittal, Argentina*
3 *Chemical Bachelor, Environmental Leader, Ternium Argentina.*
4 *Chemical Bachelor, Laboratory Manager, Instituto Argentino de Siderurgia, Argentina.*

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1 INTRODUCTION

The IRAM, Argentine Institute for Standardization and Certification was the place where meetings were held to establish the technical criteria of the standard.

The Standard is IRAM / IAS U 500-252 and consists of three parts:

Part 1. Road Use.

Part 2. Rail Use.

Part 3. General Use

First, the Standard establishes its scope and definitions that are of vital importance to it.

It is defined as steel aggregate to the coproduct coming from the manufacture of steel in melting and refining furnaces and oxygen converters.

On the other hand, a coproduct is defined as a material generated in a production process for a commercial purpose, whose characteristics are equivalent in a consistent manner to other products or raw materials.

Therefore, slag from melting or refining furnaces and oxygen converters are considered as steel aggregates for this Standard.

In this presentation the tests carried out to establish the requirements of Part 1, road use, Part 2 rail use and Part 3 general use are shown in detail.

The steel aggregate would replace the stone aggregate used in the construction of routes such as *enripiado*, granular base, granular subbase and asphalt binders.

For this reason, the tests are the same as those used for the stone aggregates.

The test standards are mostly Argentinean, and some of them are specific from the intervening agency.

In the case of part 1 road use, the agency involved is the National Direction of Roads of Argentina that has specific requirements for the aggregates of stones used for the construction of roads. The steel aggregates were tested and evaluated according to these requirements.

Regarding Part 3, general use, it establishes the requirements of steel aggregates for general uses such as the use in plant accesses, conditioning of parking lots or logistic operations.

The main requirement is related to the environmental aspect of its use, which requires the analysis of heavy metals, total hydrocarbons, phenols and pH in the leachate according to IRAM Standard 29016.

Finally, part 2 of this Standard refers to the use of steel aggregates such as ballast and rail sub-ballast. Like part 1, the requirements established by *Ferrocarriles Argentinos*, the intervener state agency, are taken into account

2 DEVELOPMENT

2.1. Steel aggregate for road use

Standard IRAM / IAS U 500 252-1 for road use includes two classifications, one according to the process of obtaining it and the second according to the size of the aggregate.

According to the process of obtaining it:

a. Electric furnace
b. LD converter
c. Secondary metallurgy

According to the size of the aggregate:

a. Fine, aggregates that pass through IRAM sieve 4.75 mm.
b. Thick, aggregates retained by the IRAM sieve 4.75 mm.

The samples of slag analyzed come from three different companies and from now on they will be referred to Sample A, Sample B and Sample C.

The sampling was carried out by personnel of the Instituto Argentino de Siderurgia (Argentine Iron and Steel Institute).

The requirements are mostly physical tests and they were made at the Instituto de Tecnología Indutrial (Institute of Industrial Technology) and the Instituto de Mecánica Aplicada y Estructuras (Institute of Applied Mechanics and Structures) of the National University of Rosario

These tests allow the evaluation of the behavior of steel aggregates and compare their performance to natural stone aggregates.

This part also takes into account the environmental aspect, which is why it is required to evaluate the content of heavy metals in the leachate according to the IRAM 29016 standard.

Below are two tables, for fine and coarse aggregate respectively, where the tests, the requirements established in the standard and the results obtained from the three samples are detailed.

In table 1, we can highlight some tests that allow evaluating specific aspects of an aggregate for road use, for example:

Attack durability of sodium sulfate

IT describes the procedure that must be followed to determine the resistance to the disintegration of the aggregates by the action of saturated solutions of sodium sulfate or magnesium.

This method provides useful information for judging the quality of the aggregates that has to be subjected to the action of atmospheric agents, especially when data on the behavior of the materials to be used are not available in the climatic conditions of the work.

Another one, is the sand equivalent test, used to evaluate the cleanliness of the fine little plastic aggregates, through an index relative to the proportion of material. The higher the Sand Equivalent (SE) the better the quality of the material.

Plasticity measures the ability of the aggregate to deform without cracking when subjected to gradual changes in water content.

Table 1. Fine Steel Aggregates

Test	Standard	Requirement according to use		Sample A	Sample B	Sample C
Fine Material that passes through 75 µm sieve	IRAM 1540	Folder bearing	report	1,18%	3,75%	6,94%
		Asphalt base	report			
		Granular base	report			
		Granular sub base	report			
Determination of relative density and apparent density	IRAM 1520	Folder bearing	report	3%	3%	3%
		Asphalt base	report			
		Granular base	report			
		Granular sub base	report			
Attack durability of sodium sulfate	IRAM 1525	Folder bearing		2,20%	6,20%	4,80%
		Asphalt base	Iqual or less than 10%			
		Granular base				
		Granular sub base				
Sand Equivalent	IRAM 1682	Folder bearing	Equal to or greater than 50 %	97%	94%	92%
		Asphalt base	Equal to or greater than 50 %			
		Granular base	Equal to or greater than 50 %			
		Granular sub base	Equal to or greater than 45%			
		Enripiado	Equal to or greater than 35%			
Plasticity of the fraction that passes IRAM 425 µm sieve	IRAM 10501	Folder bearing		Not plastic	Not plastic	Not plastic
		Asphalt base	Not plastic			
		Granular base				
		Granular sub base				

In Table 2, besides the tests mentioned above, we find others such as, for example, Lajas index.

The aggregates can have different shapes, cubic, rounded, slabs and needles but for this use it is sought that they have a preferably cubic shape since the shapes of slabs or needles present a greater risk of breakage. Therefore, the slab index should be low.

One of the most important tests is the Los Angeles Abrasion Coefficient, this method provides a measure of aggregate degradation, a consequence of the combined action of abrasion, impact and crushing, carried out in a rotating steel cylinder where a certain number of steel balls is introduced, depending on the granulometry of the aggregate under study.

After an established number of revolutions, the content of the cylinder is removed and the aggregate is sifted to determine the degradation as a percentage of loss. In this case it is necessary to have low results that indicate the greater resistance of the material analyzed.

Table 2. Coarse Steel Aggregates

Test	Standard	Requirement according to use		Sample A	Sample B	Sample C
Fine Material that passes through 75 µm sieve	IRAM 1540	Folder bearing	report	0,15%	1,01	0,16%
		Asphalt base	report			
		Granular base	report			
		Granular sub base	report			
Determination of relative density and apparent density	IRAM 1520	Folder bearing	report	3,50%	3,00%	3,00%
		Asphalt base	report			
		Granular base	report			
		Granular sub base	report			
Attack durability of sodium sulfate	IRAM 1525	Folder bearing	Equal or less than 10	0,50%	2,60%	1,30%
		Asphalt base	Equal or less than 10			
		Granular base	Equal or less than 10			
		Granular sub base	Equal or less than 10			
Adhered dust	IRAM 1883	Folder bearing	Equal or less than 1.2%	0,20%	1,40%	1,50%
		Asphalt base	Equal l or less than 1.5%			
Index of slabs	IRAM 1687-1	Folder bearing	Equal or less than 20	0,15%	1,20%	0,46%
		Asphalt base	Equal or less than 20			
		Granular base	Equal or less than 20			
		Granular sub base	Equal or less than 20			
Elongation	IRAM 1687-2	Folder bearing	report	71%	94%	77%
		Asphalt base	report			
		Granular base	report			
		Granular sub base	report			
Coefficient of abrasion Los Ángeles	IRAM 1532	Folder bearing	Equal or less than 25	14,50%	17,70%	18,80%
		Asphalt base	Equal or less than 30			
		Granular base	Equal or less than 30			
		Granular sub base	Equal or less than 35			
		Enripiado	Equal or less than 50			
Coefficient of acceleratted polish	IRAM 1543	Folder bearing	report	40	40	42
Micro Deval	IRAM 1762	Folder bearing	Equal or less than 20	9,1	9,8	10,4
		Asphalt base	Equal or less than 25			
		Granular base	Equal or less than 25			
		Granular sub base	Equal or less than 30			
Binding aggregate compatibility test	IRAM 6842	Folder bearing	Equal to or greater than a 95%	>95	>95	>95

The chemical requirements for evaluating the expansion potential of steel aggregates can be carried out on the aggregate itself or on the work mixture.
The following tables show the methods used and the required results:

Table 3. Potential requirement for the expansion of steel aggregates

Test	Standard	Requirement according to use		Sample A	Sample B	Sample C
Expansion	UNE - EN 1744-1	Folder bearing	Less than 3,5%	0,9	0,9	2,3
		Asphalt base	Less than 5%			
		Granular base	Less than 5%			

Table 4. Requirement of mixtures for granular base and sub-base

Test	Standard	Requirement according to use
Expansion	ASTM D4792	Less than 0,5%

2.2. Steel aggregate for general use

This part of the standard establishes the requirements of the aggregates for uses such as plant accesses, conditioning of parking lots or logistic operations.
The most important requirement is the one referred to the leachate evaluation.
The standard does not contain limit values for the analytes that are determined on the leachate since this is subject to the applicable legislation in the area where the aggregate will be used.

2.3. Steel aggregate for railway use.

For the application of steel aggregates such as sub-ballast, ballast or rail-shaped layer, the granulometry of the aggregates is very important.
That is why a specific granulometric profile is allowed for different uses.
The granulometry test is carried out according to the IRAM 1505 standard, then two figures where the areas of granulometry required according to each use are highlighted.

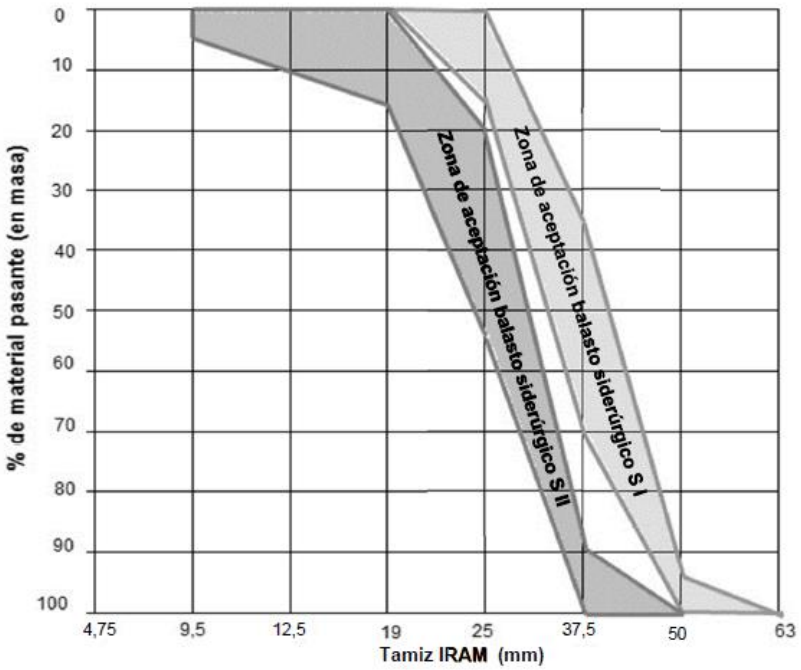

Figure 1. Granulometric acceptable zones for steel rail ballast category S I and S II

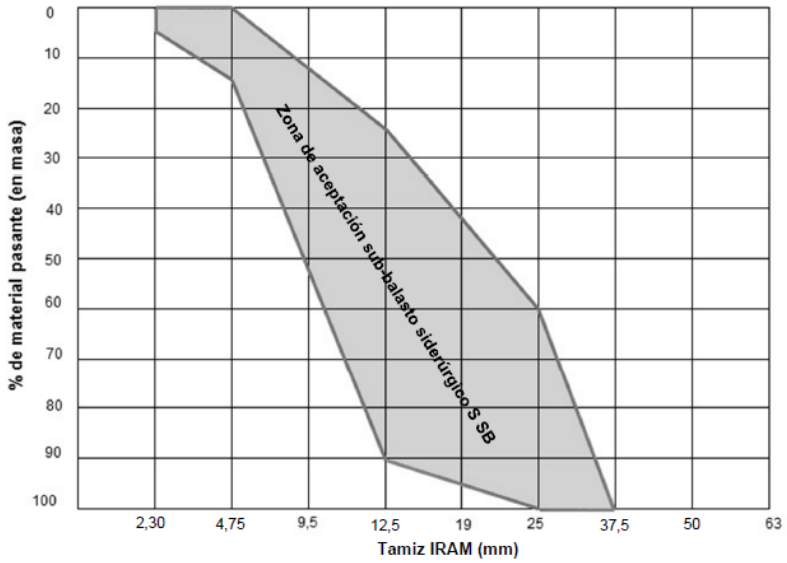

Figure 2. Acceptable granulometric dimensions of steel sub-ballast category S SB

Regarding the rest of the required tests, these coincide with those requested for road use, although they differ in the values admitted for their use.

The following table shows the most important requirements:

Table 5. Steel aggregates for railway use

Test	Standard	Requirement according to use		Sample A	Sample B	Sample C
Fine Material that passes through 75 µm sieve	IRAM 1540	S I	1%	1,18%	3,75%	6,94%
		S II	1%			
		S SB	1%			
Attack durability of sodium sulfate	IRAM 1525	S I	10%	3%	3%	3%
		S II	10%			
		S SB	10%			
Index of slabs	IRAM 1687-1	S I	5%	0,15%	1,20%	0,46%
		S II	5%			
		S SB	5%			
Coefficient of abrasion Los Ángeles	IRAM 1532	S I	30%	14,50%	17,70%	18,80%
		S II	35%			
		S SB	40%			

The chemical requirements of the aggregates for railway use are those referred to in the Part 1 road use that considers the UNE EN 1744-1 standard as indicated in table 3.

3 CONCLUSION

Since a long time ago, steel aggregates are used for different uses, the most common is for consolidated communal roads, parking lots, deposit area, among others. In order to enhance its scope, this working group gathered to give a regulated framework to three of its most important uses.

Based on the results obtained, it can be assured that the steel aggregate is suitable as a replacement for the natural stone aggregates.

The final result of this work was the publication of part 2 of the standard in May 2019 while part 1 and 3 had already been published a year earlier.

We can highlight the most relevant advantages of replacing natural aggregates by steel aggregates:

Reduction of the use of material of natural origin with its consequent environmental benefit, avoid deforestation, the impact on flora and fauna in the quarry area, a reduction in the hydrological impact.

Also, the reduction of the volume of aggregates sent to final disposition and its consequent cost reduction.

Last but not least, the substitution of natural aggregates for a co-product benefits not only the steel companies but also the potential consumers.

REFERENCES

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6 IRAM 1525 Standard
7 IRAM 1687-1 Standard
8 IRAM 1525 Standard
9 UNE EN 1744-1 Standard
10 ASTM D479
11 IRAM 1682 Standard