PROPOSAL FOR APLICATION OF STEEL SLAG IN THE PRODUCTION OF CEMENT PORTLAND CONCRETE[1]

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Abstract

This viability study for production of concrete using rcycled aggregates from the siderurgy industry aims to fullfill a need for sustainability and development in the siderurgy industrial process, which produces over 500.00 tons of solid residue yearly. Different dosages were developed for producing concretes C10, C20 and C30, using natural and artificial aggregates from recycled siderurgy residue. The concrete produced with artificial aggregates presented a higher water/cement rate if compared to the one produced with natural aggregates, in spite of their same consistency and workability, obtained through standard slump test. The mechanic characteristics of these different concrete dosages (axial compression) were determined at 3, 7, 14 and 28 days. Both concretes had similar characteristics, concerning their resistance and elasticity as well as specific mass, absortion and dimensional stability. The viability study indicated that the concretes produced with natural aggregates were as 24 times as expensive the ones using recyceled aggregates. Thus, the results point to being the concrete produced with siderurgy residue a great and feasible alternative to civil engineering constructions.

Key-words: Concrete; Steel slag; Building process; Building materials.

PROPOSTA PARA APLICAÇÃO DE ESCÓRIA DE ACIARIA NA PRODUÇÃO DE CONCRETO

Resumo

O estudo de viabilidade para produção de concreto com agregados reciclados da atividade industrial visa atender a uma demanda oriunda da necessidade de desenvolvimento e sustentabilidade do processo industrial siderúrgico, que gera por ano, aproximadamente 500 mil toneladas de resíduo sólido. Foram realizadas dosagens para concretos C10, C20 e C30, empregando agregados naturais e agregados artificiais. Dosagens produzidas com agregados artificiais apresentaram relação a/c superior àquelas produzidas com agregados naturais, para mesma consistência e trabalhabilidade, mensuradas com auxílio do slump test. As propriedades mecânicas foram determinadas por ensaios de compressão axial, para idades de 3, 7, 14 e 28 dias. Os concretos produzidos com agregados artificiais apresentaram desempenho semelhante aqueles com agregados naturais para resistências mecânicas projetadas, além de massa específica, absorção e estabilidade dimensional idênticas. Os estudos de viabilidade econômica indicaram ser viável a produção de concreto com agregados reciclados. Dessa forma, apresenta-se o concreto produzido com agregados artificiais, reciclagem de resíduos sólidos de siderurgia, como alternativa técnica e economicamente viável para aplicação a obras correntes de engenharia.

Palavras-chave: Concreto; Escória de aciaria; Processos construtivos; Materiais de construção.

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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.[1]
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 naow understood as an acceptable alternative to the nature's degradation. 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 was first used in march, 1991, by the European Commission Directive.[2]
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. The construction industry takes in from 14 to 50% of the natural resources obtained on Earth,[6] 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.
Thus, this work proposes the use of the subproduct of the metalic recovery from steel slag as a total substitute for mineral aggregates for concrete 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 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 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, and tested for their humidity, specific and unitary mass for productions concretes C10, C20, C30.

2.1 Artificial Aggregate

The material used as artificial aggregate is sieved and separated into fractions: 0-4mm, 4-10mm, 10-19mm and 19-32 mm, just like the natural aggregate is, and separated into thin and thick aggregate, as shown in Figure 1.

Figure 1. Steel slag in granulometric fractions 0-32mm

The steel slag used in this experiment was granulometric segregated according to fractions stabilished,(8) for thin and thick aggregates.

For produce the dosages, humidity;(9) specific mass(10) and unitary(11) was determnined according to ABNT.

2.2 Natural Aggregate

The natural aggregates used in this experiment are the same currently used in the procduction of Portland cement concrete.
They were also separated according to their granulomety,[8] and their humidity,[9] specific mass[10] and unitary mass[11] according to ABNT.
For produce the dosages, humidity;[9] specific mass[10] and unitary[11] was determnined according to ABNT.

2.3 Cement

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

2.4 Methods

The concretes obtained fom the dosages using natural and artificial aggregates were classified[12] according to structural use. Concretes with natural and artificial aggregates were produced and tested in order to obtain their mechanical and physical characteristics. Further analyses were done to get the viability of the use of slag as a viable aggregate for concrete production.

2.5 Dosages

So as to use the artificial aggregates in the dosages, they were tested to determine the specifc mass for the thick.[10] and the thin[13] aggregate, their unitary mass[11] and their humidity.[9]
With the results in hand, different dosages were obtained according to the methodology from IPT to produce conventional concretes with the following classes of resistence: C10, C20 and C30. theese concretes were made using natural and artificial aggregates.
The concrete obtained with the natural aggregate was used as a pattern for the analies of the results form the artificial aggregate concrete.
Consistency tests were caried aou during the dosages so that we could balance the workability and the water cement rate for these designed concrete. [14]
Their mechanic properties[15] and their resistance to compression obtained at 3,7 and 28 days to classes of resistance C10, C20 and C30.
The samples obtained for these classes of resistance were kept under water so that their expansion could be measured.

3 RESULTS AND DISCUSSION

In the Tables 2, 3 and 4, we show the results for the concrete with artificial aggregates from salg. The granulometric assay was done following the industrial segregation of the proccess: fractions 0-4mm, 4-10mm and 10-19mm.

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**				

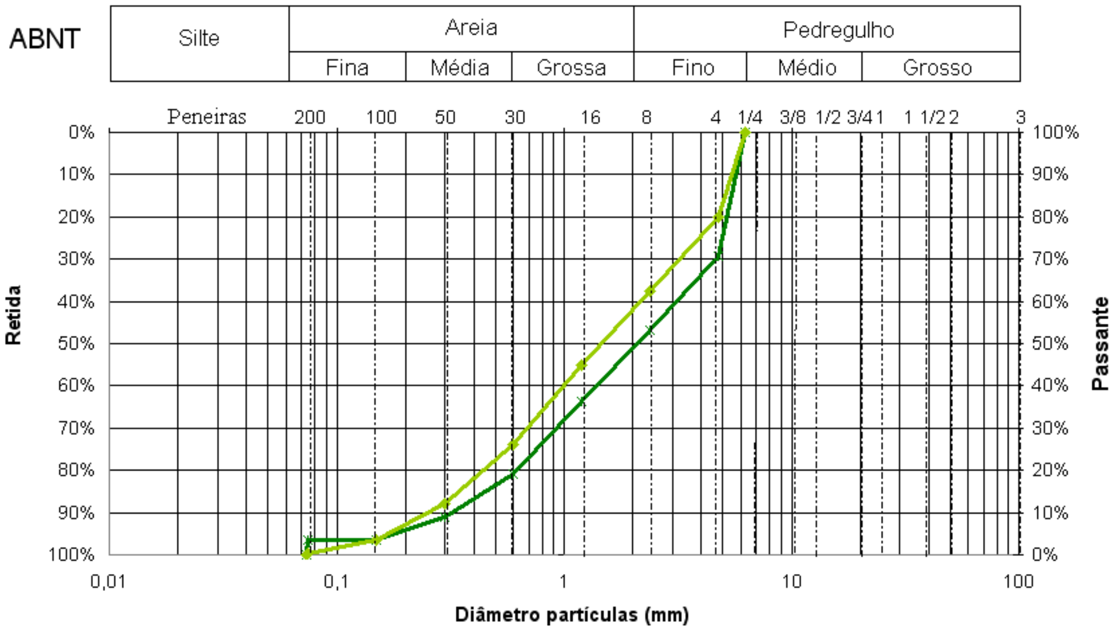

Figure 2. Granulometric curve fraction 0-4mm

Table 3. Granulometric analisys fraction 4-10mm

Granulometria Amostra 6 – Reciclos 4 - 10						
Peneiras (mm)	M1 agregados	M2 solo	% retida M1	% retida M2	% acum M1	% acum M2
19	123	48	6,7%	2,6%	6,7%	2,6%
12,5	463	581	25,2%	31,8%	31,9%	34,4%
9,5	336	346	18,3%	18,9%	50,2%	53,4%
6,3	326	269	17,8%	14,7%	68,0%	68,1%
4,8	133	152	7,2%	8,3%	75,3%	76,4%
2,4	213	207	11,6%	11,3%	86,9%	87,7%
1,2	100	99	5,4%	5,4%	92,3%	93,2%
0,6	51	52	2,8%	2,8%	95,1%	96,0%
0,3	31	31	1,7%	1,7%	96,8%	97,7%
0,15	27	26	1,5%	1,4%	98,3%	99,1%
0,075		14	0,0%	0,8%	98,3%	99,9%
Fundo	32	2	1,7%	0,1%	100,0%	100,0%
Soma	1835	1827	100,0%	100,0%		
M. Finura	**6,02**	**6,06**				
Dim. Máx	**25**	**19**				

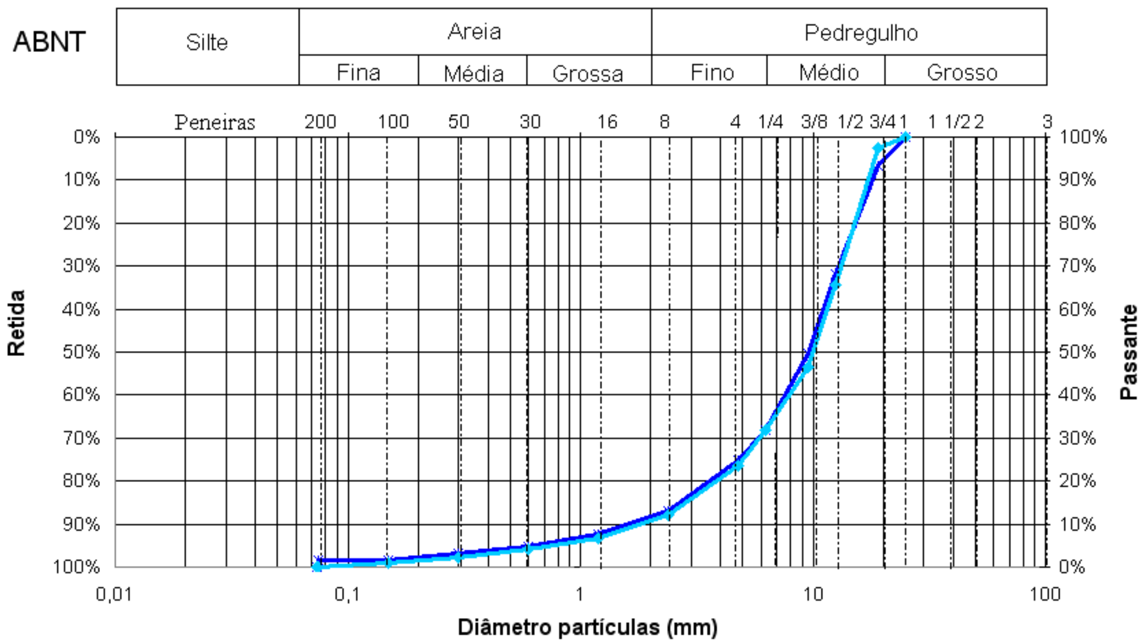

Figure 3. Granulometric curve fraction 4-10mm

Table 4. Granulometric analisys fraction 10-19mm

Granulometria Amostra 7 – Reciclos 10 - 19						
Peneiras (mm)	M1 agregados	M2 solo	% retida M1	% retida M2	% acum M1	% acum M2
32	57	-	1,2%	-	1,2%	-
25	618	-	13,4%	-	14,6%	-
19	2172	-	47,0%	-	61,7%	-
12,5	1218	-	26,4%	-	88,0%	-
9,5	338	-	7,3%	-	95,3%	-
6,3	149	-	3,2%	-	98,6%	-
4,8	32	-	0,7%	-	99,3%	-
2,4	20	-	0,4%	-	99,7%	-
1,2	3	-	0,1%	-	99,8%	-
0,6	2	-	0,0%	-	99,8%	-
0,3	1	-	0,0%	-	99,8%	-
0,15	2	-	0,0%	-	99,9%	-
Fundo	6	-	0,1%	-	100,0%	-
Soma	4618	-	100,0%	-		-
M. Finura	**7,55**					
Dim. Máx	**32**					

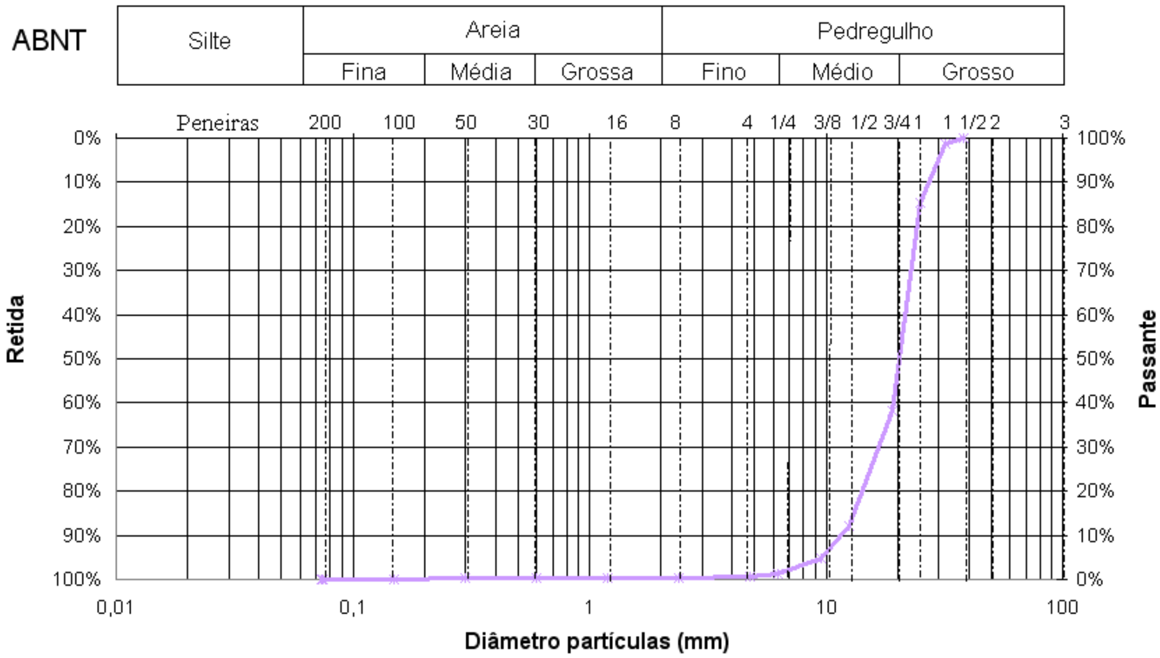

Figure 4. Granulometric curve fraction 10-19mm

We can see that this industrial classification separates the aggregate into thick sand (0-4mm), gravel 0 (4-10mm) and gravel 1 (10-19mm), respectively.
The results concernig their specific mass, dry and wet, are shown in the Figure 5 below:

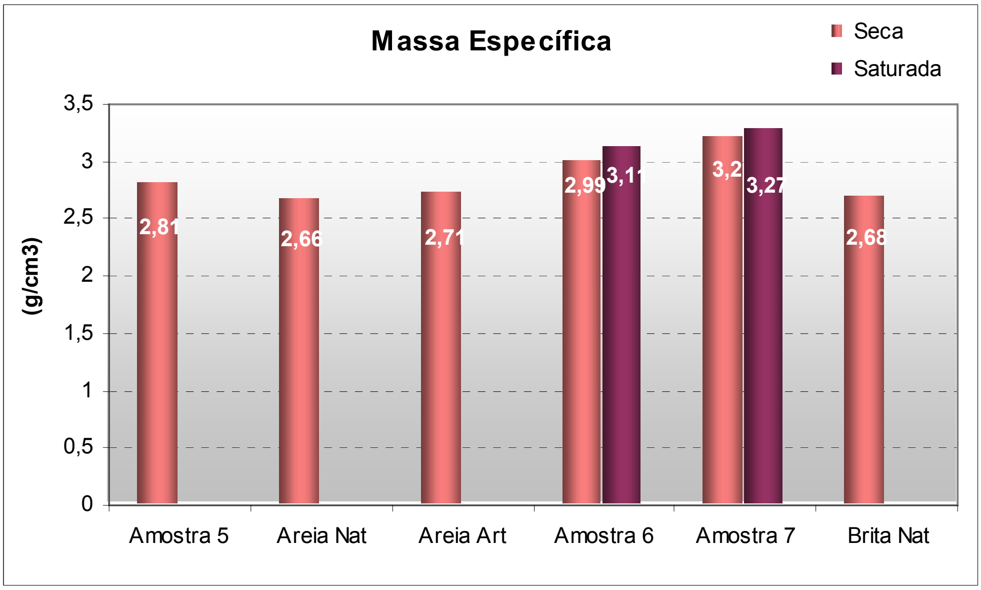

Figure 5. Specific mass for aggregates, dry and wet.

The sample number 5 has a specific mass value close to the ones found in the natural aggregate sand, while the others, the thick aggregates, present hiher values. This is due to the fact that the thicker aggegates still possess residual metallic iron embedded into their structures, making their specific mass to be higher.
Below, in the Figure 6, it is shown the figures for unitary mass for samples 5, 6 and 7, ad for natural aggregates.

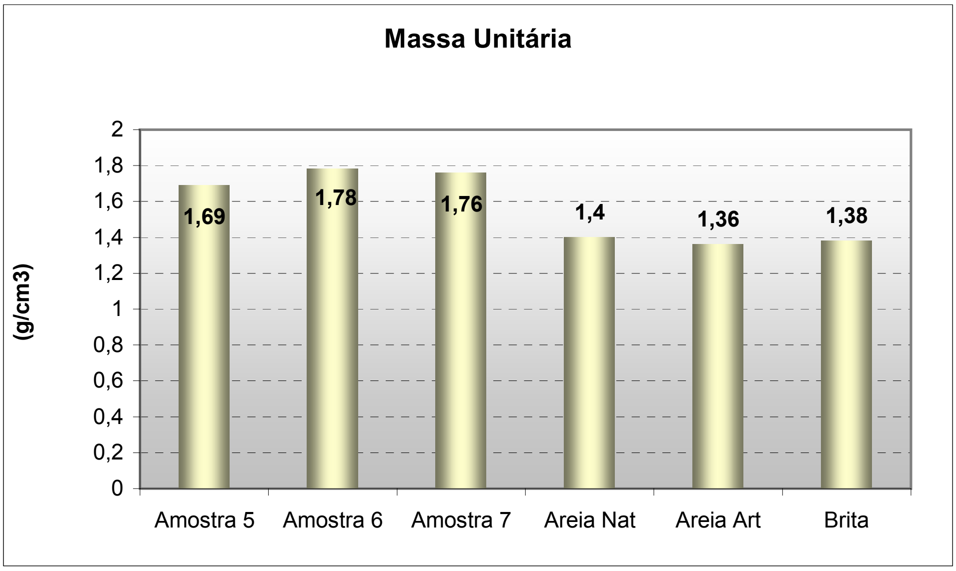

Figure 6. Unit mass for aggregates, dry and wet.

The chart in Figure 7 shows that the slag samples are prone to absorb more water, in what is called higroscopicity, as we can see in sample number 5, representative of sand, or thin aggregate. The samples for thick aggregate presented variable values, due to the presence of thin material adhered to sample 6, corresponding to gravel 1.

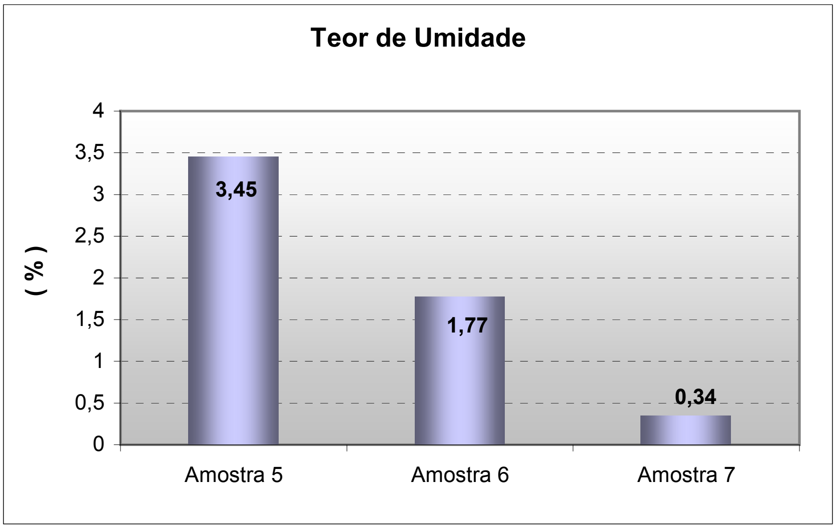

Figure 7. Wet Ratio

Considering the characteristics to the natural and artificial aggregates, fig 8 shows the results for the different concretes concerning their axial resistence to compression.
We can see that the concrete using slag have better mechanic performance for dosages which are poorer in cement, if compared to the richer ones.

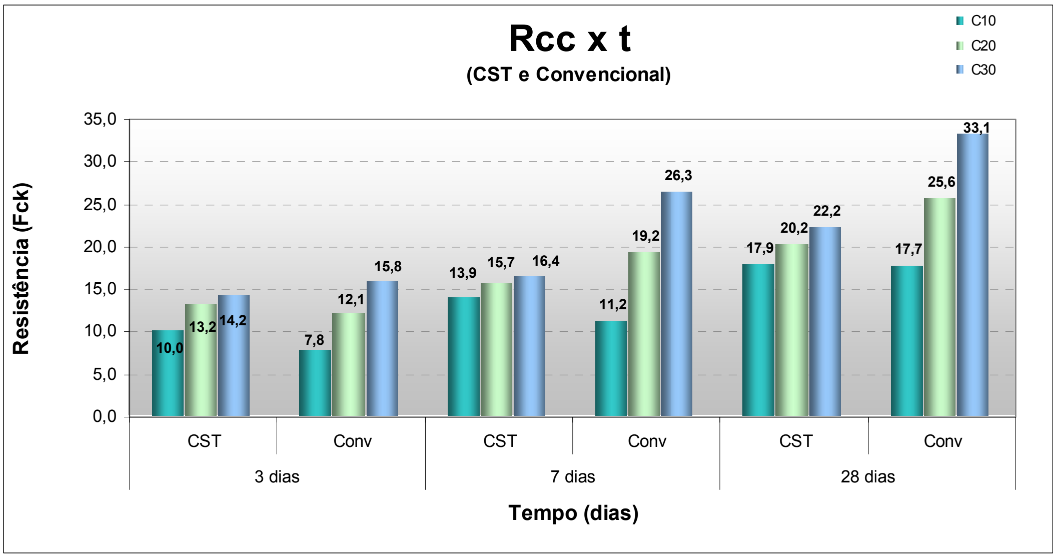

Figure 8. Resistance to compression C10, C20 e C30

The samples prodced wih salg did not present any variation in their dimensions after being submerged in water for 60 days. The samples were measured every 4 days (96 hours).

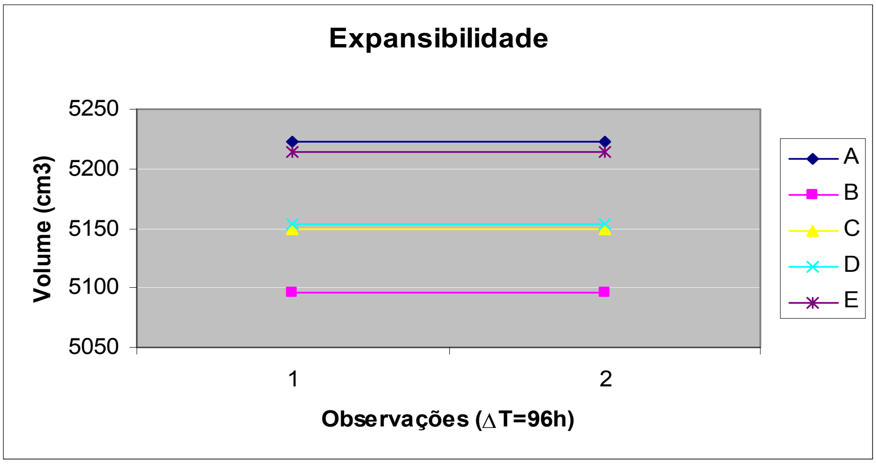

Figure 9. Dimensional stability - expansibility

The viability study, taking prices in Belo Horizonte as a basis, indicated that the concrete produced with residue from the siderurgy industry is, ore economic than the tradicional concrete, as shown in Figure 10.

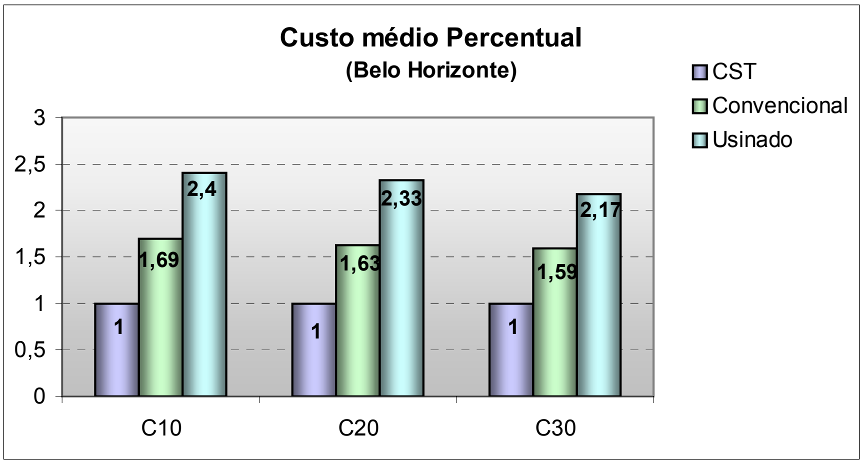

Figure 10. Cost medium percent for slag steel concrete (CST), conventional, industrialized.

4 CONCLUSION

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

- i) slag can fully substitute the natural aggregates in concrete with classes of resistance ranging from C10 to C20.
- ii) Concrete produced with slag can be up to 2,4 times cheaper than the traditional one
- iii) Concretes richer in cement presented proportionally smaller resistences than the ones with less cement
- iv) The concretes obtained with slag are dimensional stable, that means, they do not expand in experimental submersgence conditions (60 days)
- v) Concretes produced with salg can be economicly and technically viable tobe used in pavements for cyclists, pedestrian walks, industrial patios, precast elements, such as curbs, posts for fences, etc.

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