PROOF OF THE MECHANICAL PROPERTIES OF CONCRETE USING FLY ASH FROM FOUNDRY

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Abstract. *One of the biggest issues in the foundry industry is the solid waste produced, which have e a high environmental impact. In the foundry process, using blending and addictives limit the sand reuse for that this kind of industry put this waste away in a controlled landfill. The subject of this study is fly ash waste originated from core sand reuse. In this way looking for options in order to reuse in a big amount the fly ash to minimize cost discard of the steel industry and incorporate it into the production process of construction. This study aims to evaluate the potential of using the exhaustion powder to produce conventional concrete non-structural. The fly ash replaces partially natural sand fine aggregates. Experiments had been managed in the follow conditions: 0, 7.5 and 15% in mass of exhaustion powder to different taxes water/cement ratio (0.52, 0.54 and 0.56). For such the concrete and the materials had been analyzed throw characterization tests, grain size distribution and compression mechanical proprieties. In the material proprieties analyze is verified that exhaustion powder is a fine powder. The concrete compression strength with exhaustion powder incorporate of 15% was next to values found without the use of it. Analyzing the results through the analysis of experiments, it was found that it is feasible to replace the exhaustion powder in the proportion up to 15%.*

Keywords*: concrete; compressive strength; waste foundry*

1. INTRODUCTION

A major problem for the foundry industries is the generation of solid waste, and a greater part of this is the residual sand. In the casting process, the use of binders and additives limits the reuse of sand. In these cases this kind of waste is discarded in industrial waste deposits. Given the progressive increase in the cost of proper disposal and disabled environmental performance measures, so far centered on the control of pollutants, the foundry industries, like others, are focusing their efforts to develop more effective solutions (Matos, 2002).

The minimization of waste is part of a new concept of environmental management based on systematic measures designed primarily to reduce the maximum possible quantity of these to be treated or disposed. These efforts have an action framework based on prevention and recycling of waste (Mariotto, 2000). The reduction of waste generation and recycling are practices considered basic and necessary to target environmental and economic goals, by reducing material consumption and decreasing the available in controlled landfills (Peixoto, 2003). This paper has the purpose of analyzing the feasibility of the use flay ash in concrete through statistical proof results of mechanical strength of compression.

2. FOUNDRY WASTE AND APPLICATION OF CIVIL CONSTRUCTION

The foundry is an ancient art widely used untill today to produce of intermediate goods. Brazil is among the ten largest producers of castings (Oliveira, 2007). The casting process is the production of metal parts that are obtained by pouring a metal or a molten metal alloy on a hollow mold, usually made of sand (Matos, 2002). We can estimate that over 80% of the castings are produced using molds made of sand agglomerated (Armange, 2005), due to the easy extraction and the huge amount of volume available at low cost allies (Kondic, 1973). For every 1,000 kg of casting is consumed 800 to 1000 kg of sand (Scheunemann, 2005). It is estimated that the amount of sand-casting used by industries is around 3 million tons per year and generates the same amount of waste (Abifa, 2009). In order to reduce the the amount of waste disposed at landfills, foundry industries are treating the sand waste through a regeneration process. This process makes possible that this sand could come back to the process, but generate some waste, wich are classified as IIA, non-hazardous and non-inert (ABNT NBR 10004, 2004). This waste brings several environmental damage as modification of the natural landscape and occupation of large areas of landfilling, and are harmful if disposed in uncontrolled areas (Carnin, 2008).

Several researchers have reported on the use of foundry waste in construction. Pagnussat (2004) has used in his dissertation, granulated slag casting in concrete block paving. Were assessed the advantages of using waste into blocks, with a partial replacement for cement and also by the aggregate and performed tests of compressive strength, abrasion and water absorption, for substitutions in the levels of 10, 30 and 50%. The content of 10% of waste as a partial replacement of cement was the one closest to the performance of the blocks of reference. The results also showed no significant differences between the reference blocks and blocks with waste, how to abrasion and water absorption.

Wanatabe (2004) studied the use of foundry sand residual non-phenolic as aggregate to make concrete pavements. Was studied the influence of the residue on the mechanical properties and microstructural characteristics of the flooring manufactured by the process of vibration and vibro-compression process. The floors were made of industrial equipment with various traits, and characterized by compression tests, microstructural analysis and leaching tests, mass analysis and solubilization. Floors made only with vibration showed lower mechanical strength than those made with the vibration associated with compression, regardless of the addition of waste. Moreover, the mechanical strength of the floors made of vibration tends to decrease with the addition of the residue on the floor while the manufactured with vibro-compression, the mechanical strength increases with the WTS. In leaching tests, analysis of mass and solubility, the results showed that the residue has no negative influence on the concentration of chemical elements analyzed and, therefore, has no environmental impact.

Armange (2005) researched the use of residual sand for use in mortar. The studied waste was used as aggregate in lieu of common sand percentages, and ranged from 0 to 100% by mass. The specimens with and without residue 30% residue were naturally aged for six to twelve months after 28 days of healing saturated. After curing, were tested in uniaxial compression, later analyzed by scanning electron microscopy and leaching tests, mass analysis and solubilization. There were no significant effects of residue addition on the mechanical strength of mortars. The leaching tests and mass analysis were within the range permitted by the standard, showed only a slight excess of aluminum.

3. MATERIALS AND METHODS

To evaluate the properties of concrete, was first necessary to evaluate the characteristics of materials used in concrete (Ibracon, 2010). The experimental steps were:

a. characterization of the residue of smelting;
b. characterization of aggregates;
c. strength of concrete;
d. production of specimens of concrete and
e. characterization of concrete.

The materials used in the experimental process of concrete were:

a. fly ash waste foundry in Joinville / SC;
b. river sand quartz Araquari / SC;
c. crushed rock gneiss Joinville / SC;
d. Cement II-CP-Z-32 and
e. water by Aguas de Joinville Company / SC.

The material characterization was performed according to standard. Table 1 presents the physical, chemical and environmental performed with fly ash residue.

Table 1. Tests carried out with the aggregates

TEST OF FLY ASH WASTE FOUNDRY	STANDART
Determination of particle size distribution (laser diffraction method)	PR-CC-062*
Determination of chemical analysis by fluorescence spectrometry X-ray	PR-CRI-097*
Determination of atomic absorption spectrometry	PR-CRI-098*
Determination of acute toxicity	Portaria 017/2002-FATMA

(*) STANDARD FROM LCDM – SENAI/CRICIUMA

Several tests were carried out with the kid and coarse aggregates (sand and gravel) in order to verify the physical and mechanical characteristics. Table 2 shows the tests and standards to which aggregates have been submitted.

Table 2. Tests carried out with the aggregates

TESTING OF AGGREGATES	STANDART
Determination of particle size distribution	ABNT NBR NM 248
Determination of specific gravity and apparent specific gravity	ABNT NBR NM 52
Determination of organic impurities	ABNT NBR NM 49
Determination of fine material that passes through 75μm sieve	ABNT NBR NM 46
Determination of clay lumps and friable	ABNT NBR 7218
Determination of absorption and absolute density	ABNT NBR NM 53
Determination of the shape index of coarse aggregate by the method of caliper	ABNT NBR 7809
Determination of abrasion loss	ABNT NBR NM 51

After the tests with the waste fly ash and aggregates, it was determined the optimal dosage of concrete. The strength of concrete is essential to obtain the optimal ratio between the components of concrete and other materials used in concrete. To establish an assay of the concrete goal was complicated by the fact that ownership of the compression strength of concrete can be affected by any change in a specific variable. Among the variables we can mention the water / cement (w / c), excess aggregates, aggregates with a particle size constant, among others.

In all, nine mixes of concrete were produced, one for each combination of factors chosen. Altogether 81 were produced specimens of concrete non structural. The specimens of concrete produced was tested on fresh and hardened state. Tests conducted with the concrete are described in Table 3.

Table 3. Tests conducted with the specimens of concrete

TESTING OF CONCRETE BODIES OF EVIDENCE	STANDART
Determination of consistency for the subsidence of the cone change	ABNT NBR NM 67
Determination of compressive strength of cylindrical specimens	ABNT NBR NM 101

With the results of the tests of compression strength of concrete specimens was performed an ANOVA (Analysis of Variance-ANOVA). This analysis of variance allow assessed not only the isolated effect of one independent variable on a dependent, but also the interaction between the variables involved in the trial (Montgomery and Runger, 2003).

4. RESULTS AND DISCUSSION

Figure 1 shows the grading curve of the residual fly ash, the curve is S-shaped soft and still, it is observed that the residue is fine grained, a powdery material, with approximately 90% of particles below 100μm.

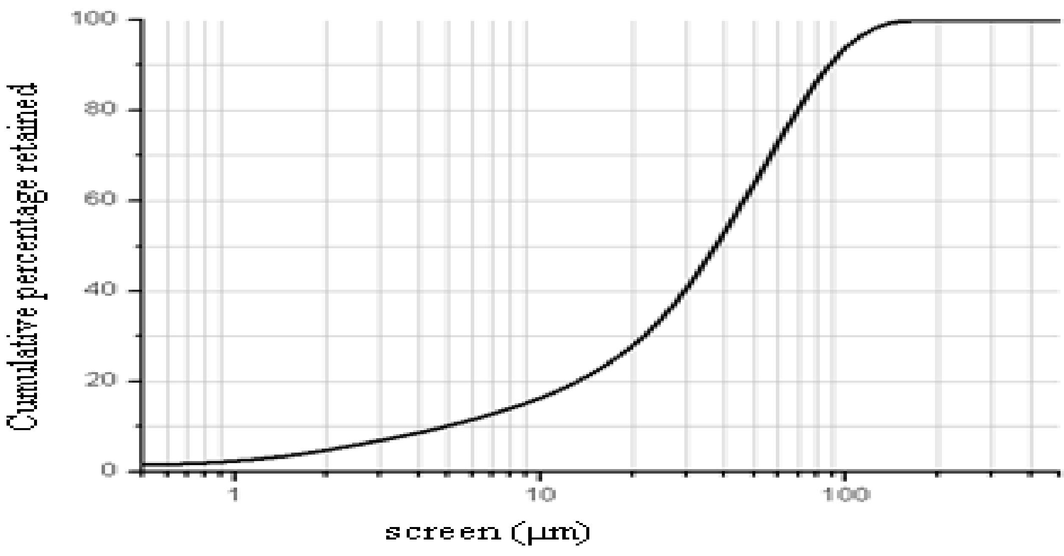

Figure 1. Grading curve of fly ash.

Table 4 described the chemical components and atomic absorption of fly ash. The residue has a greater percentage of silica in the form of quartz, because it is a waste reclaimed from river sand, the quantities of aluminum oxide and iron oxide are due to the addition of refractory materials during the manufacture of paints males (Correia, 2003).

Table 4: Chemical composition and atomic absorption of fly ash.

Element	Al_2O_3	Al_2O_3	Fe_2O_3	K_2O	*MgO*	*MnO*	Na_2O	P_2O_5	SiO_2	TiO_2	***Fire loss***
Content (%)	9,33	0,25	4,01	1,57	0,4	0,05	0,25	0,04	80,7	0,39	**2,37**

The sample of fly ash when subjected to the toxicological assay showed satisfactory results, presented no risk to public health, attending the norm of Ordinance 017/2002 (FATMA). With microcrustaceans Daphnia Magna and Vibrio fischeri showed the dilution factor was 2 to 6, with the ceiling 4 and 6, respectively, for samples from industrial activities metalworking origin.

In the following are presented the results for aggregates (sand and gravel). Figures 2-5 are shown the size distribution curves of natural sand from the river, the partial natural sand with fly ash and rubble of the curve, respectively.

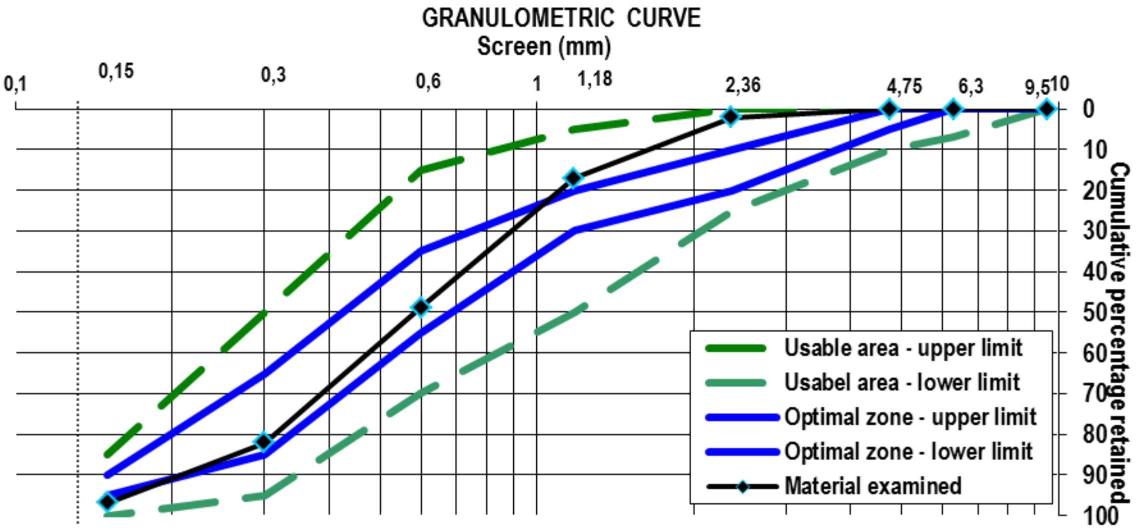

Figure 2 – Grading curve of natural sand from river.

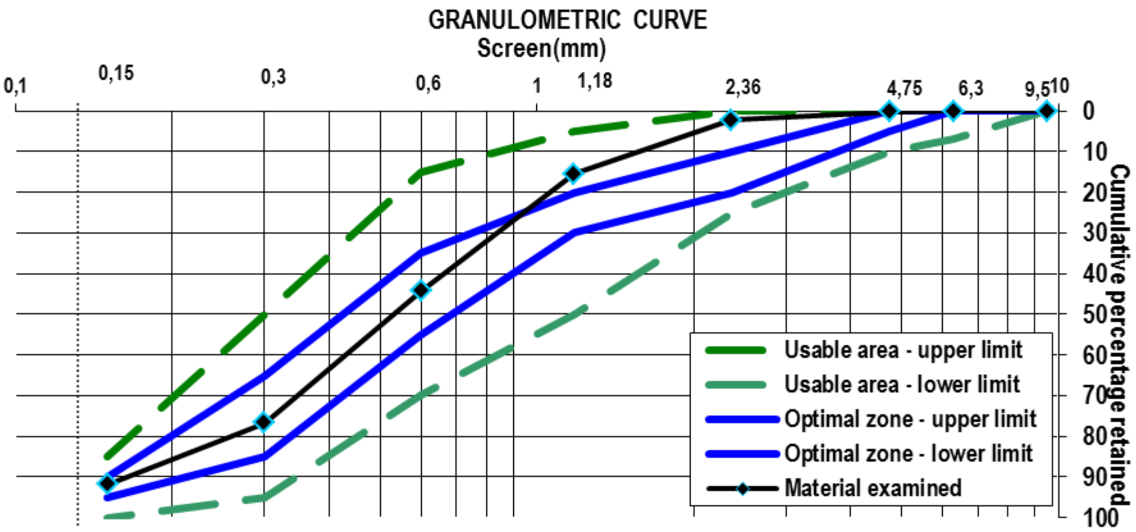

Figure 3. Grading curve of the mixture with 7.5% of fly ash

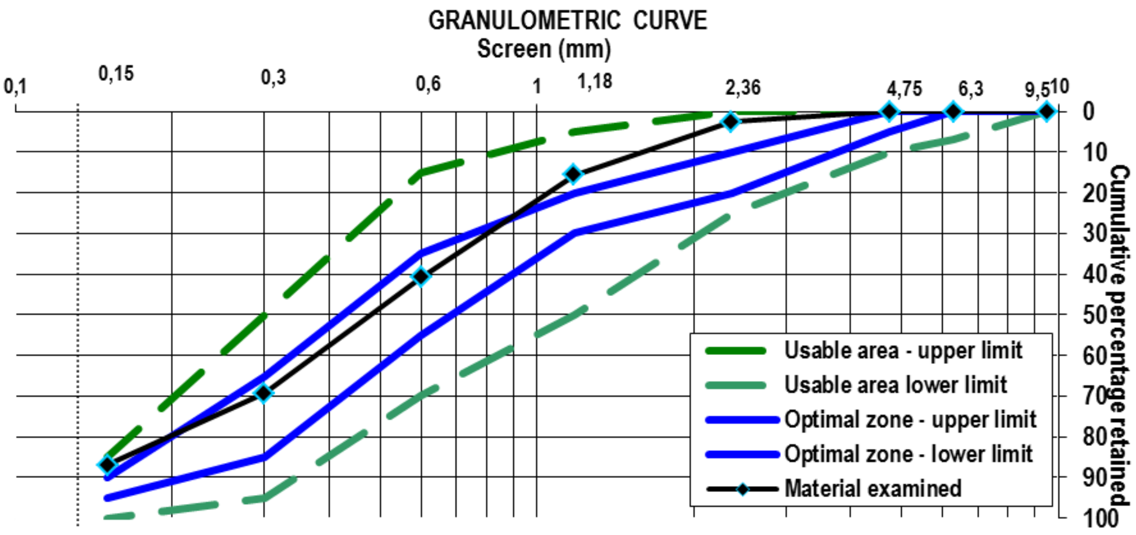

Figure 4. Grading curve of the mixture with 15% of fly ash

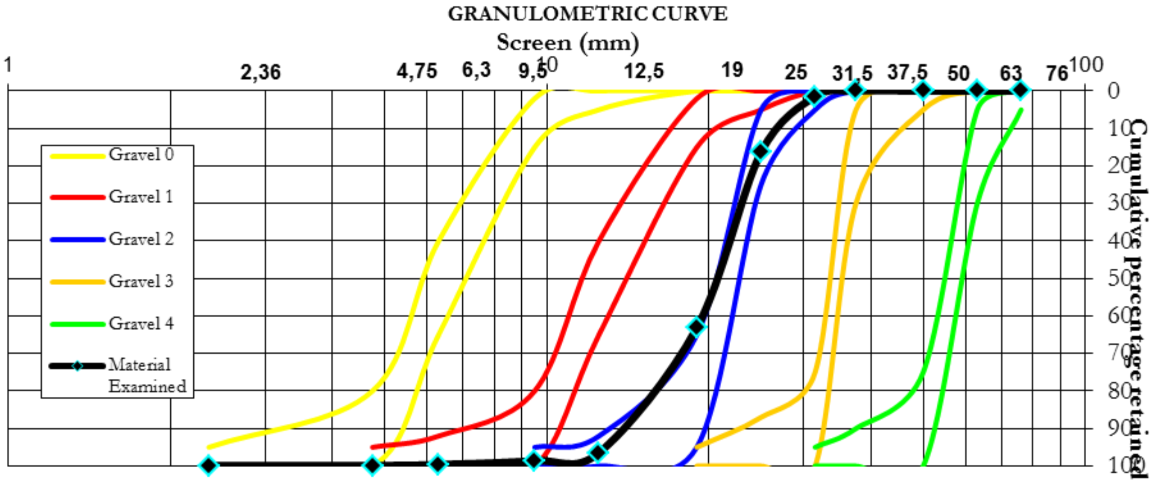

Figure 5. Grading curve of the gravel

Through the results of granulometric curves, one observes that all the samples show grain size varied in the form of "S", ideal for use in concrete. Table 5 can be verified the analysis results with other aggregates. All results are within the limits of the standarts.

Table 5. Test results with the aggregates

TESTING OF AGGREGATES	RESULTS
Determination of specific gravity and apparent specific gravity of natural sand from river	2,74 g/cm^3 - 2,68 g/cm^3
Determination of organic impurities	200ppm
Determination of fine material that passes through the sieve 75µm	1,4%
Determination of clay lumps and friable	5,7%
Determination of absorption and absolute density	0,24% - 2,66 g/cm^3
Determination of the shape index of coarse aggregate by the method of caliper	2,42
Determination of abrasion loss	21,95 %

Table 6 presents the results of the test for determining the index of consistency of fresh concrete through the reduction of the truncated cone. The determination of the consistency index is useful to verify the ease of handling concrete, also known as workability. The results obtained with the consistency index ranged from 30mm to 65mm, so as described by standard, the samples were condensed by vibrating table.

Table 6. Consistency of fresh concrete

CONSISTENCY (mm)		**Factor water/cement**		
		0,52	**0,54**	**0,56**
Percentage fly ash (%)	**0**	40	65	65
	7,5	35	45	55
	15	30	30	40

Ownership of compression strength at 28 days is the more valued property of concrete (Mehta and Monteiro, 1994). At ages 7 and 28 days were conducted to test for resistance to compression. Tables 7 and 8 contain the compressive strength of 54 specimens tested at 7 and 28 days old.

Table 7. Compressive strength of concrete at 7 days

COMPRESSIVE STRENGTH 28 DAYS (MPa)		**Factor water/cement**		
		0,52	**0,54**	**0,56**
Percentage fly ash (%)	**0**	19,52	18,11	16,15
		19,33	15,97	18,30
		20,19	15,99	16,93
	7,5	20,34	18,71	18,22
		18,82	20,57	20,09
		19,46	19,80	18,68
	15	18,12	17,17	19,19
		18,19	19,80	21,00
		17,94	15,92	20,23

Tabela 8. Compressive strength of concrete at 28 days

COMPRESSIVE STRENGTH 28 DAYS (MPa)		**Factor water/cement**		
		0,52	**0,54**	**0,56**
Percentage fly ash (%)	**0**	27,93	25,55	26,21
		27,10	26,24	21,29
		28,34	21,55	25,30
	7,5	22,15	27,18	28,45
		24,71	26,70	24,90
		22,80	24,65	22,65
	15	23,02	24,77	25,94
		21,04	23,88	24,16
		24,89	24,74	27,28

The results of compressive strength were statistically analyzed by factorial design of two levels and three factors, 32.

With the results analyzed by analysis of variance can be concluded that the percentage of fly ash and the interaction of two factors significantly affect the mechanical strength at 7 days. At 28 days, the percentage of ash and water/cement ratio dont exert significant effects on mechanical compression, only the interaction of these two factors influence the results of compressive strength.

Figure 6 presents graphically the influence of water/cement ratio, the percentage of fly ash and the interaction between the two factors on the compressive strength at 7 days.

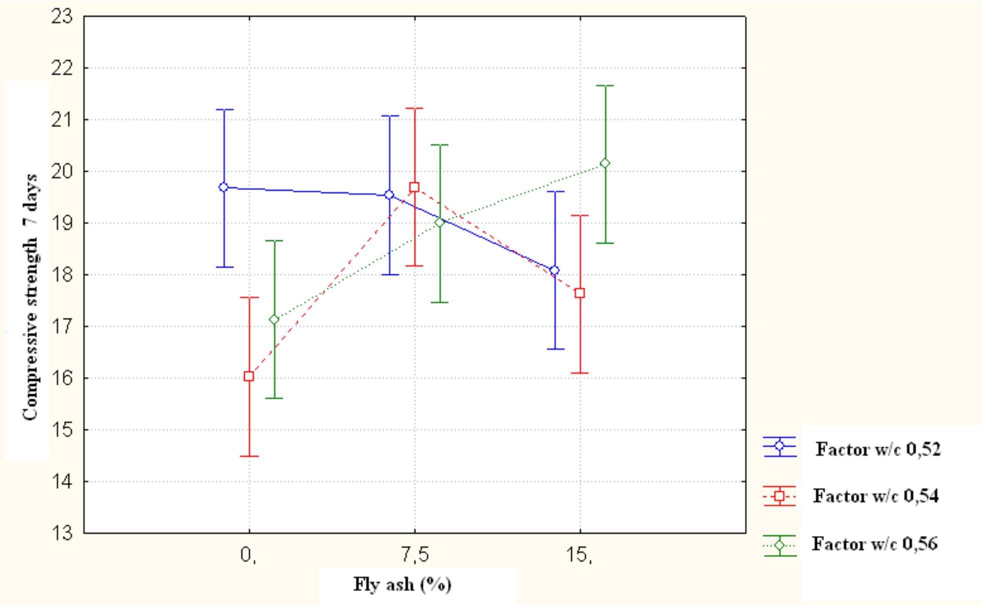

Figure 6. Graph of the interaction of the percentage of fly ash with the factor a / c on the compressive strength at 7 days.

In the interaction of factors, 0% fly ash, the highest resistance was obtained with the water/cement 0.52, and 15% fly ash, the highest resistance was obtained with the highest water/cement. Related work, water/cement, grain size and material of low surface area, the greater the amount of material of low particle size, the greater the surface area, the greater the water/cement to the concrete has the same fresh workability compared with the concrete produced without the addition of the residue. So with the addition of fly ash residue with the highest water/cement having the same workability was obtained with a concrete compressive strength without the addition of approximately fly ash.

The influence of interaction on the compressive strength at 28 days can be seen in Figure 7.

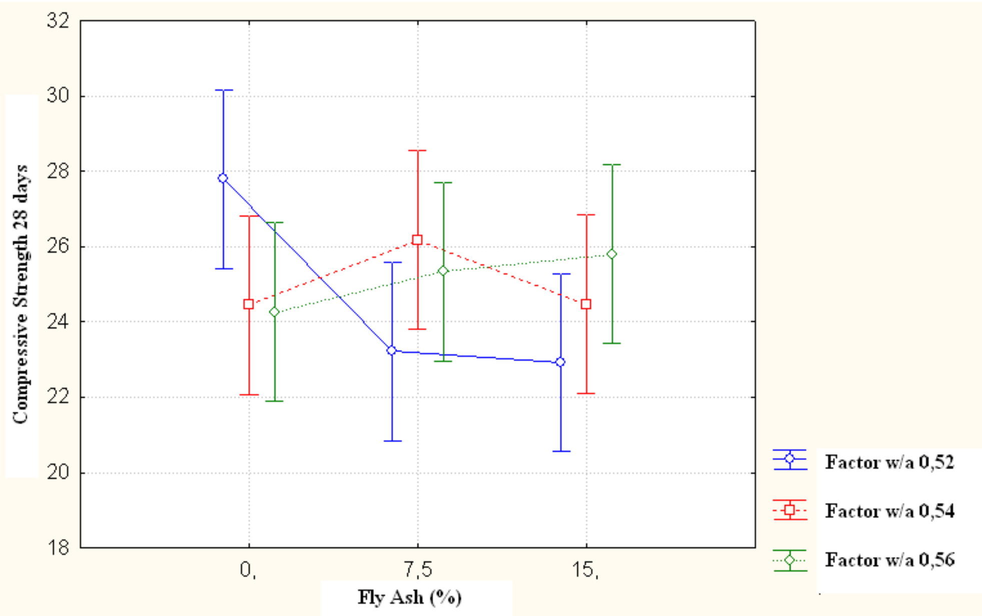

Figure 7. Graph of the interaction of the percentage of fly ash with the factor a / c on the compressive strength at 7 days

It is observed in the graph in Figure 7 that the concretes with water / cement ratio of 0.56 showed the highest resistance with the addition of fly ash. The concrete produced without the use of fly ash had the highest nominal resistance. The values of mechanical strength can best be visualized by contour plots.

Figure 8 shows the compressive strength at 7 days and Figure 12 shows the strength at 28 days.

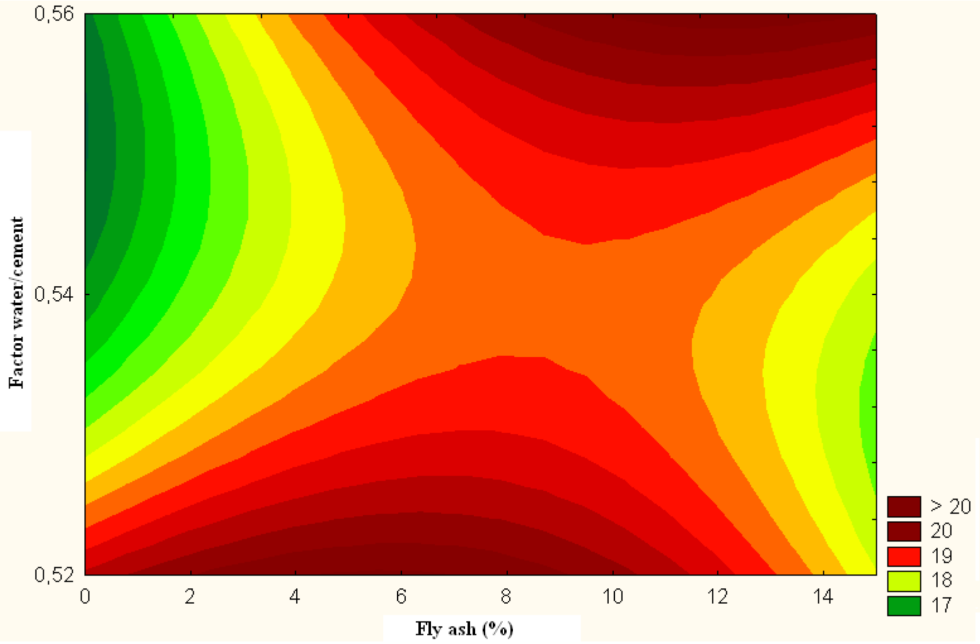

Figure 8. Contour of the compressive strength at 7 days (MPa)

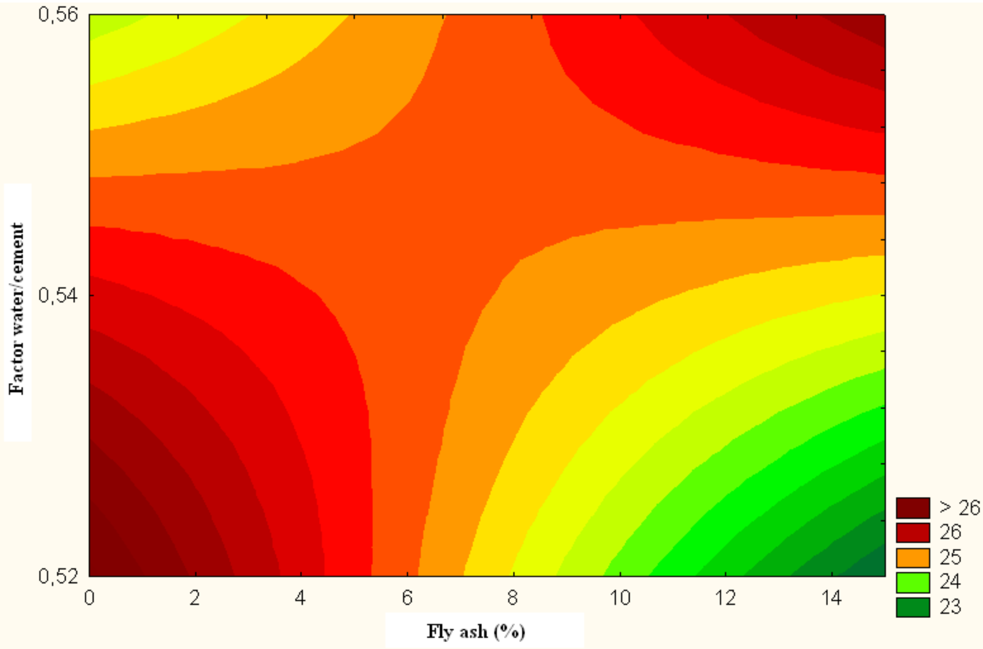

Figure 9. Contour of the compressive strength at 28 days (MPa)

The graph in Figure 8 shows that the greatest resistance was obtained with the lowest water / cement ratio and 7.5% of fly ash.

In Figure 9, it appears that the greatest strength of nominal compression with the addition of fly ash was with the water / cement ratio (0.56).

5. CONCLUSIONS

This paper was studied the effect of adding different amounts of fly ash waste foundry in different water / cement ratio, evaluating the physical, chemical, microstructural and toxic waste. The research objectives were reached regarding the analysis of theoretical material relevant to the subject, physical, chemical and morphological characteristics of the materials involved and the statistical analysis and produced concrete compressive strength of concrete.

The characterization results obtained with the coarse and fine aggregates were within the limits established by Brazilian standards. The curves of particle size distribution of fine aggregate with additions 7.5% and 15% were within usable.

In the analysis of characterization of fly ash was observed that the size distribution has the same low particle size on the order of mM in comparison to natural river sand, presenting powder. The fly ash present in their chemical composition over 80% of silica in the form of quartz, about 10% aluminum oxide and 4% iron oxide, since it was added during the molding process inks. The ecotoxicological results were within the norm in Brazil, so the residual molten fly ash poses no risk to public health.

The residue of fly ash in concrete casting was built to replace the aggregate in different proportions. The test of consistency index with the fresh concrete with satisfactory results within the limits of the standard, as well as the results of the absorption, specific gravity and voids, with the hardened concrete.

In the analysis of the microstructure of concrete, there was poor adherence to the folder with the aggregate and the existence of pores, providing lower compressive strength, common in conventional concrete.

Evaluating the results of statistical analysis, the results of mechanical tests showed that the compressive resistance of concrete depend on the percentage of fly ash and the interaction of light ash percentage and water / cement ratio at 7 days old. Verified by the contour that the greatest strength was rated at about 12% of fly ash and molten with water / cement ratio to 0.56 at 7 days old.

At 28 days old, the factors affecting the strength were the interaction of both factors. However, when analyzing the factors alone do not significantly affect the compressive strength. The highest compressive strength was rated without the addition of fly ash with lower water / cement ratio (0.54). With the percentage of 15% fly ash and water / cement ratio of 0.56, the results of compressive strength were approximated to those obtained by mixing 0% fly ash and 0.52 in the factor a / c.

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