ANALYSIS OF TECHNICAL VIABILITY OF MIXTURE OF BENEFITED STEELMAKING SLAG (ELECTRIC ARC FURNACE) AND GRANULATED BLAST FURNACE SLAG (CHARCOAL) AS MINERAL ADMIXTURES

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Introduction

In Brazil, 8.5 million tons of blast furnace slag and 5.5 million tons of steel slag[1] were generated. Almost 100% of the granulated blast furnace slag (GBFS) is recycled in cement industry, because in addition to the chemical composition similar to clinker, during the granulation process, in the abrupt cooling the material becomes amorphous giving it cement properties[2], making it commercially attractive. The steel slag (SS) has a more variable chemical composition depending on the type of steel and process and for safety reasons the cooling is slow, making the material crystalline and consequently less reactive[3] and less attractive for cement industry. Studies[4-8] indicate that the SS, if treated, has potential to be used in cement production, which is a more noble and valued application than conventional applications. Since no studies were found on blends of granulated blast furnace slag - charcoal ($GBFS_C$) and electric arc furnace slag (SS_{EAF}), this research becomes relevant to the search for an interesting alternative with technical, environmental and economic gains.

Methodology

Samples of $GBFS_C$ and SS_{EAF} were collected at ArcelorMittal Juiz de Fora. The SS_{EAF} sample was passed through a magnetic separator and afterwards a batch of about 50 kg was heated in a gas oven. The temperature was 30° C to 1080° C in 20 minutes, remaining at this temperature for 15 minutes. After heating, the SS_{EAF} sample was tilted and quenched with water jets. SS_{EAF} heated and cooled ($SS_{EAF}T$) was homogenised and coned and quartered. Approximately 0.5 kg of $GBFS_C$, SS_{EAF} and $SS_{EAF}T$ samples were separately ground in bench ring mill for 2 minutes to a particle size of 0.075 mm and sent to the CRH Brazil Laboratory to be determined specific mass[9], fineness[10], vitrification degree and refractive index by transmitted light microscopy. Mortars with $GBFS_C$, SS_{EAF} and $SS_{EAF}T$ (Table 1) were prepared and 6 cylindrical specimens of 50 x 100 mm of each mixture were made to determine the

performance index of pozzolanic materials[11]. CP II-32-F cement (standard) and CP IV-32-RS cement (ordinary cement in the state of MG) were used for these tests.

Table 1: Dosage of used mixtures

Materials	Mix Proportions (wt%)							
	#1	#2	#3	#4	#5	#6	#7	#8
Cement	100	75.0	75.0	75.0	75.0	75.0	75.0	100
$GBFS_C$		25.0			22.5	20.0	12.5	
SS_{EAF}			25.0		2.5	5.0		
$SS_{EAF}T$				25.0			12.5	
Materials	Mortar Mix for 6 Specimens (g)							
Cement	624.0	468.0	468.0	468.0	468.0	468.0	468.0	624.0
$GBFS_C$		156.0			140.4	124.8	78.0	
SS_{EAF}			156.0		15.6	31.2		
$SS_{EAF}T$				156.0			78.0	

In order to determine the performance index with Portland cement at 28 days, the following equation was used: I = fcB / fcA x 100, where: fcB = average compressive strength at 28 days of mortar with cement and pozzolanic material (MPa); fcA = average compressive strength at 28 days of mortar with cement only (MPa).

Results and Discussion

Tables 1 and 2 present the results of the chemical analyses, specific mass, specific surface area, vitrification degree and refractive index of the samples collected at the steelmaking and of the treated sample. Table 3 shows the pozzolanicity results.

Table 1 shows a lower FeO content in $SS_{EAF}T$ than SS_{EAF} due to theremoval of magnetic material. With regard to binary basicity, CaO/SiO_2, $GBFS_C$ presents acidic characteristics while SS_{EAF} and $SS_{EAF}T$ present alkaline characteristics. The lowest density of $SS_{EAF}T$ (2.90 g/cm^3) relative to SS_{EAF} (2.95 g/cm^3) correlates with the fact that it has a lower FeO. The smaller specific surface area or fineness of the SS_{EAF} sample can be explained by the greater difficulty of grinding this material. The heating and quenching treatment provided a better milling performance in the larger Specific surface area of the $SS_{EAF}T$ sample. This fact was also verified in the manual pre-grinding before milling in the bench ring mill, that is, the $SS_{EAF}T$ sample was more easily ground with the mortar and pestle than the SS_{EAF} sample. This fact was also verified[5]. The $GBFS_C$ showed a vitrification degree of 79%. After treatment, the vitrification degree of SS_{EAF} increased from 59% to 70% in $SS_{EAF}T$. For British cement the vitrification degree should be higher than 67%[12]. The $GBFS_C$ and $SS_{EAF}T$ showed higher values, indicating potential use for the manufacture of cements.

Table 2: Chemical analysis by RXF spectrometry

Samples	Oxides (%)							
	CaO	SiO_2	Al_2O_3	MgO	FeO	MnO	MnO_2	Basicity
$EGAF_{CV}$(1)	29.27	38.96	14.41	8.21	1.09	0.75	-	0.75
EA_{FEA}(1)	30.41	14.29	3.84	7.53	34.14	4.83	-	2.13
EA_{FEA}TRAT(2)	40.9	23.9	4.8	9.9	18.98	-	2.1	1.71

Notes: (1) ArcelorMittal Lab; (2) CRH Brasil Lab.

Table 3: Specific mass, specific surface area, vitrification degree and refractive index

Sample	Specific mass (g/cm^3)	Specific surface area (cm^2/g)	Vitrification degree (%)	Refractive index (n)
$GBFS_C$	2.80	3.960	79	1.61 – 1.62
SS_{EAF}	2.95	2.210	59	1.50 – 1.51
SS_{EAF}T	2.90	3.850	70	1.56 – 1.58

Table 4: Average compressive strength (28 days) and pozzolanic activity index (IAP)

Mix	CP II-F-32		CP IV-32-RS	
	MPa	IAP (%)	MPa	IAP (%)
#1 (100% cement) - reference	34.2	100	33.1	100
#2 (75% cement + 25% $GBFS_C$)	27.5	80.4	24.1	72.4
#3 (75% cement + 25% SS_{EAF})	28.4	83.0	25.4	76.3
#4 (75% cement + 25% SS_{EAF}T)	27.9	81.6	26.1	78.4
#5 (75% cement + 22.5% $GBFS_C$ +2.5% SS_{EAF})	26.8	78.4	25.1	75.4
#6 (75% cement + 20% $GBFS_C$ +5% SS_{EAF})[a]	26.9	76.9	24.1	72.8
#7 (75%cement + 12.5% $GBFS_C$ + 12.5% SS_{EAF}T)[a]	27.2	77.7	24.7	74.6
#8 (100% cement)[a] - reference	35.0	100	33.1	100
a) A second batch of reference was made due to the number of moulds.				

For the pozolanicity tests performed with CP II-32-F cement, all the mixtures showed results higher than 75%. For cement CP IV-32-RS only mixtures # 2 and # 6 did not reach the minimum limit established in standard[13].

Conclusions

Currently SS is cooled slowly obtaining a crystalline structure and becoming hard. The proposed thermal treatment altered the structure of SS_{EAF}, giving $SS_{EAF}T$ a higher friability and better grindability, making possible its use as mineral addition in cements. After treatment, the vitrification degree of SS_{EAF} increased from 59% to 70% in $SS_{EAF}T$, representing a gain of 19%, indicating potential use for the manufacture of cements. The determination of the pozzolanic activity index (IAP) for mortars with CP II-32-F cement showed that the minimum value of 75% was reached for all mixtures, evidencing the pozzolanic properties of the slags. For mortars with cement CP IV 32-RS, only mixtures # 2 and # 6 did not reach the minimum limit, but considering that the CP IV already is a cement containing pozzolans in its composition, the results do not prevent the use of the materials $GBFS_C$, SS_{EAF} and $SS_{EAF}T$ or their mixtures as pozzolans, but further studies are needed to validate the appropriate dosages.

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