PROPOSAL FOR APLICATION OF STEEL SLAG IN THE PRODUCTION OF MORTAR FOR MASONRY WALLS

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Abstract

The construction industry is one of the current economic activities which most consumes natural resources. This causes great impact to the environment due to the exploration of agregates, especially in the surroundings of big cities. Siderurgy processes in order to obtain iron from iron ore, also generate a great deal of residue which are put in dumps and also impacting the industry's surroundings. Hence, this study proposes the use of the solid residue of siderurgy processes as agregates in the production of grout and mortar for masonry walls, both for laying and covering bricks. This could provide the construction and siderurgy industries with sustainability and also contribute to the reduction of the housing shortage in big cities. Thus, three different mortar were produced with natural and artificial agreggates, following three doses: 1:2, 1:3 and 1:4 previously defined. For each dose, body tests (5x10 cm) were produced and tested for their resistance at 3, 7, 14 and 28 days. In order to determine their workability, consistency tests were also performed. The results show proper caracteristics for their use in brick laying and wall covering for masonries.

Key words: Material technology; Building processes; Civil construction; Steel slag; Siderurgic process.

PROPOSTA PARA APLICAÇÃO DE ESCÓRIA DE ACIARIA NA PRODUÇÃO DE ARGAMASSA PARA ALVENARIAS

Resumo

A indústria da construção civil é um dos setores industriais que concentra o maior consumo de matérias naturais em seu processo, impactando o meio ambiente, principalmente nos grandes centros urbanos. A indústria siderúrgica gera diariamente um significativo volume de resíduos sólidos que são destinados em depósitos, impactando também no meio em que se instalam. Visando propor soluções para sustentabilidade destes segmentos industriais, e ainda contribuir para a redução do déficit habitacional, propõe-se a utilização de resíduos sólidos de siderurgia como agregados para a fabricação de argamassas para assentamento e revestimento de alvenarias. Foram fabricados três traços com agregados naturais e artificiais nas dosagens 1:2, 1:3, e, 1:4. Foram produzidos corpos de prova (5x10cm), para idades de 3, 7, 14, 28 e 56 dias e determinada resistência mecânica à compressão, para trabalhabilidade foram determinados índices de consistência. Os resultados apontaram características adequadas para utilização do resíduo como elementos de ligação e revestimento para alvenarias de vedação.

Palavras-chave: Tecnologia de materiais; Processos construtivos; Construção civil; Escória de aciaria; Processos siderúrgicos.

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1 INTRODUCTION

The environment issue has been broadly discussed nationally and internationally in the last years, mobilizing the public opinion and playing an important role in the society.
The concept of sustainability as being the best use of the resources, re-use of the residue and correct disposal of of the improper remains is now understood as an acceptable alternative to the nature's degradation.[1] The protection of the soil and the water, the restraining on residue generation and its recycling are the keys in the concept of "Development sustainability". This concept[2] was first used in march, 1991, by the European Commission Directive 91/156/eec.
Several companies have been investing in equipment and people, so that the the waste and misuse of the resources can be extinguished, and the culture of recycling can be reinforced. Not only for the devastating impact of the residue on nature, but also as a way of maximising production and profit.
Worldly speaking, the siderurgy industry alone generates 84 million tons of steel slag a year.[3] In Brazil, 3,2 million tons of of steel slag were preoduced only in 1997, being most of it from the LD process.[4] More recent data indicates figures of approximately 3,7 million tons a year.[5] From this 3,7 million tons, 44% is stabilized in the deposit areas in the industries and used as aggregates for road construction in granulometric stabilization of bases and sub bases, and in railways; and the 56% left are storaged, aproximatel 2,1 million tons a year.
The construction industry is one of the most impacting economic ativity, due to its high consumption of raw material. According to Sjostrom, cited by John,[6] the construction industry takes in from 14 to 50% of the natural resources obtained on Earth, as well as generating huge amounts of residue. An alternative to its residue generation would be its recycling, sapring natural resources and saving energy in this area. The viability study f the use of steel slag as a sub-product, or even raw material in construction processes, is connected to the cost of recycling, which should be lower than the cost to dispose it.
For a viability study for the recycling of a certain material, it is needed to gather information about its availability; its chemical composition, mechanic and physical characteristics, range of possible aplications and identification of the final product.[1]
Thus, this work proposes the use of the subproduct of the metalic recovery from steel slag as a total substitute for mineral aggregates for mortar production, taking in consideraton the inexistence of a standard test and criteria to evaluate the potentiality of its application.

2 MATERIAL AND METHODS

The steel slag used in these work comes from ARCELOR - CST (Companhia Siderúrgica de Tubarão, from Serra, in the Brazilian state of Espirito Santo). The raw steel slag has a typical chemical composition, as shoin below (Table 1).

Table 1. Quimical compose tipical for steel slag - CST

Element	*Concentration [%]*
FeO	27 ± 0,2
Al_2O_3	1,5 ± 0,04
SiO_2	10 ± 0,2
CaO	46 ± 0,2
MgO	7 ± 0,1
MnO	6 ± 0,07
P_2O_5	2 ± 0,1

This steel slag is submitted to a recycling process, performed by the company RECICLOS, in which the subproducts composed in its majority of iron, is reintroduced in the siderurgy process and incorporated to the steel production. As a residue form this process, there is a non-metalic fraction, granulated in a range from 0 to 32 mm.

The steel slag *in natura* is submited in process of stabilization and inertization, to eliminate effects expansibility of elements calcium oxide (CaO) and magnesium oxide (MgO). The steel slag no active, that contains 27% of iron (FeO) is benefit in industrial process in the RECICLOS company (Timóteo – Brazil). The industrial process segregate the steel slag in two fractions, one metalic fraction (FeO) and other non-metalic fraction.

The industrial process development in RECICLOS company, comes product then consist essentially of iron. This product (iron) returns to siderurgic process, be incorporated in steel fabrication. The residue of RECICLOS process, the non-metalic fraction is graduate on ranges 0-4mm, 4-10mm, 10-19mm and 19-32mm, to serve at prime-matter for civil construction. The 0-4mm fraction was applied to prime-matter for production of mortar.

The environment certifications to the product of this processing were obtained by CST and RECICLOS under Brazilian national standards.(7)

The non-metalic samples were packed in *big-bags* and sent to the structure and material lab (labEST, CEFET-MG). For their use in the calculated dosages, they were separated according to their specific granulometric range for small aggregates for mortar masonry in civil construction, and tested for their humidity, specific and unitary mass for productions mortar 1:2, 1:3 and 1:4.

2.1 Materials

2.1.1 Artificial aggregate

The steel slag used that aggregate was sieved and separated for industrial process and segregate to fractions. The steel slag segregate just like the natural aggregate. The small aggregate used in dosagens follows in the Figure 1.


Figure 1 – Non-metalic fraction of steel slag (0-4mm)

The steel slag used in this experiment was granulometric segregated according to fractions stabilished by the NBR 7217/87,[8] for thin and thick aggregates.
For produce the dosages, humidity was determined according to NBR9939/87;[9] specific mass according to NBR 9776/87[10] and unitary mass according to NBR 7251/82.[8]

2.1.2 Natural aggregate
The natural aggregates used in this experiment are the same currently used in the production of Portland cement mortar, normally used for the coat and linked bricks in masonry.
They were also separated accordin to their granulomety into fractions determined by NBR 7217/87,[8] and their humidity, specific mass and unitary mass determined according toNBR 9939/87,[9] NBR 9776/87,[10] NBR 7251/82,[8] respectively.
For produce the dosages, humidity was determined according to NBR939/87; specific mass according to NBR 9776/87[10] and unitary mass according to NBR 7251/82.[8]

2.1.3 Portland cement
It was used a CP V- ARI RS type cement, CIMINAS, produced by HOLCIM do Brasil.

2.2 Methods

The mortars was produced of the experimental dosages of nature an artificial aggregates.[11] For the obtained results, the dosages 1:2, 1:3, 1:4 was determined for artificial aggregate (steel slag), 1:1:4; 1:1:6; 1:1:8 for nature and artificial aggregate with the additive lime. The analysis of mechanical properties of the mixtures hardened and determination of technical and economic viability for application the steel slag in mortar produce.

2.2.1 Dosages
The analysis conduced for the physical characterization of nature and artificial (steel slag) aggregates was enable the dosages for production of conventional mortars (nature aggregates), 1:2, 1:3 and 1:4. this dosages was executed with nature and artificial aggregates.[12] Studies was conduced for consistency in process of mixture for nature and artificial mortars for obtained workability properties of interest and water/cement relations. The Figure 2, present the process for fabrication for mortar and consistency test.

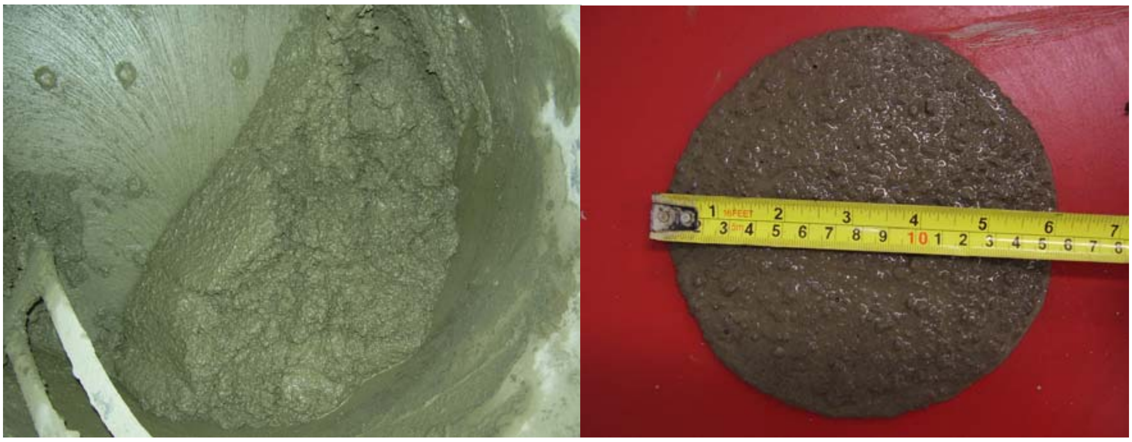

Figure 2. Mortar fabrication and consistency test.

The mortars obtained with the natural aggregate was used as a pattern for the analysis of the results form the artificial aggregate mortars.
For the mechanical properties determination, in hardened and fresh states, was molded for the nature and artificial aggregates, body tests. This body tests was submited of simple compress for resistance determinates for 3, 7, 28 and 56 ages, follows NBR 5739/94.[13] The Figure 3 present the casting and body tests molded.

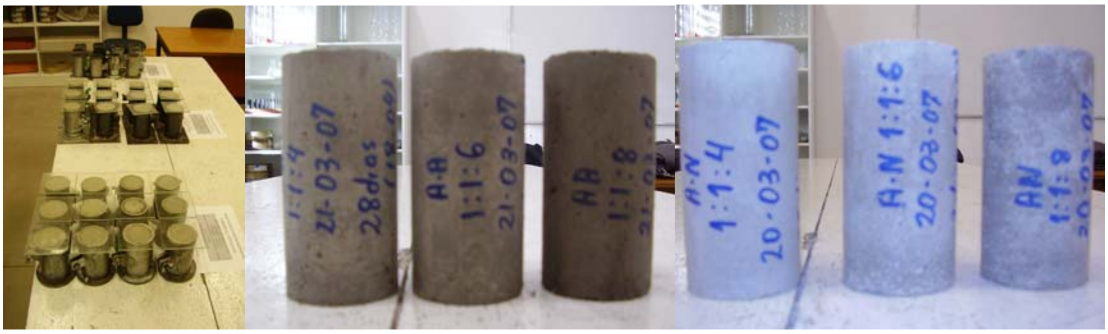

Figure 3. Body tests of mortars

The samples molded for dosages 1:2, 1:3 e 1:4 were kept under water so that their expansion could be measured.

3 RESULTS AND DISCUSSION

In the Table 2, we show the results for the granulometric analysis conduced for artificial aggregates from steel slag. The granulometric assay was done following the industrial segregation of the process for fractions 0-4mm. The presented results report to aggregates obtained for RECICLOS industrial process.

Table 2. Granulometric analisys fraction 0-4mm

Granulometria Amostra 5 - 0-4mm						
Peneiras (mm)	M1 agregados	M2 solo	% retida M1	% retida M2	% acum M1	% acum M2
4,8	145	89	29,2%	20,1%	29,2%	20,1%
2,4	88	78	17,7%	17,6%	46,9%	37,7%
1,2	83	77	16,7%	17,4%	63,6%	55,1%
0,6	86	83	17,3%	18,7%	80,9%	73,8%
0,3	51	62	10,3%	14,0%	91,1%	87,8%
0,15	26	39	5,2%	8,8%	96,4%	96,6%
0,075		14	0,0%	3,2%	96,4%	99,8%
Fundo	18	1	3,6%	0,2%	100,0%	100,0%
Soma	497	443	100,0%	100,0%		
M finura	**4,80**	**3,71**				
Dim. Máx	**6,3**	**6,3**				

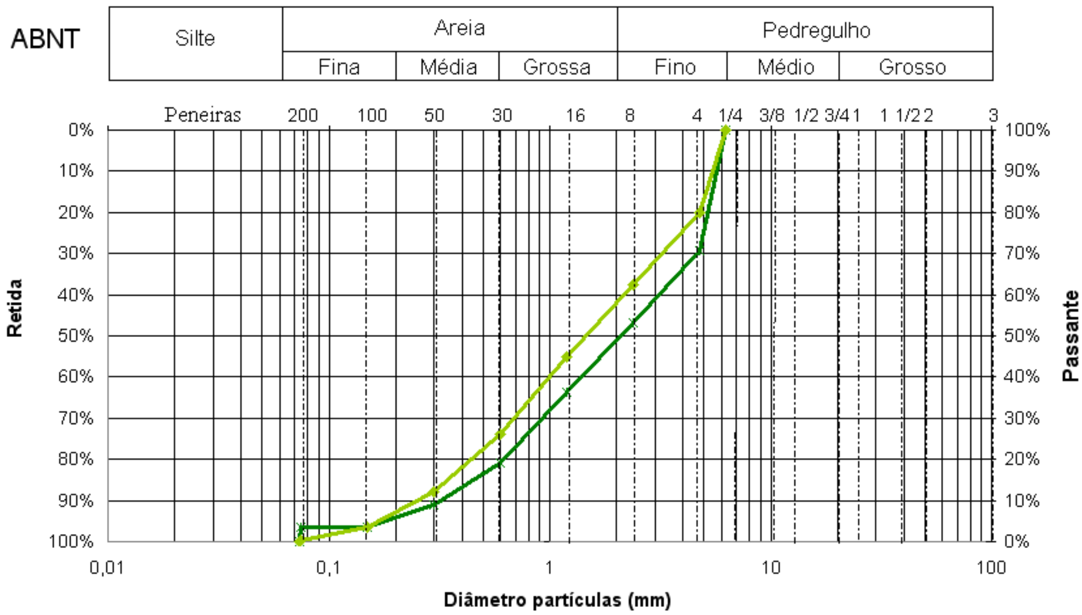

Figure 4 – Granulometric curve fraction 0-4mm

We can see that this industrial classification separates the aggregate into sand (0-4mm).

The results of specific and unit mass of nature and artificial aggregate used in mortar dosages, present follows.

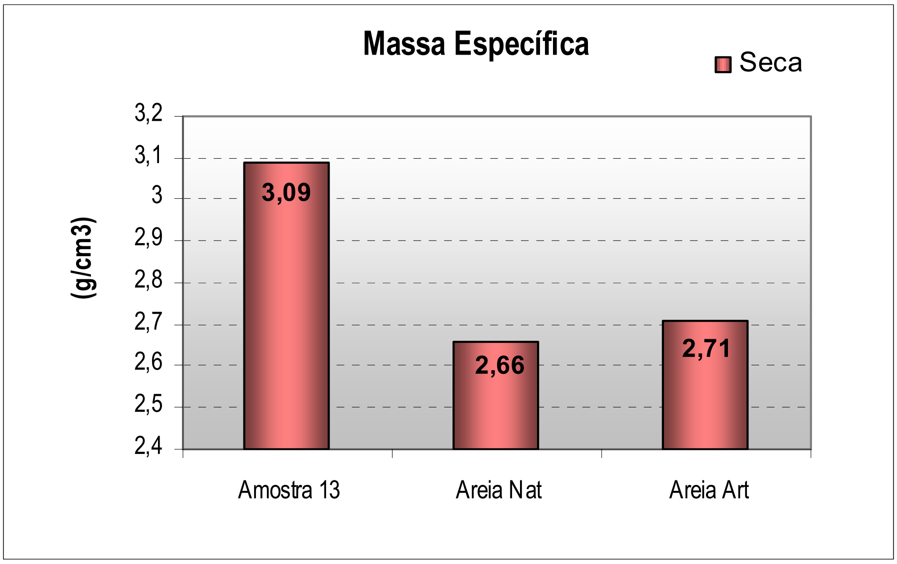

Figure 5 – Specific mass for steel slag an nature sands.

The sample number 13 has a specific mass value higher to the ones found in the natural aggregate sand.
Below, in the Figure 6, it is shown the values for unitary mass for samples 13, and nature sands (rive and crushed rock).

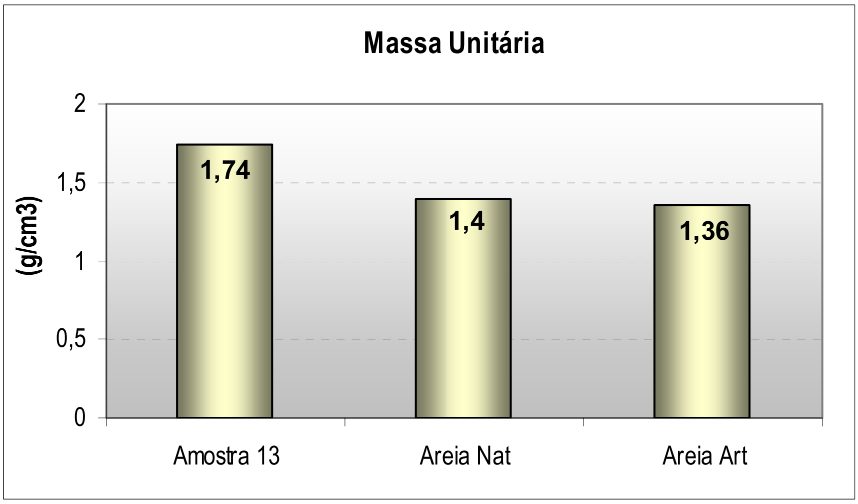

Figure 6 – Unit mass for steel slag an nature sands.

For measurement the relation water-cement factor (w/c), was determinate the water moisture for the steelsalg aggregate and the nature aggregate, was present.
The chart 7 illustrate, shown that the steel slag samples are prone to absorb more water, in what is called higroscopicity, as we can see in sample number 13, representative of sand, or small aggregate. The samples for nature small aggregate presented variable values, due to origin.

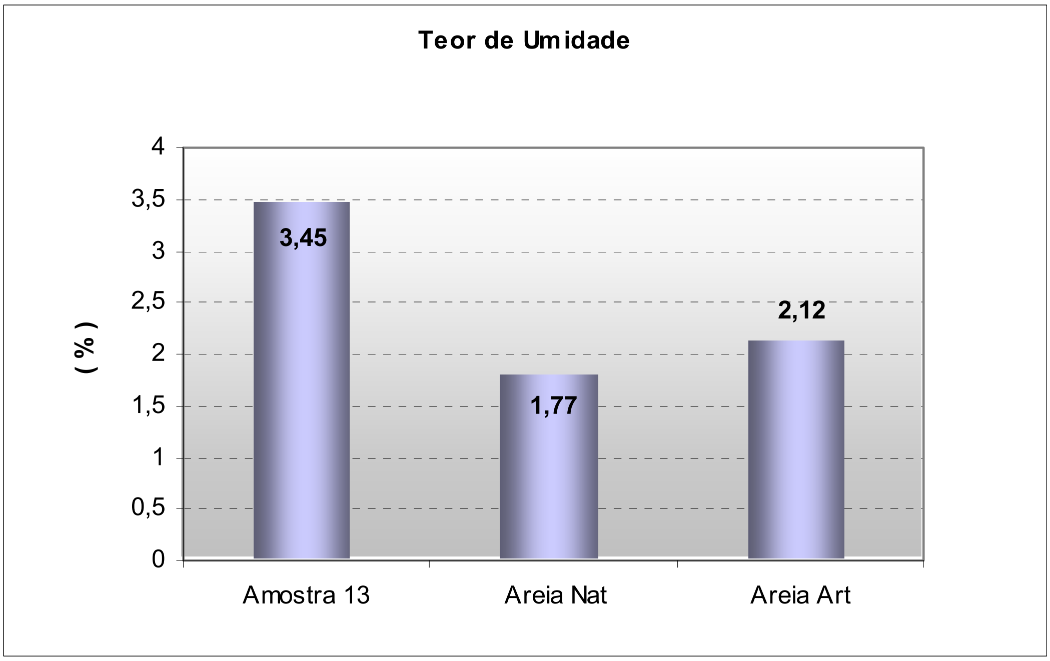

Figure 7 – Wet ratio

Considering the characteristics to the natural and artificial aggregates, Table 3 and Figure 8 shows the results for the different mortars produced concerning their axial resistence to compression.
We can see in the Figures 8 and Figures 9, that the mortar using steel slag have better mechanic performance for dosages which natural aggregates and lime, if compared ones.

Table 3. Mechanical properties for mortars

Resistence toCompression (MPa)									
Idade	Artificial Aggregate (Steel slag)			Artificial Aggregate with lime			Nature Aggregate with lime		
	AA 1:2	AA 1:3	AA 1:4	AAC 1:1:4	AAC 1:1:6	AAC 1:1:8	AN 1:1:4	AN 1:1:6	AN 1:1:8
3	18,3	10,4	5,8	3,5	1,5	0,9	4,8	1,2	0,4
7	28,0	16,4	9,5	8,4	4,1	3,0	7,8	3,7	1,2
28	32,0	22,1	15,2	12,8	7,2	5,3	11,7	6,0	2,0
56	37,9	26,0	17,3	14,0	8,2	6,0	12,9	7,2	2,3

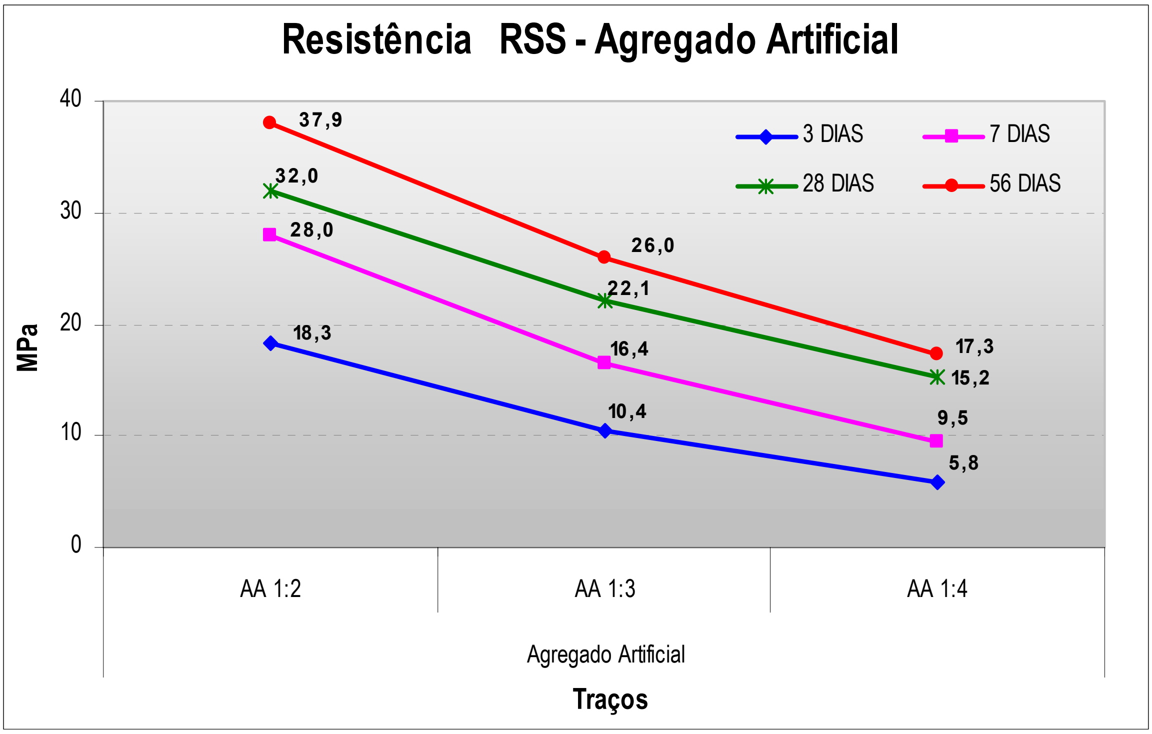

Figure 8 – Simple compression resistance for mortars AA

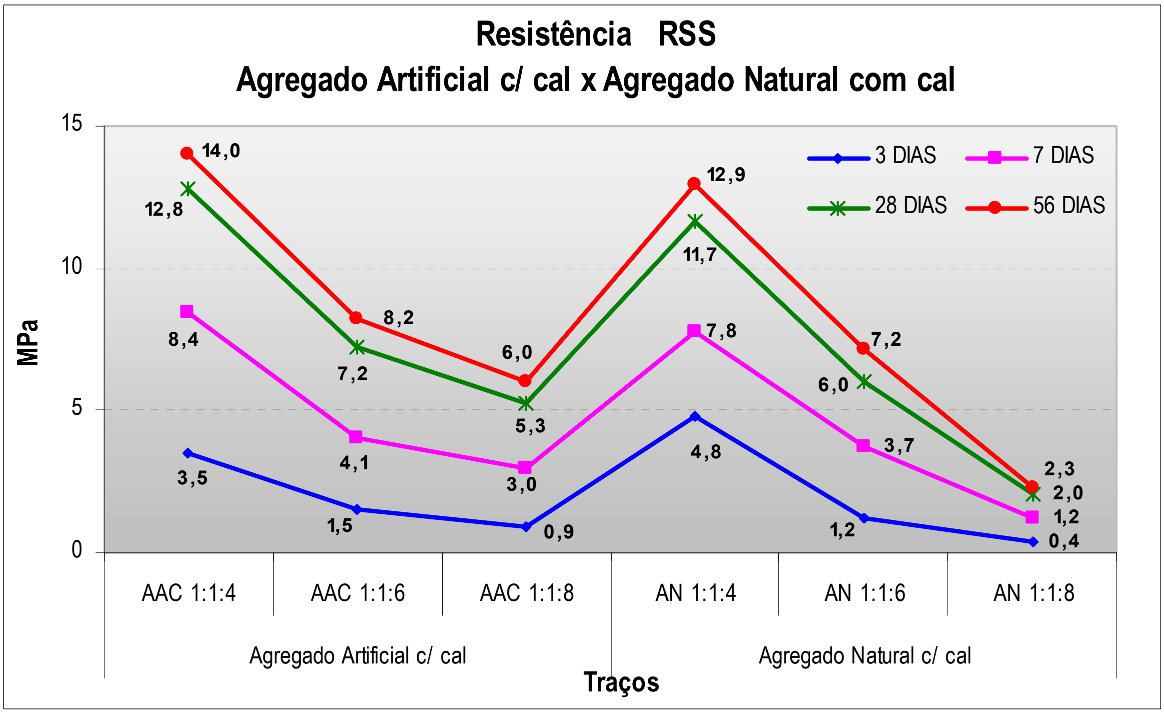

Figure 9 - Simple compression resistance for mortars AA

The body tests produce wuith steel slag did not present any variation in their dimensions after being submerged in water for 56 days. The samples were measured every 4 days (96 hours)

The viability study, taking prices in Belo Horizonte as a basis, indicated that the mortars produced with residue from the siderurgy industry is more economic than the tradicional mortars produced with natural aggregates.

4 CONCLUSION

The analysis developed in this study led to the following conclusions:

i) steel slag produced mortars with compression resistance of 32MPa and 37,9MPa for dosage 1:2, 12,8MPa and 14,0MPa for dosage 1:2 with lime (1:1:2), at 28 an 56 days age, respectively;
ii) natural aggregates produced mortars with compression resistance of 11,7MPa an 12,9Mpa for a dosage 1:2 and lime (1:1:2) at 28 an 56 days age, respectively;
iii) steel slag can fully substitute the natural aggregates in mortars, used same consistency, relation water/cement, moisture and workability properties;
iv) the mortars obtained with steel slag are dimensional stable, that means, they do not expand in experimental submergence conditions (56 days);
v) mortars produced with slag can be cheaper than the traditional one;
vi) mortars produced with steel slag can be economically and technically viable to be used in coatings and linked bricks in masonry.

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